Ramboll In-Store LCA most frequently asked questions

1. General questions

What is this Life Cycle Assessment (LCA) study about?

This LCA assesses and compares the environmental performance of single-use and multiple-use tableware used for in-store consumption of foodstuff and beverages in an average Quick Service Restaurant (QSR) over 365 days in Europe (27 EU countries + UK).

The LCA is made in accordance with ISO 14040 and 14044 standards and has been independently verified by Germany's TÜV (Technischer Überwachungsverein).

TÜV stated that *All significant parameters are available and representative and have been systematically derived and duly assessed. All type approvals have been checked. The assessments and the underlying data collection and calculation procedures are transparent and traceable*."

The LCA was recently audited by the specialized environmental agency In Extenso on behalf of ADEME, the French national agency for Environment, to be part of the ADEME reference bibliography (fiche 39)[1].

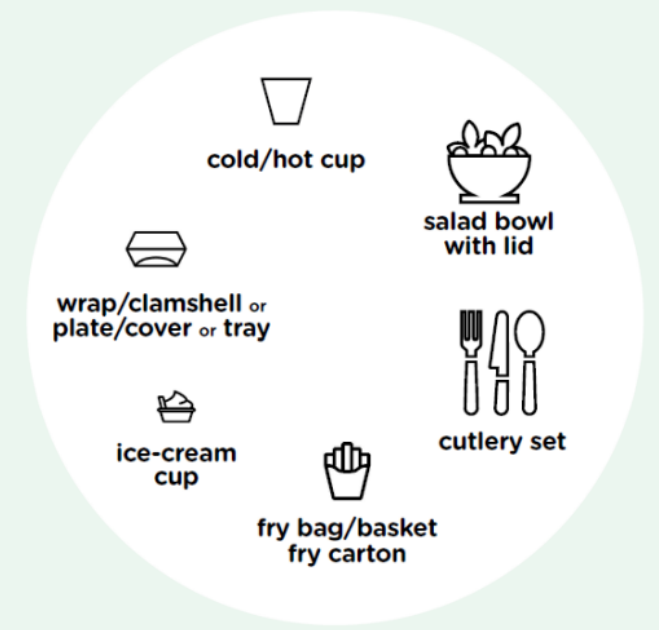

Fig. 1 Example of typical QSR table items used for the LCA

[1]

What is the "functional unit" considered in the study?

The following functional unit has been used for all assumptions and calculations:

> *Accommodating in-store consumption of foodstuff and beverages with single-use or multiple-use dishes (including cups, lids, plates, containers and cutlery) in an average QSR for 365 days in Europe in consideration of established facilities and hygiene standards as well as QSR-specific characteristics (e.g., peak times, throughput of served dishes).*

To this aim, QSR operators have provided data in terms of number of single items/servings per year (average figures) for all types of food and beverage containers considered. These figures are confidential and protected by specific NDAs; however, these have been made available for the third-party review processes.

Here below an explanation of the studied system and used functional unit is provided:

- Each system entails the following life cycle stages: 1) raw material production and processing, 2) converting, 3) distribution of product items to QSRs, 4) use stage at QSR, and 5) End-of-Life treatment (including transport to treatment facilities).
- A certain amount of tableware is sold every day and used for in store consumption of foodstuff and beverages (i.e., a certain number of cold cups, hot cups, wraps/clamshells or plates/covers or trays, fry bags/baskets/fry cartons, salad bowls with lids, cutlery sets, and ice-cream cups), either for single-use or multiple-use systems.
  To this aim, QSR operators have provided average data in terms of number of single items/servings per year for all types of food and beverage containers considered. These figures are confidential and protected by specific NDAs; however, these have been made available for the third-party review processes.
- Since the functional unit relates to the functioning of a QSR for one year, **the impacts related to each above mentioned life cycle stage have been calculated by using the number of all items used by an average QSR in one year.**
  This has to be seen in the light of the overarching goal and systems perspective of the study, which is not focused on single products, but on the functions achieved by the respective systems through a holistic understanding of the specific context. As a consequence, the impact result may not be used for product development, production process improvement, or any product-related decisions.
  In this view, comparison of results or single aspects of the study (e.g., dishwashers functioning) with respect to other studies focusing on product level cannot be made, as this can be misleading and not representative of the inherent features of the conducted LCA.

According to the critical review statement issued by TÜV "*Despite differences, the chosen systems are equivalent regarding there function. This supposition was intensively investigated as a prerequisite for the study. The scope and system boundaries of the assessment are clearly and unambiguously defined in relation to the entire system with respect to space (EU), time (2023) and technology (processes and necessary infrastructure for 2023). The future systems exist yet today, but are not adapted to QSRs. The boundaries are defined over the whole life cycle. They are compatible with the selected function unit. The assembly has been checked*."

What are the tableware analysed and their characteristics?

For this comparative assessment, two fundamentally distinct systems are taken into consideration: the current system for in-store services in QSRs based on single-use products made of paperboard, some of them with a polyethylene content lower than 10%, and their multiple-use alternative.

The comparative LCA study has taken into account the use of **7 different food and beverage containers**:

- A cold cup;
- A hot cup;
- A wrap/clamshell or plate/cover or tray;
- A fry bag/basket/fry carton;
- A salad bowl with lid;
- A cutlery set;
- An ice-cream cup.

Other food containers/packaging (i.e. shovel for coffee, placemat, drinking straw) are not included in the LCA study.

In total, the comparative LCA assessment incorporates the life cycles of:

- **10 different single-use product items** made of paperboard (if coated, PE content is < 10% w/w); and
- **14 different multiple-use product items** (represented in different scenarios and sensitivity analyses) with 2 dishes set options: one set made of polypropylene (PP; one acrylic plastic item), and one set combining PP, ceramic, glass and steel for sensitivity analyses.

The main characteristics of analysed tableware, such as materials, dimensions, volumes and weights, have been retrieved from QSRs operators as primary data. These characteristics are reported and described in section 3.1.2.4 of full report (Table 7).

Why is this study different from other LCAs on the same topic?

Main studies available in scientific literature adopt a product-focused approach in comparative assertions, mainly comparing single-use (SU) products with multiple-use (MU) products. **This LCA adopts a system-focused approach with a holistic perspective on the comparison of single-use and multiple-use products in QSRs. This study is not intended to present or interpret environmental impacts on a product level.** Modelling choices, data quality and assumptions are to be seen in the light of the overarching goal and systems perspective.

Moreover, this study is based on extensive primary data collection among QSRs operators, which lays the basis of a robust study. Primary data and information for single-use system have been further obtained from EPPA members. Also, data from scientific papers published in peer-reviewed international journals have been considered for the modelling of both SU and MU systems.

An extensive sensitivity analysis has been performed, with 12 scenarios analysed: 9 for the multiple-use system, 3 for the single-use system including different recycling rates (0%, 30%, 70%), washing scenarios (in-store or externalized washing), and different End of Life approaches (system expansion and cut-off method).

It is crucial to acknowledge and highlight that this is a tailor-made and case-specific ISO-compliant comparative assertion (e.g., several specific modelling choices are applied - which are transparently documented and explained in the full report). As a consequence, results from this study are not directly comparable with other sources and results (see next points).

This study adopts a system perspective: how is this approach different from others available in literature?

This study is not intended to present or interpret environmental impacts on a product level. Modelling choices, data quality and assumptions are to be seen in the light of the overarching goal and systems perspective. As a consequence, the impact result may not be used for product development, production process improvement, or any product-related decisions.

The adopted product items shall not be analysed individually but as a representative and equivalent system associated with well-defined upstream, core, and downstream processes to deliver the expected function to the QSR. Thus, comparisons on a product-level or conclusions concerning single items or their combination are not the objective of the conducted LCA, i.e., environmental hot-spots are not disclosed on a product-level but solely on a systems-level.

Moreover, absolute impacts associated with single items or the entire systems are to be handled with care as both data availability and the comparative nature of the conducted LCA mainly allow for disclosure and interpretation of relative impacts, i.e. the potential magnitude of differences between both situations in terms of environmental impact categories. In summary, the conducted LCA is rather disentangled from a product-specific perspective as to give recommendations on a systems-level.

According to the critical review statement issued by TÜV, "*Other studies refer more to products. Therefore a comparison with existing studies is not always correct*."

Why is this study different in terms of robustness and reliability compared to previous studies?

The robustness and reliability of the study are related to 4 key factors:

1. A system-approach based on the holistic understanding of all the products' processes.
2. Representative data and assumptions based on industry and QSR inputs.
3. Primary data for all relevant "hotspots" with state-of-the art paper upstream process data and washing/drying process data from producers and operators reflecting real use in QSRs.
4. Extensive sensitivity analysis, with 12 scenarios analysed: 9 for the multiple-use system, 3 for the single-use system including different recycling rates (0%, 30%, 70%), washing scenarios (in-store or externalized washing), and different End of Life approaches (system expansion and cut-off method). More details are reported in the specific question below *"What are the sensitivity analyses?"*.

Can the results from this study be compared to those from other studies?

In order to compare the results from two different LCA studies, the ISO standards require that such studies must share the same following technical and methodological aspects (ISO, 2006):

- functional unit;
- system boundary;
- allocation procedures;
- data quality;
- completeness/cut-off criteria, and
- Life Cycle Impact Assessment (LCIA) methodology.

These factors are equally important and must be fully met when comparing different LCAs.

This LCA is considering QSR only: to which extent is it valid for other types of restaurants?

QSRs are a specific classification of restaurants and entail certain high-volume food and beverage operations, as well as specific inherent features, as for example:

- QSRs operate under a standardized system that is long-established, quantifiable in robust data, and geographically sensitiveness.
- QSRs serve a high number of menus, drinks and food items per day.
- Demand for food and beverages occurs at two daily key peak times representing around 80% of all the orders.
- Menus are easily and quickly prepared.
- QSRs provide a referential for best-in-class dishwashers in the HORECA (hotel-restaurant-café) sector.
- QSRs are open 365 days per year and opening hours can be up to 24/7.
- Food affordability is expected and critical for a large part of restaurant's users.

While some of the aspects reported above can be seen as valid also for other types of restaurants, others may not be reflected in specific case studies not referring to QSRs. In fact, it must be noted that this study is a tailor-made and case-specific ISO-compliant comparative assertion and as such it must be considered valid within the set of assumed specific conditions and hypotheses

The study only considers in-store consumption: what about take-away?

In-store and take-away consumption entail system boundaries with specific peculiarities and intrinsic differences. In order to have a more detailed picture of both type of consumption, two different LCA studies (thirdy party reviewed) have been performed:

1. *"Comparative Life Cycle Assessment (LCA) – Single-Use and Multiple-Use Dishes Systems for In-Store Consumption in Quick Service Restaurants"*, finalized in December 2020 (that is the reference study for this Q&A).
2. *"Comparative Life Cycle Assessment (LCA) – Single-Use and Multiple-Use Tableware Systems for Take-Away Services in Quick Service Restaurants"*, finalized in November 2022.

How is the data quality assessed? Are the main used data disclosed?

According to ISO 14044, data quality requirements are included for the following aspects:

- Time-related coverage.
- Geographical coverage.
- Technological coverage.
- Precision.
- Completeness.
- Representativeness.
- Consistency.
- Reproducibility.
- Uncertainty of information.

All these aspects have been assessed and justified in detail, as described in **section 3.1.5 of the full report**.

According to the critical review statement issued by TÜV, "*all significant parameters are available and representative and have been systematically derived and duly assessed. All type approvals have been checked. The assessments and the underlying data collection and calculation procedures are transparent and traceable*."

The complete Life Cycle Inventory for both single-use and multiple-use systems listing input/output values and modelling assumptions is disclosed in **Appendix 3 of the full report** (under consideration of confidentiality issues; however, these have been made fully available for the third-party reviewer).

Regarding consumption data, did the LCA consider all the stages of the life-cycles?

Being this a Life Cycle Assessment study, it takes into account the consumption of water, materials, energy and any other consumption data associated with any life cycle stage included in the analysis, both for single-use and multiple-use tableware systems analysed.

The study also includes the outputs of all involved processes in terms of products, waste, wastewater and emissions to the environment.

Implemented data has been retrieved from different reliable sources such as QSRs operators, EPPA members as well as scientific papers published in peer-reviewed international journals. All utilized sources have been appropriately reported as reference in the study, in order to allow a clear and fair evaluation of the study, as well as reproducibility of performed analyses as long as confidentiality of data allows to. This is also reflected in the positive opinion provided by the third-party review process.

According to the critical review statement issued by TÜV, "*In summary it can be stated that all relevant factors have been identified and taken into consideration within the area investigated in accordance with the state of the art of Life Cycle Assessments*."

What is the geographical scope of the study? How is this reflected in the assumptions?

The geographical scope of the baseline comparison is Europe (EU-27 + UK). This geographical boundary is reflected in the assumptions around the systems (e.g., recycling rates) and background datasets (e.g., electricity from grid) as inventory data for the manufacturing stage of certain products will be site-specific or representing average production scenarios (e.g., global, EU).

The assumptions on the geographical scope related to End-of-Life and credits from treatment are transparently disclosed in **section 3.2.2.4 and 3.2.2.5 (for single-use and multiple-use systems, respectively) of the full report.**

Is the geographical scope representative of tableware production?

Assumptions for the upstream life cycle stage (the geographical location for raw material production of items), are representative of the EU average situation, since:

- For SU: The focus of the analysis is on items manufactured by EPPA members and partners, with their specific properties and characteristics. The raw material production and processing stage mainly entails countries like Finland and Austria, while converting data refers to production sites in countries like Germany, Finland and France.

  This geographical footprint reflects very well the geographical distribution of the pulp and paper mills in Europe included in the Best Available Techniques Reference Document for the Production of Pulp, Paper and Board issued by EU Commission[2].

- For MU: According to figures reported by Plastics Europe[3], the 6 largest European countries (Germany, Italy, France, Poland, Spain and United Kingdom) represent almost 70% of converters plastic demand.

What are the main outcomes of the third-party review process?

According to TÜV, that is the accredited verifier who performed the third-party review, the Critical review statement issued as result of the third-party review can be summarised as follow:

- *"The methods used for drawing up the Life Cycle Assessment are in accordance with the requirements of DIN EN ISO 14040:2009 / DIN EN ISO 14044:2018."*
- *"The methods are scientifically well-founded and are in accordance with the state of the art of Life Cycle Assessments".*
- *"The data used are adequate, appropriate and well-founded with reference to the objective of the assessment".*
- *"The evaluations take into consideration the objective of the assessment and the limitations which were identified".*
- *"The Life Cycle Assessment is consistent and transparent".*

The complete Critical review statement can be found in chapter 5 of the full report.

[2] https://eippcb.jrc.ec.europa.eu/sites/default/files/2019-11/PP_revised_BREF_2015.pdf
[3] https://plasticseurope.org/wp-content/uploads/2021/12/Plastics-the-Facts-2021-web-final.pdf

2. Questions related to the impact categories

Why are some environmental impact categories excluded, especially land use?

Some impact categories (ecotoxicity, human toxicity, photochemical oxidant formation, and land use) are excluded from the LCA due to the following reasons:

- The LCA predominantly focus on environmental impacts: categories solely attributable to damaging human health are therefore excluded.

- The assessment of toxicity impacts is not without controversy and would add additional uncertainty to the study.

- For certain categories, especially land use due forest operation, primary LCA data used and land use impact assessment methods are not compatible and when the scientific consensus is still missing, this creates challenges in land use modelling and when comparing different systems with different background data with each other. There are also methodological issues inherent to the available LCIA methods when applied to the forest industry.

According to the critical review statement issued by TÜV, "*Taking into consideration the objectives of the assessment, the functional unit selected and the (standard) technologies used in the assessment area, the impact categories were well defined.*"

Have you considered the impact on biodiversity?

Biodiversity is not an impact category referenced in certified LCAs: for methodological and compliance reasons, it simply could not be used for the study.

Consistent with the objective and scope of this LCA, ReCiPe was used as an LCIA method in this study, with the following impact categories: Climate Change; Freshwater Eutrophication; Freshwater Consumption; Metal Depletion; Fossil Depletion; Fine Particulate Matter Formation; Terrestrial Acidification; Stratospheric Ozone Depletion; Ionizing Radiation.

What about littering? Have you considered it in your study?

Littering occurs when a waste product is not discarded properly. Potential paper-based or plastic waste leakage through littering into the environment cannot however be adequately addressed by the underlying methodological possibilities of LCA (Federal Environment Agency Germany 2019). Therefore, littering is not included in the study.

3. Questions related to the multiple-use system

Is the multiple-use system representative of reusable systems in restaurants, cafes and public events?

As detailed in the previous answer, the analysed systems are representative of those utilised in Quick Service Restaurants. This means that the inherent features of the analysed systems are valid in the specific context of QSRs, **as detailed in section 3.2.1 of the full report**.

In accordance with the Goal and Scope of the study, and in order to build up a reliable functional unit, typical types of servings and items utilized in QSRs were retrieved from QSR operators, manufacturers and relevant scientific literature, **as detailed in section 3.2.1 and Appendix 3 of the full report**.

Moreover, note that the study respects specific data quality requirements, including those related to time-related coverage: primary datasets and inventories are not older than 2018. Crucial life cycle stages and processes refer to the most recent literature or otherwise publicly available information at the time of writing, and have been discussed with market experts in order to ensure applicability. At the time of modelling, latest available secondary data were implemented for background processes.

Nonetheless, the study adheres to attributional LCA approach, defined as "aiming to describe the environmentally relevant physical flows to and from a life cycle and its subsystems", whereas any assumption based on future scenario could be considered as a consequential LCA, which is "aiming to describe how environmentally relevant flows will change in response to possible decisions"[4] and is out of scope of this study. Any possible future scenarios, including change of type of servings and tableware within QSRs industry, are out of scope, as well as unpredictable at the time of developing the study.

Finally, a specific sensitivity analysis has been carried out to evaluate the utilisation of an alternative multiple-use set combining PP, ceramic, glass and steel. The results of this sensitivity scenarios show that, compared to the baseline, environmental impacts for MU system in certain impact categories can be slightly reduced or remain equal, while in other impact categories the impacts increase significantly. **In general, the relative difference between SU and MU system results remains stable throughout all impact categories**.

For multiple use, how many number of reuse have been taken into account?

The number of reuses has been considered according to literature standards and tableware suppliers' data: 100 times for polypropylene ("PP"), 250 and 500 times for ceramic and tableware glass, and 1000 times for metal.

It should be noted that these figures could be also considered as conservative since some full-scale experiences implemented in France have shown for PP tableware reuse rates in the range 30 to 50, mainly due to high quality standards of packaging required by QSR operators.

[4] Source: https://www.intechopen.com/chapters/69212

Washing is a hotspot of the study: what assumptions have you taken?

The washing phase is modelled by including washing and drying of multiple-use items after use in QSRs. The following key assumptions are made for the baseline scenario of the multiple-use system:

- Data for water, energy, detergent and rinse agent demand (per item basis) were retrieved from literature to build-up a reasonable average scenario reflecting different grades of devices' efficiencies. To this aim, two types of industrial dishwashers are considered suitable to be used (and installed) in QSRs in an in-house washing scenario: **undercounter and hood-type dishwashers**. These dishwashers differ in terms of washing capacity, cycle time, dimensions, drying function, energy consumption, water use, and detergent and rinse agent use.
  Note 1: **The energy demand used in the study has been benchmarked, and according with the results of the benchmark it is comparable with the energy consumption of industrial dishwashers for plastic cups** (confidential data from dishwashers' producers).
  Note 2: according to ADEME[5] (the French environmental agency), **this study is the only LCA considering the drying phase needed after washing** (representing 30% of the energy consumption).
- Average rewashing rate for all items of 5% is considered – this assumption is made to avoid persistent residues that might remain after washing (Antony and Gensch, 2017); however, the exact rate will depend on organisational structures in a QSR (e.g. time between serving of dishes and washing; pre-rinsing of dishes by hand);
- State-of-the-art detergent and rinse agent compositions are assumed.
  Details are provided in Table 20 of the full report.

According to the critical review statement issued by TÜV, "*The main processes in the individual areas were modelled realistically. The data sources are based on generally accepted files or are primary data from the industry, e.g. paper producer or washing machines, they are comprehensible and representative as regards this Life Cycle Assessment. The data basis is extremely comprehensive. The data can be understood and traced*."

Have you considered external washing?

External washing is considered in the sensitivity analysis as performed with highly efficient dishwashers. This sensitivity analysis scenario shows that:

- **the baseline scenario of the single-use-system still presents advantages in different impact categories** (such as Climate Change, Fine Particulate Matter Formation, Fossil depletion, Freshwater Consumption, and Terrestrial Acidification), also due to the additional environmental impacts associated with the transport of multiple-use items between the QSR and the service provider performing the washing process.
- For the remaining impact categories, the environmental benefits of the multiple-use system are increased due to optimised washing.

The relative impacts variation for the external washing scenario compared to the baseline are available in the full report.

[5] ADEME Réemploi & Plastique_Fiche EPPA_20210909 (see link to the document p.1)

Did you consider the production of dishwashers in the study? What is the effect of this production on the results of the study?

Production of simplified dishwashers is considered (generic assumption of two additional devices to be installed inside a QSR to perform in-house washing; ten-year lifetime of the dishwasher): list of materials is based on bill-of-materials (cut-off approach for processes with relative weight <1%) reported in Porras (2019).

This has been done in order to ensure that all relevant differences between the two systems were taken into account in the system boundaries of the study. For instance, all other infrastructure (production sites, QSRs, waste management and treatment facilities) are excluded from the considered system boundaries, since they can be deemed equal for both single-use and multiple-use systems, thus their inclusion in the study would have led to no differences between the systems. **Details are available in section 3.1.3 of the full report.**

Nonetheless, results of the study show that the impacts related to dishwasher production are totally negligible and have no effect on the multiple-use system.

4. Questions related to End-of-Life

How is the End-of-Life considered in the study?

In order to have the most reliable and fair approach, an extended analysis has been conducted related to the End-of-Life phase.

All wastes are generated and discarded within the QSRs, thus the analysed system is equivalent to a Business-to-Business: such systems are generally recognised to have better waste management, including collection and separation, compared to household/municipal waste stream. Then, waste collection phase may be deemed as not of concern for both SU and MU systems.

Regarding recycling rate of waste streams, and considering the perimeter of the Study (EU average), the main publicly available source is **Eurostat**[6], that refers to overall packaging waste streams (including Paper and Plastic packaging). When considering rates for the SU system, on the one side, Eurostat reports recycling rate for "paper and cardboard packaging" (**82.9%**), but it is clear that this value could be highly affected by cardboard share, which is associated to very high recycling rates, and it cannot be representative for the study. On the other hand, recycling rate for plastic packaging reported by Eurostat (**41.8%**) includes all types of polymers and both commercial/household streams, whose consideration does not completely reflect the context of this study.

Due to the lack of product-specific recycling rates, a symmetrical approach for paper and PP was assumed: this means that hypothetical recycling and incineration share (of 30% and 70%, respectively) were assigned to the treatment of both SU and MU items. These figures considered the followings:

1. Conservative approach: low recycling rates might be more penalizing for paper.
2. Fair comparison: using the same assumption to each system.
3. To maximize transparency, recycling and energy credits are disclosed separately in the LCA.
4. **Sensitivity analyses were undertaken for 0% recycling and 100% incineration with energy recovery and for 70% material recycling and 30% incineration with energy recovery for both systems**.

Results about End-of-Life phases highlighted the following:

- Different EoL recycling rate in general have minor effects on results of MU system (0%, 30% and 70% were tested for both systems).
- Higher recycling rate (i.e., 70%) reduces impacts for SU system mainly in the following impact categories: fine particulate matter, freshwater consumption, freshwater eutrophication, ionizing radiation, terrestrial acidification
- **In general, implementing different EoL recycling rates does not alter significantly the overall comparison of the two systems**.
- Although the baseline has been investigated using the "system expansion" approach, results have also been tested using the so-called "cut-off" approach in the sensitivity analysis when

[6] https://ec.europa.eu/eurostat/databrowser/view/ten00063/default/table?lang=en

credits from system expansion are not accounted for. The comparative assertion between both systems is quite stable, despite altering the allocation approach.

Which data have been used for the End-of-Life stage of single-use items?

The following key assumptions are made for the treatment and disposal of **single-use items** after they reach their end of life in QSRs:

- Product waste is collected and sorted at QSRs and transported over a distance of 100 km to a waste incineration plant or recycling facility;
- **30% of paper waste material fractions are materially recycled by means of state-of-the-art recycling processes**. This has been modelled by using primary data: (e.g., energy consumption, water consumption, material consumption, emissions and waste) **reported in Appendix 3 of the full report**. The quantitative figures are covered by confidentiality, but all the processes and flows are disclosed, including water consumption.
  Environmental credits associated with the avoided production of virgin pulps are entirely attributed to the system. To this end, it is assumed that 53% from the obtained recycled pulps substitute chemical pulp (i.e., sulphate and sulphite pulps) and the remaining 47% substitute mechanical pulp (i.e., TMP and CTMP).[7]
- **70% of paper waste material fractions as well as all PE from coating associated with certain single-use products within the system are entirely incinerated with energy recovery. Environmental credits associated with the avoided provision of average electricity from grid and thermal energy from natural gas in the EU-28 are entirely attributed to the system**;
- Other minor constituents of the single-use waste products (e.g., inks, glue) are neglected during the EoL treatment. Hence, no environmental impacts or credits are accounted for;
- Corrugated board wastes from packaging of single-use products to the QSRs are modelled according to background data adhering to a cut-off approach and thus the eventual recycling of such wastes is already taken into account;
- PE waste from dispatch packaging occurring at QSRs is assumed to be incinerated with energy recovery. Environmental credits associated with the avoided provision of average electricity from grid and thermal energy from natural gas in the EU-28 are entirely attributed to the system;
- Paper waste from dispatch packaging (only relevant for wooden cutlery sets) occurring at QSRs is assumed to be materially recycled.

Details are available in the full report in section 3.2.2.4.

[7] This assumption is based on primary industry information as it is likely that recycled pulp is replacing more mechanical pulp than chemical pulp than the average market shares (chemical pulp 75% and mechanical pulp 25%) would suggest (https://www.cepi.org/wp-content/uploads/2020/07/Final-Key-Statistics-2019.pdf). The assumed split between chemical and mechanical pulp to be replaced is further based on the circumstance that the technical properties of recycled fibres are closer to mechanical pulps and in many products that eventually use recycled pulps, the used virgin pulp is mechanical pulp. To the aim of the study, also other industry statistics have been analysed to use the most reliable data available (According to industry data (https://www.cepi.org/wp-content/uploads/2020/07/Final-Key-Statistics-2019.pdf) the sulphite pulp share makes up about 4% of the total chemical pulp production in 2019.)

Which data have been used for the End-of-Life stage of multiple-use items?

The following key assumptions are made for the treatment and disposal of **multiple-use items** after they reach their end of life in QSRs:

- Items are separately collected and disposed of in dedicated containers in QSRs (without implications for environmental impacts);
- Items are expected to be transported by waste collection company from QSR to waste treatment facility (100 km transport distance via lorry is assumed);
- End-of-life treatment: In order to facilitate a symmetric comparison with the single-use system **30% of the PP is assumed to be recycled** in the baseline scenario (material recycling of pure plastic fractions with the aim of substituting primary material), **and 70% of PP as well as acrylic are incinerated with energy recovery (electricity and thermal energy provision in the EU)**;
- Sensitivity analyses are performed with 0% recycling (100% incineration) and 70% recycling (30% incineration), respectively;
- Packaging waste (upstream for transport from manufacturing to QSR) is sent to incineration with energy recovery.

Details are available in the full report in section 3.2.2.5.

How did you choose the End-of-Life allocation approach?

Allocation of burdens represent the process of assigning to each of the functions of a multiple-function system only those environmental burdens and impacts that each function generates (Azapagic and Clift, 1999). This represents a methodological aspect well known to LCA practitioners and widely discussed in sectoral scientific literature.

Allocation on the product system level adheres to the ISO hierarchy (Hauschild, 2017), described in the full report. A prominent allocation issue in relation to the analysed product systems is the handling of End-of-Life treatment processes (Hohenthal, Leon, et al., 2019). Hence, where (intermediate) products have both recycled content and outputs for recycling or recovery, it is necessary to apply consistent allocation procedures. According to the ISO hierarchy, system expansion (i.e., avoided burdens approach) is the preferred approach for solving multifunctionality in certain end-of-life scenarios (e.g., open- or closed-loop recycling, incineration with energy recovery) (Hauschild, 2017).

More specifically, material outputs from recycling processes are credited based on the assumed reduced requirement of virgin material production. Similarly, incineration of some materials in the EoL stage produces heat and electricity, which is credited using average energy equivalents (e.g., energy mix from grid) based on the assumption that respective primary energy generation is substituted. Since this approach should be used wherever possible, and system expansion is arguably always possible in recycling cases, the ISO standard advices against all other methods (e.g. cut-off or recycled content approach) in this regard. **More details are available in section 3.1.3.1 of the full report.**

In addition, we conducted an extended analysis of alternative approaches, in order to confirm further the best-fitting one to the conducted LCA study.

For instance, among the several analysed literature sources, the comprehensive paper by Ekvall et al. (2020) describes and compares the remarkable number of twelve End-of-Life allocation methods, assessing them against ten different criteria, and assigning a score for each criterion.

The study shows that all the methods present benefits and drawbacks, but to different extents. The method chosen for the conducted LCA study (system expansion/avoided burden method, also termed as “allocation to material losses”), may be deemed as one of the most appropriate and best-fitting for the conducted LCA, since it is one of those with the highest overall scoring for all the assessed criteria.

Finally, two variants of the allocation of credits resulting from energy or material recovery have to be considered in order to fulfil the ISO 14040/14044 standards. This has been ensured by a sensitivity analysis where a different allocation approach was tested for both systems. Specifically, a 50:50 allocation approach is applied to both systems (i.e., instead of assigning the full credits, only 50% of the calculated credits are attributed to either of the system). This sensitivity analysis is particularly important if the hypothetical effect of environmental credits affects the compared systems in different ways, as is a natural characteristic of comparisons between single-use and multiple-use product systems (Antony and Gensch, 2017; Federal Environment Agency Germany, 2019).

This sensitivity scenario shows that, while the different allocation approach affects the single-use system more due to the larger material fractions involved, **the relative significance remains stable throughout all impact categories when compared to the baseline scenario** of the multiple-use system. **More details are available in section 3.3.2.7 of the full report.**

Is landfill taken into account?

The baseline scenario comparing single-use paper-based tableware with polypropylene multi-use tableware does not take landfill into account, but 30% recycling and 70% incineration for both systems (explained above).

Other hypotheses of recycling rates are also evaluated through sensitivity analysis (explained above).

Ceramic and glass items are assumed to be landfilled after they reach their End-of-Life (after 250 or 500 reuses). Landfilling is considered a realistic End-of-Life scenario as ceramic is very rarely recyclable and tableware glass is currently not recyclable (opposite to bottle glass).

Nonetheless, it should be noted that, for the conducted LCA, the end-of-life (EoL) stage is not a main environmental hotspot. In fact, when changing the assumptions around EoL (see previous question for details), the relative difference between SU and MU system results remains stable throughout all impact categories. Therefore, and considering also that the study assumes a symmetrical approach for the EoL assumptions of the two systems, **the inclusion of landfilling in the study might have a limited effect**.

5. Questions related to water consumption

What are the main drivers of water consumption?

For the *Freshwater consumption* impact category, both direct and indirect impacts have to be taken into account.

It shall not be confused direct water consumption as Life Cycle Inventory data (i.e., direct consumption data) and impacts on the Freshwater Consumption category, which is instead a Life Cycle Impact Assessment result influenced by all the consumption data used (energy, materials, water) that thus considers the indirect effect associated with upstream processes contributing to the overall water footprint.

Based on the critical interpretation of the results, **indirect impacts are predominant mainly due to upstream processes of electrical energy production**.

For example, potential environmental impact in the *Freshwater consumption* category associated to the European electricity grid mix, are mainly driven by many indirect upstream processes, such as nuclear electricity production in pressure water reactors, or in electricity production by hydro power plants, or in heat and power co-generation power plants (source: documentation of Ecoinvent 3.8).

For this reason, the geographical scope of the study (and thus the considered energy mix) can have an effect on the results, mainly due to the upstream energy production processes.

What are the main results in terms of impacts in the Freshwater consumption category?

Here below an overview of results of this impact category is reported. However, results for the Freshwater consumption category and all other impact categories are **available in the full report in section 3.3**, together with the charts for an intelligible interpretation of results and comparison between the two analysed systems.

Single-use system

Paper manufacturing and electricity demand for converting and the paper incineration process are significant contributors in the baseline scenario of the single-use system. Despite the relatively high impact from the actual incineration process, freshwater consumption credits associated with energy recovery and recycling more than outweighs these impacts.

Multiple-use system

The main contributor to freshwater consumption in the baseline scenario of the multiple-use system is the water demand of the washing process. However, the net effect is rather small as most of the water is only used temporarily and made available again through a wastewater treatment process (for details about the methodology, **please see section 3.4.2.1 of the full report**). Other significant contributions to freshwater consumption arise again from electricity demand of the washing process and upstream items production as well as from chemicals production for the washing process.

Within the use phase, the indirect impacts related to electricity demand represent 90% of total impacts on Freshwater Consumption category. For the explanation, please see previous question.

Did the LCA considered the water consumed during the production and the recycling of paper and paper-based packaging? Where can we find the data in the LCA?

Being this a Life Cycle Assessment study, it takes into account the consumption of water, materials, energy and any other consumption data associated with any life cycle stage included in the analysis. With specific reference to water consumption related to the production and the recycling of paper and paper-based packaging, it has been included as primary data and accordingly documented in the full report. Specifically, data associated with paper production and paper recycling are reported in **Appendix 3 of the full report**. The quantitative figures are covered by confidentiality, but all the processes and flows are disclosed, including water consumption.

6. Questions related to sensitivity analysis

What are the sensitivity analyses?

"Sensitivity analysis" is standard practice for LCA studies and allows to assess the robustness of results and their sensitivity to uncertainty factors, enhances interpretation of results and determines whether data quality needs to be improved.
In total 12 sensitivity analyses were completed:
For the single-use system:

1. **different recycling rates of paperboard (0% and 70%).**

For the multiple-use system:

2. **different recycling rates of polypropylene (0% and 70%);**
3. **a varied demand for items (30% higher, 30% lower);**
4. **an alternative "traditional" set of items including ceramic, tableware glass and metal; the specific composition of each item is reported in section 3.3.2.6 of the full report.**
5. **an optimized washing scenario** using only hood-type dishwasher with higher efficiency. The relative differences of the energy, water and chemicals demands between baseline scenario and the optimised washing scenario are:
    - Energy demand [kWh/item]: equal to 52% of the baseline scenario value.
    - Water demand [l/item]: equal to 25% of the baseline scenario value.
    - Combined detergents and rinse demand: equal to 40% of the baseline scenario value.

   Absolute values are available in section 3.3.2.4 of the full report.
6. **an external washing with band-transport dishwasher**: items are assumed to be collected and transported to external washing facilities after each use. Washing and rinsing at the service-provider takes place using a band transport dishwasher, and it is assumed to represent best-available-technique (BAT). Information is provided by Profimiet, and data is reported for PP cup washing in the year 2020, including a dedicated drying module to achieve highest hygiene standards.
   The relative differences of the energy, water and chemicals demands between baseline scenario and the optimized washing scenario are
    - Energy demand [kWh/item]: equal to 33% of the baseline scenario value.
    - Water demand [l/item]: equal to 20% of the baseline scenario value.
    - Combined detergents and rinse demand: equal to 18% of the baseline scenario value.

   Further underlying key assumptions for this scenario can be summarized as follows:

- Additional transport to and from service provider is assumed to be 100 km (via lorry);
- Additional weights for packaging using reusable racks are accounted for;
- Production and disposal of racks for transport is excluded;
- Dedicated service providers with respective equipment in place are existing and therefore no new dishwashers need to be produced and installed ;

All other assumptions of the baseline scenario (e.g. reuse rates of multiple-use items) remain unchanged.

More details are available in section 3.3.2.5 of the full report.

Finally, for both systems a different allocation of End-of-Life approach using the "cut-off" method was evaluated.

According to the critical review statement issued by TÜV, "*Numerous sensitivity analyses are carried out. Seven are referred in the study. In order to verify the possible predictions, calculations regarding sensitivities and the associated parametering were performed at the client's premises. There were no indications that further sensitivity calculations were needed at the moment*".

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