STUDY REPORT

COMPARATIVE LIFE CYCLE ASSESSMENT (LCA) STUDY OF TABLEWARE FOR ALIMENTARY USE

Disposable dishes in PP, PS, PLA, cellulose pulp and reusable porcelain dishes

Disposable drinking cups in PP, PS, PLA, PE laminated cardboard and reusable glass cups

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REVISION HISTORY		
Revision	**Date**	**Description of the modifications**
0	30/05/2015	First issue
1	12/06/2015	Transposition of findings emerged from SGS Critical Review - phase 1
2	19/06/2015	Transposition of findings emerged from SGS Critical Review - phase 2
3	24/06/2015	Finalisation of the LCA Report with the inclusion of SGS Critical Review Report

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Table of contents

The present version of the LCA Study Report does not contain Annexes 1 and 2, which were omitted upon the request of the Contractor, since they contain sensitive information and data that are strictly confidential. The present report, intended for external communication, has been subjected to a Critical Review and considered has having self-supported content even in the absence of the above-mentioned annexes (see section "External Communication" of Critical Review report, chapter 5).

Introduction

The present LCA study has been carried out by Pro.mo, an Industry Group consisting of the companies operating in the disposable plastic tableware production sector, and belonging to the Rubber Plastics Federation adhering to Confindustria.
The group consists of 6 Italian companies (Aristea Spa, Dopla SpA, Flo SpA, Ilpa SpA, Isap SpA, and Tim Monouso SpA), and can be considered as being representative of the national production of disposable plastic tableware, covering about 80% of the turnover of the sector.
The main purposes of Pro.mo are the protection of the industry image, and the deepening and the dissemination of economic, social and environmental information related to this product category.

In order to achieve these goals, among other initiatives, Pro.mo supports demonstrative activities involving the collection and the valorisation of disposable tableware used in the so-called "mass catering", and awareness raising activities related to consumers' environmental education. In addition, the Group is engaged in promoting and supporting scientific studies on disposable plastic tableware, its use and end of life.
The latter is an area of activity of the utmost importance: as a matter of fact, product environmental impacts in general, and of disposable plastic tableware in particular, are a matter of strong interest also for public administrations (European, national and local), despite the lack of objective data on the matter.

Since 2012, Pro.mo has been adopting a Life Cycle Thinking approach, in order to acquire greater knowledge and awareness of the environmental impact related to the product category manufactured by the adhering companies.
For the purposes of the present LCA study, all Pro.mo Group companies supplied data and information on the production of disposable tableware in polymeric materials, and declared their availability to share data on a new production technology for the manufacture of the same cellulose pulp made items (details in paragraph 2.2.3).
As mentioned above, Pro.mo Group represents almost all the operators in the sector, hence the present study amounts to a sector study, and provides a comparison with products with a similar use from other production sectors (e.g., reusable tableware).

The present report describes the comparative Life Cycle Assessment (LCA) study of tableware for alimentary use by following a Cradle-to-Grave approach. The analysis has been applied to two types of tableware, that is flat dishes (PP, PS, PLA, cellulose pulp disposable dishes and reusable porcelain dishes) and cups (PP, PS, PLA, PE laminated cardboard disposable drinking cups and reusable glass cups).
The life cycle assessment was performed in accordance to ISO 14044 and 14040, by following the path including the goal and scope definition, the inventory analysis (LCI), the impact assessment (LCIA) and the interpretation of results.

The study is based on the most current reference standards (for both LCA methodology and waste management) and takes into account the indications supported by Pro.mo Group with regard to the end of life of disposable tableware. Moreover, environmental indicators are evaluated through the most updated and globally widespread calculation methods, including the method used by the new scheme of the European Commission (PEF methodology) that is currently under development.

The software SimaPro v8 and the database Ecoinvent 3.1 have been used for the analysis. Disposable plastic tableware primary data, directly acquired at the production plants of one of the companies of the

Group, have also been used. These plants have been identified, after a validation conducted on statistical bases, as being representative of the Group production of disposable tableware.

The LCA study will undergo a Critical Review for the verification of its compliance with the methodologies and the principles contained in the standards ISO 14040 and ISO 14044.
The Contractor of the study has appointed an independent Third Party to conduct the Critical Review of the LCA study, renouncing to entrusting a committee of interested parties with the review (as envisaged by the point 6.3 of ISO 14044). The choice of appointing a Certifying Body ensures, in fact, the full compliance with the principle of independence, and the review procedure to be carried out by expert and qualified reviewers.

1. Goal and scope definition

1.1 Goal of the study

1.1.1 Reasons motivating the conduct of the study

The main goal of the study commissioned by Pro.mo is to acquire knowledge and quantify the environmental impacts generated during the whole life cycle of disposable tableware, which is the product category manufactured by the adhering companies. Moreover, the study is also a comparative analysis between the environmental performances of tableware for alimentary use produced with different materials, including reusable tableware made from durable materials.

In support of the research and dissemination activities realised by Pro.mo, the present comparative Life Cycle Assessment study has the goal to contribute to the acquisition of knowledge that could, on the one hand, facilitate the companies of the Group in their strategies and business policies aimed at reducing as much as possible the environmental impact of their products and, on the other hand, be useful to the interested parties for a greater understanding of the issues related to the life cycle of the products under study, and of the connected environmental impacts.
Under a different point of view, and coherently with Pro.mo spirit applied to its operative mode, the study is a contribution to the debate on environmental issues, a step on the path of improvement for the companies involved, and a starting point for further studies.

The LCA study covers two different types of tableware - flat dishes and cups - taking into consideration the following alternatives:

DISHES	CUPS
Disposable made of polypropylene (PP)	Disposable made of polypropylene (PP)
Disposable made of polystyrene (PS)	Disposable made of polystyrene (PS)
Disposable made of polylactic acid (PLA)	Disposable made of polylactic acid (PLA)
Disposable made of cellulose pulp	Disposable made of (PE) polyethylene laminated cardboard
Reusable made of porcelain	Reusable made of glass

Tab. 1.1 - Products included in the comparative LCA study

1.1.2 Intended applications and target audience

The results of the present LCA study will be shared within Pro.mo Group, providing useful information to understand the potential environmental impacts associated with the products under study, and ensuring a reliable comparison between different alternatives.

The present LCA report will also become the reference document for the preparation of a summary report to be used for environmental communication purposes that will be established, depending on the Contractor's decision, starting with the certified parts of the present study, in compliance with the Fifth Chapter of ISO 14044 (see disclosure guidelines in paragraph 4.3.3.).

Therefore, recipients are both internal and external to the group. Externally, the results of the study may be used to support comparative assertions intended for the public, once they have been subjected to the Critical Review process, according to the provisions of the standards ISO 14040 and ISO 14044.
Given the characteristics of the product, which is intended to contain food and is currently used in mass catering, the study in its full version is addressed not only to Pro.mo associated companies, but also to legislators, administrators and technical referents within the public administration, as well as, more generally, to the stakeholders committed to environmental issues.

To this end, environmental communication will be conducted according to the principles defined in the standard ISO 14063, hereinafter listed:

- **Transparency**: make the processes, procedures, methods, data sources and assumptions used in environmental communication available to all interested parties, taking account of the confidentiality of information as required. Inform interested parties of their role in environmental communication;
- **Appropriateness**: make information provided in environmental communication relevant to interested parties, using formats, language and media that meet their interests and needs, enabling them to participate fully;
- **Credibility**: conduct environmental communication in an honest and fair manner, and provide information that is truthful, accurate, substantive and not misleading to interested parties. Develop information and data using recognized and reproducible methods and indicators;
- **Responsiveness**: ensure that environmental communication is open to the needs of interested parties. Respond to the queries and concerns of interested parties in a full and timely manner. Make interested parties aware of how their queries and concerns have been addressed;
- **Clarity**: ensure that environmental communication approaches and language are understandable to interested parties to minimize ambiguity.

A further intended application envisages the use of the LCA tool to identify the most beneficial solutions, from an environmental viewpoint, related to tableware end of life scenario, also in view of the most recent directive on packaging.

Please note that the results contained in Annex 1 of the study report are for internal use only, since they use computational approaches that are not admitted by the reference models for comparative environmental claims.

1.2 Scope of the study

1.2.1 Function, functional unit and reference flow

The scope of the LCA must clearly specify the function of the system(s) under study.
The function of the systems under analysis is to contain meal, in the case of dishes, and to contain a beverage, in the case of cups.

The functional unit is represented by 1000 tableware uses to contain a meal in the case of dishes, and to contain 200 ml of beverage in the case of cups.

Once the functional unit has been defined, it is necessary to determine the reference flow in each product system, in order to meet the intended function, i.e. the amount of product necessary to fulfil the function. The following tables report the reference flows related to each system under study.

DISHES		
Type	**Reference flow**	**Weight (1 item)**
Disposable made of polypropylene (PP)	1000 items	15 g
Disposable made of polystyrene (PS)	1000 items	15 g
Disposable made of polylactic acid (PLA)	1000 items	16 g
Disposable made of cellulose pulp	1000 items	18 g
Reusable made of porcelain	1 item*	470 g

Tab. 1.2 – Reference flow for the different types of flat dishes

* for the porcelain dish, within the LCA study, the washing necessary to make the dish reusable will be considered (for a total of 1000 washings).

CUPS		
Type	**Reference flow**	**Weight (1 item)**
Disposable made of polypropylene (PP)	1000 items	6 g
Disposable made of polystyrene (PS)	1000 items	6 g
Disposable made of polylactic acid (PLA)	1000 items	6 g
Disposable made of polyethilene laminated (PE) cardboard	1000 items	6 g
Reusable made of glass	1 item*	190 g

Tab. 1.3 – Reference flow for the different types of cups

* for the glass cup, within the LCA study, the washing necessary to make the cup reusable will be considered (for a total of 1000 washings).

The introduction of the reference flow to meet the pre-set functional unit is essential in this type of comparative study, since it compares disposable tableware and durable reusable tableware that need a washing phase. In fact, for the latter, the use phase is also considered (whereas it is not applicable to disposable tableware).

It is particularly complicated to assess the duration of the reusable tableware, since the decision to destine a porcelain dish or a glass cup to the end of life phase is completely subjective, and depends on the subjects in charge with the management of the catering activity. The choice is primarily influenced by economic factors, which in the previously assumed mass catering scenario (see assumptions in par. 1.2.8.) are of the utmost priority, regardless the technical features of the dish and the cup.

However, technical considerations should be applied to account for the wear of materials and, particularly, for the wear of the superficial layers of the tableware that, in the case of both the dish and the cup, makes the material porous. Porosity is considered a risk factor for food safety since it allows the formation of a bio-film on which pathogenic bacteria can easily reproduce. In the case of mass catering, it is of the utmost importance to avoid the formation of bio-films and to keep the surfaces intact and non-porous. In this regard, a series of studies of the University of Milan (DISTAM, Prof. L. Piergiovanni) are soon to be published: these studies examined as a realistic life cycle an amount of washings that is much lower than a thousand (as assumed as reference flow in the present study). No other literature data is currently available. Therefore, the reference flows defined for the porcelain dish and the glass cup, 1 piece for 1000 uses, are considered as conservative, as well as respective weights. A sensitivity analysis, given in paragraph 3.4.2 of this report, has also highlighted how the use of a reference flow equal to two pieces instead of one involves a variability that is not relevant for the purposes of the comparison; the most important contribution to environmental impact is, in fact, given by the washing phase of the dish.
The weights of disposable tableware are also conservative, as tableware with the highest strength features has been considered, which requires a greater amount of basic material and, as a consequence, has a larger environmental impact.

1.2.2 System boundaries

System boundaries, as presented in Figure 1.1, include all stages of the life cycle of the products considered from the cradle to the grave (*cradle-to-grave LCA*). In addition to the post-production phases, pre-production and production phases of the various items under study are also included.

Pre-production processes include:

- Extraction and processing of virgin raw materials;
- Cultivation and harvesting of plants (e.g. corn);
- Production of basic materials for manufacture (e.g. polymers, cellulose pulp, mineral fillers)
- Production of basic materials for packaging;
- Production of primary and secondary packaging for the final product;

Production processes include:

- Transport of basic inputs to the production phase;
- Production:
    - Extrusion and thermoforming of dishes made of plastic and cellulose pulp;
    - Folding of cardboard dishes;
    - Melting and moulding of glass tableware;
    - Forming and firing of porcelain tableware.

Post-production processes include:

- Distribution of the final product;
- Use phase (washing of porcelain dish and glass cup);
- Product end of life.

The consumption of energy, water and the production of waste along the life cycle phases are included within the system boundaries.

Fig. 1.1 - System boundaries

The inventory construction for all the phases included in the system boundaries is provided in detail in chapter 2.

1.2.3 Cut-off criteria

The rules of the programs for the development of a certified Environmental Product Declaration, which operate according to ISO 14025, set cut-off levels ranging from 1% to 5 %. In the present LCA study, the applied cut-off value is 2% in terms of mass.

However, in view of the critical aspects of the analysis, it was considered appropriate not to apply the cut-off for all processes in which exact and reliable data have been obtained. Basically, the cut-off value of 2% was applied only to specialities (patent-covered organic molecules) used as additives for disposable tableware.

1.2.4 Allocation methods

The LCA study required the application of allocation procedures for the distribution of energy and water consumption related to thermoforming processes of tableware produced by the Group. For these processes, primary annual data have been used, which were allocated completely to the total production of the reference year (2014). Further details are given in the chapter on the Life Cycle Inventory Analysis.

1.2.5 Methodology for impacts assessment and impact categories

In line with the goal of the study, the internationally accepted impacts assessment methodologies that were considered during the LCIA phase are:

1. **CML-IA baseline**, midpoint method limited to 4 impact categories required for communicative purposes in view of an Environmental Product Declaration EPD (*ref. General Program Instructions of the International EPD System, compliant with ISO 14025*). The method has been chosen as the main reference for the calculation of results, and to carry out all analyses meant to support this calculation (e.g. sensitivity analysis, contribution analysis, etc.). The impact categories taken into account are, in fact, among the most widespread and acknowledged on the international level, thanks to the ever-increasing use of Environmental Product Declarations. They are also among the most effective categories for the communication of the environmental profile of a product;

2. **ILCD 2011 Midpoint+,** midpoint method with 16 impact categories, used by the new PEF methodology of the European Commission. Through the Recommendation 2013 /179/UE of April 9, 2013, the European Commission opened a phase of study and application of common methodologies to measure and communicate the environmental performances of products and organizations. This methodology has been developed on the basis of the International Reference Life Cycle Data System (ILCD) Handbook, as well as on other methodological standards and guidance documents, such as ISO 14040-44. The methodology is currently being tested through a series of pilot projects which are defining specific product category rules (PEFCR). It is important to bring to the attention of the stakeholders the impact categories results, calculated through the ILCD method, by following the European Community approach and anticipating future measures for the reporting of products environmental performance.

The following tables (Tab. 1.4, 1.5) contain the impact categories for both the methods, and the related assessment models, category indicators, and sources.

CML-IA baseline			
Impact Category	**Impact evaluation model**	**Category indicator**	**Source**
Global Warming	Bern Model - global warming potential in 100 years.	CO_2-equivalents [kg]	Intergovernmental Panel on Climate Change, 2007
Photochemical oxidants formation	UNECE Trajectory model	C_2H_4-equivalents [kg]	Jenkin & Hayman and Derwent
Acidification	RAINS 10	SO_2-equivalents [kg]	Huijbregts
Eutrophication	Heijungs Model	PO_4^{3-}-equivalent [kg]	Heijungs

Tab. 1.4 – Impact categories, CML method

ILCD 2011 Midpoint			
Impact Category	**Impact evaluation model**	**Category indicator**	**Source**
Climate Change	Bern Model - global warming potential in 100 years.	CO_2-equivalents [kg]	Intergovernmental Panel on Climate Change
Ozone depletion	EDIP model based on depletion potentials of the ozone layer of the World Meteorological Organization over an infinite time scale.	CFC-11-equivalents [kg]	OMM
Ecotoxicity – freshwater	USEtox Model	CTUe (comparative toxic unit for ecosystems)	Rosenbaum et al.
Human toxicity - cancer effects	USEtox Model	CTUh (comparative toxic unit for human beings)	Rosenbaum et al.
Human toxicity – non cancer effects	USEtox Model	CTUh (comparative toxic unit for human beings)	Rosenbaum et al.
Particulate/smog caused by emissions of inorganic substances	RiskPoll Model	$PM_{2.5}$-equivalents [kg]	Humbert
Ionising Radiation - effects on human health	Effects on Human Health Model	U_{235}-equivalents [kg] (in the air)	Dreicer et al.
Ionising Radiation - effects on the ecosystem	USEtox Model	CTUe (comparative toxic unit for ecosystems)	Garnier-Laplace et al.
Photochemical ozone formation	Model LOTOS-EUROS	NMVOCS-equivalents [kg]	Van Zelm et al., applied in ReCiPe
Acidification	Accumulated Exceedance model	H-equivalents [moles]	Seppälä et al., Posch et al.

Eutrophication - terrestrial	Accumulated Exceedance model	N-equivalents [moles]	Seppälä et al., Posch et al.
Eutrophication - freshwater	EUTREND model	Fresh water: N-equivalents [kg]	Struijs et al. , implemented in ReCiPe
Eutrophication - marine	EUTREND model	sea water: N-equivalents [kg]	Struijs et al. , implemented in ReCiPe
Depletion of resources - water	Swiss model for Ecological Scarcity	use of m^3 of water related to local water scarcity	Frischknecht et al.
Depletion of resources - minerals, fossils	CML2002 model	Sb-equivalents [kg]	van Oers et al.
Land use	Soil Organic Matter model	C [kg] (scarcity)	Milà i Canals et al.

Tab. 1.5 - Impact categories, ILCD method

The methods *CML-IA baseline v. 3.02* and *ILCD 2011 Midpoint+ v.1.05*, both included in the software *SimaPro*, have been used to evaluate impact categories. These methods contain characterization models with the corresponding multiplying factors, and automatically calculate the values for each category.

Appendix 1 of the study report contains the glossary of impact categories of CML and ILCD methods.

With the purpose of providing the Contractor with a comprehensive set of results by using the most updated characterization models, the *IMPACT 2002+* and *ReCiPe Endpoint* methods have also been applied. These methods provide environmental indicators expressed as single score by applying the weighting or conversion and aggregation of indicators results between the impact categories, using numerical factors based on choices of scientific nature.
In accordance with paragraph 4.4.5 of ISO 14044, the results calculated through the above mentioned methods will not be used for communicative purposes to make comparative assertions, as they apply a weighting criteria. Therefore, they are listed in Annex 1 of the present report, and are intended for internal use only. Moreover, they will not be subjected to certification by a third party.

1.2.6 Data type and sources

As prescribed by ISO 14044, the data selected for the LCA depend on the goal and scope of the study. Data can be collected directly in production sites (specific or primary data) and associated to the processes within the system boundaries, or from other public sources or estimates (generic data or secondary and tertiary data). In practice, the inventory can include a set of measured, calculated or estimated data.

For the LCA study under examination, the following types of data have been used:

- **Specific or primary**: data on the production processes of disposable tableware, i.e. the products manufactured by the companies of the Group. Data have been acquired in 2014 directly at the production facilities of one of the Group companies. These plants have been identified, after a validation conducted on statistical bases (see section 2.2.2 and Appendix 2), as being representative of the Group production of disposable tableware. Data relate, in particular, to electric energy consumption, water consumption and the consumption of inputs in the form of raw materials. The use of specific data is limited to the products on which the Contractor has direct control.

  As regard to the dish made of cellulose pulp, primary data were collected in a relocated production plant (Eastern Europe), specialized in the production of cellulose pulp tableware, which is the result of a joint venture formed by some of the six companies of Pro.mo Group (see par. 1.2.8 and 2.2.3);

- **Generic or secondary**: obtained from the database Ecoinvent v. 3.1. These data have been used for pre-production and post-production processes, i.e. for the extraction and processing of raw materials phases, for the production of basic materials and chemicals, for energy production and, in general, for all those processes in which it was not possible to acquire specific data;

- **Tertiary data** obtained from estimates based on similar processes whose data are known, or from literature. This type of data has been used in the absence of specific or generic data.

As regards transports related to the supply of raw materials for the products manufactured by the companies of the Group, a mix of specific and tertiary data has been used (see detail in paragraph 2.2.1).

Further information on the data used in the present study is provided in the next chapter on inventory analysis.

1.2.7 Data quality requirements

A LCA study must specify the requirements on data quality for the goal and scope to be met. Particularly in a study intended to be subjected to comparative assertions, the evaluation of compliance with data quality requirements must be guaranteed.

The data quality of the present study was evaluated on the basis of the criteria defined by the PEF methodology of the European Commission (*ref. 2013/179/EU - Commission Recommendation of 9 April 2013*).

The method represents the most current procedures for data quality assessment in compliance with ISO standards 14040 and 14044, and was applied to ensure the reliability and transparency of results, also in view of external communication.

The quality requirements used for the evaluation are:

- **Completeness**: percentage of resource flows and emissions covered during the inventory phase;
- **Methodological adequacy and consistency**: compliance with the methodological requirements established by the reference standards;

- **Temporal representativeness**: age and update level of inventory data;

- **Technological representativeness**: deviation degree of collected data with respect to the technology that has actually been used**;**

- **Geographical representativeness**: how much data reflect the real situation as regards the geographical location;

- **Uncertainty of parameters**: accuracy and precision of inventory data, in particular those related to direct measures.

Each requirement is given a quality indicator from 1 to 5 (where 1 indicates the highest quality level). The average of indicators (DQR, expressed by the formula below) determines the overall data quality level.

$$DQR = \frac{TeR + GR + TiR + C + P + M}{6}$$

- DQR: quality indicator of data set;

- TeR: technological representativeness;

- GR: geographical representativeness;

- TiR: temporal representativeness

- C: completeness;

- P: uncertainty of parameters;

- M: methodological adequacy and consistency.

Once the overall data quality indicator has been obtained, it is possible to determine the quality level through the matches defined in the following table (tab. 1.6).

Overall data quality indicator (DQR)	Overall data quality level
≤ 1,6	“High quality”
from >1.6 to ≤2.0	“Very good quality”
from >2.0 to ≤3.0(1)	“Good quality”
from >3.0 to ≤4.0	“Satisfactory quality”
> 4	“Low quality”

Tab. 1.6 - Overall data quality indicators based on the obtained data quality indicator

The semi-quantitative assessment was carried out using as a support - in attributing the quality indicator - the data quality matrix reported in the PEF guide (Recommendation 2013/179/UE), i.e. Table 5, "C*riteria for semi-quantitative assessment of overall data quality of life cycle inventories dataset used in the environmental footprint study*". The matrix is given in Appendix 3 of this report.

The data quality assessment has been applied to the two main types of data used, that is to the specific data acquired on the production phase, and to the generic data retrieved in the Ecoinvent database.
According to the PEF recommendation, it is established that data are to be considered compliant when attaining at least a "good quality" level, i.e. a DQR ranging from 2 to 3. Data quality assessment is given in paragraph 2.4.

1.2.8 General assumptions

The comparison between the results of different Product Systems is possible only if the assumptions and the context of each analysed system are explicitly defined and declared within the scope.
Therefore, it is important to specify in a transparent manner the assumptions adopted in implementing the LCA study under examination, so as to make clear from the beginning to the Contractor and third parties authorized to consult the present report the assumptions on which the subsequent phases of inventory analysis and impacts evaluation have been based.
The general assumptions adopted in the present study are listed below:

- The Pro.mo Group consists of companies present mainly in Italy and represents approximately 80% of the Italian market of disposable tableware. For the LCA study, reference has been made to the production of disposable tableware manufactured and marketed in North-central Italy, with the intent of obtaining valid results at a national level;
- As regards reusable tableware (porcelain and glass), which on the Italian market present a substantial import component (e.g. China), a scenario was considered that refers to the production mix at the global level;
- It has also been assumed that disposable and reusable tableware are distributed and used in school /companies canteens, since data arising from collective use are the most structured, allowing a LCA comparative study;
- Pre-production and post-production phases have been entirely modelled using secondary data from the database Ecoinvent 3.1;
- The use of specific data has been extended to the production phase of the items manufactured by the Pro.mo Group companies, i.e. disposable PP, PS, PLA tableware, on which the Contractor has direct control. Data have been acquired directly at the production plants of one of the Group's companies. These plants have been identified, following a validation performed on statistical bases (see paragraph 2.2.2 and Annex 2) as being representative of the Group as regards disposable tableware production. The selection of the representative plant has been made on the basis of its technological mix (thermoforming lines, moulds, general service to productive lines), and due to fact that the plant processes a wide range of polymeric materials (PP, PS, and PLA), and in significant quantities. Moreover, it offers a significant availability of exact data on electrical energy consumption of thermoforming lines, allowing for the collection of direct electrical energy consumption data differentiated on the basis of the raw material that has been used, the type and the weight of the manufactured item.

- As regards the cellulose pulp dish, primary data were collected in a relocated production plant (Eastern Europe) specialized in cellulose pulp tableware production. The plant is the result of a joint venture formed by some of the six companies of Pro.mo Group, and represents the advanced stage of an experiment aiming at industrializing an existing technology in cellulose pulp processing, to adapt it to the forming of disposable tableware. In fact, the products made of cellulose pulp actually present on the Italian market are mainly trays, obtained through different moulding processes of flat sheets, but presenting some critical aspects, such as folds on the edges, with consequent problems related to the strength of the tableware. On the Italian market there are also products made of cellulose pulp imported from the Far East, probably obtained through processes that are similar to the one that Pro.mo Group is now developing in Europe, and that is under examination in this study.

  The primary data acquired in the sample plant, in the particular case of this new technology introduced by the Pro.mo Group, were compared to the technology-characteristic data provided by the manufacturer of the machinery, which correspond to applications that are different from disposable tableware (e.g. eggs containers). Through this processing, data have been obtained, which can be considered representative of the industry of disposable tableware produced in Europe with this specific technology. In fact, current data provided by Pro.mo Group also reflect the state of the art, which is why they have been used as a basis for the LCA study. Further details on the processing used to obtain the data for the LCA modelling of the cellulose pulp dish are provided in paragraph 2.2.3 and in Annex 2.

- In the case of the porcelain dish, the wash in the dishwasher to reuse the dish (school / company canteen use) has been examined. Estimated data (tertiary data) related to water, electrical energy and detergent consumption have been used;

- In the case of the glass cup, it is assumed that wash-related consumption is half the one pertaining to the washing of dishes: the smaller amount of space required by cups in the dishwasher basket means that, in a standard washing cycle, twice the amount of cups - in comparison to dishes - can be washed;

- For disposable tableware, a distribution equal to 400 km on a container to an intermediate storage location and a subsequent transport for 100 km on a light commercial vehicle for the delivery to the canteen have been considered. For reusable (porcelain and glass) tableware, instead, "market" processes of the Ecoinvent database, already containing a default distribution scenario, have been used.

1.2.8.1 End of life scenarios

Among the assumptions adopted, there also are the end of life scenarios used in the LCA study. In fact, different end of life scenarios were defined so as to take into account the variability of final treatments to which tableware is subjected, once its use has reached an end.

The end of life scenarios taken into consideration are the following:

1. **CONSERVATIVE**: this is the most adverse scenario for the disposal of the various items considered in the study, which consists of disposal in a landfill;
2. **TARGET**: this is the scenario identified as the technically viable solution for the disposal of the material at end of life, which refers to the objectives established by the European Directive on waste 2008/98/EC;
3. **REAL**: this scenario was defined for, and applied solely to, the disposal of single-use tableware made of plastics (PP and PS) for which reliable data on packaging end of life solutions were available on a national scale (source: Corepla 2013).

As regards the porcelain dish, for which there is no kind of separate collection, a single end of life scenario has been considered, that provides for disposal in a landfill for inert waste.

End of life scenarios applied to the various basic materials are summed up in the following table:

PLASTIC (PP, PS) Scenario			
	target	**conservative**	**real (Corepla 2013)**
	%	%	%
Recycling	50		38,6
Energy recovery	50		36,8
Landfill		100	24,6
PLA/cellulose pulp Scenario			
	target	**conservative**	
	%	%	
Composting	50		
Energy recovery	50		
Landfill		100	
Polyethylene (PE) laminated CARDBOARD Scenario			
	target	**conservative**	
	%	%	
Ricycling[1]	50		

[1] The materials with the CA marking (symbol of the cardboard joined together with other foil-lined materials, e.g. Tetra Pak) were accepted as recyclable. Details on the matter are also provided by Tetra Pack on the website http://www.tiriciclo.it

Energy recovery	50	
Landfill		100
GLASS Scenario		
	target	**conservative**
	%	%
Recycling	100	
Landfill		100
PORCELAIN Scenario		
	%	
Landfill	100	

Tab. 1.7 - End of life scenarios by type of material

In the LCA study, the benefits due to recycling and energy recovery by incineration have been considered. The "System expansion" procedure has been applied, by calculating the impacts avoided in product systems subsequent to the System(s) under examination.
Benefits derive from avoiding the production of new virgin raw material (as a result of recycling) and of electrical/thermal energy (thanks to waste-to-energy) in new Product Systems.
As regards the PLA and the cellulose pulp, the benefits of the composting activities have not been considered. In this context, composting processes are still based on models that are not currently shared, as proven, for instance, by the Ecoinvent database, which does not provide the identification of avoided products for these processes.
Further to the present study, a sensitivity analysis has been carried out (see paragraph 3.4.2) to assess the incidence on results in case of inclusion of avoided products.

The use of the System expansion approach with the inclusion of credits generated by avoided impacts is due to the necessity of making realistic overall comparison scenarios, in the light of the ever-increasing attention and sensitivity of stakeholders toward issues related to products' end of life. The approach also responds to the principle of responsiveness of environmental communication that envisages for the communication to be open to the demands of the interested parties, by answering completely and quickly to their questions and concerns.

1.2.9 Limitations of the LCA study

The main limitations of the present LCA study are related to the limited use of primary data for the LCA modelling of production processes of the various articles under study, with particular reference to reusable tableware (porcelain and glass), for which specific data cannot be acquired.

This limit is considered overcome, since the main contribution to the various environmental impact categories is borne by the production of basic materials (e.g., polymers) for disposable tableware, and by the washing operations in the case of reusable tableware. For these pre-production and post-production processes secondary data from the same database (Ecoinvent 3.1) have been used: the quality level of these data is such as to ensure a reliable comparison, in accordance with the data quality criteria set in the present study (par. 1.2.7). Details on data quality assessment are available in paragraph 2.4, and additional considerations on limitations are reported in chapter 4 concerning the LCA Study interpretation.

1.2.10 Comparisons between systems

In comparative LCA studies, prior to interpreting the results, the equivalence of the compared systems has to be assessed. As a consequence, the scope of the study must be defined so as to allow the comparison between the systems.

In this comparative study, the equivalence of the systems has been assessed by ensuring the use of common parameters and approaches, that is:

- The use of the same function and functional unit;
- The same performance;
- Equivalent system boundaries;
- The same decision-making procedures for the assessment of inputs and outputs, and for the impact assessment.

As far as data quality is concerned, a series of minimum requirements has been defined (see paragraph 1.2.7) in view of ensuring the reliability of the comparison between product alternatives. However, the use of specific data for the category of disposable tableware produced by the group, allows for higher quality with respect to other tableware types under examination, as confirmed by the data quality assessment carried out in paragraph 2.4. These considerations will be recalled in chapter 4 on Interpretation and taken into consideration when assessing the limitations of the study.

1.2.11 Type of critical review

The results of the present LCA study may be used for communication purposes to make environmental claims, which is why it is necessary to conduct a critical review in accordance with ISO standards 14040/44.

The Contractor of the study has appointed the certification body SGS Italia S.p.A. as the review panel to conduct the Critical Review. The choice to entrust an external body with the review ensures both the compliance to the principle of independence, and the review procedure to be carried out by qualified expert reviewers with specific expertise, including a thorough understanding of the applicable standards.
The critical review will be conducted by the verification body in 3 distinct phases, as described below:

<u>Phase 1</u>: on-site, documentation analysis, LCA studies content control and analysis;

<u>Phase 2</u>: on-site, control of the procedures and methodologies of quantification, data consistency and their implementation;

<u>Phase 3</u>: off-site, Critical Review report writing for each comparative LCA study presented.

1.2.12 Type and format of the report required for the study

The present study report is drawn up in compliance with ISO 14044, in accordance with the minimum content to be included in the Third Party reports envisaging environmental claims for public disclosure.

This document is registered and managed in a controlled manner. Therefore, it is forbidden to deliver to third parties or reproduce this document, to use its content or disclose it to third parties without explicit permission of the study contractor. All rights arising from patents granted for industrial inventions are reserved.

2. Life cycle inventory analysis (LCI)

Data collected for the inventory analysis, in accordance with the scope definition, include specific, generic and tertiary data.

As regards the production of electrical energy, the process related to the Italian MV energy mix production of the database Ecoinvent 3.1 has been used.

The inventory analysis will be discussed in the following paragraphs, considering separately the phases of:

- Basic materials production and packaging (pre-production processes);
- Disposable and reusable tableware production (production processes);
- Products distribution, use and end of life (post-production processes).

A series of observations and assumptions are reported for each phase, for a better understanding of the choices made in the project implemented with the SimaPro software.

2.1 Inputs production and packaging (pre-production processes)

The inventory analysis of this first phase has been conducted using the databases Ecoinvent. In the absence of specific processes, alternative processes have been used, which are related to comparable processes and products, and in which the main phases of the process/product life cycle are considered equivalent.

2.1.1 Inputs production

The basic materials used for the production of disposable tableware can be considered as being commodities; therefore, there are no special distinctions between raw materials used by the diverse companies of Pro.mo Group.
The following is a description of the basic materials, with indications on the databases used for the inventory analysis.

***Polypropylene** (PP)*

Material	Used for	Description	Notes on the database used
Polypropylene (PP)	Disposable dish made of PP Disposable drinking cup made of PP	Thermoplastic polymer that can present diverse tacticity. The most interesting product, from a commercial viewpoint, is the isotactic one: it is a semi-crystalline polymer characterized by high breaking load, low density, and good thermal and abrasion resistance. The density of the isotactic polypropylene is equal to 900 kg/m³ and the melting point is often beyond 165 °C. Propylene originates from cracking processes in refineries and has to be purified from residual water, oxygen,	*Polypropylene, granulated {RER}| production* • Data have been obtained from the eco-profile of the European plastics association PlasticsEurope. • Included activities encompass all processes, from extraction of raw materials up to the production of polymer chips. • Data were collected from 28 plants located in Europe. • Last database update: year 2014.

		carbon monoxide and sulphur compounds that can poison the catalyst. The process takes place at 60-70 °C at a pressure of 10 atm. The isotactic product is recovered through centrifugation, dried and added with stabilizers before being exposed to air. The powder is then extruded into pellets.	

For the production of the disposable dish made of PP, in addition to virgin basic material, a PP compound supplemented with mineral filler (PPCA, 70% calcium carbonate) is also used. A special record has been created in SimaPro for the compound which is commonly used in the mixtures for the manufacture of the dish.

Polystyrene (PS)

Material	Used for	Description	Notes on the database used
Polystyrene (PS)	Disposable dish made of PS Disposable drinking cup made of PS	Thermoplastic aromatic polymer with linear structure. At ambient temperature, it is a glassy solid; beyond its glass transition temperature of about 100 °C, it acquires plasticity and it flows; it starts to decompose at a temperature of 270 °C. The polymerization of styrene is spontaneous, but very slow even at ambient temperature, if styrene does not contain special inhibitory compounds. The polymerization of styrene is a reaction by addition that is often started by products (called initiators) able to produce radicals, such as peroxides, for example. The production takes place according to different modalities, depending on the type of plant and the production volumes involved. Polystyrene is generally sold in the form of small spheres or small transparent chips, suitable to be melted and injected into moulds, or to be processed by calendering in plates for thermoforming or for bonding.	*Polystyrene, general purpose {RER}| production* • Data have been obtained from the eco-profile of the European plastics association PlasticsEurope. • Included activities encompass all processes, from extraction of raw materials up to the production of polymer chips. • Data were collected from 20 plants located in Europe. • Last database update: year 2014.

High impact polystyrene (HIPS)	Disposable dish made of PS	Thermoplastic polymer made of polystyrene and styrene-butadiene rubber (or SBR rubber). With respect to common polystyrene, high impact polystyrene has the following peculiarities, due to the presence of SBR rubber: - increased toughness, i.e. higher elongation at break; - greater resilience, i.e. greater resistance to impact; - slight decrease in resistance to traction; - slight decrease in flexural strength; - slight decrease in the Young's modulus; - slight decrease of hardness.	*Polystyrene, high impact {RER}| production* • Data have been obtained from the eco-profile of the European plastics association PlasticsEurope. • Included activities encompass all processes, from extraction of raw materials up to the production of polymer chips. • Data were collected from 15 plants located in Europe. • Last database update: year 2014.

For the production of the disposable dish made of PS, in addition to virgin basic material, a high impact PS compound supplemented with mineral filler (PSCA, 70% calcium carbonate) is also used. A special record has been created in SimaPro for the compound that is commonly used in the mixtures for the manufacture of the dish.

Polylactic acid (PLA)

Material	Used for	Description	Notes on the database used
Polylactic acid (PLA)	Disposable dish made of PLA Disposable drinking cup made of PLA	Polymer derived from plants such as corn, wheat or beet, rich in natural sugar (dextrose). It exists in two enantiomeric forms (L-D), but it is possible to obtain the crystalline polymer that melts at 180 °C only from the optically active isomer (L). The only way to obtain the optically active form is to resort to the fermentation that produces the isoform L. The preparation steps can be summarized as follows: - Separation of starch from fibres and gluten; - Liquefaction and saccharification of starch; - Fermentation with reuse in the culture broth of the proteic part separated from the starch; - Purification and concentration of lactic acid salt solutions; - Polymerization; Two distinct stages: synthesis by fermentation and isolation of the L-lactic acid, polymerization of the obtained acid. The main properties are rheological, mechanical and of biodegradability.	*Polylactide, granulated {GLO}| production* • The inventory includes LCI data obtained from the LCA report of the manufacturer NatureWorks; • Included activities encompass all processes from cultivation and harvesting of corn plants up to the production of polymer chips; • Data were collected in the largest production plant in the world (NatureWorks); • Last update of the database: year 2014.

Cellulose pulp

Material	Used for	Description	Notes on the database used
Cellulose pulp	Disposable dish made of cellulose pulp	The cellulose pulp is obtained from wood through different processes. However, all processes start from wood trunk or chips, small pieces of wood obtained from the processing of timber by-products. In case the whole trunks are being processed, after being stripped, they get chopped or grounded, to reduce the wood to a suitable size for subsequent processes. The three main production chains of pulp are the sulphate cycle (about 80 %), the sulphite cycle and the semichemical process.	*Thermo-mechanical pulp {RER}| production* • The inventory includes data from a LCA study on cellulose pulp produced in Switzerland and Germany, and from studies carried out by the Swedish Environmental Protection Agency; • The activities include all processes from the cultivation of trees up to the production of the pulp; • Data were collected in various plants around Europe. • Last update of the database: 2014.

PE Polyethylene laminated cardboard

Material	Used for	Description	Notes on the database used
Polyethylene laminated cardboard (PE)	Disposable drinking cup made of PE laminated cardboard	Cardboard suitable for food contact, laminated with a thin layer of polyethylene.	*Liquid packaging board container {RER}| production* • For the LCA modelling of the cardboard cup, a pre-set Ecoinvent process on the production of cardboard containers for liquids has been used. • The inventory includes data from a LCA study on containers manufactured by a Swiss manufacturer of packaging materials; • Raw materials required in the laminated cardboard production are included in the Ecoinvent process, which encompasses also the production and the cardboard lamination stages, and the subsequent cutting, lamination and folding operations to form the cup. • The original Ecoinvent process has been modified by removing the aluminium and glue components (not present in the cup) and increasing the polyethylene content to 10%.

			• Last update of the database: 2014.

Raw materials for porcelain production

Materials	Used for	Description	Notes on the database used
Minerals (kaolin, quartz and feldspar)	Reusable porcelain dish	Porcelain manufacture requires mixtures consisting of more components, usually kaolin, quartz and feldspar. Kaolin confers plasticity and workability to the slurry, while quartz and feldspar reduce shrinkage; the presence of kaolin, which is quite refractory, requires, in order to obtain a sufficient degree of vitrification, high firing temperatures; the feldspar acts as a flux, forming at the firing temperature, along with other components (impurities, part of silica), a molten mass which allows sufficient vitrification at relatively low firing temperatures. The molten mass solidifies and the crystalline components (silica, kaolin processing products) get incorporated into a compact mass.	*Sanitary ceramics {GLO} |market for* • For the LCA modelling of the porcelain dish, a pre-set Ecoinvent process, pertaining to the production of sanitary ceramics, has been used. Specific processes related to porcelain for tableware are not available in Ecoinvent, but the selected substitute process can be considered adequate, since both used raw materials and forming and firing processes are equivalent; • The inventory includes data derived from LCA studies of an European manufacturer; • Raw materials required in the manufacture of the product are included in the Ecoinvent process, which also encompasses the forming and firing phases of the final product; • Data have been collected in 2 Austrian plants; • Last update of the database: 2014.

Raw materials for glass production

Materials	Used for	Description	Notes on the database used
Minerals (silica, calcium carbonate and sodium carbonate)	Reusable glass cup	The basic raw materials used to obtain the vitrifiable mixture, which due to melting and solidification becomes glass, are silica sand, sodium carbonate and calcium carbonate. The sand is the vitrifying raw material and the source of silica (SiO2), and is present in different proportions depending on the glass type, usually around 70-74% for industrially manufactured glass containers. Sodium oxide (Na2O) is used as a flux or as adjuvant substance in the	*Packaging glass, white {GLO}| market for* • For the LCA modelling of the glass, a pre-set Ecoinvent process, pertaining to the production of white glass containers, has been used; • The inventory includes data related to input raw materials derived from literature sources and from production plants across Europe;

		fusion process, in various proportions ranging from 13% to 16% for glass containers. It is added to the vitrifiable mixture through soda - sodium carbonate of industrial origin. Calcium carbonate is used to add calcium oxide (CaO) to the glass, a stabilizer that makes the glass more stable from a chemical and mechanical viewpoint, and affects the viscosity of the molten mixture by shortening the processing time. In the glass composition, it generally represents up to 12-13% of the weight.	Data related to energy, water consumption, emissions and waste production are derived from literature sources; • The raw materials needed in the manufacture of the product are included in the Ecoinvent process, which also encompasses all the container production phases; • Data are based on the EU-IPCC report on the European glass industry; • Last update of the database: 2014.

2.1.2 Packaging production

The inventory of packing materials encompasses both the packaging used to deliver the basic materials to the production site, and the one that has been used for final products.
As regards disposable tableware (e.g. polymers), basic materials are delivered by silo trucks, except for the PLA, which is packaged in octabins with polyethylene bags containing a ton of material. As regards the final products, the primary (polyethylene film) and secondary (cardboard box) packaging have been considered.
For the quantities of packaging materials related to each type of tableware, primary data have been used (Table 2.1).

Product	**PE Film** [kg/kg of product]	**Cardboard, box** [kg/kg of product]
PP Cups	0.0160	0.1067
PS and PLA Cups	0.0160	0.0943
PP Dishes	0.0083	0.0749
PS and PLA Dishes	0.0075	0.0586
Cardboard Cups	0.0160	0.0943
Cellulose Pulp Dish	0.0107	0.1167

Tab. 2.1 - Quantity of primary and secondary packaging for disposable tableware

No specific data is available for reusable porcelain and glass dishes: in these cases, the "market" processes of the Ecoinvent database have been used, since they also provide for the packaging materials consumption for the distribution of the final product.

2.2 Disposable and reusable tableware production (production processes)

The inventory analysis of production processes includes both specific and generic data from the Ecoinvent database.
In the absence of specific processes, alternative ones - related to comparable processes and products - have been used, since the respective main phases of the process/product life cycle are considered equivalent.

2.2.1 Transport of inputs for the production phase

As regards the supply of basic materials for the products manufactured by the companies of the Group, a mix of specific and estimated (tertiary) data has been used. Specific data cover the transport distance of PLA, whose exact origin is known, since there is currently a single production plant in the world (United States). The following transport distances have been considered:

- For PP and PS, a transport distance of 1500 km with silo trucks from Europe to North-central Italy;
- For PLA, the raw material is produced in North America, moved to the coast (1500 km), transported by ship to Rotterdam (6000 km), and again transported by lorry to the site in North-central Italy (1500 km);
- For cellulose pulp, a transport from the vicinity of the production plant has been considered (400Km); in fact, this type of material is commonly obtained in areas close to production sites;
- For the compound with calcium carbonate (PPCA and PSCA), after the compounding there is a second transport from North-central Italy (400km) to supply the "processor" (who carries out the thermoforming), again on silo trucks.

For the supply of basic materials for the glass cup and the porcelain dish, the Ecoinvent database "market" processes, already containing a supply scenario, have been used.
The supply of materials is not reported in the case of the cardboard cup, since usually the cardboard is manufactured and laminated within the same site where the item is manufactured (hypothesis also confirmed by the Ecoinvent database).

2.2.2 Production of PP, PS, PLA plastic disposable tableware.

The examined production process of plastic disposable tableware is the in-line thermoforming process, consisting of the following phases:

- Extrusion: process of plastic material transformation for the production of films, sheets and plates;
- Calendering: the process is carried out by using calenders that crush and cool the sheet or plate after the extrusion, and determine its flatness and thickness regularity;
- Thermoforming: manufacturing process of items through the heat moulding of a sheet or plate on a mould and a counter mould.

In-line thermoforming process differs from simple thermoforming (where the plastic sheet fed from a roll at the inlet of the line is separately manufactured), because the extrusion and the calendering are made directly at the inlet of the thermoforming machine. During the thermoforming process, the plastic sheet is transformed into one to several tens of items in each cycle; 30% to 50% of the sheet material fed at the inlet is not going to be used for the manufacture of an item, and it is called scrap. In these productions processes, the scrap is systematically recovered in line by means of grinding mills that feed directly the hopper of the extrusion line. Hence, specifically, both electrical energy consumption and other information related to its reworking are always included in the data collection of individual production processes.

For PP, PS, and PLA disposable tableware, specific data have been acquired as regards raw materials, water and electrical energy consumption. Primary data have been collected in the production plant of a Pro.mo Group company that uses in-line thermoforming to manufacture its products.

The production plant has been chosen on the basis of its mix of technologies (thermoforming lines, moulds, general service to productive lines), and due to the fact that the plant processes a wide range of polymeric materials (PP, PS, and PLA) in significant quantities. Moreover, the sample plant offers a significant availability of exact data on electrical energy consumption of the thermoforming lines, allowing for the acquisition of direct electrical energy consumption data based on the raw material used, the type, and the weight of the manufactured item. A validation on statistical bases has also been carried out, which shows the representativeness of the sample plant (see annex 2).

The validation was carried out starting from primary data provided by the six companies of the Group, as regards electric energy consumption per kg of finished product, calculated on electricity annual metering. Each company has linked with these data a description of the technologies and materials currently used.
For statistical analysis it is assumed that variability in the consumption of kWh/kg, which distinguishes the different orders of the sample plant (variability within), is comparable to or greater than the variability of the same consumption linked to individual factories of the six companies (variability between). Practically, it is assumed that the mix of items, products and technologies used by the sample plant has a kWh/kg value variability greater than or equal to the variability found between typical kWh/kg values of different Group factories. This hypothesis, if confirmed, would make it possible to conclude that the mix of items and technologies of the sample plant covers certainly the various possible cases which may occur in Pro.mo Group factories and in most companies of the same productive sector.
The validation has proven that the sample plant has an energy consumption with conservative average value, i.e. higher than Group Pro.mo other companies values. This value implies a variability called “productive", which is the double of the "technological" variability presented by companies in the Group, which differ from each other in the solutions used in their plants and factories. The plant sampled is therefore fully representative for this sector technology and it can be taken as reference for experimentation of detailed data collection.

The bills of material for disposable plastic tableware used for the LCA modelling are reported in the following tables. They are representative of the products as used on the Italian mass catering market (see validation in Annex 2):

DISHES		
Type	**Material**	**%**
Disposable made of polypropylene (PP)	Polypropylene	64.3
	PP Compound (70% calcium carbonate)	35.7
Disposable made of polystyrene (PS)	High Impact Polystyrene	56.7
	Polystyrene	7.6
	PS Compound (70% calcium carbonate)	35.7
Disposable made of polylactic acid (PLA)	Polylactic acid	100

Tab. 2.2 - Dishes bill of material

CUPS		
Type	**Materials**	**%**
Disposable made of polypropylene (PP)	Polypropylene	100
Disposable made of polystyrene (PS)	Polystyrene	100
Disposable made of polylactic acid (PLA)	Polylactic acid	100

Tab. 2.3 - Cups bill of material

As regards electrical energy consumption, the plant constantly monitors electrical consumption, which is provided directly to the thermoforming lines for each polymer type.
As regards PLA tableware production, an in-depth analysis on energy consumption has been conducted (see Annex 2, par A5.3), as the development of production lines is still in progress - given the recent introduction of this kind of polymer on the market. In fact, in the last five years the main PLA manufacturer has managed, in partnership with the most significant European tableware manufacturers, a series of industrialization tests to adapt the current thermoforming technologies to PLA. From exact data on consumption of PLA productions collected at the reference plant, there emerged higher electrical energy consumption values than those related to PP and PS, confirming the inefficiencies typically connected to the industrialization phase of new polymers. Pro.mo Group has therefore decided not to penalize PLA using as transformation energy data those relating to PS, which, given the nature of the two polymers, can be assumed as being the target value that will be reached once operation conditions will be brought up to speed.

In addition to this energy consumption, defined as "direct", further consumption is attributed to all-lines generalised support services to the main process (water, compressed air, and vacuum distribution). To assess the contribution of these services to the overall energy supplied to the line, estimates have been rounded up: the consumption values monitored and collected on the thermoforming lines have been subtracted from the overall plant consumption of 2014 (including also the use of offices, lift trucks, warehouses, etc.). The difference obtained has been divided by the total amount of kg produced during the year.

As regards water consumption, estimates have been rounded up: the overall plant consumption of 2014 has been subdivided over the total amount of items produced during the year, expressed in kg.
The following table shows data related to energy and water consumption for plastic tableware production.

	Electrical energy		**Water**
	Consumption [kWh/kg]		Consumption [litre/kg]
	Dishes	Cups	Dishes/Cups
PS	1.42	1.63	2.41
PP	1.68	1.95	
PLA	1.42	1.63	

Tab. 2.4 - Electrical energy and water consumption for plastic tableware production

Ecoinvent databases have been used for the extrusion, calendering, and thermoforming processes: *Extrusion, plastic pipes {RER}| production* and *Thermoforming with calendering {RER}| production*, respectively. The two Ecoinvent processes have been adapted to the production process of plastic tableware, keeping unchanged the input/output structure and entering specific electrical energy and water consumption data for each type of plastic.

2.2.3 Production of cellulose pulp disposable dishes

In the production process of the dishes, cellulose pulp (consisting of fibres of different length and plant origin) is progressively diluted in water until it reaches very low concentrations, which allows for a high relative mobility of the fibres. The liquid obtained is poured in a pre-mould on which most of the water is eliminated; a "film" of fibres, not yet consistent, will form. Subsequently this film is placed in a drilled mould in which, through pressure, vacuum and temperature, the remaining water component is eliminated, so as to obtain a dish with the characteristics that are necessary for use.

As regards the cellulose pulp dish, as already mentioned in paragraph 1.2.8 (general assumptions), primary data have been collected in a relocated factory (Eastern Europe), specialized in the production of cellulose pulp tableware, and resulting from a joint venture formed by some of the six companies of Pro.mo Group. This production plant represents the advanced stage of an experiment aiming at industrializing an existing technology in cellulose pulp processing, to adapt it to the forming of disposable tableware. This approach represents an innovation compared to traditional plants actually present in Europe.
As the process is still at a fine-tuning stage, all electrical energy consumptions are monitored, including those related to auxiliary services: therefore, it has been possible to obtain consistent data onthe entire process. Water consumption is essentially related to replenishment, since the process is a closed-loop one; total consumption has been rounded up to about 1l of water for each 100 kg of dishes manufactured.
Data related to energy consumption underwent a consistency check by comparison with the data plate of the system made available by the manufacturer, which has a solid expertise, on a global level, in the various applications of these technologies. The check showed that the specific data of the plant under examination were significantly higher than the average data of the technology applied in terms of kWh/kg of finished product. It was therefore necessary to include a critical verification of available information, which highlighted that the construction methods of the plant under examination were the main cause of "penalty" in terms of energy consumption. The system was in fact designed to test a specific technology,

already consolidated in the field of some "commodities" (e.g. eggs containers), in the production of goods with a high qualitative criticality, such as disposable dishes and trays for direct contact with the food.
The realisation of the plant - in the function of innovative plant - has led the joint venture of Pro.mo companies to build a line with 50% less production yield in comparison to the standard proposed by the manufacturer, and this limit is clearly the first cause of the overestimated energy consumption data. However, a production yield equal to 50% of the optimal one cannot be the criterion used to readjust the energy data calculation. In fact, the plant design and the services associated with it result in a 50% less productivity that corresponds to only 30% lower energy data, and this is confirmed by the verification between plant specific data and the data supplied by the manufacturer as typical of these technologies. In this study, in order to use the specific data of the plant (at present, the sole operating plant with this technology and on these specific products) as representative of the sector, a validation has been conducted, in view to examine detailed parameters related to these technologies and to concretely realised productions. The validation thus made it possible to obtain data both representative of the sector, and specific for this technology in an application that can be considered at the initial stages of industrialization.
Further details on the validation and processing carried out to obtain the data used in the LCA modelling of the cellulose pulp dish are provided in Appendix 2.

	Electrical energy		**Water**
	Consumption [kWh/kg]		Consumption [litre/kg]
Cellulose pulp	5.78	/	0.01

Tab. 2.5 - Electrical energy and water consumption for cellulose pulp dish production

2.2.4 Production of disposable drinking cups made of PE laminated cardboard

The production process of the cardboard cup consists in cutting to size the laminated cardboard that will form the body and the bottom of the cup, and in folding and assembling the two components by heat welding.

For the LCA modelling of the PE laminated cardboard cup, the Ecoinvent database *Liquid packaging board container {RER}| production* has been used.

2.2.5 Production of reusable porcelain flat dishes

The porcelain tableware manufacturing process starts with the preparation of the slurry from the main minerals (kaolin, quartz and feldspar) by mixing. The next stage involves the forming of the "biscuit" that can occur with various techniques, depending on the type of tableware (e.g. isostatic pressing, bonding in moulds). There follows the thermal treatments that include drying, the firing of the biscuit and the subsequent firing of the applied enamel.

For the LCA modelling of porcelain dish, the *Sanitary ceramics {ROW}| market for Ecoinvent process*, related to the production of sanitary ceramics, has been used. Specific processes related to porcelain tableware are not available in Ecoinvent, but the selected substitute process can be considered appropriate, since both the raw materials used and the forming and firing processes can be considered equivalent.

2.2.6 Production of reusable glass cups

Industrially manufactured hollow glass containers are obtained by blowing the molten material into moulds. The production phases can be summed up as follows:

- Fusion: raw materials, contained in silos, are conveniently measured out, mixed and placed in the melting furnace by means of conveyor belts. The furnace, built of refractory material able to withstand for years the high melting temperatures (1,600 °C), is predominantly powered with methane gas, and self-adjusted in all its functions.
- Forming: the molten liquid at the furnace outlet enters the thermal conditioning channels and, when the appropriate viscosity is reached, gets "cut" in drops having a size and weight proportional to the item to be manufactured. The drop of incandescent glass (1,200 °C) arrives, by guided vertical falling, in the mould of the forming machine.
- Annealing: the forming is followed by the "annealing" phase, a process that allows eliminating stresses in the glass by preliminary heating and subsequent gradual cooling of the item until ambient temperature is reached.

For the LCA modelling of the glass cup, the Ecoinvent process *Packaging glass, white {GLO}|market for,* concerning the production of white glass containers, has been used.

2.3 Products distribution, use and end of life (post-production processes)

The inventory analysis of post-production processes has been carried out using Ecoinvent databases. In the absence of specific processes, alternative ones have been used, related to similar processes and products and whose main phases of the process/product life cycle are considered equivalent.

2.3.1 Distribution of final products

As regards the distribution scenario of disposable tableware, a first transport has been assumed, consisting of 400 km on a container toward an intermediate storage location, together with the subsequent delivery to the point of use (school /corporate canteen) on a light commercial vehicle for 100 km. These distances are considered representative of a typical distribution scenario of this type of product within the territory of North-central Italy.

Specific data have been acquired at one of the Group's companies to determine the product quantities commonly carried on the two types of vehicles.

As regards reusable dishes, for which no specific data is available, "market" processes of the Ecoinvent database have been used, which already contain a pre-set and validated distribution scenario for this type of product.

2.3.2 Use and washing of reusable tableware

Disposable tableware, as such, does not envisage any washing, hence there are no environmental impacts related to the use phase. Conversely, porcelain and glass tableware, in order to be reused, have to undergo washing that commonly occurs in a dishwasher, after a first rinse to remove coarse food remains.

In the LCA model, washing has been accounted for by considering the electrical energy, water and detergent consumption of the dishwasher. The table below reports the data related to the washing of one single piece of tableware, and obtained from the estimates based on technical data of professional dishwashers marketed in Italy by three of the largest manufacturers (sources in the Bibliography). In particular, a hood type dishwasher was considered, with a 50X50 cm basket (16 dishes) and a 120 seconds washing cycle.

Consumption	Unit of measure	Porcelain dish	Glass cup
Electrical energy	kWh	0.015	0.0075
Water	litres	0.25	0.125
Detergent	grams	2	1

Tab. 2.6 - Electrical energy, water and detergent consumption for the washing of one piece of reusable tableware

2.3.3 Products end of life

Disposable tableware is commonly disposed of in the "dry" category of municipal solid waste, and then sent to landfills or incinerators. However, in the recent years the attention toward the end of life of this kind of products has significantly increased, and consumer habits are changing toward a culture that increasingly promotes waste sorting and recovery.

The definition of a single end of life scenario for different tableware is very complicated, which is why this study has envisaged three different scenario options, as previously indicated in paragraph 1.2.8.1.

1. **CONSERVATIVE:** this is the most adverse scenario for the disposal of the various items considered in the study, which consists of disposal in a landfill - *Today, this scenario is no longer representative. In fact, throughout Europe, the alignment to the Directives has significantly reduced the quantity of such materials being disposed of in landfills;*

2. **TARGET:** this is the scenario identified as the technically viable solution for the disposal of the materials at end of life, which refers to the indications on the optimisation of waste disposal as defined in the objectives of the European legislator *(European Directive 2008/98/CE: " by 2020, the preparing for re-use and the recycling of waste materials such as at least paper, metal, plastic and glass from households […], shall be increased to a minimum of overall 50 % by weight);*

3. **REAL:** this scenario was defined for, and applied solely to, the disposal of single-use tableware

made from plastics (PP and PS) for which reliable data on packaging end of life solutions were available on a national scale (source: Corepla 2013).

In the future, in the LCA study, a fourth "IDEAL" scenario could be considered, envisaging the recycling of post-consumption materials within the same production cycle, as hoped for in recent documents "end-of-waste", and as already technically applicable by Regulation 282/2008.

The LCA modelling of waste treatment has been carried out using Ecoinvent databases. The transport distance that has been considered for waste to be sent toward the previously considered various end of life treatments is of 150 km.

The following table reports a description of the databases that have been used, and of related benefits (avoided products) provided by the calculation model for each material involved.

Material	Disposal	Ecoinvent Database	Products avoided (from Ecoinvent)
PP	**Recycling**	*PP (waste treatment) {GLO}| recycling of PP*	1kg PP/kg (per cup) 0.643 kg PP/kg (per dish)
	Energy recovery	*Waste polypropylene {CH}| treatment of, municipal incineration*	Electrical energy: 3.74 MJ/kg Thermal energy: 7.54 MJ/kg
	Landfill	*Waste polypropylene {CH}| treatment of, sanitary landfill*	/
PS	**Recycling**	*PS (waste treatment) {GLO}| recycling of PS*	1kg PP/kg (per cup) 0.643 kg PP/kg (per dish)
	Energy recovery	*Waste polystyrene {CH}| treatment of, municipal incineration*	Electrical energy: 4.51 MJ/kg Thermal energy: 9.05 MJ/kg
	Landfill	*Waste polystyrene {CH}| treatment of, sanitary landfill*	/
PLA	**Composting**	*Biowaste {RoW}| treatment of, composting*	/(*)
	Energy recovery	*Biowaste {GLO}| treatment of biowaste, municipal incineration*	Electrical energy: 0.41 MJ/kg Thermal energy: 1 MJ/kg
	Landfill	*Municipal solid waste {RoW}| treatment of, sanitary landfill*	/
Cellulose	**Composting**	*Biowaste {RoW}| treatment of, composting*	/(*)

pulp	**Energy recovery**	*Biowaste {GLO}| treatment of biowaste, municipal incineration*	Electrical energy: 0.41 MJ/kg Thermal energy: 1 MJ/kg
	Landfill	*Waste paperboard {RoW}| treatment of, sanitary landfill*	/
Cardboard	**Recycling**	*Paper (waste treatment) {GLO}| recycling of paper*	0.9 Kg, cellulose pulp/kg
	Energy recovery	*Waste paperboard {CH}| treatment of, municipal incineration*	Electrical energy: 1.55 MJ/kg Thermal energy: 3.23 MJ/kg
	Landfill	*Waste paperboard {RoW}| treatment of, sanitary landfill*	/
Glass	**Recycling**	*Packaging glass, white (waste treatment) {GLO}| recycling of packaging glass, white*	0.68 kg silica/kg 0.22 kg calcium carbonate/kg 0.16 kg calcium carbonate/kg
	Landfill	*Waste glass {CH}| treatment of, inert material landfill*	/
Porcelain	**Landfill**	*Inert waste, for final disposal {RoW}| treatment of inert waste, inert material landfill*	/

(*) As regards PLA and cellulose pulp, benefits related to composting have not been considered. In this context, the composting processes are still based on models which are not currently shared, as proven, for instance, by the Ecoinvent database, which has chosen not to provide the identification of avoided products for these processes. As an insight, a sensitivity analysis has been carried out within the present study (see paragraph 3.4.2) in order to assess the incidence on results in case avoided products are included.

2.4 Data quality assessment

A data quality assessment has been conducted according to the method given in paragraph 1.2.7 of this report, applied to categories of generic data of the database Ecoinvent 3.1, and to specific data used in the manufacturing processes.

The semi-quantitative analysis was performed by using, as a support in attributing quality indicators, the data quality matrix included in the PEF guide (Recommendation 2013/179/UE). The matrix is also given in Appendix 3 of this report.

2.4.1 Semi-quantitative data quality assessment - Ecoinvent 3.1 Data

2.4.1.1 Production processes of basic materials: PP and PS

	Comments	Assessment results	Quality level	Quality indicator
Completeness	The Ecoinvent database has been built on unitary processes, and ensures high data completeness. Conservatively,	Good completeness (80% - 90%)	Good	2

	a level of completeness ranging from 80% to 90% is assigned.			
Methodological adequacy and consistency	The applied life cycle inventory methods and methodological choices (for instance, allocation, etc.) are aligned to the goal and scope of the data set, and fully compliant with the requirements of ISO 14040 and ISO 14044.	Full compliance to all requirements of ISO standards 14040/44	Very good	1
Temporal representativeness	The use of the latest version of the database (Ecoinvent 3.1), issued in 2015, ensures high temporal representativeness. It is therefore considered legitimate to assign a "good" data quality level.	Good temporal representativeness	Good	2
Technological representativeness	The technology used for polymerization is specified in the Ecoinvent database, and is representative of the European context (processes carried out in Europe, RER) for this type of polymers: PP and PS. The polymers PP and PS considered in the study come from European manufacturers: it is then considered licit to assign at least a “good” data quality level to their technological representativeness.	Good technological representativeness	Good	2
Geographical representativeness	Ecoinvent data have been obtained from the eco-profile of the European plastics association PlasticsEurope, in factories located within the European territory. The polymers PP and PS considered in the study come from European manufacturers, hence their geographical representativeness is considered to be of a "good" level.	Good geographical representativeness	Good	2
Uncertainty of parameters	The measurement uncertainty that the Ecoinvent database, or other used sources, associates to input data or emissions is sometimes rather high, around 20%. It is therefore considered prudent to declare an overall uncertainty between 20% and 30 %.	Acceptable uncertainty, between 20% and 30%	Satisfactory	3

$$\mathrm{DQR} = \frac{2+1+2+2+2+3}{6} = 2 \rightarrow \text{Very good quality}$$

2.4.1.2 Production processes of basic materials: PLA

	Comments	Assessment results	Quality level	Quality indicator
Completeness	The Ecoinvent database has been built on unitary processes, and ensures high data completeness. Conservatively, a level of completeness ranging from 80% to 90% is assigned.	Good completeness (80% - 90%)	Good	2

Methodological adequacy and consistency	The applied life cycle inventory methods and methodological choices (for instance, allocation, etc.) are aligned to the goal and scope of the data set, and fully compliant with the requirements of ISO 14040 and ISO 14044.	Full compliance to all requirements of ISO standards 14040/44	Very good	1
Temporal representativeness	The use of the latest version of the database (Ecoinvent 3.1), issued in 2015, ensures high temporal representativeness. It is therefore considered legitimate to assign a "good" data quality level.	Good temporal representativeness	Good	2
Technological representativeness	The Ecoinvent inventory includes LCI data derived from the LCA report of the manufacturer NatureWorks, at the moment the main PLA manufacturer at the global level. Data refer to the specific technology used for PLA production: it is then considered licit to assign at least a “good” data quality level to their technological representativeness.	Good technological representativeness	Good	2
Geographical representativeness	Ecoinvent data have been collected in the production plant of NatureWorks, located in the United States. The PLA considered in the study is supplied by the same American manufacturer, hence the geographical representativeness of the data used in this study is considered to be of a "good" level.	Good geographical representativeness	Good	2
Uncertainty of parameters	The measurement uncertainty that the Ecoinvent database, or other used sources, associates to input data or emissions is sometimes rather high, around 20%. It is therefore considered prudent to declare an overall uncertainty between 20% and 30 %.	Acceptable uncertainty, between 20% and 30%	Satisfactory	3

$$DQR = \frac{2 + 1 + 2 + 2 + 2 + 3}{6} = 2 \rightarrow \text{Very good quality}$$

2.4.1.3 Production processes of basic materials: Cellulose pulp

	Comments	Assessment results	Quality level	Quality indicator
Completeness	The Ecoinvent database has been built on unitary processes, and ensures high data completeness. Conservatively, a level of completeness ranging from 80% to 90% is assigned.	Good completeness (80% - 90%)	Good	2

Methodological adequacy and consistency	The applied life cycle inventory methods and methodological choices (for instance, allocation, etc.) are aligned to the goal and scope of the data set, and fully compliant with the requirements of ISO 14040 and ISO 14044.	Full compliance with all requirements of ISO standards 14040/44	Very good	1
Temporal representativeness	The use of the latest version of the database (Ecoinvent 3.1), issued in 2015, ensures high temporal representativeness. It is therefore considered legitimate to assign a "good" data quality level.	Good temporal representativeness	Good	2
Technological representativeness	The Ecoinvent inventory includes data from a LCA study on cellulose pulp produced in Switzerland and Germany, and from studies carried out by the Swedish Environmental Protection Agency. Data refer to technologies used at the European level, which are fully representative of the production processes that constitute the LCA analysis of the product under exam. It is then considered licit to assign at least a “good” data quality level to their technological representativeness.	Good technological representativeness	Good	2
Geographical representativeness	Ecoinvent data were collected in various plants around Europe, hence geographical representativeness of data is of a "good" quality.	Good geographical representativeness	Good	2
Uncertainty of parameters	The measurement uncertainty that the Ecoinvent database, or other used sources, associates to input data or emissions is sometimes rather high, around 20%. It is therefore considered prudent to declare an overall uncertainty between 20% and 30 %.	Acceptable uncertainty, between 20% and 30%	Satisfactory	3

$$\text{DQR} = \frac{2+1+2+2+2+3}{6} = 2 \rightarrow \text{Very good quality}$$

2.4.1.4 Production processes of the porcelain dish (Sanitary ceramics)

	Comments	Assessment results	Quality level	Quality indicator
Completeness	The Ecoinvent database has been built on unitary processes, and ensures high data completeness. Conservatively, a level of completeness ranging from 80% to 90% is assigned.	Good completeness (80% - 90%)	Good	2
Methodological adequacy and consistency	The applied life cycle inventory methods and methodological choices (for instance, allocation, etc.) are aligned to the goal and scope of the data set, and fully compliant with the requirements of ISO 14040 and ISO 14044.	Full compliance to all requirements of ISO standards 14040/44	Very good	1
Temporal representativeness	The use of the latest version of the database (Ecoinvent 3.1), issued in 2015, ensures high temporal representativeness. It is therefore considered legitimate to assign a "good" data quality level.	Good temporal representativeness	Good	2
Technological representativeness	Specific processes related to porcelain tableware are not available in Ecoinvent, but the chosen substitute process (Sanitary Ceramics) can be considered representative because both input raw materials and the forming and firing processes can be considered equivalent. It is therefore considered licit to assign at least a "satisfactory" data quality level as far as technological representativeness is concerned.	Satisfactory technological representativeness	Satisfactory	3
Geographical representativeness	The Ecoinvent inventory includes data derived from LCA studies of a European manufacturer in 2 Austrian plants. As regards the porcelain dish, which on the Italian market presents a substantial import component, the LCA study considers a scenario depicting the productive mix at the global level. Due to this fact, the Ecoinvent "GLO" process has been used, since it adapts specific European data to a global context, by integrating, for instance, the energy mixes and the global distribution scenarios. As a precaution, being the data acquired in Europe, a satisfactory data quality level has been assigned.	Satisfactory geographical representativeness	Satisfactory	3
Uncertainty of parameters	The measurement uncertainty that the Ecoinvent database, or other used sources, associates to input data or emissions is sometimes rather high, around 20%. It is therefore considered prudent to declare an overall uncertainty between 20% and 30 %.	Acceptable uncertainty, between 20% and 30%	Satisfactory	3

$$DQR = \frac{2 + 1 + 2 + 3 + 3 + 3}{6} = 2{,}3 \quad \rightarrow \text{Good quality}$$

2.4.1.5 Production processes of the cardboard cup (Liquid packaging board container)

	Comments	Assessment results	Quality level	Quality indicator
Completeness	The Ecoinvent database has been built on unitary processes, and ensures high data completeness. Conservatively, a level of completeness ranging from 80% to 90% is assigned.	Good completeness (80% - 90%)	Good	2
Methodological adequacy and consistency	The applied life cycle inventory methods and methodological choices (for instance, allocation, etc.) are aligned to the goal and scope of the data set, and fully compliant with the requirements of ISO 14040 and ISO 14044.	Full compliance to all requirements of ISO standards 14040/44	Very good	1
Temporal representativeness	The use of the latest version of the database (Ecoinvent 3.1), issued in 2015, ensures high temporal representativeness. It is therefore considered legitimate to assign a "good" data quality level.	Good temporal representativeness	Good	2
Technological representativeness	The Ecoinvent process is related to the production of cardboard containers for PE poly-coupled liquids and aluminium. This process can be considered to be representative for the LCA modelling of the cardboard cup because both input raw materials and the rolling, cutting and bending processes are equivalent. It is therefore considered licit to assign at least a "satisfactory" data quality level as far as technological representativeness is concerned.	Satisfactory technological representativeness	Satisfactory	3
Geographical representativeness	The Ecoinvent inventory includes data derived from the LCA study of a Swiss manufacturer. The geographical representativeness of data in the LCA study applied to the cellulose cardboard cup is considered to be of a "good" level.	Good geographical representativeness	Good	2
Uncertainty of parameters	The measurement uncertainty that the Ecoinvent database, or other used sources, associates to input data or emissions is sometimes rather high, around 20%. It is therefore considered prudent to declare an overall uncertainty between 20% and 30 %.	Acceptable uncertainty, between 20% and 30%	Satisfactory	3

$$DQR = \frac{2 + 1 + 2 + 3 + 2 + 3}{6} = 2{,}2 \rightarrow \text{Good quality}$$

2.4.1.6 Production processes of the glass cup

	Comments	Assessment results	Quality level	Quality indicator
Completeness	The Ecoinvent database has been built on unitary processes, and ensures high data completeness. Conservatively, a level of completeness ranging from 80% to 90% is assigned.	Good completeness (80% - 90%)	Good	2
Methodological adequacy and consistency	The applied life cycle inventory methods and methodological choices (for instance, allocation, etc.) are aligned to the goal and scope of the data set, and fully compliant with the requirements of ISO 14040 and ISO 14044.	Full compliance to all requirements of ISO standards 14040/44	Very good	1
Temporal representativeness	The use of the latest version of the database (Ecoinvent 3.1), issued in 2015, ensures high temporal representativeness. It is therefore considered legitimate to assign a "good" data quality level.	Good temporal representativeness	Good	2
Technological representativeness	The data relate to the most used technologies at the global level for the production of white glass containers, which are, generally, fully representative of the production processes and services that constitute the LCA analysis of the white glass cup under examination. Quality data level is at least "good" as far as technological representativeness is concerned.	Good technological representativeness	Good	2
Geographical representativeness	The Ecoinvent inventory includes data from LCA studies of European producers. As regards the glass cup, which on the Italian market has a substantial import component, the study LCA considered a scenario related to the productive mix at the global level. The Ecoinvent "GLO" process has been used, since it adapts specific European data to the global context, by integrating, for instance, the energy mixes and the global distribution scenarios. As a precaution, since data have been acquired in Europe, a satisfactory data quality level has been assigned.	Satisfactory geographical representativeness	Satisfactory	3
Uncertainty of parameters	The measurement uncertainty that the Ecoinvent database, or other used sources, associates to input data or emissions is sometimes rather high, around 20%. It is therefore considered prudent to declare an overall uncertainty between 20% and 30 %.	Acceptable uncertainty, between 20% and 30%	Satisfactory	3

$$DQR = \frac{2 + 1 + 2 + 2 + 3 + 3}{6} = 2,2$$ →Good quality

2.4.2 Semi-quantitative data quality assessment - Production specific data

2.4.2.1 Production of PP, PS, and PLA items

	Comments	Assessment results	Quality level	Quality indicator
Completeness	Specific data include all relevant flows, i.e. at least 98% of input/output flows in terms of mass and energy; hence, they are complete for the calculation of each impact category.	Very good completeness (≥ 90 %)	Very good	1
Methodological adequacy and consistency	Applied life cycle inventory methods and methodological choices (for instance, allocation, etc.) are aligned to the goal and the scope of the dataset, and fully compliant with the requirements of ISO 14040 and ISO 14044.	Full compliance to all requirements of ISO standards 14040/44	Very good	1
Temporal representativeness	The data refer to the year 2014.	Age of data compatible with technologies currently in use	Very good	1
Technological representativeness	Data are specific of production plants in which the products under study are manufactured, i.e. data are fully representative of the extrusion and thermoforming processes of the various materials included in this study.	Technological representativeness fully satisfied	Very good	1
Geographical representativeness	Data are specific of production plants in which the products under study are manufactured, and representative of Italian production. Data regarding the cellulose pulp dish are the only ones that were not collected in Italian plants, but they can be considered to be of good quality because they have been acquired within the European Community. Conservatively, they are assigned a "good quality" level.	Good geographical representativenes s	Very good	1
Uncertainty of parameters	The uncertainty of measurement that can be associated with input data related to the various processes covered by the LCA study can be considered lower than or equal to 10%. In fact, data are available in the form of population (all production data are 100% recorded within the management accounting, where they have been extracted from to compile data collection sheets), thus it has been possible to estimate the uncertainty, which is included within the 10% of the average value.	Very low uncertainty (< 10 %)	Very Good	1

$$DQR = \frac{1+1+1+1+1+1}{6} = 1$$ →Highest quality

2.4.2.2 Production of the cellulose pulp dish

	Comments	Assessment results	Quality level	Quality indicator
Completeness	Specific data include all relevant flows, i.e. at least 98% of input/output flows in terms of mass and energy; hence, they are complete for the calculation of each impact category.	Very good completeness (≥ 90 %)	Very good	1
Methodological adequacy and consistency	Applied life cycle inventory methods and methodological choices (for instance, allocation, etc.) are aligned to the goal and the scope of the dataset, and fully compliant with the requirements of ISO 14040 and ISO 14044.	Full compliance to all requirements of ISO standards 14040/44	Very good	1
Temporal representativeness	The data refer to the year 2014.	Age of data compatible with the technologies currently in use	Very good	1
Technological representativeness	Data are specific of production plants in which the products under study are manufactured, even if they cannot be considered as being fully representative of the cellulose pulp dish forming processes, since the plant, at the moment when the data were collected, was working at 50% of its capacity.	Satisfactory technological representativeness	Satisfactory	3
Geographical representativeness	Data regarding the cellulose pulp dish are the only ones that were not collected in Italian plants, but they can be considered to be of good quality because they have been acquired within the European Community. Conservatively, they are assigned a "satisfactory quality" level.	Satisfactory geographical representativeness	Satisfactory	3
Uncertainty of parameters	The uncertainty of measurement that can be associated with input data related to the various processes covered by the LCA study can be considered lower than or equal to 10 %. In fact, data are available in the form of population (all production data are 100% recorded within the management accounting, where they have been extracted from to compile data collection sheets), thus it has been possible to estimate the uncertainty, which is included within the 10% of the average value.	Very low uncertainty (< 10 %)	Very Good	1

$$DQR = \frac{1 + 1 + 1 + 3 + 3 + 1}{6} = 1.7 \rightarrow \text{Very good quality}$$

The assessment confirms the reliability of the data used in the study as compliant with the requirements of ISO 14040/44. The requirements defined in the scope of the study demand for data quality to be of overall "good quality" (DQR between 2 and 3): the analysis carried out in the present report has highlighted a quality level equal to or higher than the required one.

Moreover, quality indicators that have emerged are all compatible with the minimum quality requirements envisaged by the PEF methodology.

3. Life cycle impact assessment (LCIA)

The LCIA phase aims at quantifying the magnitude of potential environmental impacts using life cycle inventory analysis data. It consists of associating inventory data related to pollutants to certain environmental impact categories.

For the evaluation of impact categories, consistently to what has been defined in the phase related to the scope of the study, the methods *ILCD 2011 Midpoint+ v.1.05* and *CML-IA baseline v.3.02* have been used, both present within the *SimaPro* software.

The application of these methods within the calculation software allows the automatic execution of the classification and characterization operations envisaged by ISO standards 14040/44, providing impact categories results in the desired units of measure.

The comparison is performed according to the defined functional unit, i.e. *"1000 tableware uses for meal containing in the case of the dishes and for containing 200 ml of beverage in the case of cups"*. The following tables report the reference flows defined to meet the functional unit.

DISHES	
Type	**Reference flow**
Disposable made of polypropylene (PP)	1000 items
Disposable made of polystyrene (PS)	1000 items
Disposable made of polylactic acid (PLA)	1000 items
Disposable made of cellulose pulp	1000 items
Reusable made of porcelain	1 item*

*for the porcelain dish, within the LCA study, the washing necessary to make the dish reusable will be considered (for a total of 1000 washings).

CUPS	
Type	**Reference flow**
Disposable made of polypropylene (PP)	1000 items
Disposable made of polystyrene (PS)	1000 items
Disposable made of polylactic acid (PLA)	1000 items
Disposable made of (PE) polyethylene laminated cardboard	1000 items
Reusable made of glass	1 item*

* for the glass cup, within the LCA study, the washing necessary to make the cup reusable will be considered (for a total of 1000 washings).

The following paragraphs report the results of the whole life cycle impact assessment for the two tableware categories: flat dishes and drinking cups.

The results of the evaluation are reported in comparative terms according to the three assumed end of life scenarios. The sensitivity analysis (see paragraph 3.4.2) applied to the different end of life scenarios has, in fact, revealed significant differences in the calculation of impact categories, which is why the results of the LCA study will be reported separately for each assumed scenario.

As stated in the standard ISO 14044, the LCIA results are based on a relative approach, they do not predict actual impacts on category endpoints, the exceeding of thresholds, or safety margins or risks.

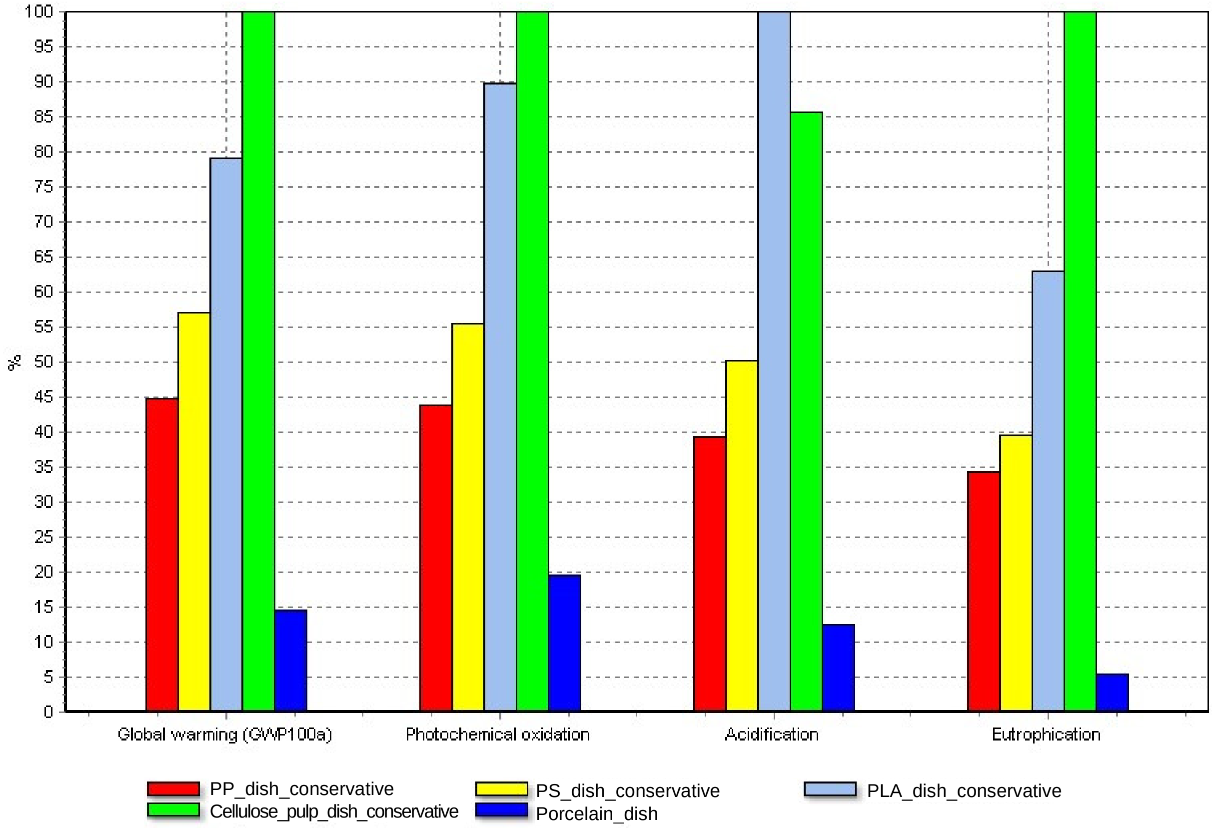
3.1 LCIA Results - flat dishes

The following graphs report the comparative results for each impact category. The graphical representation is expressed in percentages: the 100% value is assigned to the alternative that has the greatest environmental impact related to each impact category, whereas the remaining options are quantified in a proportional manner.

In addition to the comparative graph, a table reports the absolute values of impact categories expressed according to the standard unit of measurement of the specific characterisation method.

3.1.1 Results obtained with the CML method

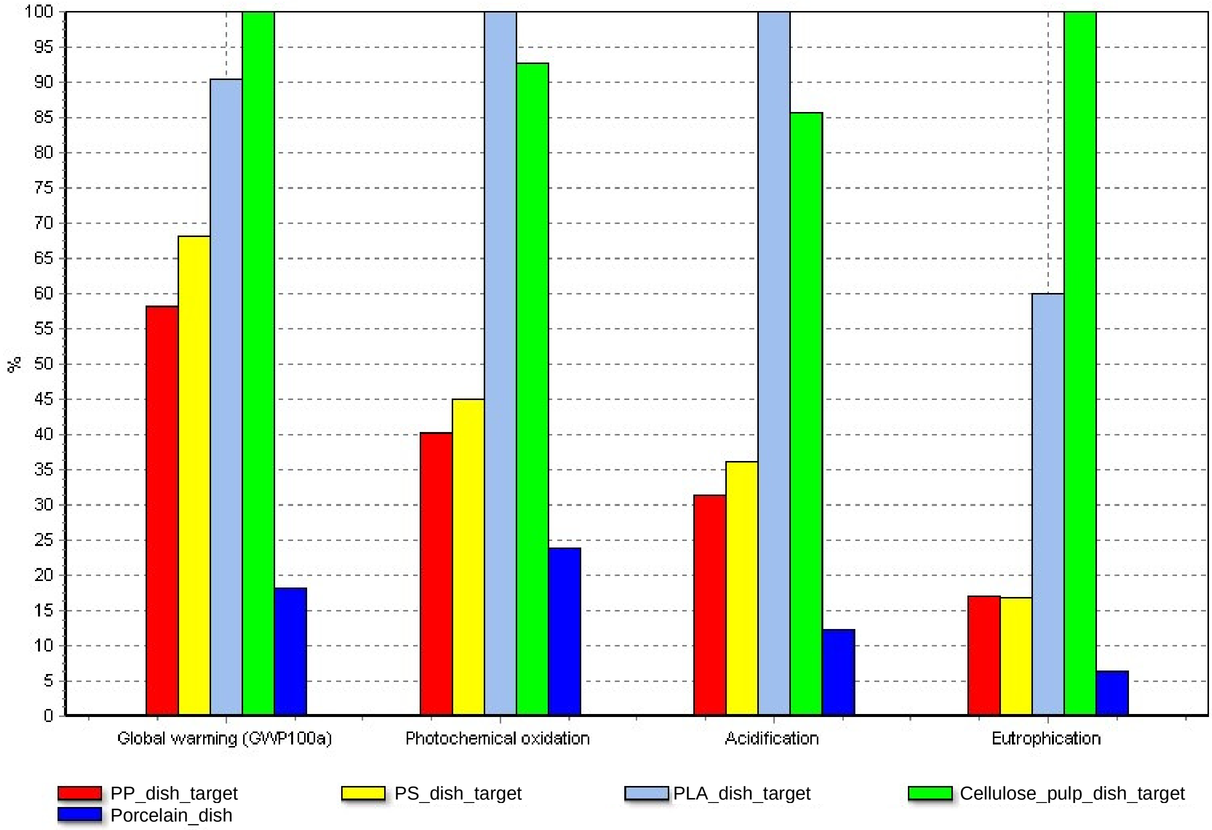
3.1.1.1 *Life Cycle Impact Assessment results - CONSERVATIVE end of life scenario*



Product phases comparison, Method: CML-IA baseline V3.02/EU25/Characterization

LCIA Results with CONSERVATIVE scenario - CML method						
Impact Category	**Unit of measure**	**PP**	**PS**	**PLA**	**Cellulose pulp**	**Porcelain**
Global Warming	kg CO_2 eq.	54.390	69.199	95.969	121.191	17.562
Photochemical oxidants formation	kg C_2H_4 eq.	0.012	0.015	0.024	0.027	0.005
Acidification	kg SO_2 eq.	0.203	0.259	0.516	0.442	0.064
Eutrophication	kg PO_4^{3-} eq.	0.123	0.142	0.226	0.359	0.020

3.1.1.2 *Life Cycle Impact Assessment results - TARGET end of life scenario*

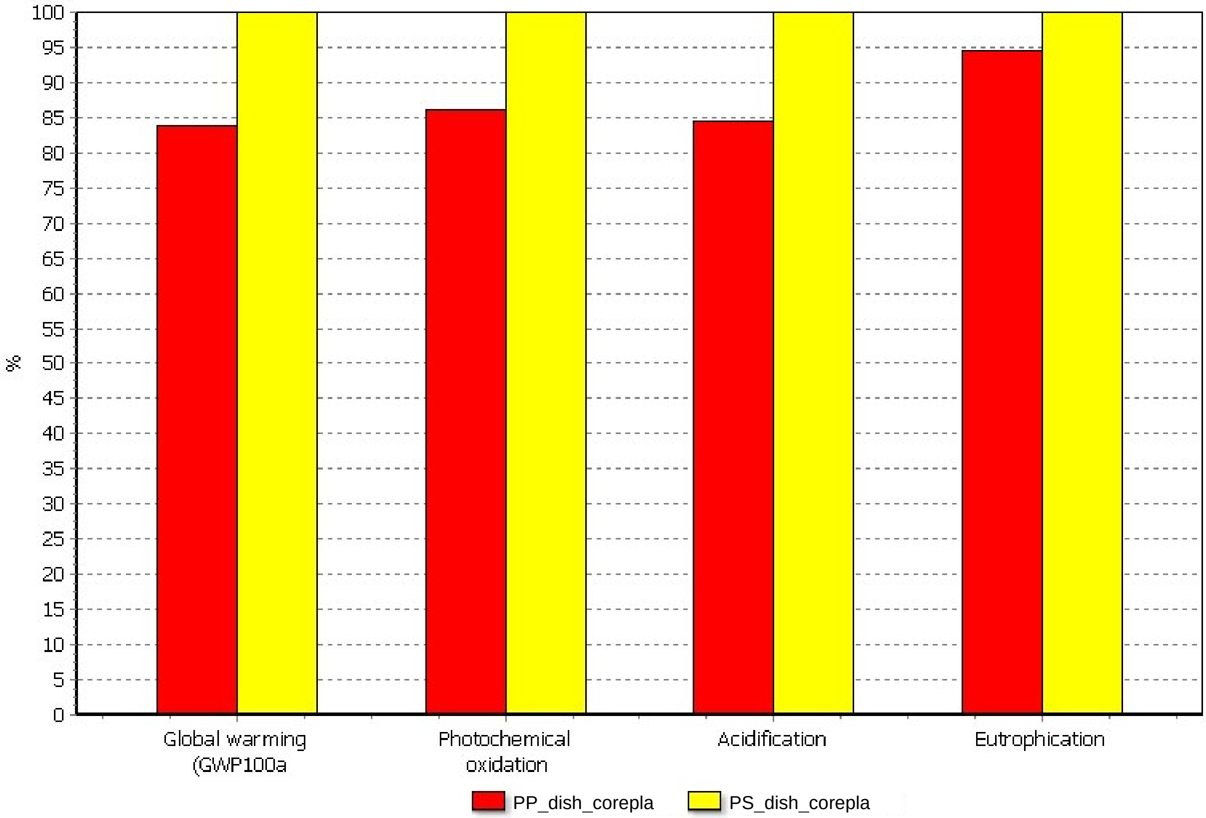


Product phases comparison, Method: CML-IA baseline V3.02/EU25/Characterization

LCIA Results with TARGET scenario - CML method						
Impact Category	**Unit of measure**	**PP**	**PS**	**PLA**	**Cellulose pulp**	**Porcelain**
Global Warming	kg CO_2 eq.	56.623	66.262	87.886	97.176	17.562
Photochemical oxidants formation	kg C_2H_4 eq.	0.009	0.010	0.022	0.021	0.005
Acidification	kg SO_2 eq.	0.164	0.188	0.520	0.446	0.064
Eutrophication	kg PO_4^{3-} eq.	0.053	0.052	0.185	0.309	0.020

3.1.1.3 *Life Cycle Impact Assessment results - REAL end of life scenario (Corepla)*

This scenario was defined for, and applied solely to, the disposal of single-use tableware made from plastics (PP and PS) for which reliable data on packaging end of life solutions were available on a national scale (source: Corepla 2013).



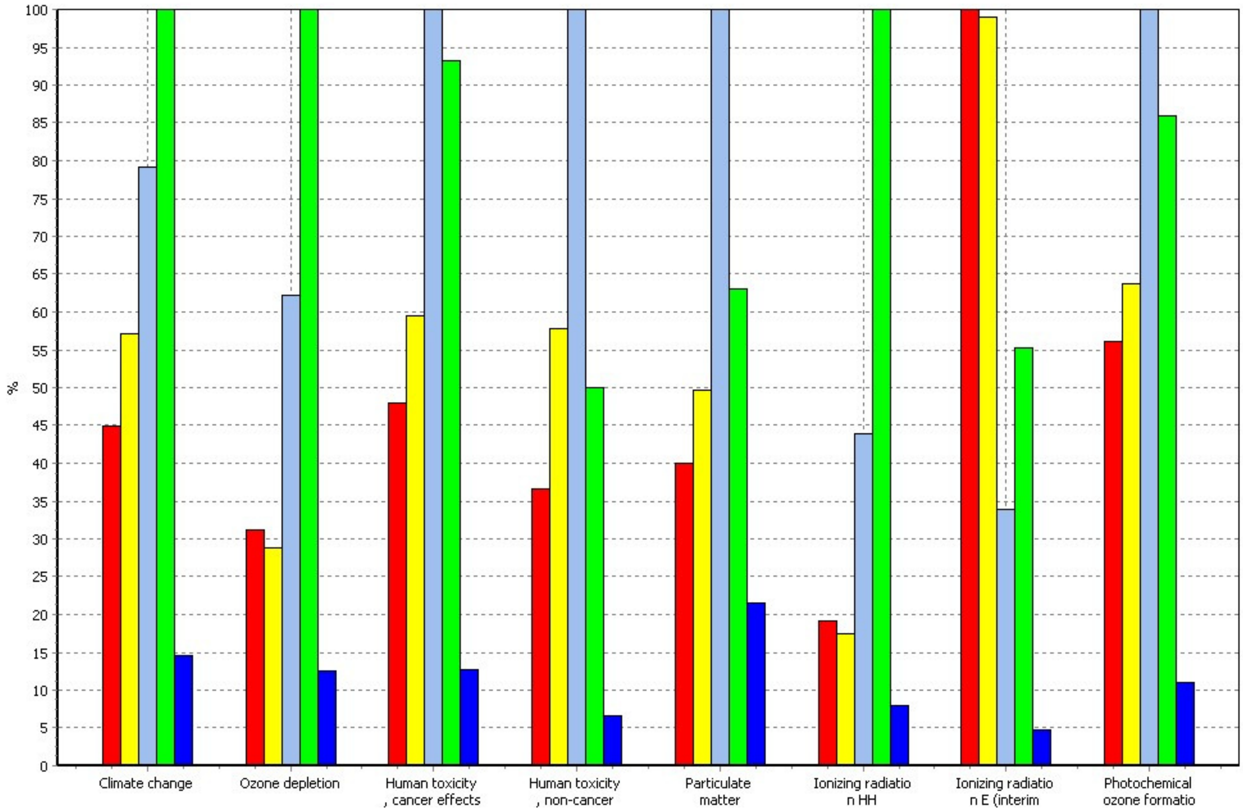
Comparison between 1E3 p 'PP_dish_corepla' and IE3 p 'PS_dish_corepla'; Method: CML-IA baseline V3.02/EU25/Characterization

LCIA results with REAL scenario - CML method			
Impact Category	**Unit of measure**	**PP**	**PS**
Global Warming	kg CO_2 eq.	55.755	66.473
Photochemical oxidants formation	kg C_2H_4 eq.	0.010	0.011
Acidification	kg SO_2 eq.	0.174	0.205
Eutrophication	kg PO_4^{3-} eq.	0.070	0.074

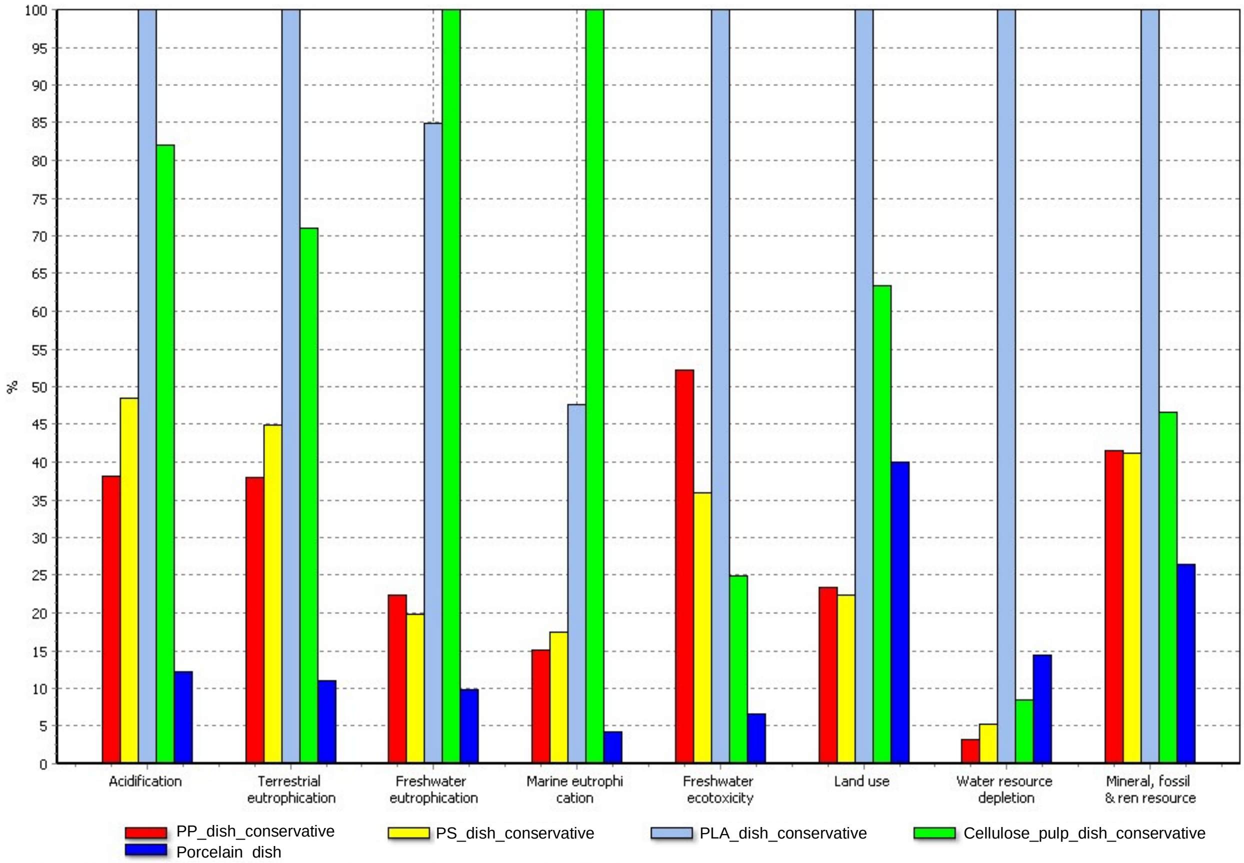
3.1.2 Results obtained with the ILCD method

3.1.2.1 *Life Cycle Impact Assessment results - CONSERVATIVE end of life scenario*

Part 1



Part 2

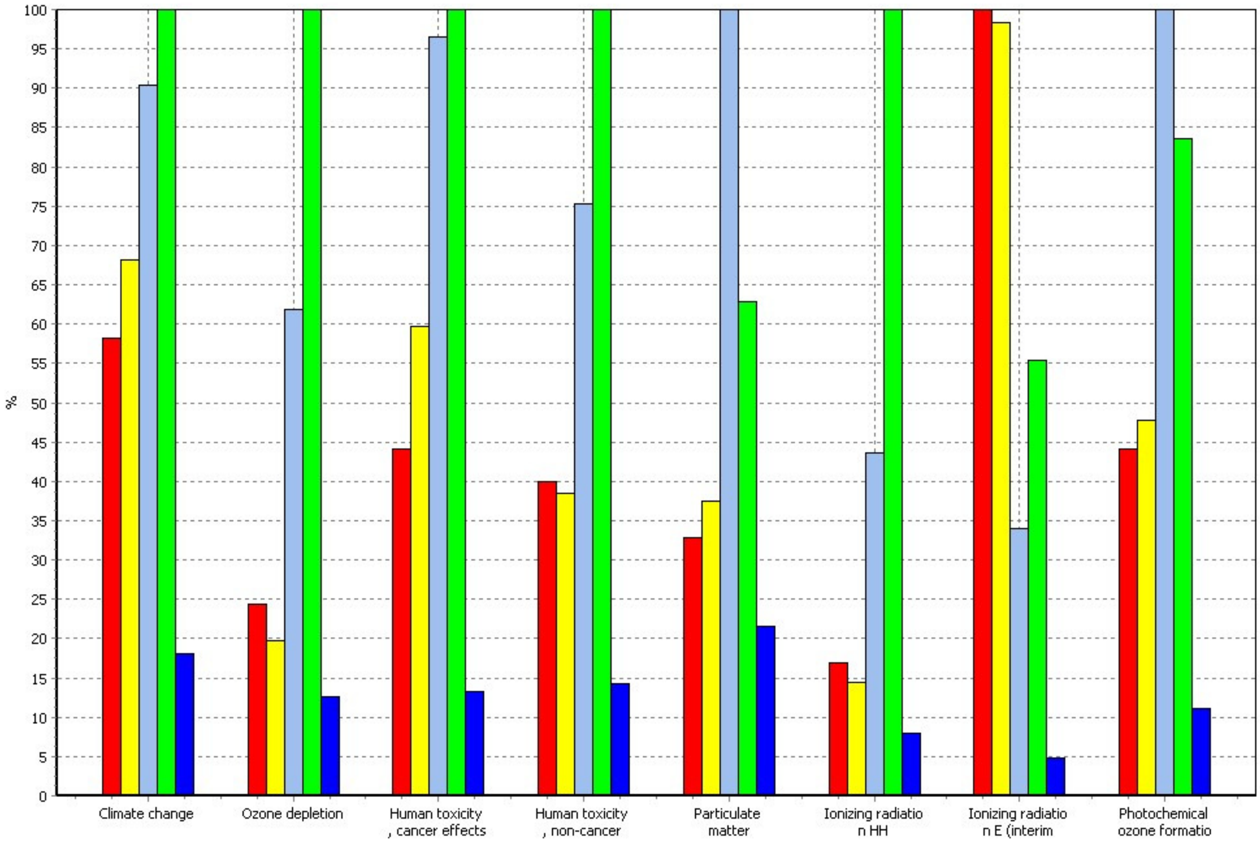


Product phases comparison; Method: ILCD 2011 Midpoint+ V1.05/EU27 2010, equal weighting/ Characterization

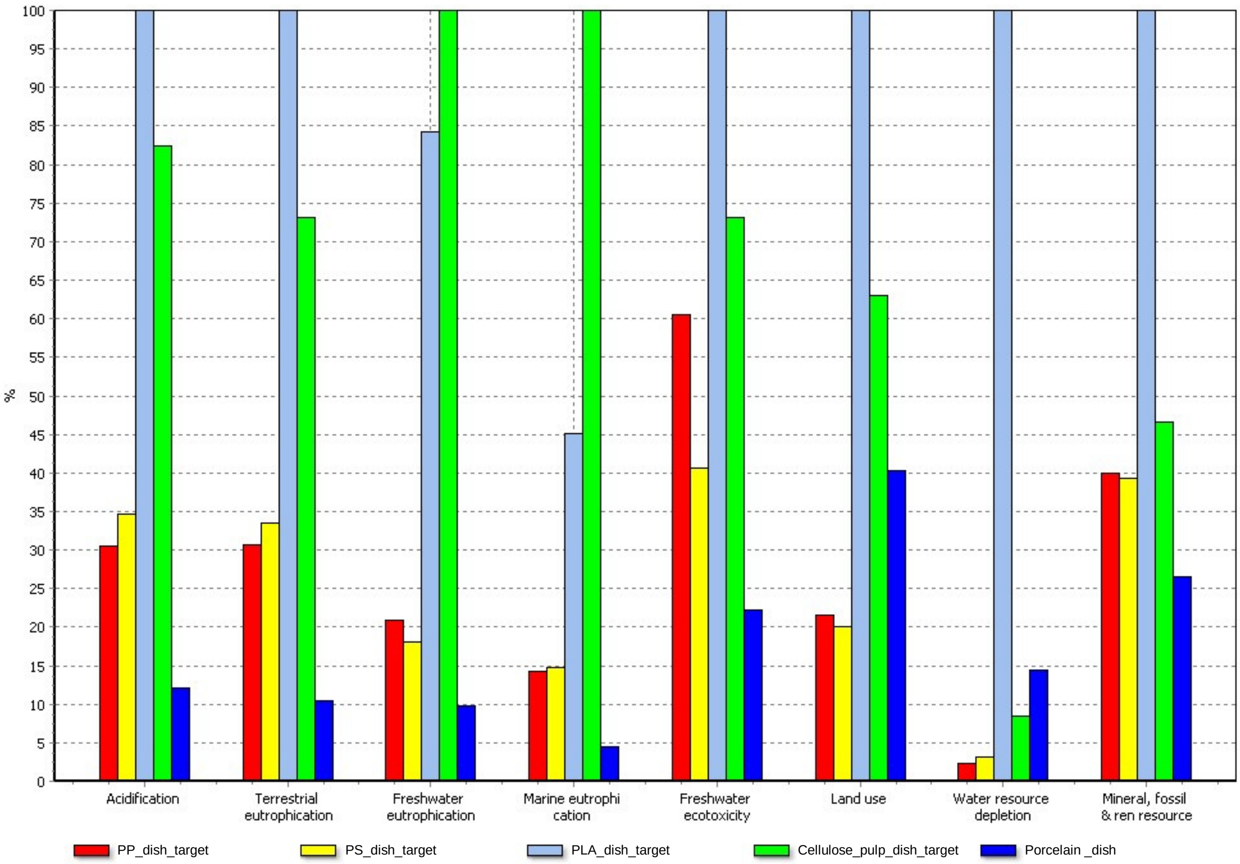
LCIA results with CONSERVATIVE scenario - ILCD method						
Impact Category	Unit of measure	PP	PS	PLA	Cellulose pulp	Porcelain
Climate Change	kg CO_2 eq.	5.44E+01	6.92E+01	9.60E+01	1.21E+02	1.76E+01
Ozone depletion	kg CFC-11 eq.	4.15E-06	3.82E-06	8.27E-06	1.33E-05	1.66E-06
Human toxicity - cancer effects	CTUh	1.72E-06	2.14E-06	3.59E-06	3.35E-06	4.56E-07
Human toxicity - non cancer effects	CTUh	1.42E-05	2.25E-05	3.89E-05	1.94E-05	2.54E-06
Particulate/smog, emissions of inorganic substances	kg $PM_{2,5}$ eq.	2.42E-02	3.01E-02	6.06E-02	3.82E-02	1.31E-02
Ionising Radiation - effects on human health	kg of U^{235} eq.	4.75E+00	4.32E+00	1.09E+01	2.47E+01	1.96E+00
Ionising Radiation - effects on the ecosystem	CTUe	8.90E-05	8.81E-05	3.02E-05	4.91E-05	4.26E-06
Photochemical ozone formation	kg NMVOC eq.	1.87E-01	2.12E-01	3.33E-01	2.86E-01	3.69E-02
Acidification	mole H+ eq.	2.45E-01	3.11E-01	6.42E-01	5.27E-01	7.86E-02
Eutrophication - terrestrial	mole N eq.	5.03E-01	5.95E-01	1.32E+00	9.39E-01	1.46E-01
Eutrophication – freshwater	kg P eq.	6.40E-03	5.69E-03	2.43E-02	2.86E-02	2.81E-03
Eutrophication - marine	kg of N eq.	7.96E-02	9.22E-02	2.52E-01	5.30E-01	2.21E-02
Ecotoxicity - freshwater	CTUe	1.44E+03	9.91E+02	2.77E+03	6.89E+02	1.85E+02
Use of land	kg C (deficit)	7.42E+01	7.10E+01	3.18E+02	2.02E+02	1.27E+02
Depletion resources - water	m^3 of water	9.14E-02	1.50E-01	2.89E+00	2.44E-01	4.19E-01
Depletion of resources - minerals, fossils	kg of Sb eq.	1.43E-03	1.42E-03	3.45E-03	1.61E-03	9.11E-04

3.1.2.2 *Life Cycle Impact Analysis results – TARGET end of life scenario*

Part 1



Part 2



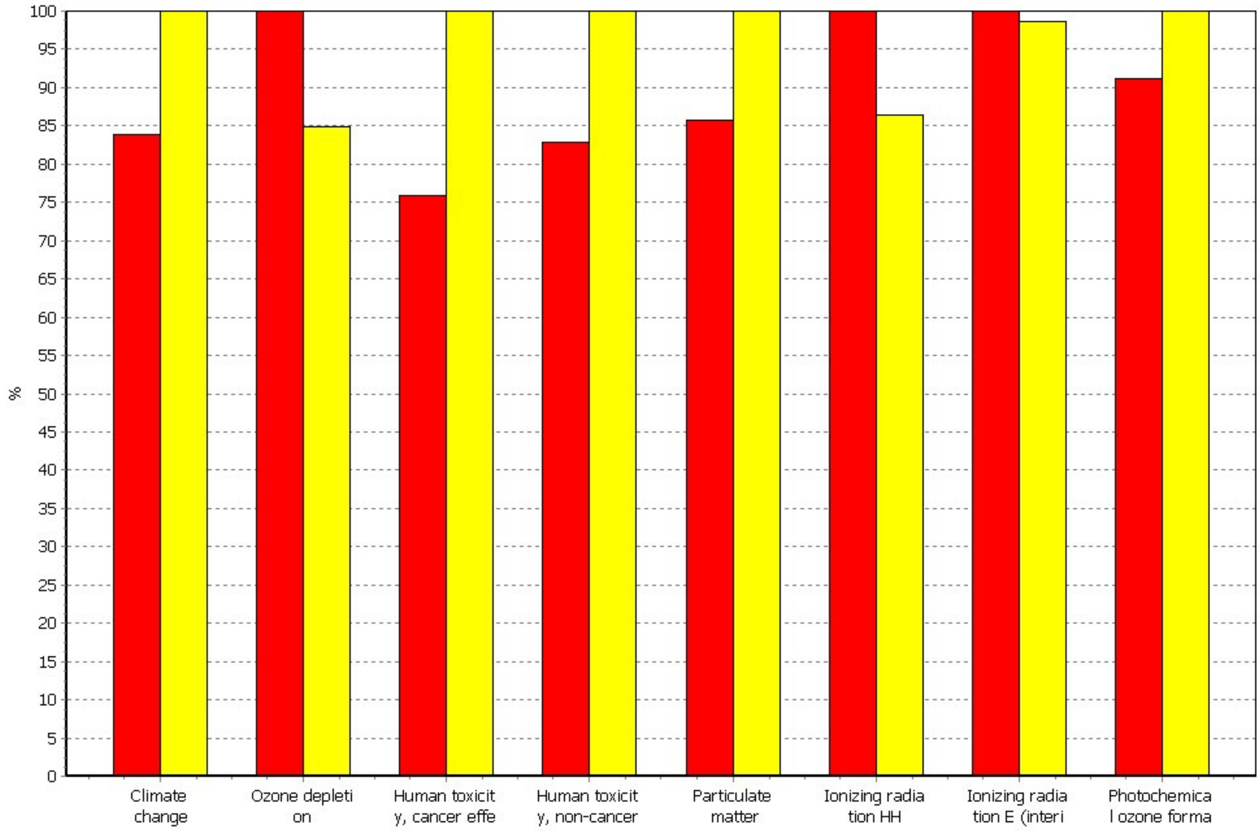
Product phases comparison, Method ILCD 2011 Midpoint+ V1.05/EU27 2010, equal weighting/ Characterization

LCIA results with TARGET scenario - CML method						
Impact Category	**Unit of measure**	**PP**	**PS**	**PLA**	**Cellulose pulp**	**Porcelain**
Climate Change	kg CO_2 eq.	5.66E+01	6.63E+01	8.79E+01	9.72E+01	1.76E+01
Ozone depletion	kg CFC-11 eq.	3.18E-06	2.59E-06	8.08E-06	1.31E-05	1.66E-06
Human toxicity - cancer effects	CTUh	1.51E-06	2.04E-06	3.30E-06	3.42E-06	4.56E-07
Human toxicity - non cancer effects	CTUh	7.10E-06	6.82E-06	1.34E-05	1.78E-05	2.54E-06
Particulate/smog. emissions of inorganic substances	kg $PM_{2.5}$ eq.	2.00E-02	2.28E-02	6.07E-02	3.82E-02	1.31E-02
Ionising Radiation - effects on human health	kg of U^{235}eq.	4.17E+00	3.52E+00	1.07E+01	2.46E+01	1.96E+00
Ionising Radiation - effects on the ecosystem	CTUe	8.78E-05	8.64E-05	2.98E-05	4.87E-05	4.26E-06
Photochemical ozone formation	kg NMVOC eq.	1.46E-01	1.58E-01	3.31E-01	2.77E-01	3.69E-02
Acidification	mole H+ eq.	1.99E-01	2.27E-01	6.53E-01	5.38E-01	7.86E-02
Eutrophication - terrestrial	mole N eq.	4.27E-01	4.66E-01	1.39E+00	1.02E+00	1.46E-01
Eutrophication – freshwater	kg P eq.	6.05E-03	5.23E-03	2.43E-02	2.89E-02	2.81E-03
Eutrophication - marine	kg of N eq.	7.03E-02	7.33E-02	2.24E-01	4.95E-01	2.21E-02
Ecotoxicity – freshwater	CTUe	5.04E+02	3.38E+02	8.33E+02	6.09E+02	1.85E+02
Use of land	kg C (deficit)	6.82E+01	6.34E+01	3.16E+02	1.99E+02	1.27E+02
Depletion of resources - water	m^3 of water	6.61E-02	9.09E-02	2.89E+00	2.42E-01	4.19E-01
Depletion of resources - minerals, fossils	kg of Sb eq.	1.37E-03	1.35E-03	3.44E-03	1.60E-03	9.11E-04

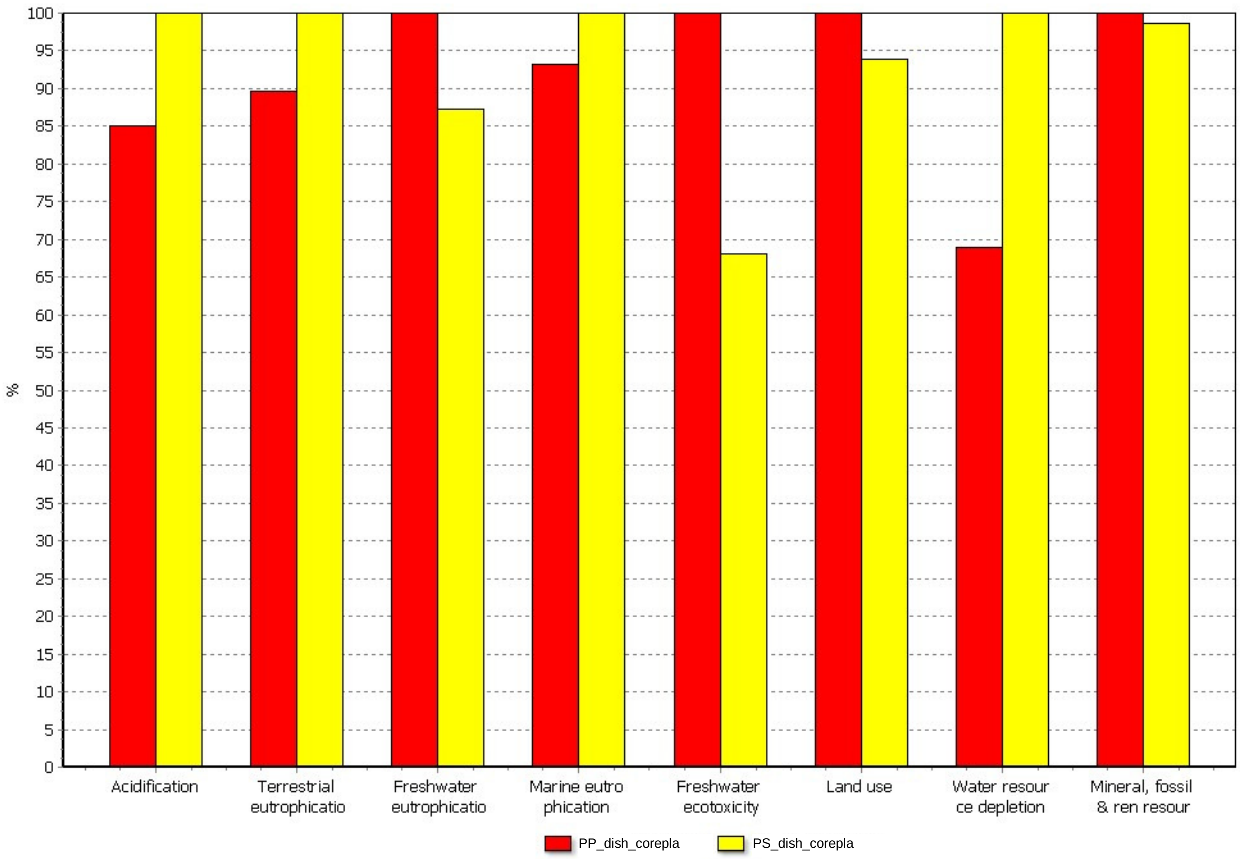
3.1.2.3 *Life Cycle Impact Assessment results with REAL end of life scenario (Corepla)*

This scenario was defined for, and applied solely to, the disposal of single-use tableware made from plastics (PP and PS) for which reliable data on packaging end of life solutions were available on a national scale (source: Corepla 2013).

Part 1



Part 2



Comparison IE3 p ‘PP_dish_corepla’ and IE3 p ‘PS_dish_corepla’; Method: ILCD 2011 Midpoint+ V1.05/EU27 2010, equal weighting/ Characterization

LCIA results with REAL scenario - CML method			
Impact Category	**Unit of measure**	**PP**	**PS**
Climate Change	kg CO_2 eq.	5.58E+01	6.65E+01
Ozone depletion	kg CFC-11 eq.	3.45E-06	2.93E-06
Human toxicity - cancer effects	CTUh	1.56E-06	2.05E-06
Human toxicity - non cancer effects	CTUh	8.86E-06	1.07E-05
Particulate/smog, emissions of inorganic substances	kg $PM_{2,5}$ eq.	2.10E-02	2.45E-02
Ionising Radiation - effects on human health	kg of U^{235} eq.	4.34E+00	3.75E+00
Ionising Radiation - effects on the ecosystem	CTUe	8.82E-05	8.69E-05
Photochemical ozone formation	kg NMVOC eq.	1.56E-01	1.71E-01
Acidification	mole H+ eq.	2.11E-01	2.47E-01
Eutrophication - terrestrial	mole N eq.	4.45E-01	4.97E-01
Eutrophication – freshwater	kg P eq.	6.17E-03	5.38E-03
Eutrophication - marine	kg of N eq.	7.27E-02	7.80E-02
Ecotoxicity – freshwater	CTUe	7.31E+02	4.97E+02
Use of land	kg C (deficit)	6.99E+01	6.55E+01
Depletion of resources - water	m^3 of water	7.24E-02	1.05E-01
Depletion of resources - minerals, fossils	kg of Sb eq.	1.39E-03	1.37E-03

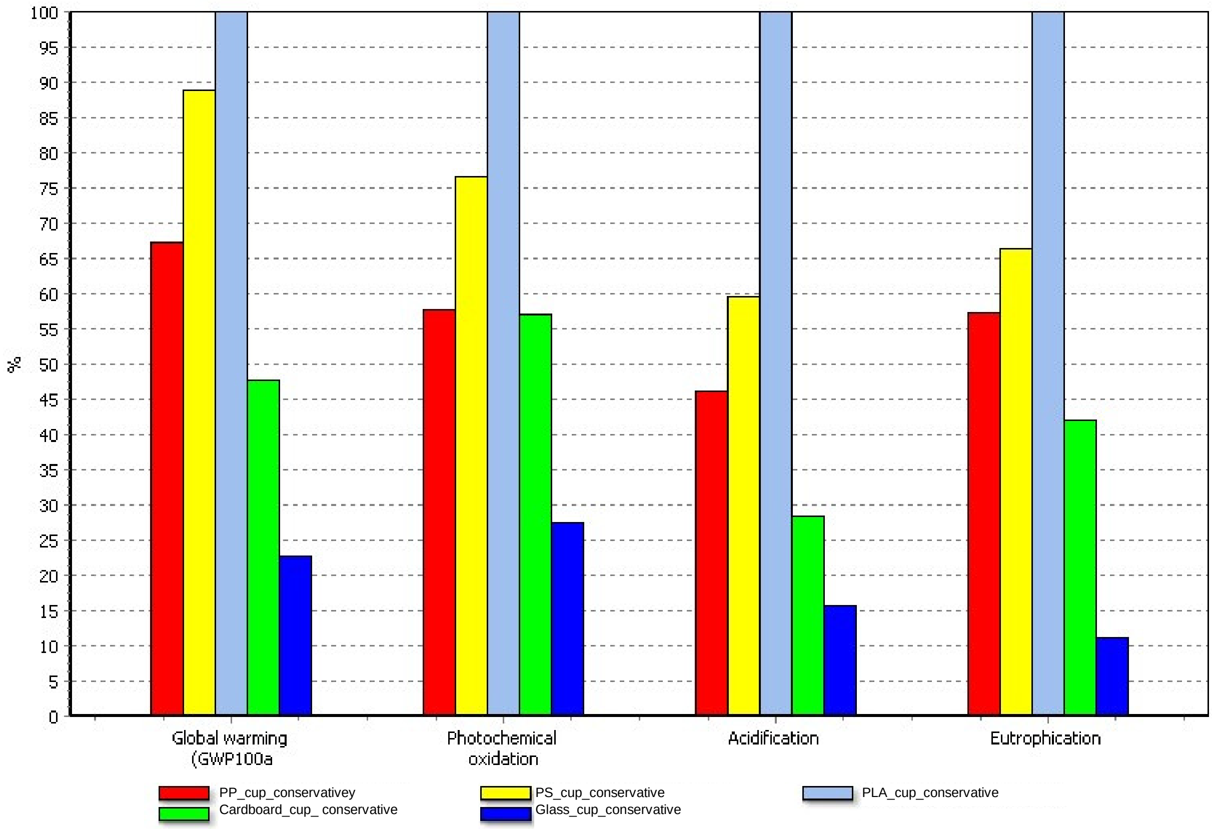
3.2 LCIA results - Cups

The following graphs report comparative results by impact category. The graphical representation is expressed in percentages: the alternative that has the greatest environmental impact in relation to each individual impact category has been assigned a 100% value, while the remaining options are quantified proportionally.

In addition to the comparative graph, a table reports absolute values of impact categories expressed according to the standard unit of measurement of the specific method of characterization.

3.2.1 Results obtained with the CML method

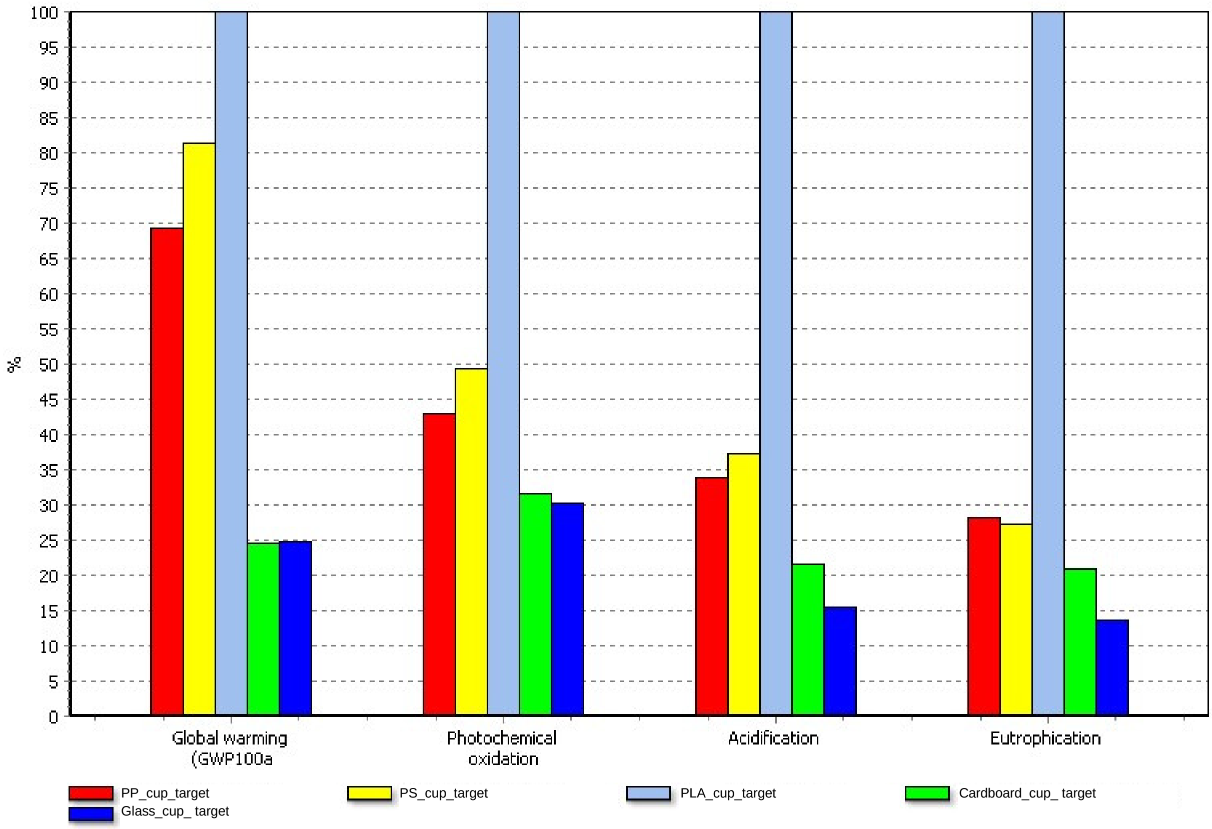
3.2.1.1 *Life Cycle Impact Assessment results - CONSERVATIVE end of life scenario*



Product phases comparison, Method CML-IA baseline V3.02/EU25/Characterization

LCIA results with CONSERVATIVE scenario - CML method						
Impact Category	Unit of measure	PP	PS	PLA	Laminated cardboard	Glass
Global Warming	kg CO_2 eq.	25.083	33.163	37.295	17.785	8.471
Photochemical oxidants formation	kg C_2H_4 eq.	0.005	0.007	0.009	0.005	0.003
Acidification	kg SO_2 eq.	0.092	0.118	0.199	0.057	0.031
Eutrophication	kg PO_4^{3-} eq.	0.050	0.058	0.087	0.037	0.010

3.2.1.2 *Life Cycle Impact Assessment - TARGET end of life scenario*

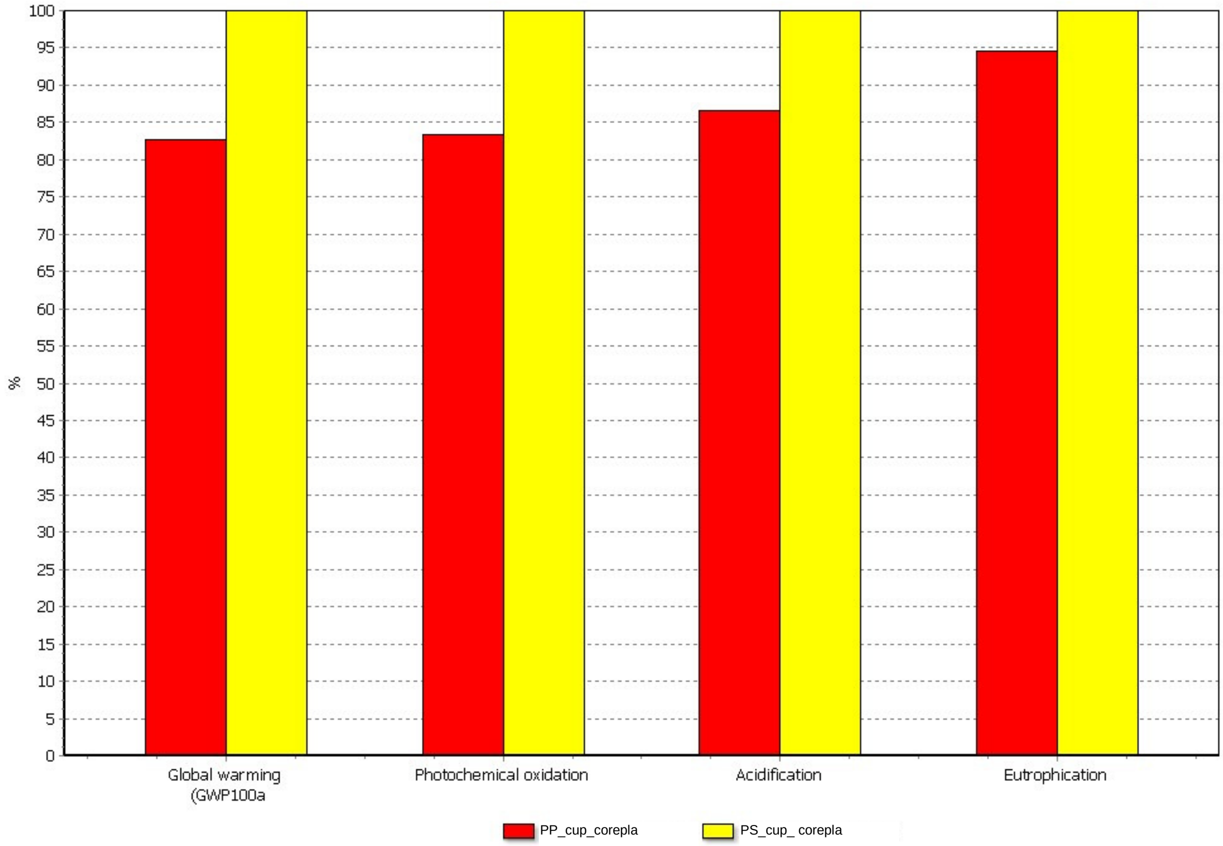


Product phases comparison, Method CML-IA baseline V3.02/EU25/Characterization

LCIA results with TARGET scenario - CML method						
Impact Category	**Unit of measure**	**PP**	**PS**	**PLA**	**Laminated cardboard**	**Glass**
Global Warming	kg CO_2 eq.	23.636	27.769	34.140	8.390	8.446
Photochemical oxidants formation	kg C_2H_4 eq.	0.004	0.004	0.009	0.003	0.003
Acidification	kg SO_2 eq.	0.068	0.075	0.200	0.043	0.031
Eutrophication	kg PO_4^{3-} eq.	0.020	0.020	0.072	0.015	0.010

3.2.1.3 *Life Cycle Impact Assessment results - REAL end of life scenario (Corepla)*

This scenario was defined for, and applied solely to, the disposal of single-use tableware made from plastics (PP and PS) for which reliable data on packaging end of life solutions were available on a national scale (source: Corepla 2013).



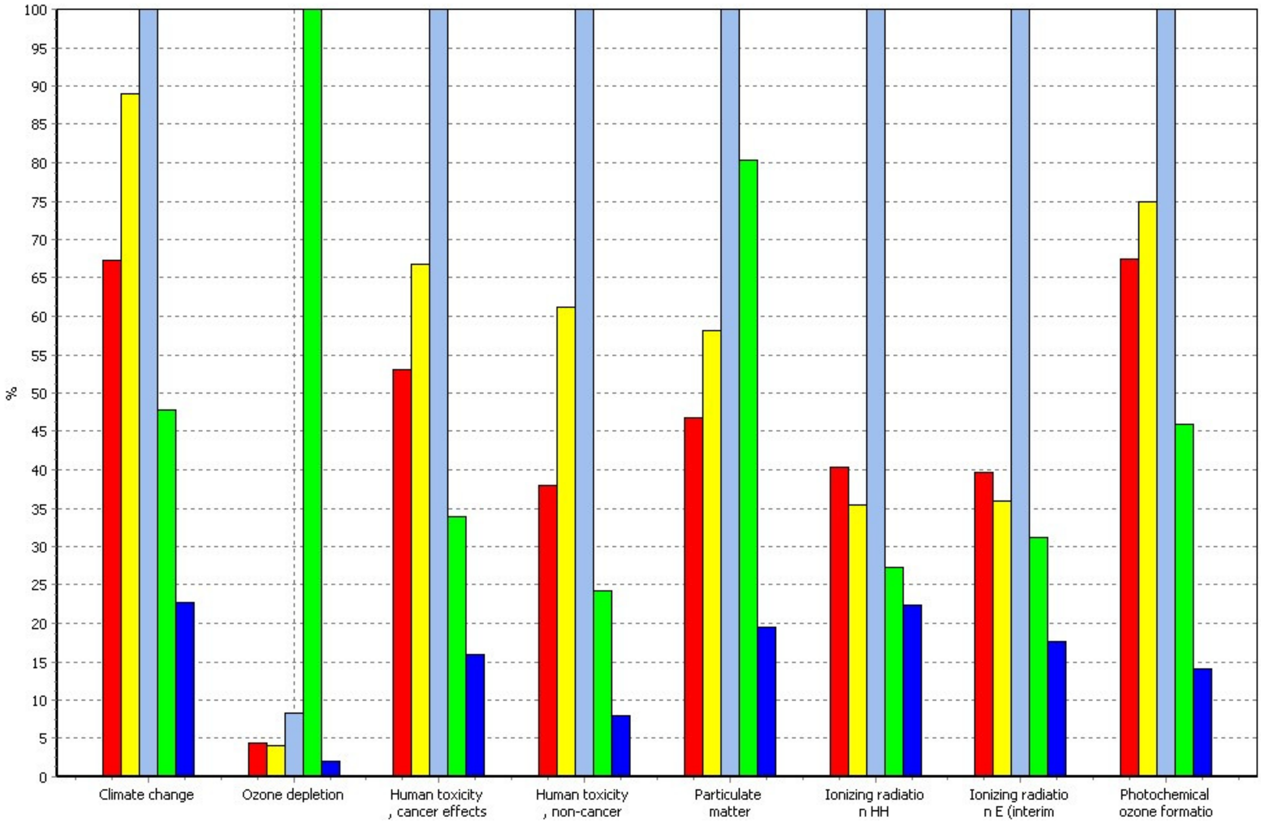
Comparison between IE3 p 'PP_cup_corepla' and IE3 p 'PS_cup_corepla' Product phase comparison, Method CML-IA baseline V3.02/EU25/Characterization

LCIA results with REAL scenario - CML method			
Impact Category	**Unit of measure**	**PP**	**PS**
Global Warming	kg CO_2 eq.	23.817	28.808
Photochemical oxidants formation	kg C_2H_4 eq.	0.004	0.005
Acidification	kg SO_2 eq.	0.074	0.085
Eutrophication	kg PO_4^{3-} eq.	0.027	0.029

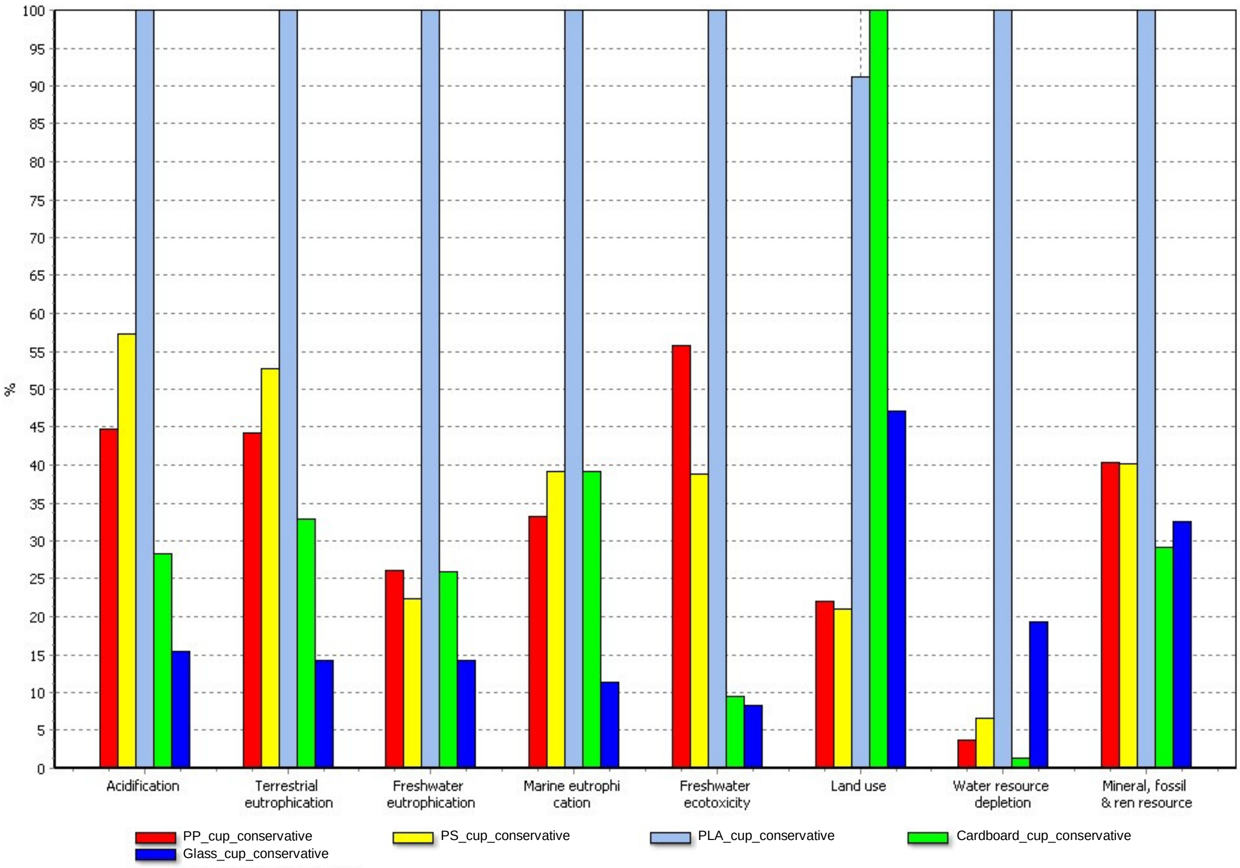
3.2.2 Results obtained with the ILCD method

3.2.2.1 *Life Cycle Impact Assessment - CONSERVATIVE end of life scenario*

Part 1



Part 2

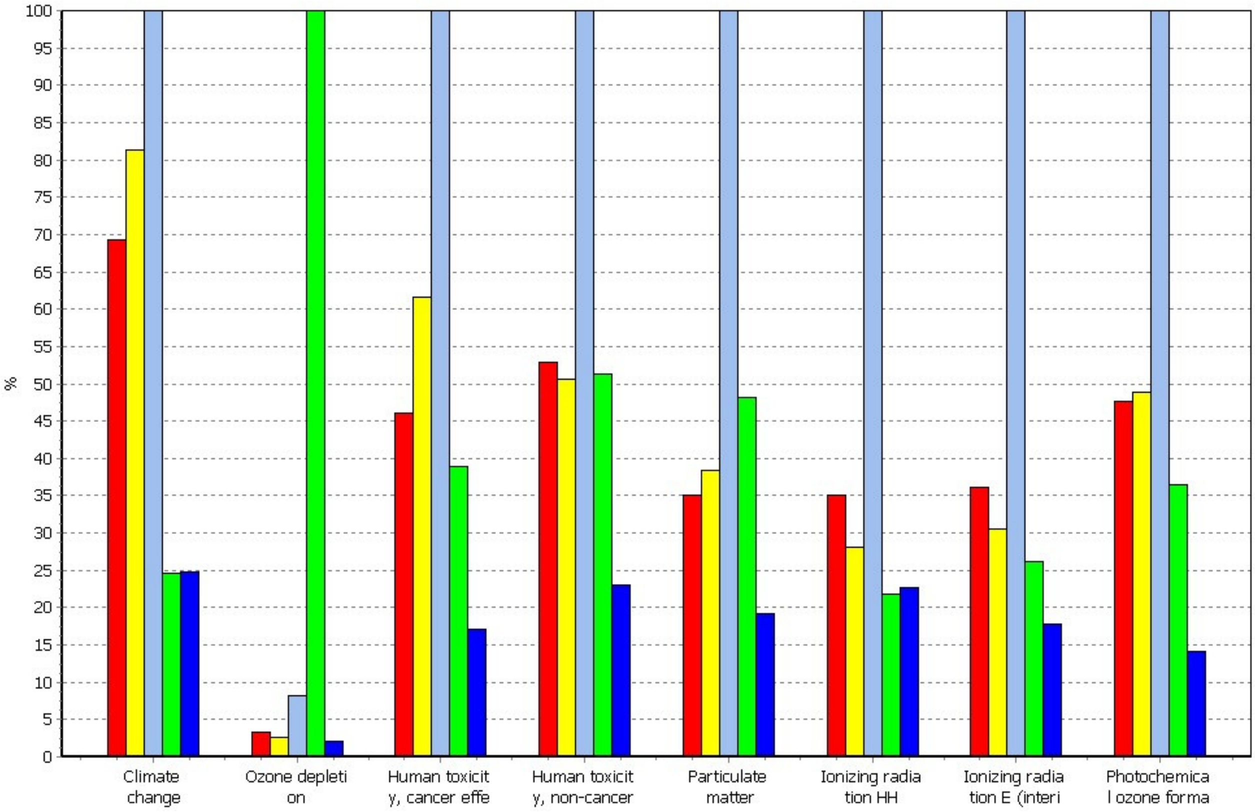


Product phases comparison, Method ILCD 2011 Midpoint+ V1.05/EU27 2010, equal weighting/ Characterization

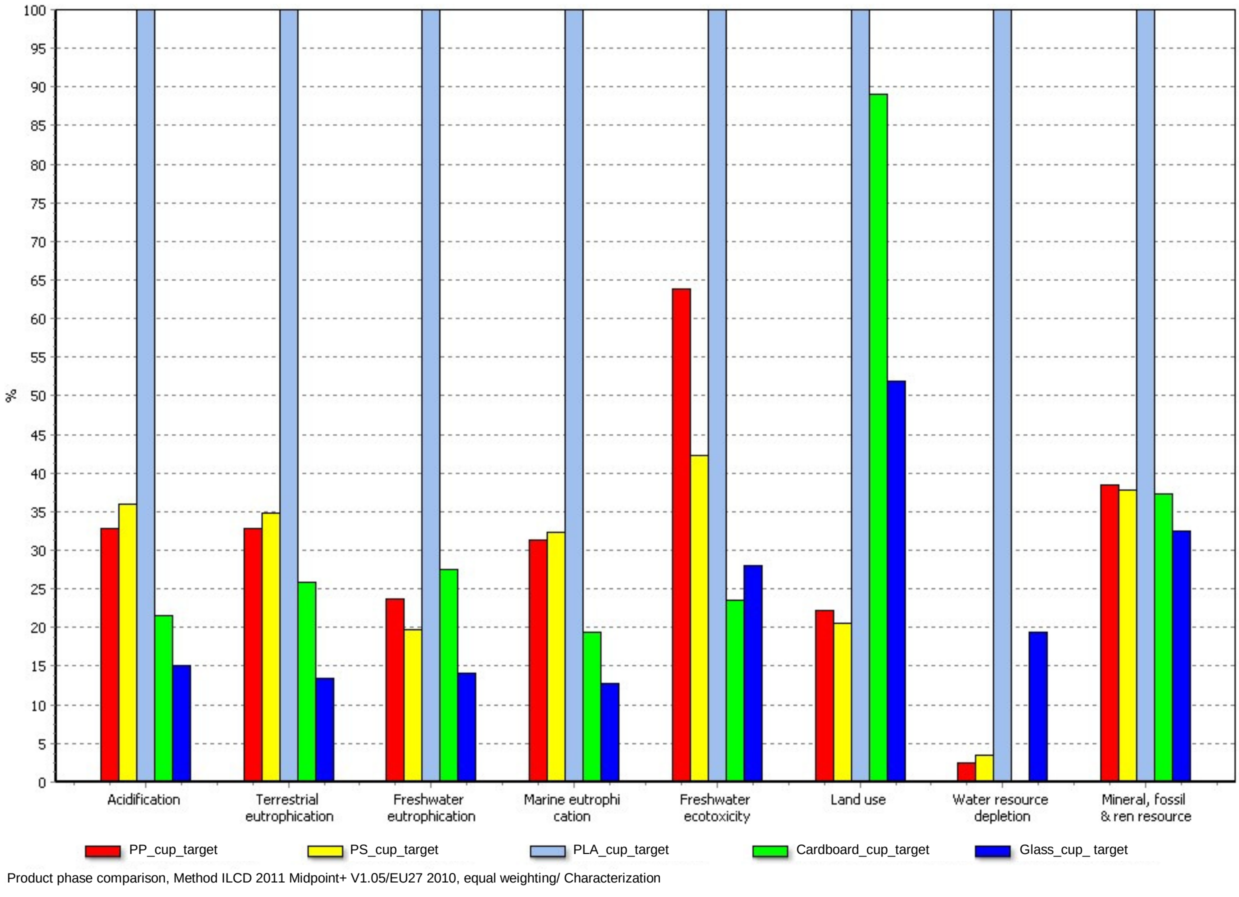
LCIA results with CONSERVATIVE scenario - ILCD method						
Impact Category	**Unit of measure**	**PP**	**PS**	**PLA**	**Laminated cardboard**	**Glass**
Climate Change	kg CO_2 eq.	2.51E+01	3.32E+01	3.73E+01	1.78E+01	8.49E+00
Ozone depletion	kg CFC-11 eq.	1.71E-06	1.56E-06	3.23E-06	3.88E-05	8.14E-07
Human toxicity - cancer effects	CTUh	7.41E-07	9.31E-07	1.40E-06	4.74E-07	2.21E-07
Human toxicity - non cancer effects	CTUh	5.75E-06	9.27E-06	1.52E-05	3.67E-06	1.21E-06
Particulate/smog, emissions of inorganic substances	kg $PM_{2,5}$ eq.	1.09E-02	1.35E-02	2.32E-02	1.87E-02	4.51E-03
Ionising Radiation - effects on human health	kg of U^{235} eq.	1.72E+00	1.51E+00	4.26E+00	1.16E+00	9.51E-01
Ionising Radiation - effects on the ecosystem	CTUe	4.66E-06	4.23E-06	1.18E-05	3.68E-06	2.08E-06
Photochemical ozone formation	kg NMVOC eq.	8.64E-02	9.60E-02	1.28E-01	5.88E-02	1.81E-02
Acidification	mole H+ eq.	1.10E-01	1.41E-01	2.47E-01	6.98E-02	3.82E-02
Eutrophication - terrestrial	mole N eq.	2.23E-01	2.67E-01	5.06E-01	1.66E-01	7.22E-02
Eutrophication – freshwater	kg P eq.	2.45E-03	2.09E-03	9.38E-03	2.43E-03	1.34E-03
Eutrophication - marine	kg of N eq.	3.25E-02	3.83E-02	9.77E-02	3.83E-02	1.10E-02
Ecotoxicity - freshwater	CTUe	5.98E+02	4.16E+02	1.07E+03	1.01E+02	9.00E+01
Use of land	kg C (deficit)	2.95E+01	2.81E+01	1.22E+02	1.34E+02	6.31E+01
Depletion of resources - water	m^3 of water	4.07E-02	7.27E-02	1.09E+00	1.53E-02	2.10E-01
Depletion of resources - minerals, fossils	kg of Sb eq.	5.37E-04	5.34E-04	1.33E-03	3.88E-04	4.33E-04

3.2.2.2 *Life Cycle Impact Assessment results - TARGET end of life scenario*

Part 1



Part 2



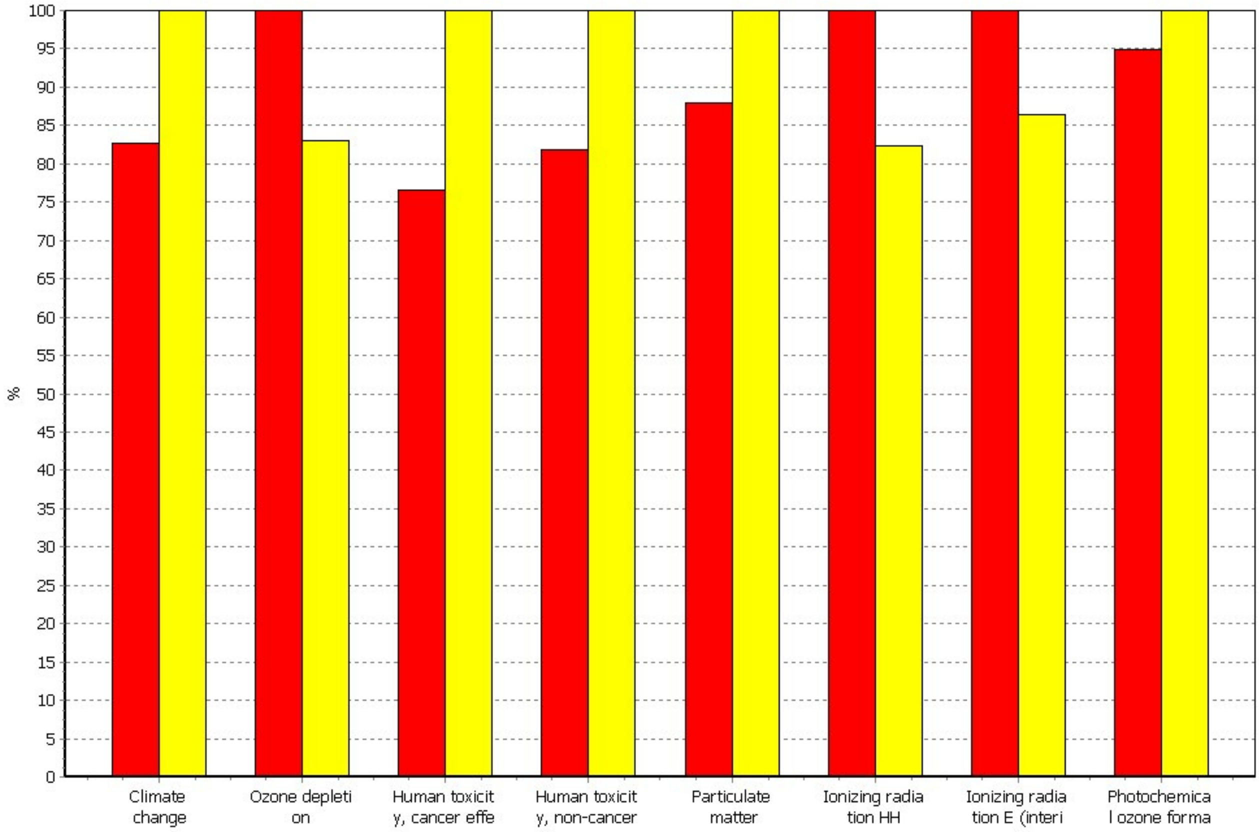
Product phase comparison, Method ILCD 2011 Midpoint+ V1.05/EU27 2010, equal weighting/ Characterization

LCIA results with TARGET scenario - CML method						
Impact Category	**Unit of measure**	**PP**	**PS**	**PLA**	**Laminated cardboard**	**Glass**
Climate Change	kg CO_2 eq.	2.36E+01	2.78E+01	3.41E+01	8.39E+00	8.46E+00
Ozone depletion	kg CFC-11 eq.	1.31E-06	1.04E-06	3.16E-06	3.85E-05	8.12E-07
Human toxicity - cancer effects	CTUh	5.93E-07	7.91E-07	1.29E-06	5.01E-07	2.20E-07
Human toxicity - non cancer effects	CTUh	2.76E-06	2.64E-06	5.22E-06	2.68E-06	1.21E-06
Particulate/smog, emissions of inorganic substances	kg $PM_{2,5}$ eq.	8.17E-03	8.95E-03	2.33E-02	1.12E-02	4.48E-03
Ionising Radiation - effects on human health	kg of U^{235} eq.	1.47E+00	1.18E+00	4.20E+00	9.12E-01	9.49E-01
Ionising Radiation - effects on the ecosystem	CTUe	4.18E-06	3.54E-06	1.16E-05	3.03E-06	2.07E-06
Photochemical ozone formation	kg NMVOC eq.	6.06E-02	6.23E-02	1.27E-01	4.64E-02	1.80E-02
Acidification	mole H+ eq.	8.23E-02	9.02E-02	2.51E-01	5.40E-02	3.79E-02
Eutrophication - terrestrial	mole N eq.	1.75E-01	1.86E-01	5.32E-01	1.38E-01	7.15E-02
Eutrophication – freshwater	kg P eq.	2.22E-03	1.85E-03	9.39E-03	2.58E-03	1.33E-03
Eutrophication - marine	kg of N eq.	2.70E-02	2.79E-02	8.65E-02	1.68E-02	1.10E-02
Ecotoxicity - freshwater	CTUe	2.04E+02	1.35E+02	3.20E+02	7.54E+01	8.98E+01
Use of land	kg C (deficit)	2.69E+01	2.49E+01	1.21E+02	1.08E+02	6.30E+01
Depletion of resources - water	m^3 of water	2.71E-02	3.81E-02	1.09E+00	-3.86E-04	2.10E-01
Depletion of resources - minerals, fossils	kg of Sb eq.	5.12E-04	5.02E-04	1.33E-03	4.95E-04	4.31E-04

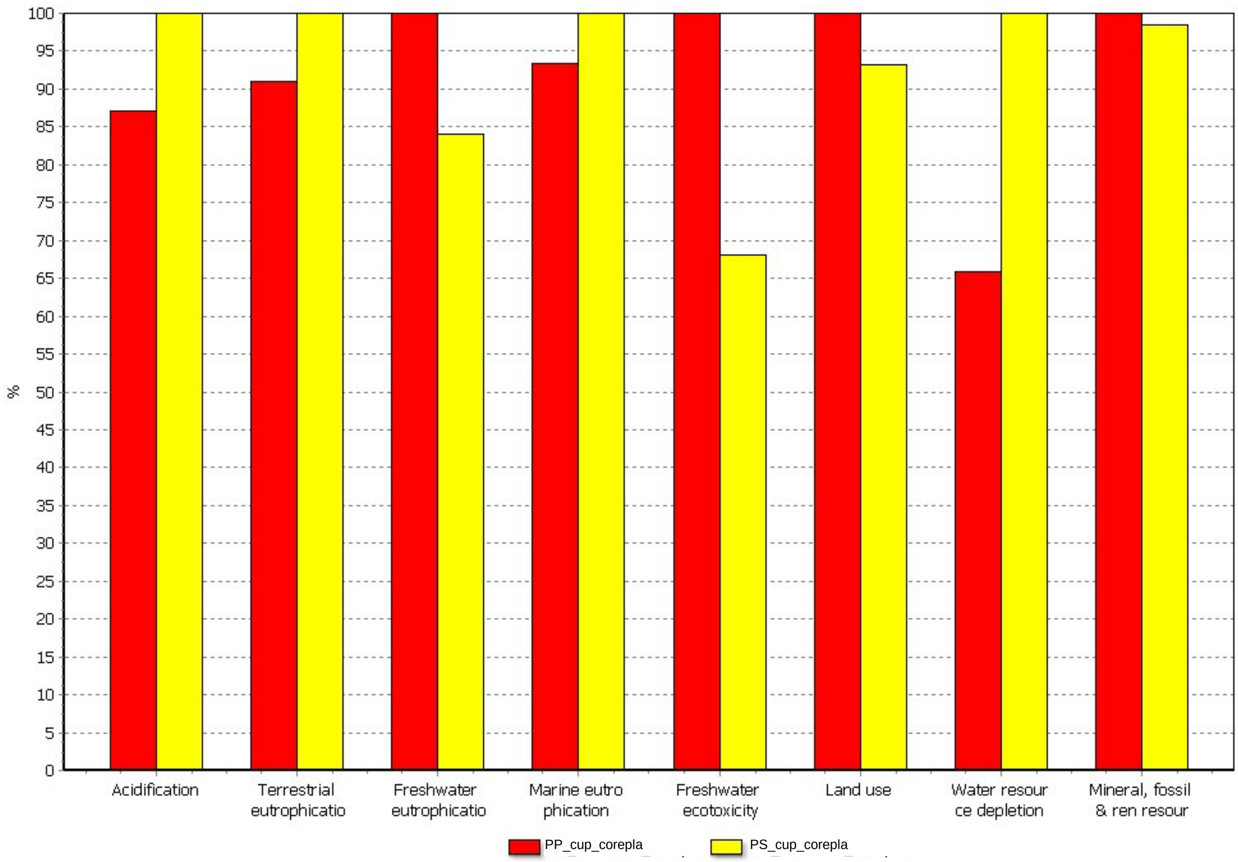
3.2.2.3 *Life Cycle Impact Assessment results - REAL end of life scenario (Corepla)*

This scenario was defined for, and applied solely to, the disposal of single-use tableware made from plastics (PP and PS) for which reliable data on packaging end of life solutions were available on a national scale (source: Corepla 2013).

Part 1



Part 2



Comparison IE3 p PP_cup_corepla with IE3_PS_cup_corepla, Method ILCD 2011 Midpoint+ V1.05/EU27 2010, equal weighting/ Characterization

LCIA results with REAL scenario - CML method			
Impact Category	**Unit of measure**	**PP**	**PS**
Climate Change	kg CO_2 eq.	2.38E+01	2.88E+01
Ozone depletion	kg CFC-11 eq.	1.42E-06	1.18E-06
Human toxicity - cancer effects	CTUh	6.27E-07	8.19E-07
Human toxicity - non cancer effects	CTUh	3.49E-06	4.27E-06
Particulate/smog, emissions of inorganic substances	kg $PM_{2,5}$ eq.	8,82E-03	1,00E-02
Ionising Radiation - effects on human health	kg of U^{235} eq.	1.54E+00	1.27E+00
Ionising Radiation - effects on the ecosystem	CTUe	4.33E-06	3.74E-06
Photochemical ozone formation	kg NMVOC eq.	6.67E-02	7.02E-02
Acidification	mole H+ eq.	8.92E-02	1.02E-01
Eutrophication - terrestrial	mole N eq.	1.86E-01	2.05E-01
Eutrophication – freshwater	kg P eq.	2.29E-03	1.93E-03
Eutrophication – marine	kg of N eq.	2.84E-02	3.04E-02
Ecotoxicity – freshwater	CTUe	2.99E+02	2.04E+02
Use of land	kg C (deficit)	2.76E+01	2.58E+01
Depletion of resources - water	m^3 of water	3.05E-02	4.62E-02
Depletion of resources - minerals, fossils	kg of Sb eq.	5.18E-04	5.10E-04

3.3 Contribution analysis

In order to identify the most significant life cycle stages from the environmental impact viewpoint, a contribution analysis has been carried out, expressing the contribution of the various phases on the total result of environmental impact categories for each item.

The analysis was applied to results calculated with the CML method, which collects the most significant impact categories; a conservative scenario has been adopted, thus considering the greatest impacts connected to the product end of life.

As regards disposable tableware, the examined life cycle stages are:

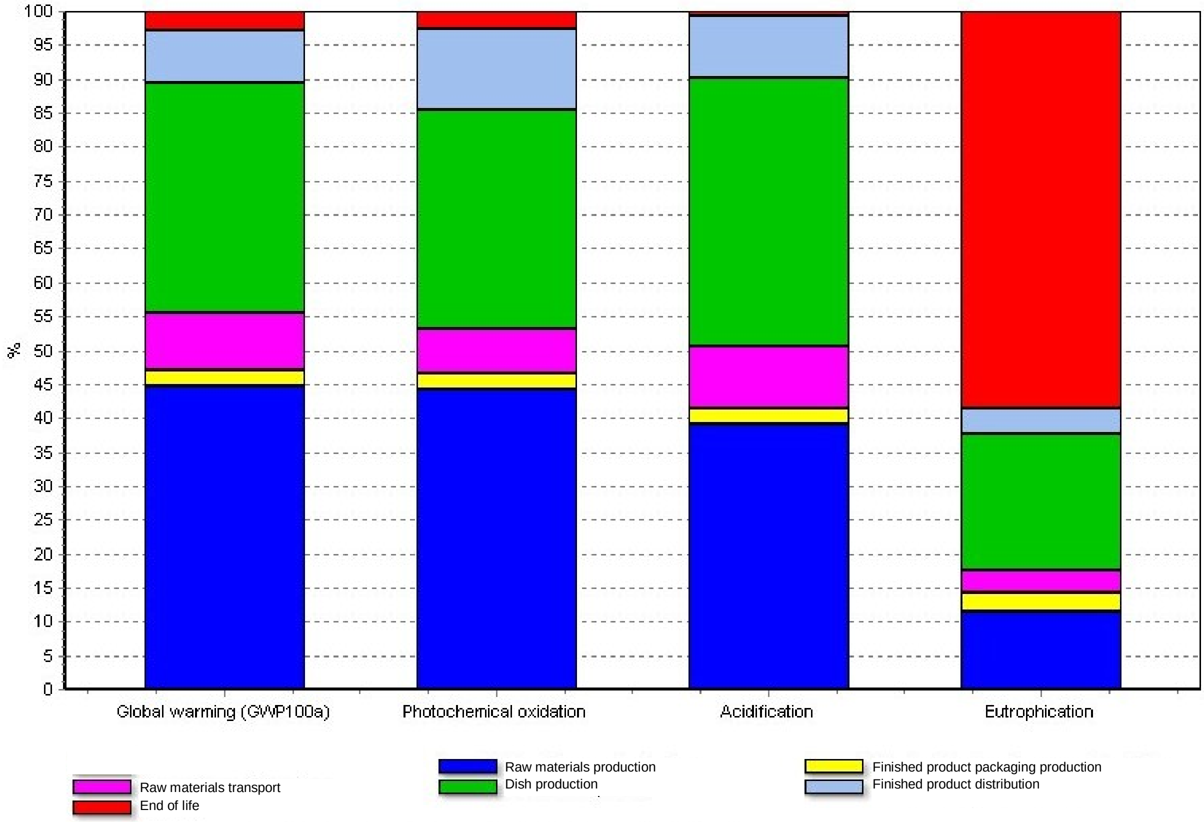
- Production of basic materials for the manufacture (e.g., polymers, cellulose pulp, mineral fillers);
- Production of primary and secondary packaging for the final product;
- Transport of input basic materials for the production phase;
- Production of the item (dish/cup);
- Distribution of the final product;
- Product end of life.

As regards reusable tableware (porcelain dish and glass cup), the contribution analysis encompassed the life cycle stages of tableware production (1 piece), washing (1000 uses) and tableware end of life, without going into detail as regards intermediate stages according to the above list (intermediate phases are in any case included in the tableware life cycle). The contribution of the washing phase is, in fact, very high and makes not computable - and of little significance for the purpose of the analysis - the contribution of the intermediate phases.

The following paragraphs report the graphs obtained with the SimaPro software, with the evidence of life cycle stages contribution for the 4 impact categories previously analysed with the CML method for each item under study.

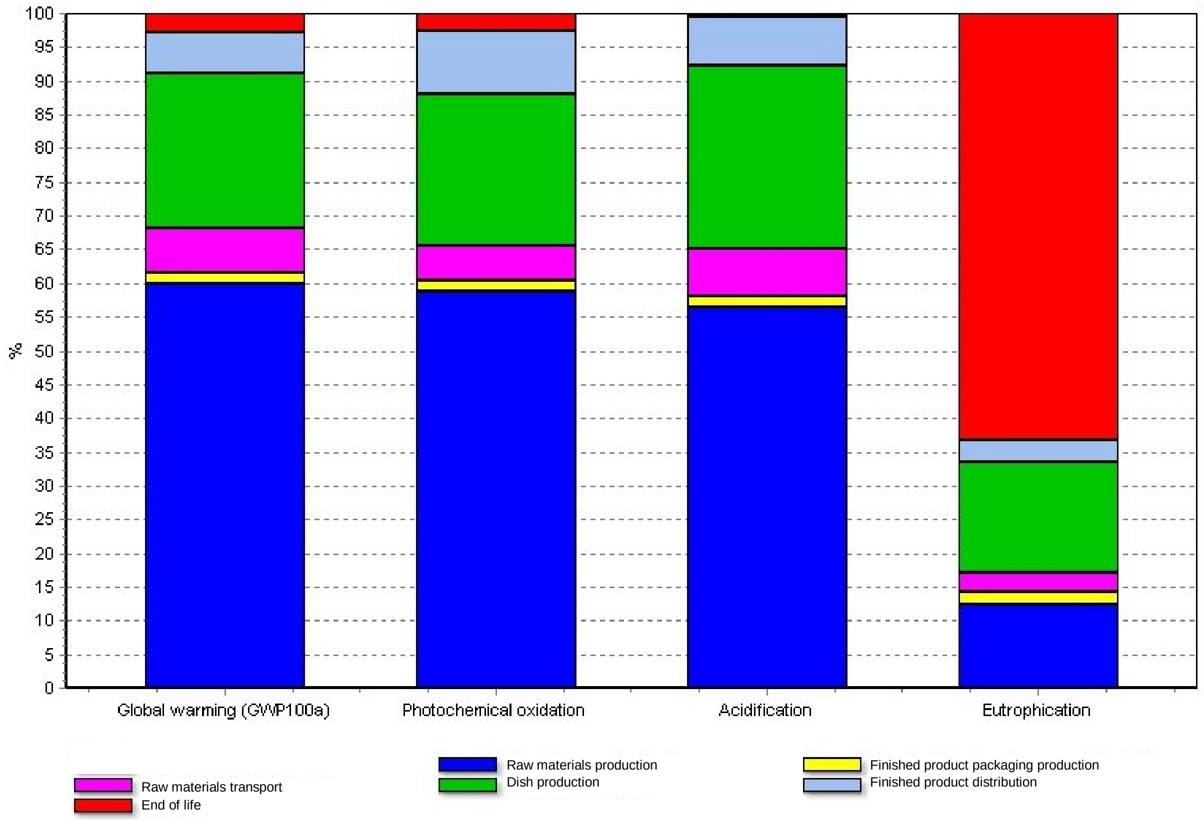
3.3.1 Contribution analysis - DISHES

3.3.1.1 *PP dish*



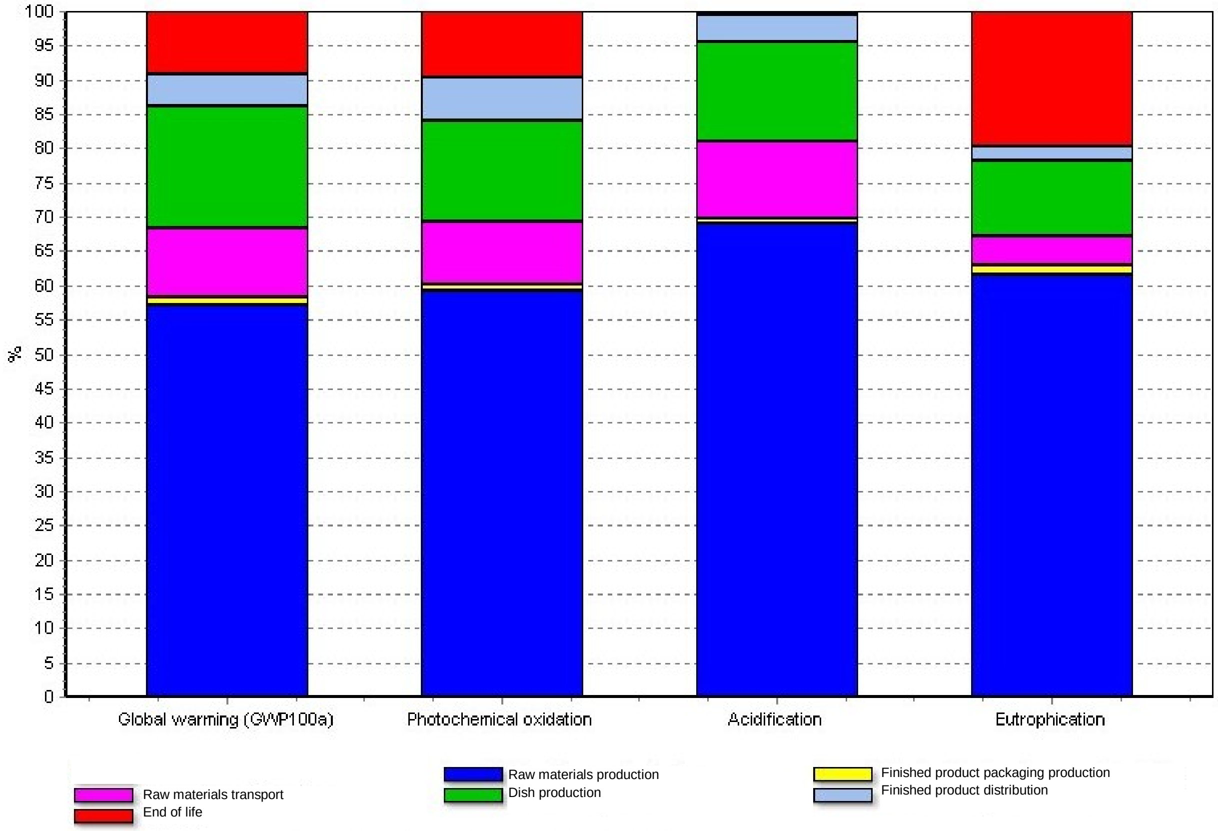
Analyzing 1p "PP_dish_conservative"; Method CML-IA baseline V3.02/EU25/Characterization

3.3.1.2 *PS dish*



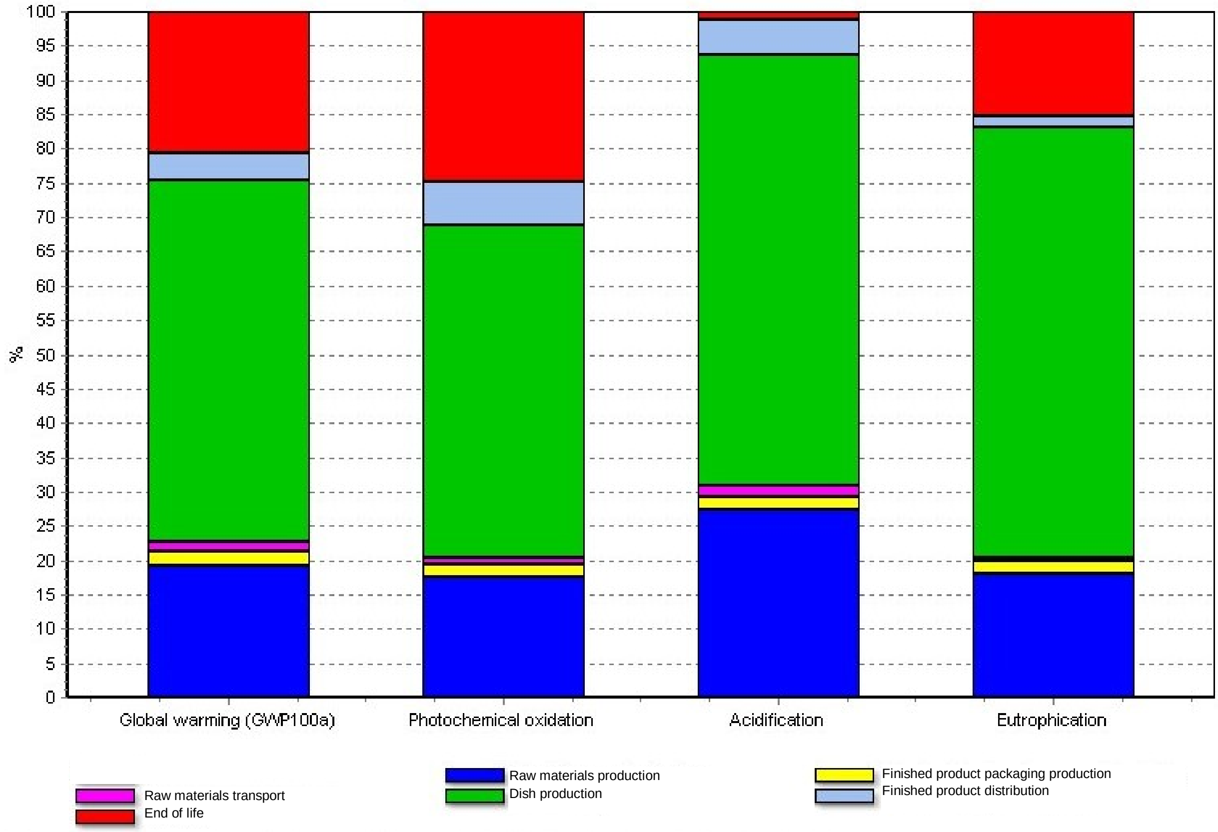
Analyzing 1p "PS_dish_conservative"; Method CML-IA baseline V3.02/EU25/Characterization

3.3.1.3 *PLA dish*



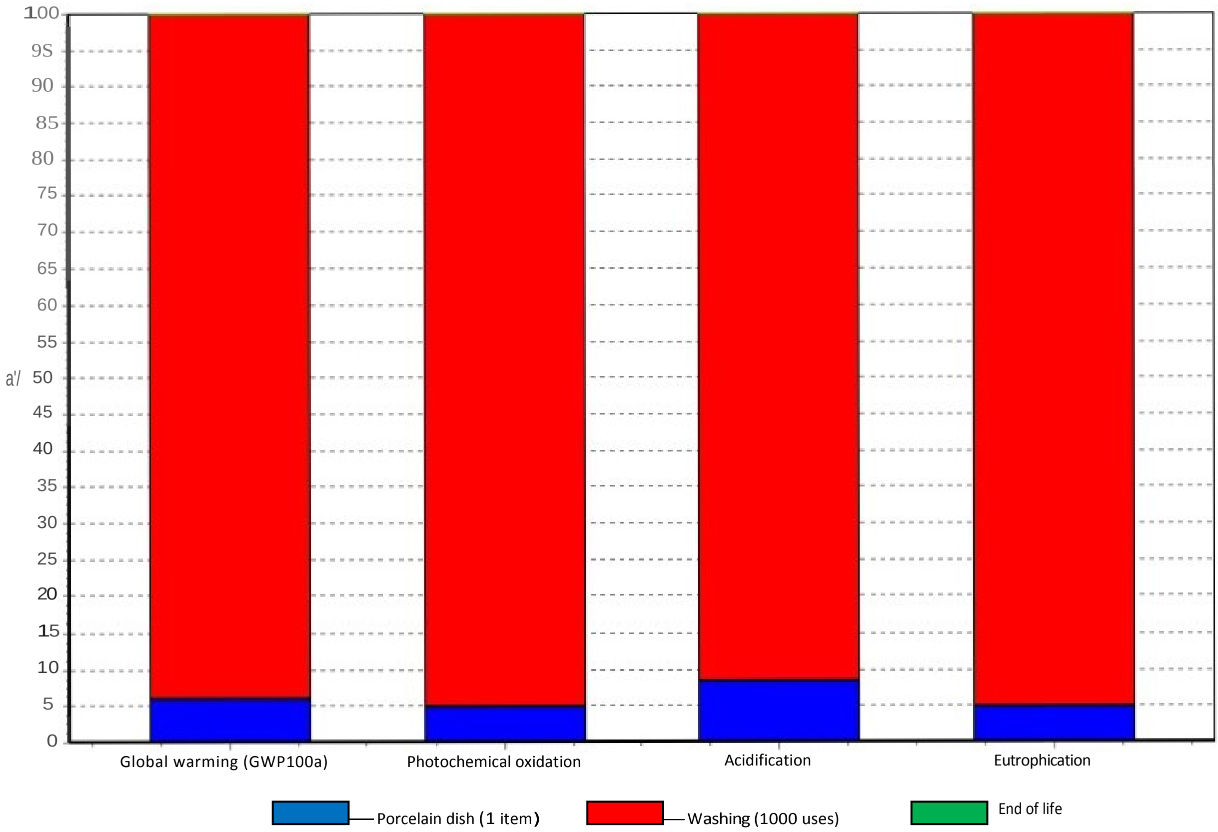
Analyzing 1p "PLA_dish_conservative"; Method CML-IA baseline V3.02/EU25/Characterization

3.3.1.4 *Cellulose pulp dish*



Analyzing 1p "Cellulose_pulp_dish_conservative"; Method CML-IA baseline V3.02/EU25/Characterization

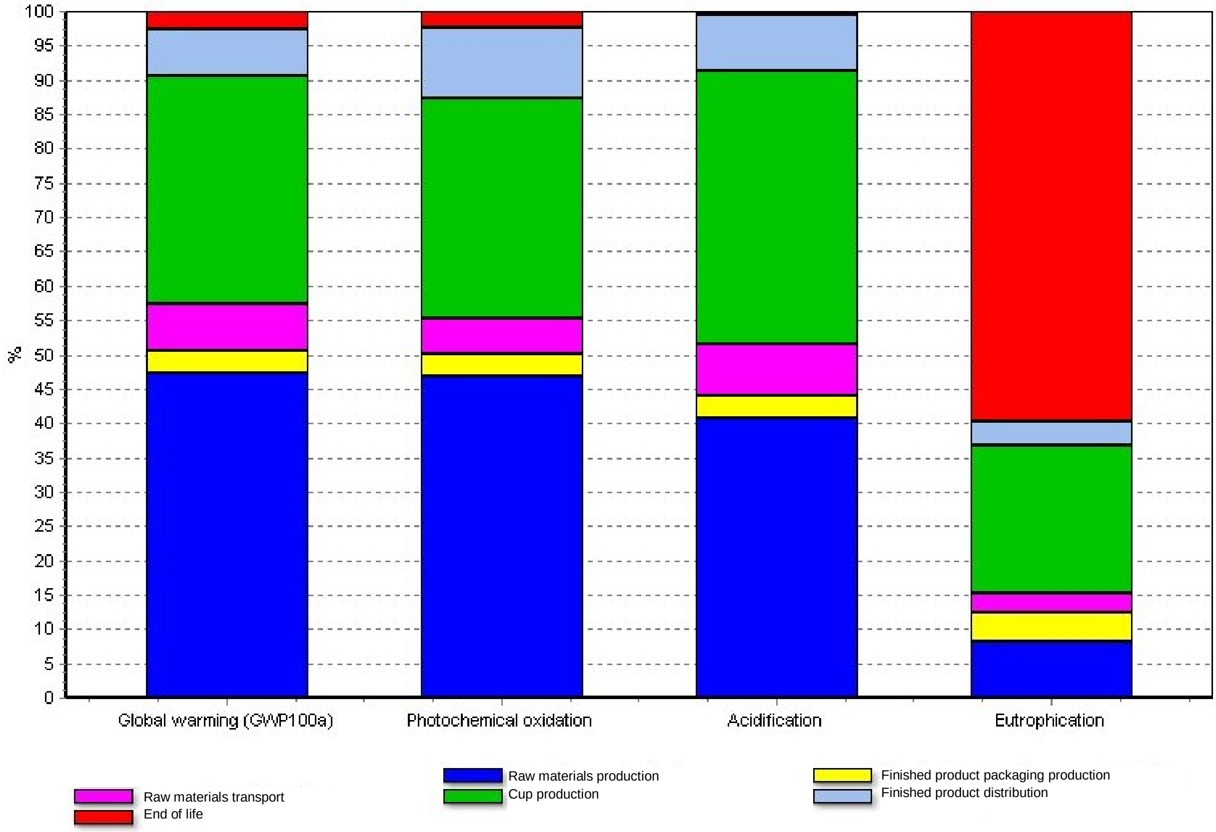
3.3.1.5 *Porcelain dish*



Analyzing 1p “Porcelain_dish”; Method CML-IA baseline V3.02/EU25/Characterization

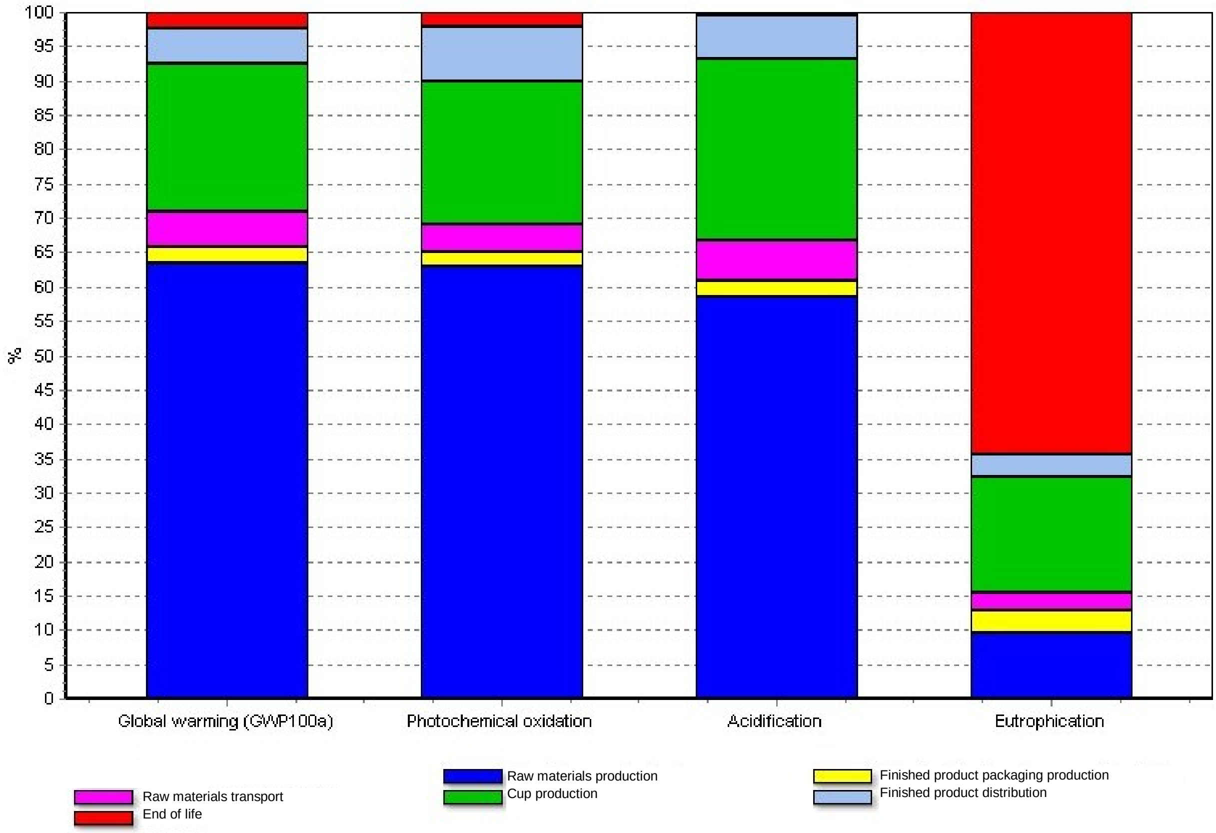
3.3.2 Contribution analysis - CUPS

3.3.2.1 *PP cup*



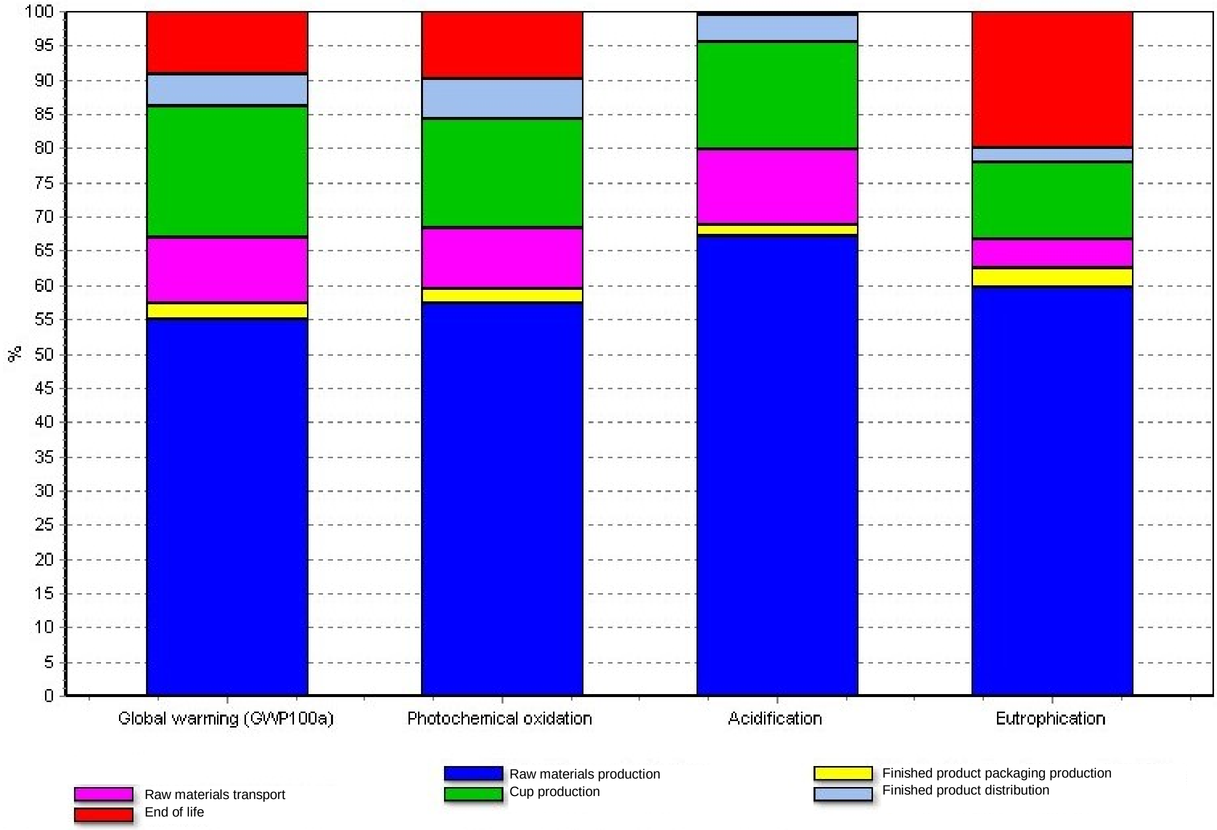
Analyzing 1p "PP_cup_conservative"; Method CML-IA baseline V3.02/EU25/Characterization

3.3.2.2 *PS cup*



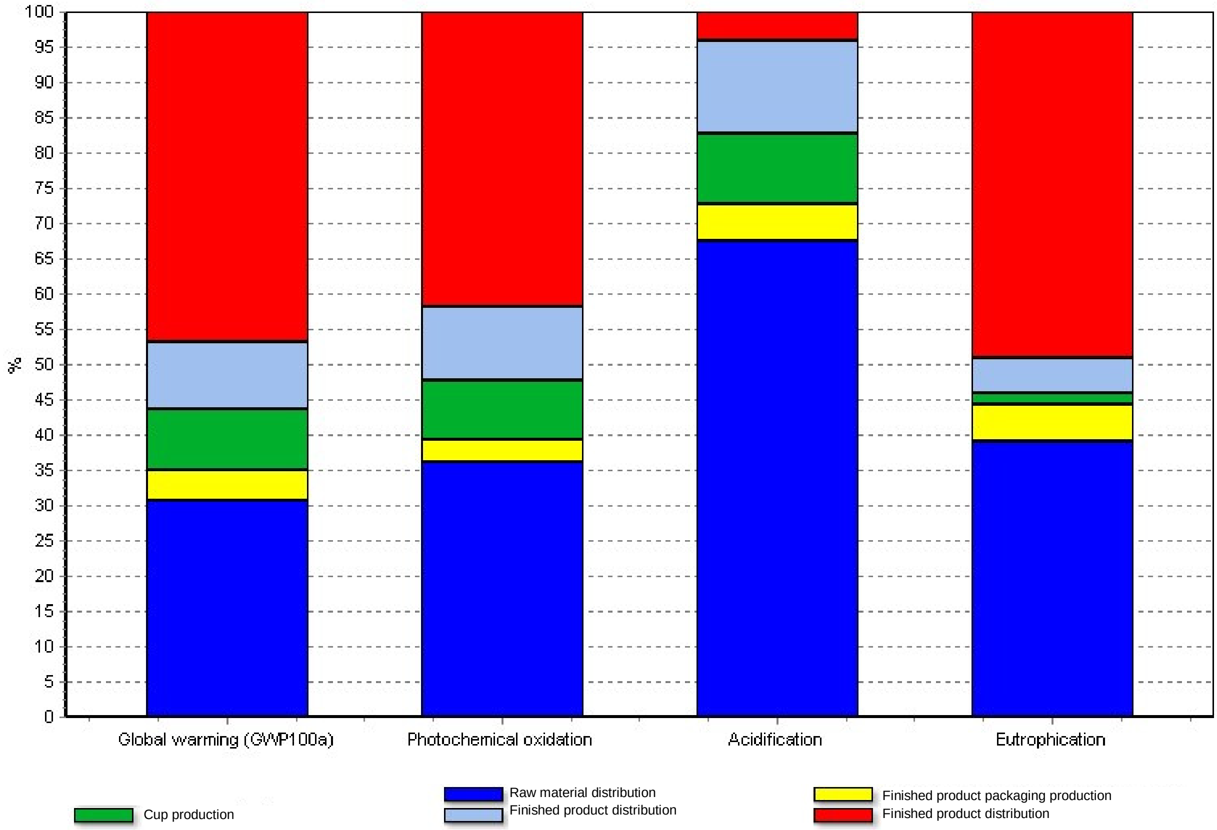
Analyzing 1p "PS_cup_conservative"; Method CML-IA baseline V3.02/EU25/Characterization

3.3.2.3 *PLA cup*



Analyzing 1p "PLA_cup_conservative"; Method CML-IA baseline V3.02/EU25/Characterization

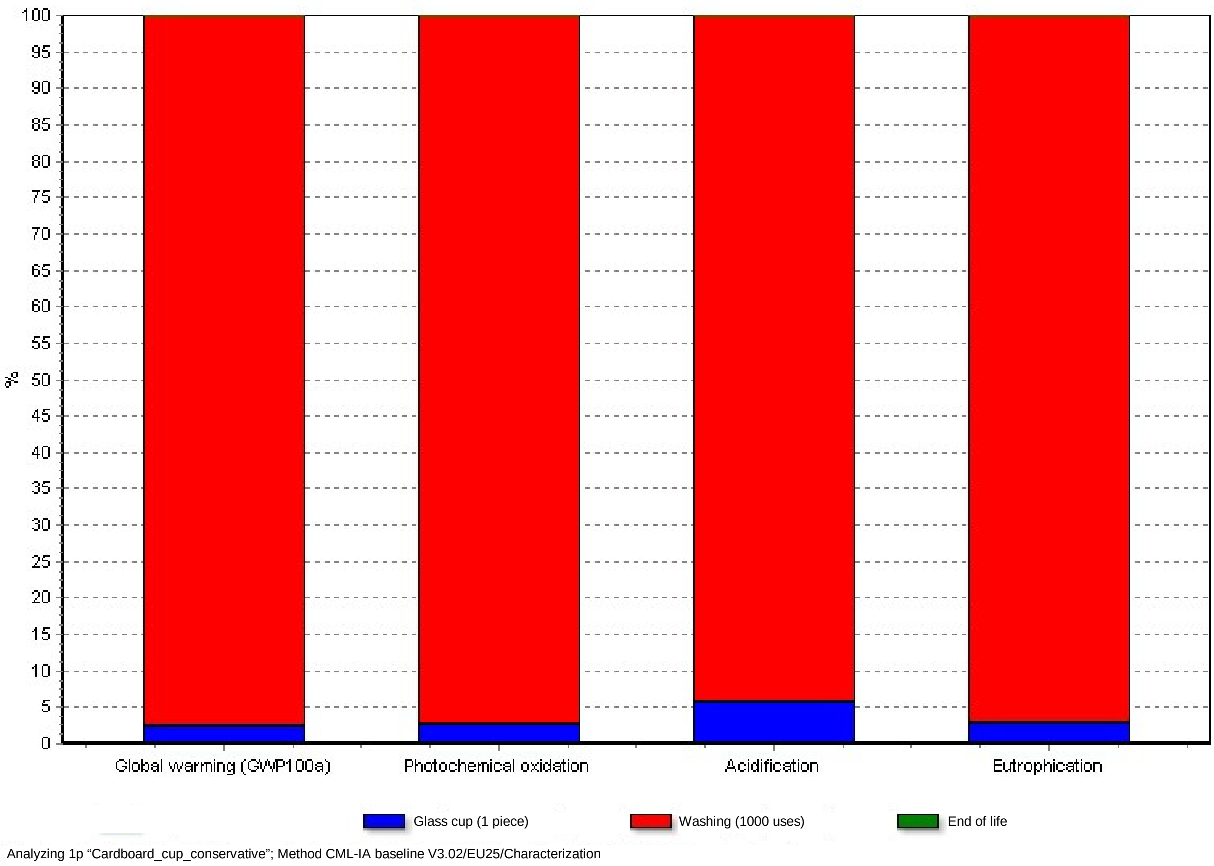
3.3.2.4 *Cardboard cup*



Analyzing 1p "Cardboard_cup_conservative"; Method CML-IA baseline V3.02/EU25/Characterization

The transport of input basic materials for the production phase is not reported in the case of the cardboard cup, since usually cardboard is manufactured and laminated within the same site where the item is subsequently manufactured (the assumption is also confirmed by the Ecoinvent database).

3.3.2.5 Glass cup



3.4 Additional LCIA data quality analyses

As prescribed by the standard ISO 14044, additional techniques and information may be needed to understand better the significance, uncertainty and sensitivity of the LCIA results in order:

- to help distinguish if significant differences are or are not present;
- to identify negligible LCI results; or
- to guide the iterative LCIA process.

The need for and selection of techniques depends on the accuracy and detail that are necessary to meet the goal and the scope of the LCA.
In case of comparative studies intended to be used for comparative assertions, it is necessary to proceed to the following additional analyses:

1. the **uncertainty analysis,** a procedure to assess how data and assumptions uncertainties are progressing in the calculations, and how they affect the reliability of LCIA results;

2. the **sensitivity analysis**, a procedure to determine how changes in data and methodological choices affect the results of the LCIA.

The following paragraphs describe the analyses conducted to assess uncertainty and sensitivity.

3.4.1 Uncertainty analysis

The uncertainty analysis is a systematic procedure to quantify the uncertainty brought in the life cycle inventory analysis results by the cumulative effects of the model imprecision, by the uncertainty of inputs, and by data variability.

The most reliable procedures for uncertainty estimation provide a quantitative analysis and, in this respect, there are essentially two different procedures: the statistical sampling or the application of analytical formulas based on the propagation of errors.
One of the random sampling methods is the Monte Carlo analysis, based on the following procedure:

1. The various input parameters are considered as stochastic variables, each having a specified probability distribution.
2. The LCA model is constructed with a given configuration of each stochastic parameter;
3. The results of the LCA study are calculated with this particular configuration;
4. The previous two phases are iterated for a pre-set number of times;
5. The results sample is investigated as regards its statistical properties (such as average, standard deviation, confidence intervals).

The uncertainty analysis has been performed with the application included in the SimaPro calculation software that uses the Monte Carlo method for the estimation of uncertainties on impact categories final results.
Appendix 2 reports the summary tables of the uncertainty analyses carried out on the results obtained with the two different methods of characterization (CML and ILCD). This analysis was carried out for each product using, here too, the results related to the conservative end of life scenario.

Hereinafter, the parameters and the input information on the analyses performed are reported:

Number of executions carried out	1000
Part of values containing uncertainty data	70%
Confidence interval	95%
Distribution type prevalent in parameters	lognormal

Tab. 4.1 - Parameters and input information regarding the uncertainty analysis

Among the most significant aspects emerging from the uncertainty analysis there are the following:

- The number of algorithm executions carried out for the calculation of the uncertainty of the study equals to 1000, and it is certainly more than adequate to ensure the robustness with which the uncertainty value associated to impact categories values has been estimated;

- The database parts that contain uncertainty values are in average equal to 70% (with an oscillation between 68% and 71%), hence the uncertainty estimate is reliable, since the uncertainty contribution of 3 data out of 4 is available;

- The use of the Monte Carlo method can be considered conservative compared to other approaches that would provide, conversely, a more targeted uncertainty assessment, but would require a detailed study of specific data distribution curves.

A first interpretation of the uncertainty values calculated with the Monte Carlo method highlights that the uncertainties related to impact categories values obtained with the CML method are on the whole acceptable: the order of magnitude of uncertainty is in fact always comparable (equal to or lower than) to the order of magnitude of the average of the values to which it is applied.

As for the ILCD method, uncertainties to be associated with the results show very high values in some specific impact categories:

- Human toxicity - cancer effects;
- Human toxicity - non cancer effects;
- Use of land;
- Depletion of resources - water.

In the interpretation phase of the LCA study (chapter 4), the uncertainty evaluation results will be analysed and examined in depth.

3.4.2 Sensitivity analysis

The contribution analysis described in paragraph 3.3 has made it possible to identify the most impacting life cycle phases of the various products, allowing focusing the sensitivity analysis on methodological choices and data that have generated such significant contributions.

The sensitivity analysis has been carried out by varying some parameters within the most significant phases from an environmental viewpoint, and by verifying the variations produced on impact categories as compared to the final results given in this report. The analyses encompassed:

1. The production of basic materials for PP, PS, PLA and cardboard disposable tableware;
2. The cellulose pulp dish production;
3. The washing of the porcelain dish and of the glass cup;
4. The duration of reusable tableware;
5. The end of life of compostable materials;
6. Products end of life scenarios.

The sensitivity analyses have been carried out taking as a reference the results obtained with the CML method.

The first four analyses relate to the LCA results obtained with the conservative end of life scenario, whereas the fifth refers to the target scenario (where composting is applied); in the various graphs, red bars correspond to final results (reported in the LCIA chapter of the present report), whereas blue bars correspond to the results obtained by varying the parameters.

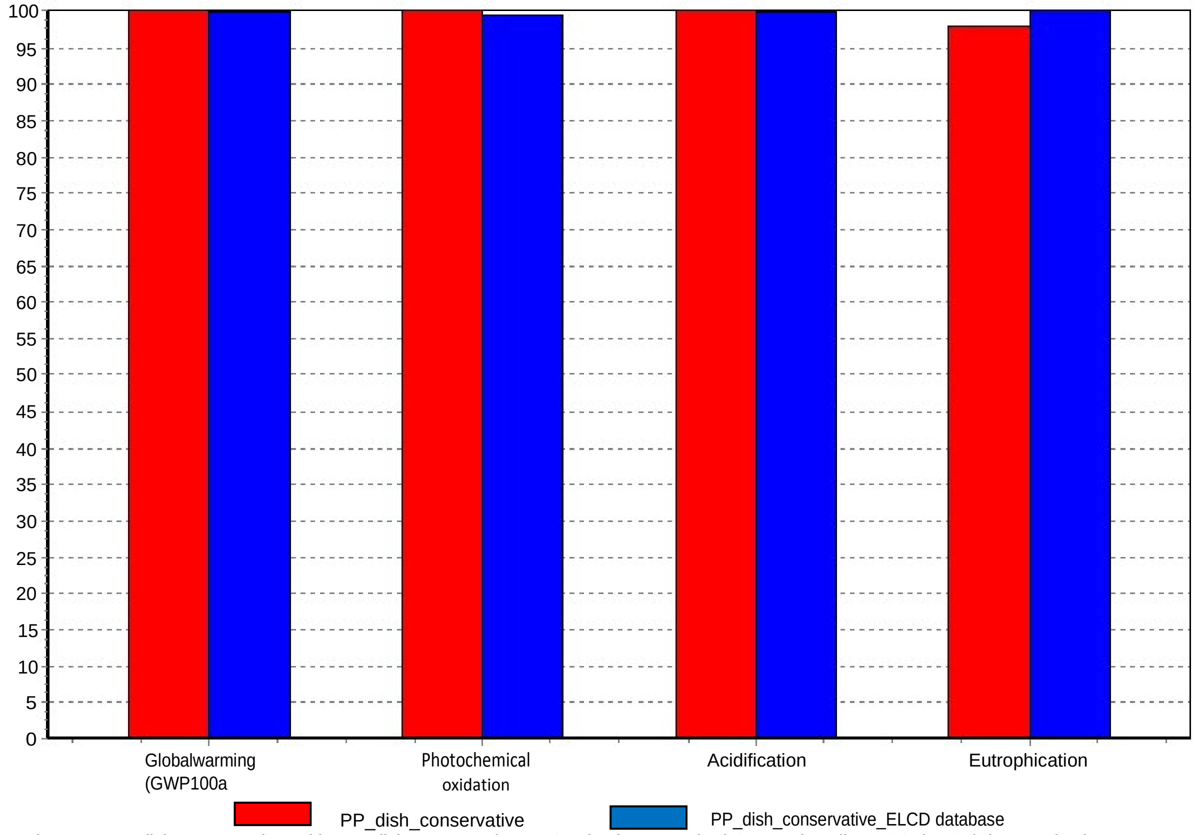
The sensitivity analysis will be considered positively concluded when at least three impact categories out of four present a variation lower than 10%. This acceptance value is borrowed from the approach of some programs operating according to ISO 14025 that consider values lower than 10% as non-influential compared to the impact categories results reported in Environmental Product Declarations.

Therefore, the present study will be considered "robust" with respect to the variation of significant parameters if, as a result of the sensitivity analysis, most of the impact categories contain their variation within 10%. Consequently, the parameters used in this study will have to be considered validated, and the study itself approved.

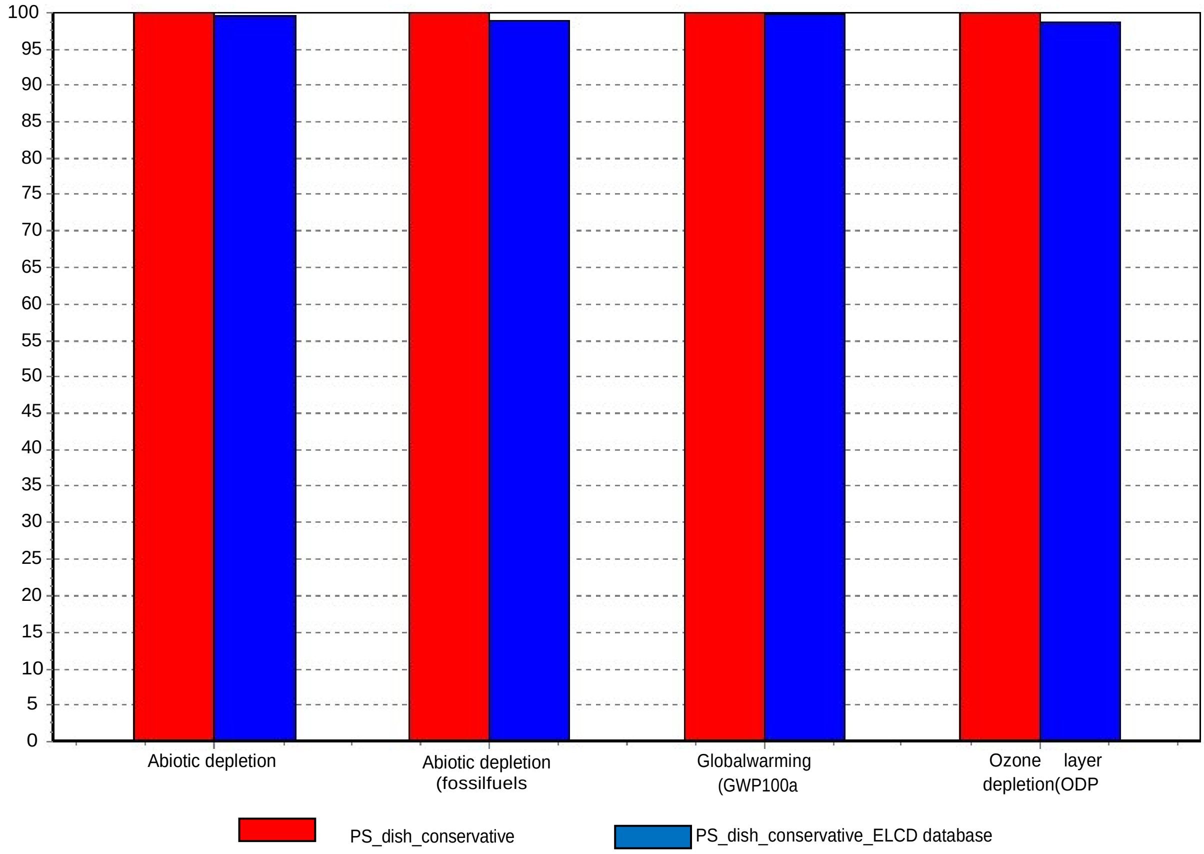
Analysis no. 1 – Production of basic materials

PP and PS: comparison flat dish life cycle, ELCD database

As regards PP and PS, the analysis has been carried out by varying the raw materials database, using the ELCD database. Being the construction of the model for the dish and the cup equivalent, the sole comparison regarding the analysis carried out on the dish is reported, and considered fully representative also of the case of the cup. As you can see from the graphs below, the results obtained from the comparison have a minimum variation, lower than 5% in all four impact categories.



Comparison 1p “PP_dish_conservative” with “PP_dish_conservative_ELCD database” Method CML-IA baseline V3.02/EU25/Characterization

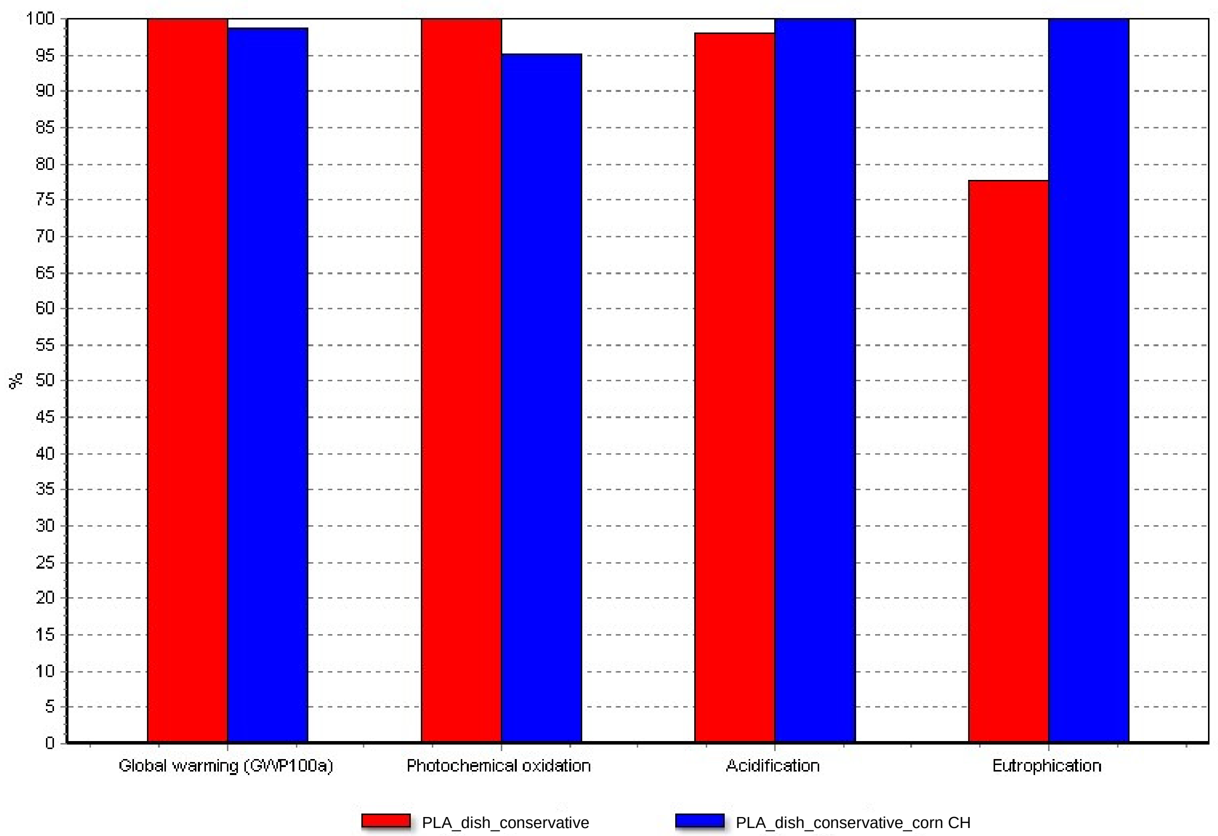


Comparison between 1p “PS_dish_conservative” and “PS_dish_conservative_ELCD database” Method CML-IA baseline V3.02/EU25/Characterization

PLA: comparison flat dish life cycle, European corn production

In the PLA case, there is no database suitable for comparison other than Ecoinvent, used for the calculation of the final results of the study. However, being the corn production a significant phase, the sensitivity analysis was performed by varying, in the PLA database, the sole unitary process of corn production, from global to European, Swiss production (given the poor corn production in Switzerland, data are considered conservative). The results of the comparison carried out for the dish are reported, given the equivalence between the dish and the cup models.

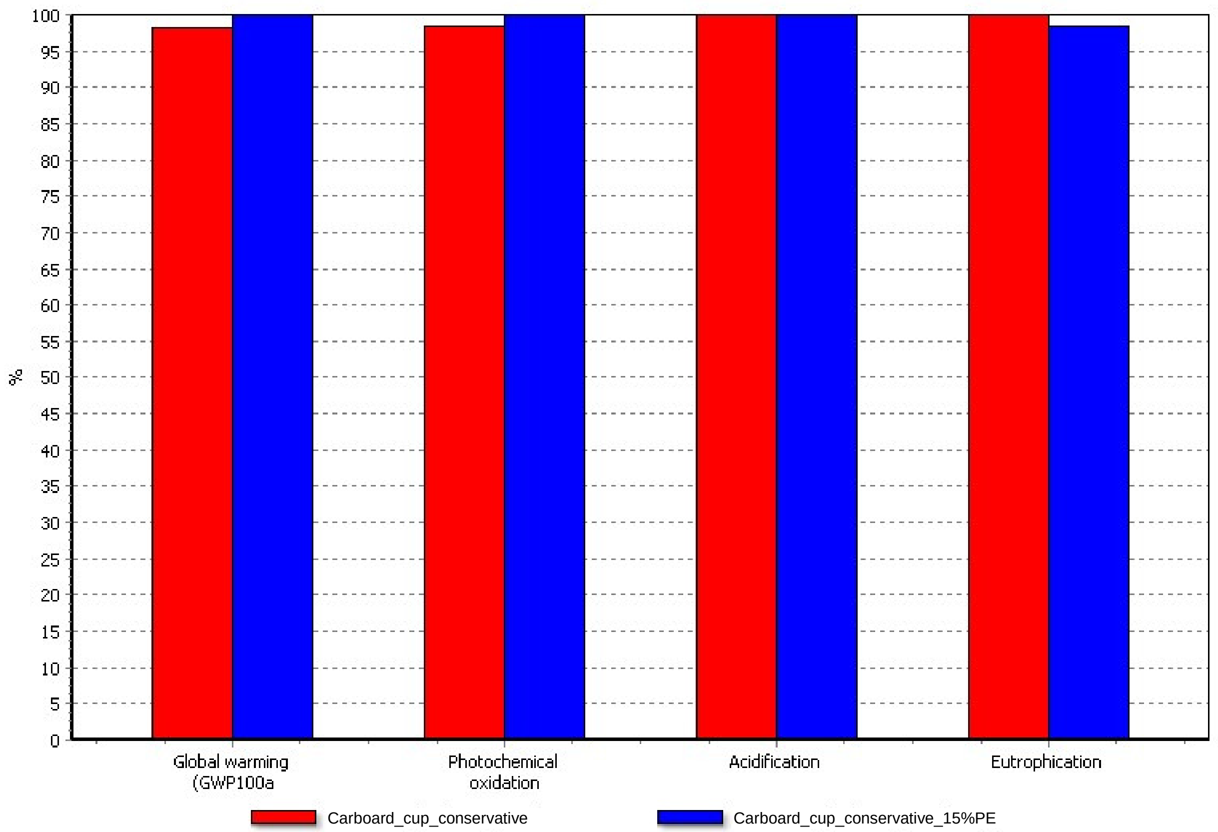
The following graph reports a variation lower than 5% in all categories, except for eutrophication, which presents a variation of about 20%.



Comparison 1p “PLA_dish_conservative” with “PLA_dish_conservative_corn CH”; Method CML-IA baseline V3.02/EU25/Characterization

Cardboard: comparison cup life cycle, 15% PE (lamination)

As regards the production of laminated cardboard, there is no available database other than Ecoinvent. Therefore, the sensitivity analysis is focused on a parameter that may frequently vary within this product type, i.e. the polyethylene content on the laminated cardboard. The percentage of PE on the product has been increased from 10% to 15 %. As you can see from the graph that follows, the comparison shows how variations in the results are lower than 5% in all impact categories.

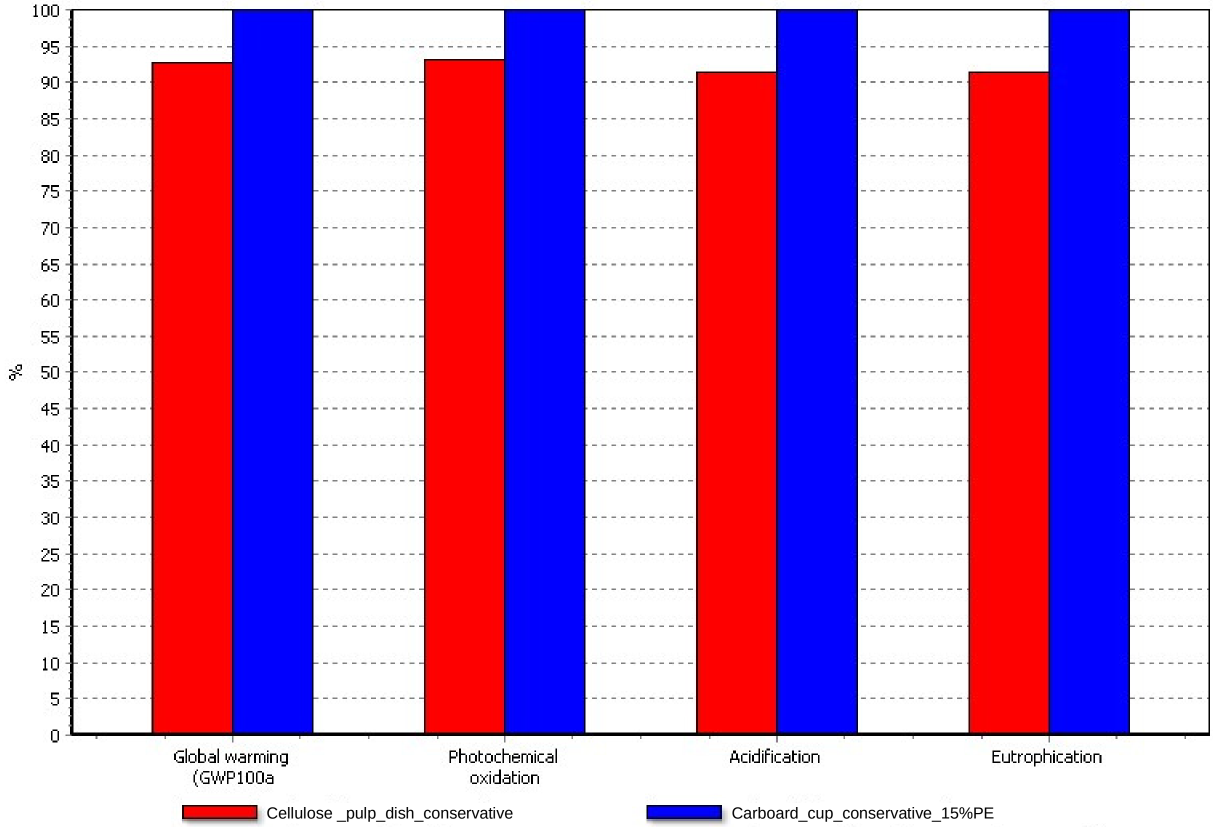


Comparison between 1p “Carboard_cup_conservative” and “Carboard_cup_conservative _15%PE”; Method CML-IA baseline V3.02/EU25/Characterization

Analysis No. 2 - Cellulose pulp dish production

In the case of the cellulose pulp dish, the most impacting phase is the production of the dish starting from the cellulose pulp, which is realised through a process that is particularly energy consuming. The sensitivity analysis in this case has involved the electrical energy consumption of the forming phase incremented by 15% in order to evaluate how this variation affects the final results of the study.

As you can see from the graph, the variation in the impact categories never exceeds 10%.



Comparison between 1p “Carboard_cup_conservative” and “Carboard_cup_conservative_15%PE”; Method CML-IA baseline V3.02/EU25/Characterization

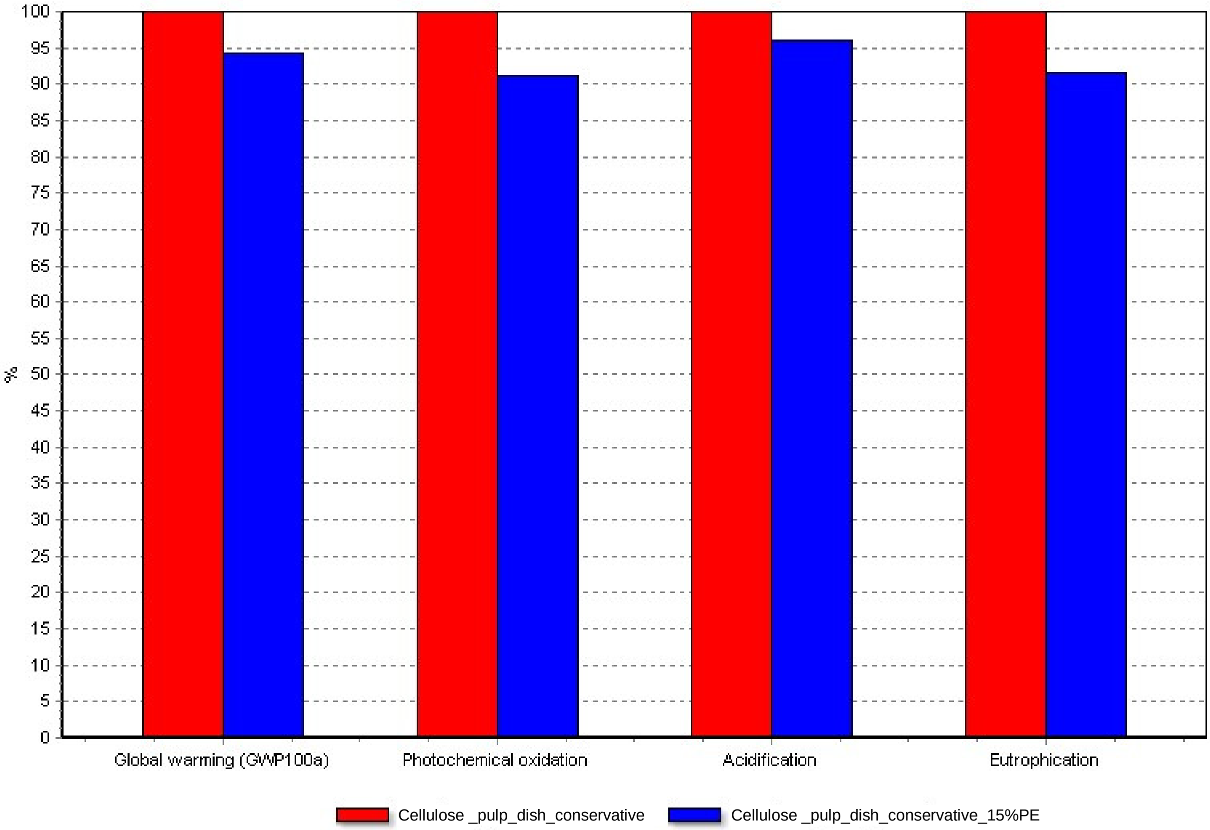
Analysis No. 3 - Washing of the porcelain dish and of the glass cup

The impact of the washing phase (1000 uses) in the case of reusable tableware is so significant that it makes negligible the contribution to the life cycle of the same piece of tableware. The sensitivity analysis performed has involved one of the most significant inputs of the washing phase, i.e. the detergent: in fact, the amount of used detergent can be highly variable (depending also on specific choices related to the different countries in which washing is performed and the habits of users). In this case, a decrease of 15% has been applied to the amount of used detergent.

The comparative graphs for the porcelain dish and the glass cup cases are given below.

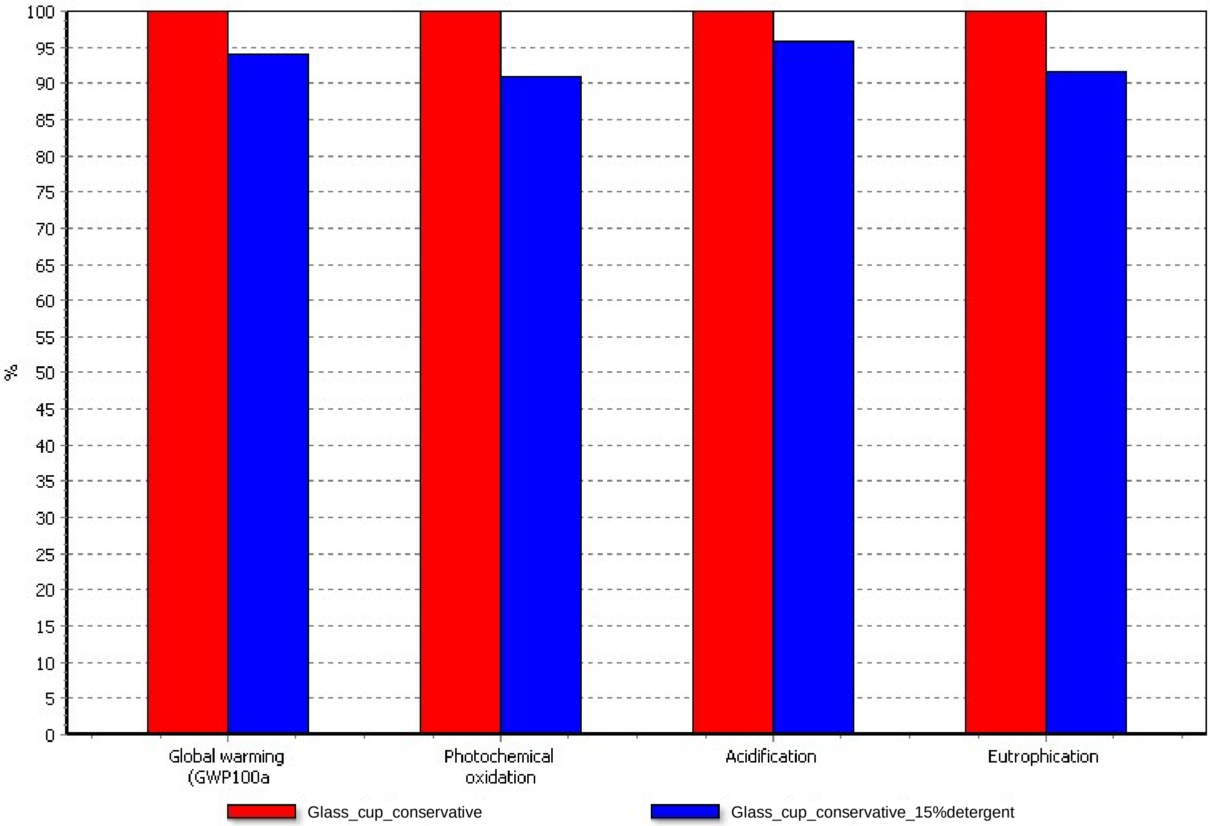
The results show that the decrease in impacts is contained within 10% in all studied impact categories.

Life cycle comparison with detergent reduction equal to 15% - PORCELAIN DISH



Comparison between 1p “Porcelain_dish” ans “Porcelain_dish_15%detergent”; Method CML-IA baseline V3.02/EU25/Characterization

Life cycle comparison with a reduction of the detergent equal to 15% - GLASS



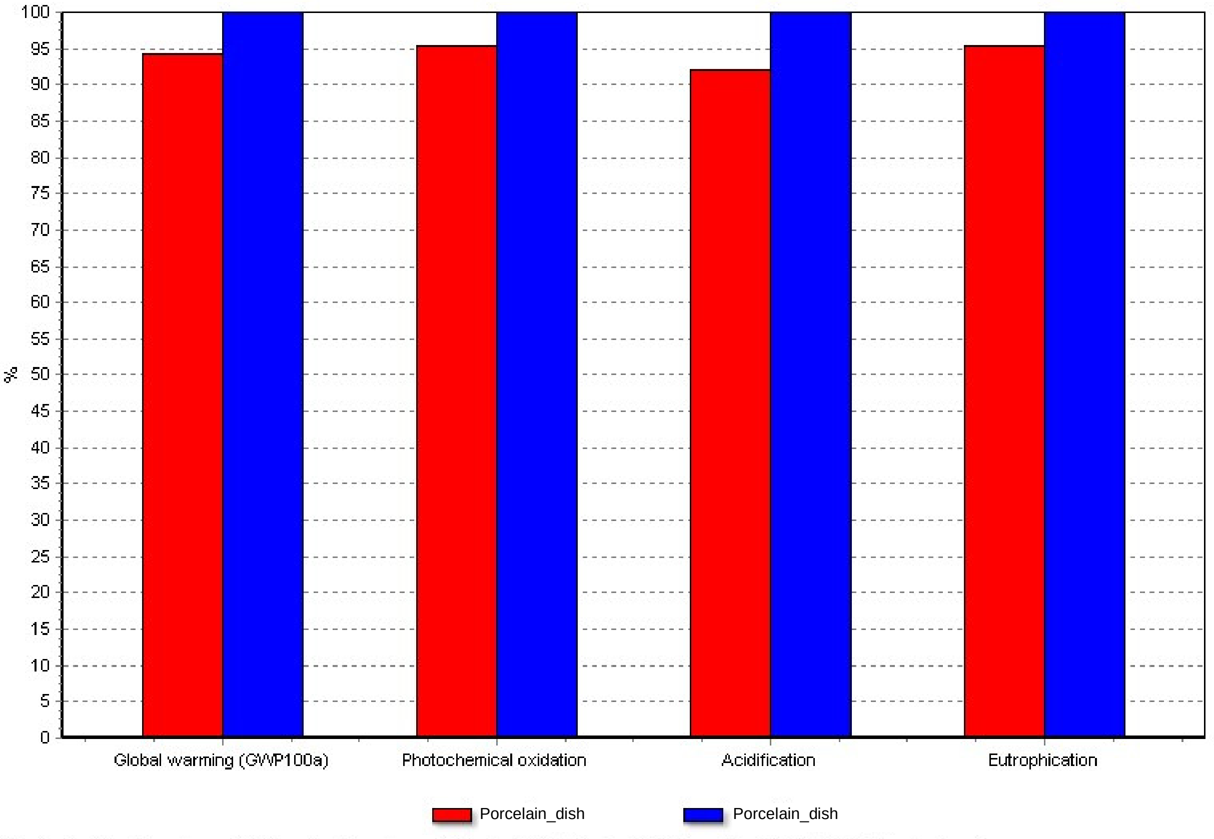
Comparison between 1p “Glass_cup_conservative” and “Glass_cup_conservative_15%detergent”; Method CML-IA baseline V3.02/EU25/Characterization

Analysis No. 4 – Duration of reusable tableware

The sensitivity analysis was conducted in order to evaluate the variations in environmental impacts in case that a duration of reusable tableware equal to half (500 uses) is considered, i.e. by bringing the reference flow to two pieces instead of one in the 1000 uses envisaged by the functional unit.

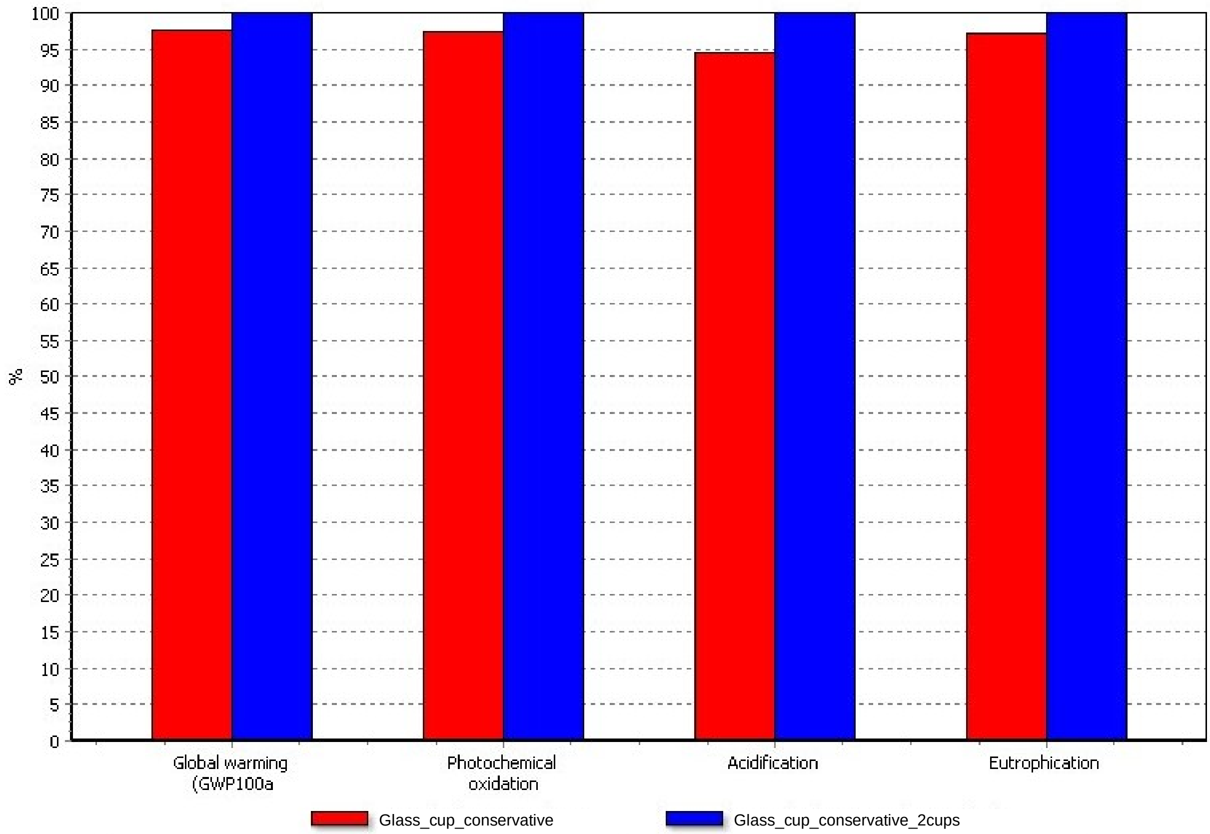
As it can be seen from the graphs below, the comparison shows how the variations in the results are below 10% in all impact categories.

<u>Porcelain dish: life cycle comparison with two pieces in 1000 uses</u>



Comparison 1p "Porcelain_dish" with "Porcelain_dish"; Method CML-IA baseline V3.02/EU25/Characterization

Glass cup: life cycle comparison with two pieces in 1000 uses



Comparison between 1p “Glass_cup_conservative” and “Glass_cup_conservative_2cups”; Method CML-IA baseline V3.02/EU25/Characterization

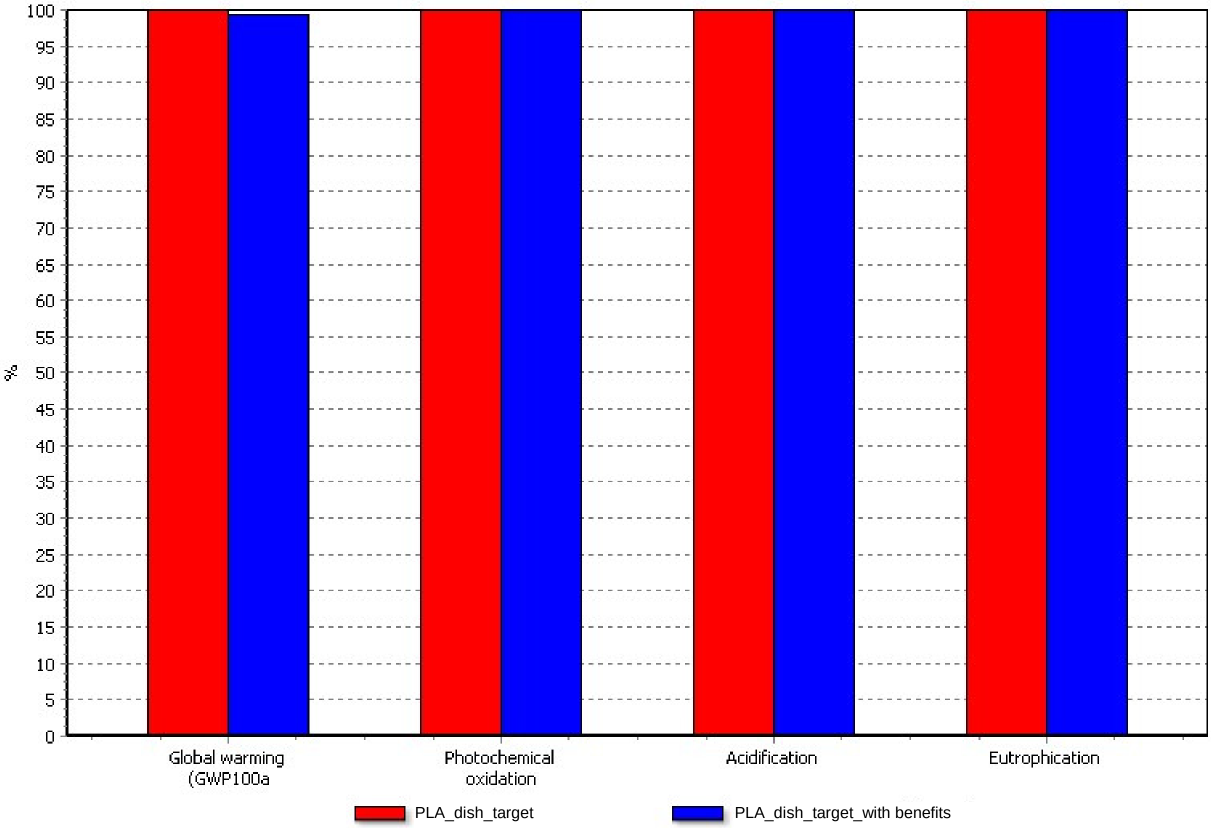
Analysis No. 5 – End of life of compostable materials

This analysis was carried out to evaluate the variations in the results arising from the application of the approach of system expansion also to compostable materials (PLA and cellulose pulp), with the inclusion of benefits gained by avoiding the production of soil improver. Annex 2 includes a validation for the determination of the type and quantity of soil improver avoided thanks to the composting operations of the materials under study. The material chosen as avoided product is the nursery-use peat in the amount of 50 g per kg of compost waste in PLA, and of 250 gr per kg of cellulose pulp compost waste.

Hereinafter you can find the comparative graphs for the PLA dish and cellulose pulp dish.

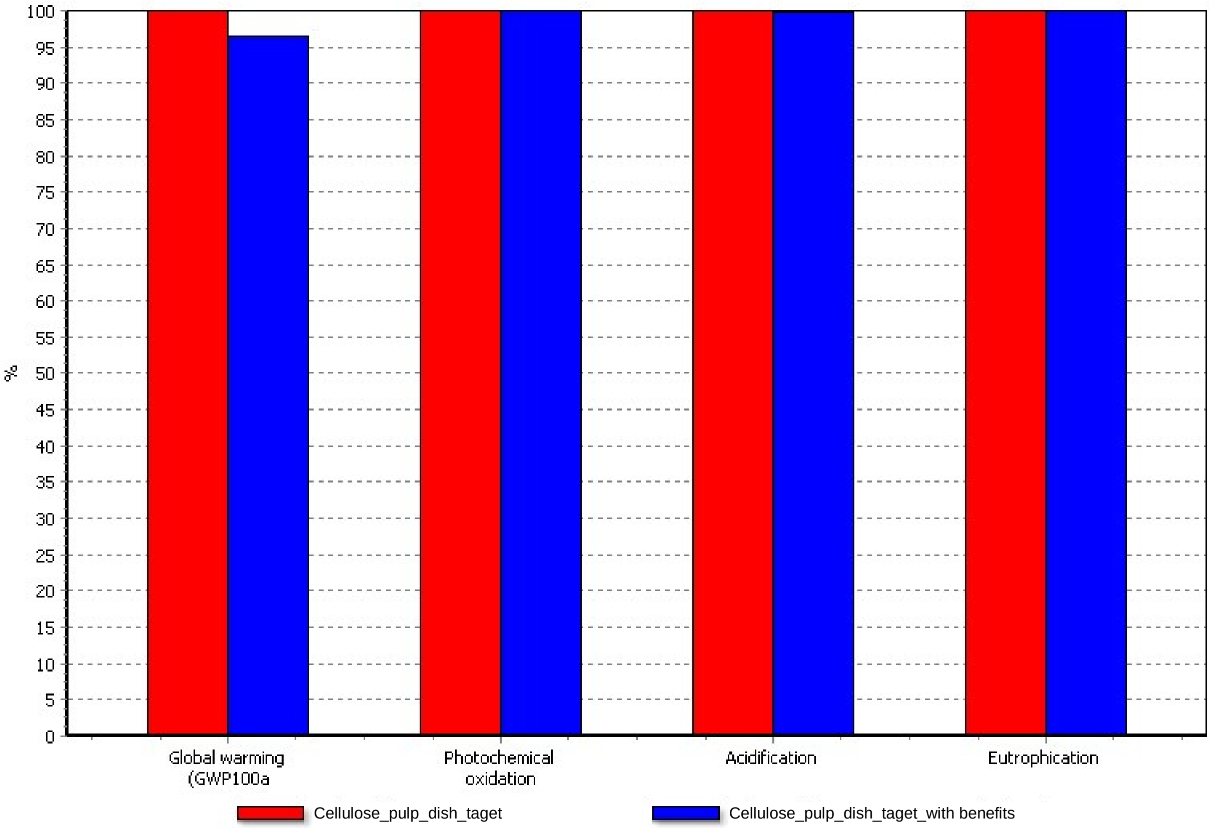
The comparison highlights that no significant variation influences impact categories. The only indicator that has a minimum incidence (less than 4%) is the Global Warming category in the case of the cellulose pulp dish.

Life cycle comparison with System expansion approach - PLA dish



Comparison between 1p “PLA_dish_target” and “PLA_dish_target_withbenefits”; Method CML-IA baseline V3.02/EU25/Characterization

Life cycle comparison with System expansion approach - Cellulose pulp dish



Comparison between 1p “Cellulose_pulp_dish_taget” and “Cellulose_pulp_dish_taget_withbenefits”; Method CML-IA baseline V3.02/EU25/Characterization

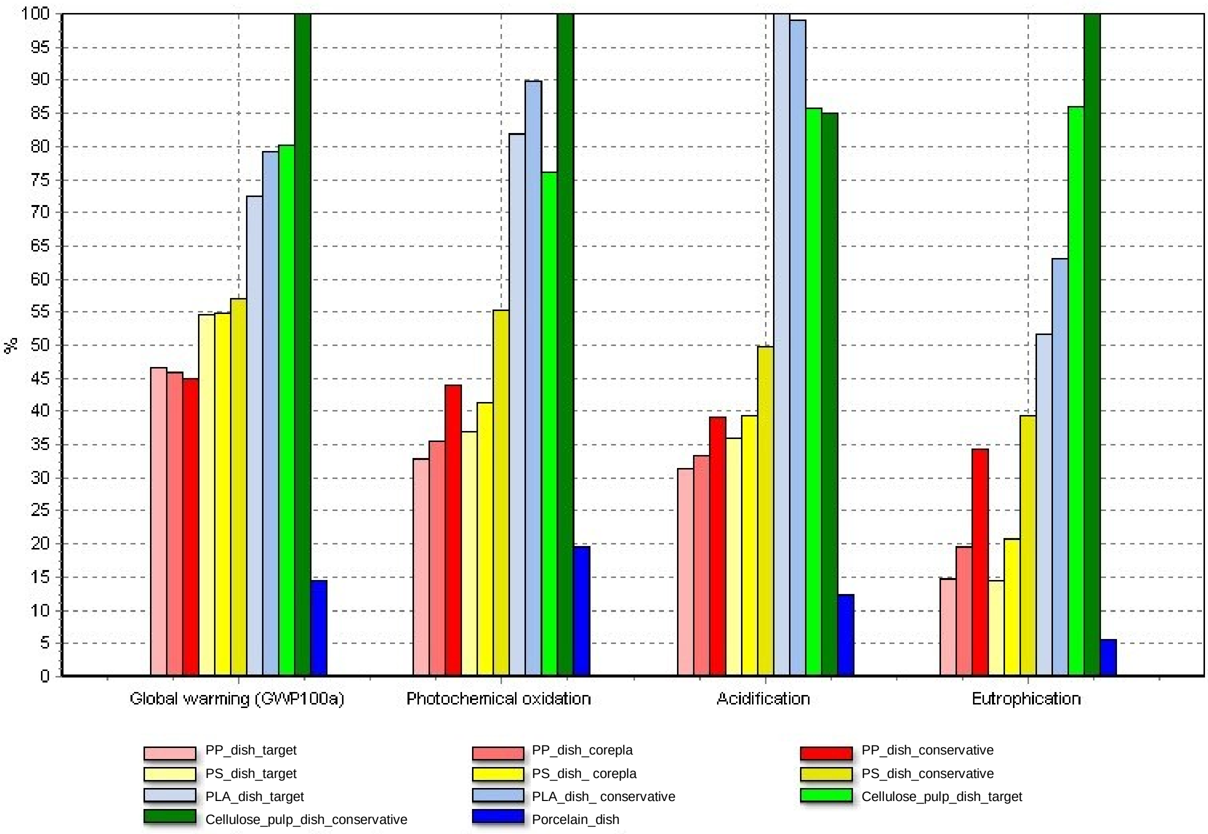
Analysis No. 6 – Products end of life scenarios

The analysis has compared the final results of the study, as calculated by applying the three different end of life scenarios previously assumed: conservative, target, and real.

The following graphs report the comparisons carried out for the two different types of tableware: dishes and cups.

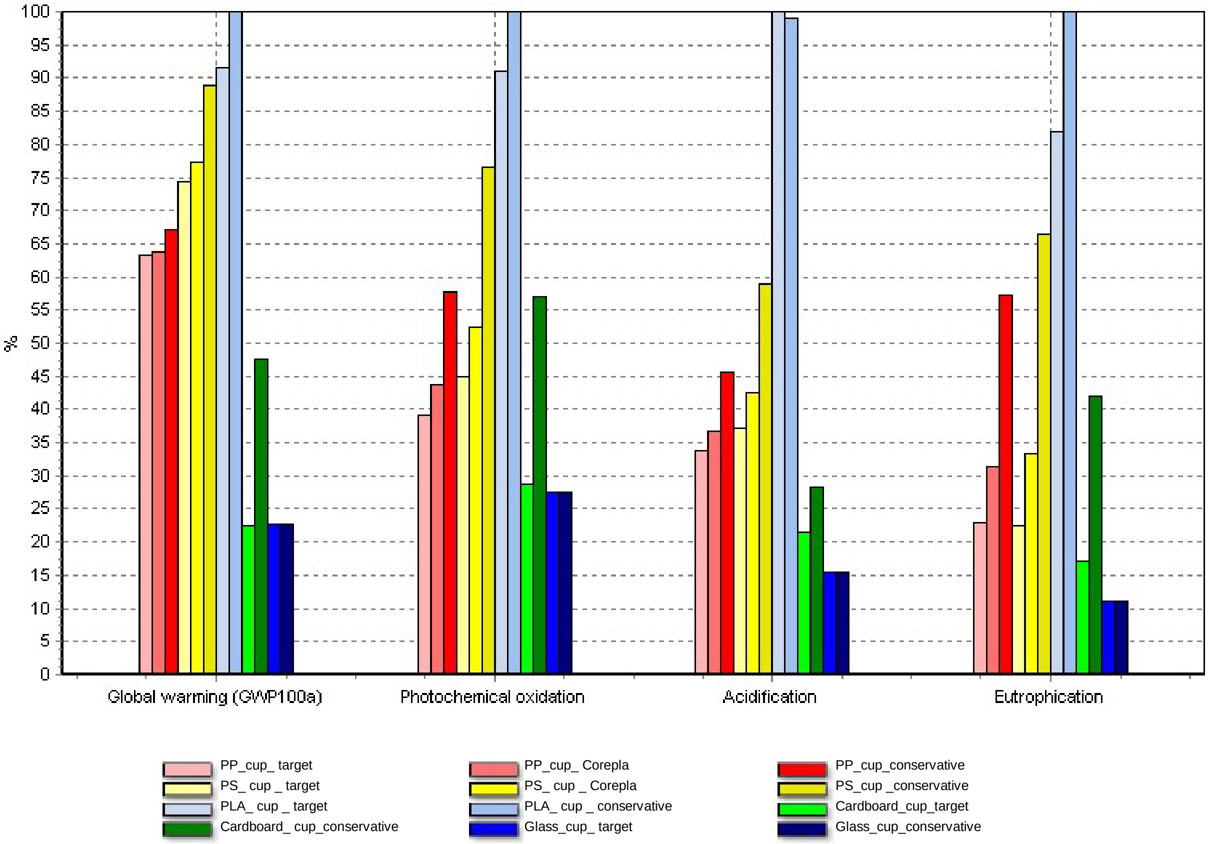
As can be seen, the variations between the different scenario options are so significant to exceed, in some cases, 50% (e.g. for the cardboard cup). Consequently, the life cycle impacts assessment (LCIA, paragraphs 3.1 and 3.2) has been extended to all three scenarios, and the results of the life cycle of each product are reported separately for each assumed scenario.

<u>Life cycle comparison with the three end of life scenarios - DISHES</u>



Product phase comparison; Method CML-IA baseline V3.02/EU25/Characterization

Life cycle comparison with the three end of life scenarios - CUPS



Product phase comparison; Method CML-IA baseline V3.02/EU25/Characterization

4. Life cycle interpretation

In accordance with the standard ISO 14044, the life cycle interpretation phase of the LCA study comprises the following elements:

- The identification of significant issues based on the results of the LCIA phase;
- An evaluation that encompasses completeness, sensitivity and consistency checks;
- Conclusions, limitations, and recommendations.

4.1 Identification of significant issues

This paragraph identifies the essential contributions of the life cycle phases to the final results reported in chapter 3 concerning the LCIA phase. The identification of the phases with the greatest impact within the life cycle of each individual Product System under examination allows deepening the comparison by providing a more detailed profile of the various products life cycle.
Paragraph 3.3 reports a contribution analysis of the various phases on the final result of the environmental impact categories for each studied item; the following table shows a synoptic diagram that sums up the analysis performed.

DISHES- Greatest impact phases by impact category (CML method)				
Type	**Global Warming**	**Photochemical oxidants formation**	**Acidification**	**Eutrophication**
Disposable made of polypropylene (PP)	1. Production of raw materials (45%) 2. Dish Production (34%)	1. Production of raw materials (44%) 2. Dish Production	1. Production of raw materials (39%) 2. Dish Production (40%)	1. End of life (58%) 2. Dish Production (20%)
Disposable made of polystyrene (PS)	1. Production of raw materials (60%) 2. Dish Production (23%)	1. Production of raw materials (59%) 2. Dish Production (23%)	1. Production of raw materials (57%) 2. Dish Production (27%)	1. End of life (63%) 2. Dish Production (16%)
Disposable made of polylactic acid (PLA)	1. Production of raw materials (57%) 2. Dish Production (18%)	1. Production of raw materials (60%) 2. Dish Production (15%)	1. Production of raw materials (70%) 2. Dish Production (15%)	1. Production of raw materials (62%) 2. End of life (20%)
Disposable made of cellulose pulp	1. Dish Production (53%) 2. End of life (21%) 3. Production of raw materials (19%)	1. Dish Production (48%) 2. End of life (25%) 3. Production of raw materials (18%)	1. Dish Production (63%) 2. Production of raw materials (27%)	1. Dish Production (63%) 2. Production of raw materials (18%) 3. End of life (15%)
Reusable made of porcelain	1. Washing (94%) 2. Dish life cycle (6%)	1. Washing (95%) 2. Dish life cycle (5%)	1. Washing (92%) 2. Dish life cycle (8%)	1. Washing (95%) 2. Dish life cycle (5%)

CUPS - Greatest impact phases by impact category (CML method)				
Type	**Global warming**	**Photochemical oxidants formation**	**Acidification**	**Eutrophication**
Disposable made of polypropylene (PP)	1. Production of raw materials (47%) 2. Dish Production (33%)	1. Production of raw materials (47%) 2. Dish Production (32%)	1. Production of raw materials (41%) 2. Dish Production (40%)	1. End of life (60%) 2. Dish Production (21%)
Disposable made of polystyrene (PS)	1. Production of raw materials (64%) 2. Dish Production (22%)	1. Production of raw materials (63%) 2. Dish Production (21%)	1. Production of raw materials (58%) 2. Dish Production (27%)	1. End of life (64%) 2. Dish Production (17%)
Disposable made of polylactic acid (PLA)	1. Production of raw materials (55%) 2. Dish Production (19%)	1. Production of raw materials (58%) 2. Dish Production (16%)	1. Production of raw materials (67%) 2. Dish Production (16%)	1. Production of raw materials (60%) 2. End of life (20%)
Disposable made of polyethylene (PE) laminated cardboard	1. End of life (47%) 2. Production of raw materials (31%)	1. End of life (42%) 2. Production of raw materials (36%)	1. Production of raw materials (68%) 2. Distribution of the finished product (13%)	1. End of life (49%) 2. Production of raw materials (39%)
Reusable made of glass	1. Washing (97%) 2. Dish life cycle (3%)	1. Washing (97%) 2. Dish life cycle (3%)	1. Washing (94%) 2. Dish life cycle (6%)	1. Washing (97%) 2. Dish life cycle (3%)

4.2 Evaluation

As envisaged by the reference standard, the assessment must be performed in accordance with the objective and the scope of the study by taking into consideration the following three techniques:

- completeness check;
- sensitivity check;
- consistency check.

4.2.1 Completeness check

The goal of the completeness check is to make sure that all information and relevant data required for the interpretation are available and complete.

The LCA study has been conducted using a cradle-to-grave approach, thus including all life-cycle phases of the products under exam. It is believed that the goal and scope are met, consistent, and do not require adjustment. There is no missing information except for those excluded from the defined cut-off threshold. The previous phases (LCI and LCIA) do not need to be reconsidered for lack or omission of relevant data.

4.2.2 Sensitivity and uncertainty check

The sensitivity analysis allows assessing the extent of methodological choices and the robustness of results by means of an evaluation of the most critical aspects that can generate variations.
This analysis has been carried out in paragraph 3.4.2 by varying certain parameters within the most significant phases from an environmental viewpoint for the various products under examination, and by checking the consequent variations produced in the impact categories as regards the final results given in this report.

The sensitivity analyses carried out involved:

1. The production of basic materials for PP, PS, PLA and cardboard disposable tableware;

2. The cellulose pulp dish production;

3. The washing of the porcelain dish and of the glass cup;

4. The duration of reusable tableware;

5. The end of life of compostable materials;

6. Products end of life scenarios.

The results of the various analyses confirm that the study can be considered robust: the value of variation of 10% in the impact categories, set as the threshold of significant variation, has never been exceeded. The sensitivity check is therefore considered positively concluded and the parameters used in carrying out the study can be considered validated.

In paragraph 3.4.1 of the present report, the uncertainty analysis was also carried out. The analysis has been performed with the application included in the SimaPro calculation software, which uses the method Monte Carlo to estimate uncertainties in the final results of the impact categories.
Appendix 2 reports the summary tables of the uncertainty analysis carried out on the results obtained with the two different characterization methods (CML and ILCD) for each product.

As already mentioned in paragraph 3.4.1, among the most significant aspects that emerged from the analysis of uncertainties there are:

- The number of algorithm executions carried out for the calculation of the uncertainty of the study equals to 1000, and it is certainly more than adequate to ensure the robustness with which the uncertainty value associated to impact categories values has been estimated;

- The database parts that contain uncertainty values are in average equal to 70% (with an oscillation between 68% and 71%). Therefore, the uncertainty estimate is reliable, since the uncertainty contribution of 3 data out of 4 is available;

- The use of the Monte Carlo method can be considered conservative compared to other approaches that would provide, conversely, a more targeted uncertainty assessment, but would require a detailed study of specific data distribution curves.

The interpretation of uncertainty values calculated with the Monte Carlo method highlights how the uncertainties related to impact categories values, obtained with the CML method, are on the whole acceptable: the order of magnitude of the uncertainty is in fact always comparable (equal to or lower than) to the order of magnitude of the average of the values to which it is applied.

As for the ILCD method, the uncertainties to be associated with the results show very high values in some specific impact categories:

- Human toxicity – cancer effects;
- Human toxicity – non cancer effects;
- Use of land;
- Depletion of resources - water.

The high uncertainty values for the above categories can be explained by the complexity of the models used by the ILCD method. This complexity level makes it possible to evaluate very specific impact categories - such as those of the human and environmental toxicity - on which, on the international level, scientific evaluations are still open. This aspect makes the ILCD method a particularly advanced and challenging instrument, as highlighted by the choice of the European Community through the Recommendation 2013/179/UE (PEF methodology), that requires a specific database to be developed.

Thereupon, it is envisaged a development and an update of the databases managed by the European Community, to ensure complete compatibility between the input data and the characterization performed through the ILCD method. This update, currently in progress, will ensure the robustness of impact categories results calculation, which is not possible to obtain yet in the present study.

However, in light of these aspects, the performed uncertainty analysis is considered acceptable as representative of the current state of the art. These considerations will be included in the conclusions and limitations of the study, in paragraph 4.3.

4.2.3 Consistency check

The goal of the consistency check is to determine whether assumptions, methods and data are consistent with the goal and the scope of the study.
The consistency check carried out for the present study has proven that:

- Temporal and/or regional differences have been consistently applied;
- The allocation rules and the system boundaries have been consistently applied across all product systems;
- The elements of the impact assessment have been consistently applied.

As regards data quality, minimum requirements have been defined (see paragraph 1.2.7) in order to ensure that the comparison between product alternatives is reliable. The data quality assessment carried out in paragraph 2.4 has confirmed the compliance with these requirements: indeed, the level achieved is always of good quality or higher. However, the use of specific data for the category of disposable tableware manufactured by the Group allows achieving a higher quality level than the one reached for other types of tableware under examination, and this aspect will have to be taken into consideration in the limitations and in the final recommendations.

4.3 Conclusions, limitations and recommendations

The goal of this part of the life cycle interpretation consists in drawing conclusions, identifying the limits and making recommendations for the LCA target audience.

4.3.1 Conclusions

The present LCA study is the first comparative analysis, verified by a Third Party, carried out in the sector of tableware for alimentary use in Italy and, as such, it is expected to stand out as a reference document for the sector. For this reason, the Pro.mo Group sought a particularly articulated and robust model on which to base the comparison.
Among the strong points that make this study reliable and allow for it to be recognised as representative of the sector, there are:

- An accurate choice of the items to be compared - dishes and cups - and a consistent application of functional units (e.g., 1000 uses) and systems boundaries, so as to best represent the context of use of tableware in mass catering in Italy;
- The choice to perform a comparative study according to three possible end of life scenarios (conservative, target, real), so as not to ignore any of the events that may occur in the variable and complex field of disposal and/or reuse of materials that constitute the tableware under study;
- The use of two calculation methods, CML and ILCD, which today represent the most interesting approaches to LCA as a tool to disseminate environmental products assessment: in fact, CML represents the ambit of EPD product certification according to ISO 14025 (e.g. IES), whereas ILCD places the study within the framework of the Recommendation 2013/179/UE and the future application of environmental requirements to products, established by the European Community;
- The system expansion approach, which makes scenarios of comparison realistic, and thus consistent with the goals of the study;
- The use of well-established international rules for the identification of reference criteria not defined in ISO 14040 and ISO 14044. Among these, the cut-off value (ref. EPD), the acceptance criterion for sensitivity tests (REF. EPD), the acceptance criterion for data quality (Ref. Recommendation 2013/179/UE) and for the uncertainty analysis (Ref. Recommendation 2013/179/UE);
- A large series of sensitivity analyses centred on the most critical aspects of the study, and all able to demonstrate the robustness of the study itself;
- The use of specific - thus of better quality – data, supported by an extensive use of the validation approach (also according to statistical models) to ensure their actual representativeness of the sector;
- The choice to submit the study to critical review by a Third Party represented by a Certification Body that is an expert in life cycle studies and Accredia accredited for the EPD evaluation according to ISO 14025.

The LCA study is presented in a report that complies with the requirements set by the reference standards ISO 14040 and ISO 14044, and can provide with great detail and transparency all necessary information to interested parties for the assessment of the represented environmental performances. Clear technical explanations illustrate some of the choices made in the use of the data and in scenarios definition. The report features some appendices and a bibliography meant to support the non-professional user in understanding its content.

Results are collected in the report and organised by sections which follow the requirements of the reference standards and the subdivision by item, scenarios, and computation models. This level of completeness of information enables a wide range of possible interpretations, depending on the needs of the user and on the real situations that are to be measured. In this case, as for all LCA studies, there is no results interpretation in absolute terms; the considerations may vary depending on impact categories and on considered and compared products. However, it is worth to mention some results that, being recurrent in the study, can be considered of general value as regards tableware for alimentary use:

- In terms of impact categories, the various results associated with products generally maintain constant relations and proportions between them at the variation of the end of life scenario and of characterization methods (CML, ILCD), as confirmed by the robustness of the study demonstrated in the sensitivity analysis phase;
- The ILCD model offers interesting details, such as impact categories typical of the USEtox model (e.g. various types of human and environmental toxicity) or the Land Use and the Water Depletion categories, but at the moment it still presents very high uncertainty values;
- The products made of bio-polymers present average values higher than those made of conventional polymers for numerous significant impact categories;
- Reusable tableware has impact categories values significantly lower than disposable tableware, but the most impacting phase proves to be the use phase, with the washing process. Further insights on the washing phase may be carried out in the light of recent studies that deal with issues related to hygiene and food safety guarantees linked to tableware washing in mass catering;
- The products derived from the wood processing industry (cellulose fibre or cardboard) have their environmental performance very much influenced by tableware production technologies;
- The composting process of disposable tableware that can follow this end of life does not seem to bring special benefits for the purposes of the products environmental impact, as confirmed by the sensitivity analysis.

4.3.2 Limitations

The present LCA study contains a wide range of results and information, all widely accompanied by comments and technical explanations. However, it is appropriate to mention here some limitations, already illustrated in the text, to which the user of this report’s contents shall pay close attention:

- The various systems present non-homogeneous data quality levels, and this could affect the uncertainty value of the final results. However, the overall data quality always complies with the data quality requirements defined by the Recommendation 2013/179/UE for the calculation and disclosure of the environmental footprint;

- The ILCD method presents uncertainty values calculated with the Monte Carlo method and that, therefore, in the case of certain impact categories, are very high;
- The technology applied to cellulose pulp tableware has provided for specific data, but collected in a phase that is still experimental and of early industrialization. To have them considered as representative of the sector of disposable tableware obtained with this specific production technology in Europe, a validation has been carried out to examine detailed parameters of developing plants and productions. Such validation has been subjected to verification by the Verification Body responsible for the Critical Review.

4.3.3 Recommendations

The distribution of this LCA report, as mentioned above at par. 1.1.2, will also include a public release.
This document, in its full version including appendices and attachments, is kept confidential at the Rubber & Plastics Federation, which is its owner, and can be made available upon request only for scientific purposes related to the study.
The study, in a version devoid of sensitive and confidential information (contained in Annexes 1 and 2), is also kept at the Rubber & Plastics Federation, and it can be required through a form available on the Pro.mo website (www.pro-mo.it), currently under construction. Pro.mo reserves the possibility to insert integral parts of the study, duly highlighted as "data and information derived from the comparative Life Cycle Assessment (LCA) study of tableware for alimentary use, Rev. 3 - 24/06/2015" in a communication for public disclosure.
Each reference will be provided with the necessary indication on how to access the study (see above), and in any case according to the principles of ISO 14063 already mentioned in par. 1.1.2.

The amount of information and data made public by Pro.mo with this study can generate value for all companies in the sector, if used to deepen the analysis of the environmental performance of disposable products. Among the most interesting uses, it is worth mentioning eco-design supported by the LCA methodology. In fact, this represents the most current "engineering" tool for product improvement, since it integrates technical characteristics and environmental performances from the earliest stages of development and design.

5. Critical review

This chapter provides the Critical Review Report, conducted by the SGS Italia S.p.A. Certifying Body. The report sums up all carried out verification phases, the points that emerged during the review process and how these have been incorporated in the definitive LCA study.

SGS ITALIA S.p.A. – Systems & Services Certification

Critical Review Statement

chapter 6, ISO 14044:2006

Organization:	**Pro.mo**		
Address:	**Via San Vittore 36, 20123 Milano**		
Standards:	**ISO 14040:2006, ISO 14044:2006, ISO\TS 14071:2014**		
Organization Representative:	**Marco Omboni**	Audit Dates:	**04/06/2015 15/06/2015 24/06/2015**
Lead auditor:	**Ambra Morelli**	Other Members of the Audit Team::	**Cristiana Reho**

This report is confidential and its distribution is limited to the audit team to the Organization representative and SGS Italy.

1. Scope of the Critical Review Process

The Critical Review process is a technique for verifying that the LCA study was conducted according to the methodology and principles contained in the ISO 14044 regulations, allowing the Organization, applying for this review, to strengthen the credibility of the conducted LCA study.

The Critical Review process *"ensures that the classification, characterization, normalization, grouping and weighting elements are sufficient and are documented in such a way that enables the life cycle interpretation phase of the LCA to be carried out*"

As indicated in paragraph §7.1 of ISO 14040 *"a critical review can neither verify nor validate the goals chosen for an LCA* by the study commissioner*, nor the ways in which the LCA results are used".*

The scope of the Critical Review process is to enable the intended audience of the LCA study to understand the complexity and reliability/limits of the study itself.

The Critical Review process was conducted by the SGS audit team (Panel) in order to ensure that:

- ✓ the scope and the type of critical review have been defined during the definition of the LCA scope (§ 4.2.3.8 ISO 14044);
- ✓ the methods used to carry out the LCA are consistent with the ISO 14044 standard and are scientifically and technically valid;
- ✓ the data used are appropriate and reasonable in relation to the goal of the study;
- ✓ the interpretations reflect the limitations identified and the goal of the study;
- ✓ the study report is transparent and consistent.

2. Critical Review Report

OVERALL INFORMATION

The critical review applies to the following LCA Report:

"COMPARATIVE LIFECYCLE ASSESSMENT (LCA)STUDY OF TABLEWARE FOR ALIMENTARY USE

Disposable dishes in PP, PS, PLA, cellulose pulp and reusable porcelain dishes
Disposable drinking cups in PP, PS, PLA, PE laminated cardboard and reusable glass cups"

3rd Edition 24/06/2015

Comprehensive of the following appendixes and annexes

Appendix 1 - Glossary of environmental impact categories
Appendix 2 - Results of uncertainty analysis using the Monte Carlo method
Appendix 3 - PEF data quality matrix
Appendix 4 - Correlation matrix between requirements of the standard and contents, for the external communications report

Annex 1 - Application of additional calculating methods
Annex 2 - Data validation

The Critical Review process was developed through a first phase of preliminary documents analysis of the LCA study, and a second phase of discussion with the practitioners of the LCA study in which the methodological and technical aspects were deeply analysed.

Following the first stage of document review the Panel prepared and shared with the commissioner of the study a preliminary Critical Review Report reporting on potential issues to be further investigated.

The consequent analysis performed by the panel, conducted with the direct participation of people who contributed to the LCA study, reviewed the appropriateness of the methodologies used for data collection and the computational models used, in accordance with what was already identified in the preliminary documents review.
The Panel Review has conducted a check of the original data sources used in the study, the activity was performed by a sampling technique on critical data.

The panel review met with the following people responsible for data management and LCA study:

Mr. Marco Ombon (President of Pro.mo Association)
Eng.Bruno Spozio (Deputy Administrator ISAP Packaging)
Eng. Mauro Biasiolo (Operation Manager - RSPP ISAP Packaging)
Eng. Luca Borghi (Research&DevelopmentSupervisor - ISAPPackaging)
Mrs. Valeria Danti (Quality Assurance ISAP Packaging)
Mrs.Michela Zangrandi (Business Planning - ISAP Packaging)
Eng. Paolo Simon Ostan (LCA Specialist - PRO.MO Consultant)
Mrs. Anna Bortoluzzi (PRO.MO Management Consultant)

Introduction

The study states the equivalence of the product systems compared and includes a definition of scope which is consistent and allows a comparison of the systems.
The systems use the same functional unit and equivalent methodological considerations, such as the performance, system boundaries, data quality, allocation procedures, decision making on the assessment of input and output elements and on the impact evaluation.
Any difference between the systems regarding these parameters have been identified and highlighted.
The present LCA study has been commissioned by Pro.mo, a Group, within the Rubber Plastics Federation, part of Confindustria, which includes companies that operates in the disposable plastic tableware production sector.
The group is made by 6 Italian companies (Aristea Spa, DoplaSpA, Flo SpA, Ilpa SpA, Isap SpA e Tim MonousoSpA), and can be considered as being representative for the national production of disposable plastic tableware, covering about 80% of the turnover of this industry sector.

Goal and Scope of the Study

The goal, scope, objectives and the intended application of the study are clearly reported in the study; the intended audience and limitations of the analysis have also been included.
The LCA report shows, in detail, in the chapter "Scope of the study": the description of the functional unit, the system boundaries, the cut-off criteria, the allocation methods, the types and data sources, the data quality requirements, the general assumptions and the description of the Critical Review process.
During the Critical Review process the Panel requested to provide more details concerning:

1. The group of companies represented by Pro.Mo and their representativeness in the Italian disposable tableware sector
2. The motivations that have led Pro.Mo to develop the LCA study.

The last version of the report (ed 3) was integrated with the information required (introduction, § 1.2.8, annex 2-A5.1).

System Boundaries and Exclusions

The system boundaries were clearly stated, by considering a cradle-to-grave approach which covers all the life cycle stages from the acquisition of raw materials, production and packaging, distribution, use (where applicable) and end of life treatment of the product;

Overall, this approach is considered consistent with the objective of the study.
During the Critical Review process, the Panel has prompted to:

- ✓ clarify in Paragraph 1.2.2 how the production processes, listed in paragraph 1.2.2, were selected and to declare if any process had been omitted from the life cycle.

The last version of the report (ed 3) contains the details requested (§ 1.2.2, 2.2.2 , Annex 2-A5.2).

- ✓ With regards to the completeness of the life cycle, clarify why, in the conservative scenario described in paragraph1.2.8.1, PP and PS present a 50% of waste-to-energy disposal, while this is 0% for the remaining materials analyzed.

The report was modified and now presents a consistent end of life scenario.

It has also been required to detail in the LCA study limitations the fact that no primary data has been used for reusable tableware and the implications that such limit may have in the data quality assessment and sensitivity analysis.
The last version of the report (ed 3) contains the details requested (§ 1.2.9 –2.4.1.4 - 3.4.2).

Selection of the environmental indicator

The characterization methods used in the evaluation phase of the LCIA are:

1. **CML - IA baseline**, midpoint method, limited to 4 impact categories:
   Global Warming, photochemical oxidants formation, acidification and eutrophication.

2. **ILCD 2011 Midpont+**, midpoint method with 16 impact categories: Climate change, Ozon depletion, Ecotoxicity - freshwater, Human toxicity - Cancer effects, Human toxicity– non cancer effects, Smog particulate caused by emissions of inorganic substances, Ionising radiation- effects on human health, ionizing radiation - effects on the ecosystem, photochemical oxidant formation, acidification, terrestrial eutrophication, freshwater eutrophication, marine eutrophication, resource depletion- water, mineral resources depletion - fossils, land use.

Comments relating to the method applied

The panel has prompted to clarify in the report the following issues relating to the method applied:

✓ Each data which has been elaborated or estimated needs to be validated through a process which shall be described in the report, in particular this is required for:

-the validation of the representativeness of the plant sampled for the production of plastic disposable tableware
- the validation of data (production energy consumption) for PLA disposable tableware
- the validation of data (production energy consumption) for paper pulp disposable tableware

The analysis of data, validation criteria and results were detailed in the 3rd edition of the report in Annex2.
Annex 2 - Data validations- describes:
- *The validation of the representativeness of the sampled plant for the production of plastic tableware, conducted through the analysis and comparison of qualitative information, analysis of polymers used and production lines and statistical validation in order to calculate the average and standard deviation of Pro.Mo group data in relation to the selected sample plant data.*
- *The validation of the specific data representativeness for the production of paper pulp tableware through the comparison between plant data, which, at the time of the study, was using 50% less of its productive capacity, and rating plate data declared in the purchase contract. The values are consistent with average data in the same industry sector.*
- *The validation of the energy consumption data for PLA production*

✓ Paragraph 1.2.1 - Clarify the criteria used to determine the life of reusable tableware (how durable they are) and if available insert reference sources.

Information on these criteria was added in the report (§ 1.2.1).The report declares the absence of an official publication of reference.

Although the approach used is conservative (as confirmed by Prof. Piergiovanni communication), the use of official publications, (such as scientific articles, product claims, field studies) is recommended, at the next review / update of the study (if they become available).

- ✓ Better specify the meaning of "performance characteristics" (i.e. if this relates to product quality or environmental performance) and how they can correlate to a conservative scenario.

The expression has been replaced and integrated with "the weights of disposable tableware are conservative, as the tableware considered displays the highest strength features, i.e. requires a greater amount of basic material to be produced and, as a consequence, has a higher impact on the environment".

- ✓ Paragraph 1.2.3 - Clarify if the impacts associated with additives are actually negligible.

Paragraph 1.2.3 was completely rewritten in the new version of the report, by declaring a cut-off in terms of mass of 2%, and its exclusive application to specialties (organic molecules covered by patent) used as additives for disposable tableware.

- ✓ Paragraph 1.2.6 - with regards to raw materials transport data, clarify which type of data are included.

The clarification required was added in the report. The origin of data regarding transport and the supply of raw materials for the products manufactured by the Group companies is now clearly reported in paragraph 1.2.6.

- ✓ Paragraph 1.2.8 - In order to further increase the study transparency, it is required to integrate and clarify certain aspects such as: the extent of the geographic representativeness, criteria used to determine the number of washing for the cups, the number of companies involved in the project.

The new report includes the clarifications required

- ✓ Paragraph 2.2.2 – in this paragraph mass allocation is mentioned, this is allocation method is to be included within the methods reported in paragraph 1.2.4

The report was integrated with a modification in paragraph 1.2.4 .with further detail on the mass allocation applied to general services consumption of the plant.

- ✓ Specify the energy and water consumption calculating method and how scraps are considered in the study.

The 3rd edition of the report includes the details required

- ✓ Paragraph 2.2.3 - Clarify the origin of data relating to the paper pulp dishes

The report was integrated at this regard.

- ✓ Paragraph 2.3.2- Provide further detail on the technical references used for the industrial dishwasher consumption data and their allocation. Be reminded that in case of allocation this must be declared in the specific paragraph which deals with allocation.

The new version of the report was integrated with the details required (§2.3.2 and bibliography)

- ✓ Paragraph 2.4 – data quality analysis - With reference to the data quality assessment, please consider whether to apply the model proposed in the study to all the raw materials considered.

The report was integrated; the evaluation on data quality has been extended to any type of raw material considered.

- ✓ Paragraph 2.3.3 - Please consider whether to perform a sensitivity analysis in order to assess the impact of the system expansion scenario for the PLA and cellulose pulp (composting)

The report was integrated with the sensitivity analysis, which showed that applying the system expansion approach to the case of the PLA and cellulose pulp compost, does not produce significant variations in the final results.

- ✓ Paragraph 3.4.2 - A sensitivity analysis relative to the variation in the durability of reusable tableware needs to be added to the report.

This analysis was added in the report (§ 3.4.2 analysis nb. 4)

Result and interpretation

The audit team has found to be a point of strength the fact that the study was designed and developed using the database and data management tools already present in the sampled company, which are designed to provide a continuous monitoring of the data.
The results are correctly presented per functional unit and they are presented also for three possible different end of life scenarios, which maximize transparency for the recipients of the study.
The study provides in the appendix 2 the results of the uncertainty analysis using Monte Carlo method, this point is also commented in the conclusions of the study**.**

- ✓ With reference to the different types of raw materials used in the production of disposable and reusable tableware, the audit team has recommended to highlight also within the study limitations the differences in the data quality

The report now declares in a clear and transparent way the limitations regarding the differences in the type of data related to the various raw materials and processes.

During the Critical Review process, the Panel also provided the following remarks regarding the results and interpretation:

- ✓ Paragraph 4.3.1, 4.3.2:
    a. the comments on the reusable tableware are not completely consistent with the hypothesis and sensitivity analysis,
    b. clarify with regards to the cellulose pulp tableware the path of data validation carried out and enclosed to the study,
    c. add recommendations - if any - on the uncertainty analysis.

The report was integrated with the details required.

External communication

For the purposes of external communication, LCA studies which support comparative assertions intended to be disclosed to the public, shall meet the requirements of paragraphs 5.1, 5.2 and 5.3 of the ISO14044.

As envisaged by 14044, §5.2, confidential information may not be included in the public document.

The audit team confirms that the LCA study reviewed is self-supporting (in terms of contents of the study included for external communication purposes) with regards to annexes 1 and 2, which contain sensitive information. The findings and conclusions of the LCA are communicated in an equitable, complete and precise manner to the target audience. Data methods assumptions and limitations are presented transparently and in sufficient detail for the reader to understand the complexity of the study.

3. Conclusions

The audit team has found the study to be transparent in describing the analysis carried out, the main contributions to the considered impacts and of the results and related uncertainty factors.

The LCI model is consistent with the study objectives and the reference sampled data for the LCI were found to be reliable.

The computation software chosen (SimaPro v8) the assumptions and the methodological choices (e.g. allocations, limitations etc.) are appropriate with respect to the stated objectives.

The audit team encourages the use of data and information ever more detailed and relevant for the processes involved in the life cycle of the products, as this approach will help the planning of effective actions towards impact reductions.

Milan, 29/06/2015

Technical Reviewer: ANGELO FERLINI

Authorized by: PAOLA SANTARELLI

Technical Reviewer: ANGELO FERLINI

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Appendix 1 - Glossary of environmental impact categories

This appendix reports the definitions of impact categories used in the life cycle impact assessment (LCIA) phase, related to the characterization methods *CML-IA baseline* and *ILCD 2011 Midpoint+*. Be reminded that the various emissions into the air, water and soil mentioned in the definitions - which allow for the computation of the impact categories - relate to the entire life cycle of a product/service and do not pertain to emissions directly released by the product concerned.

ILCD 2011 Midpoint+ (source: Recommendation of the European Commission 2013/179/UE)	
Impact Category	**Definition**
Climate Change	Impact category referring to the ability of influencing the changes in the average global temperature of the air at the ground level and to the subsequent variations of different climate parameters and of their effects, such as the frequency and intensity of storms, the precipitation intensity and the frequency of floods, etc.
Ozone depletion	Impact category representing the degradation of stratospheric ozone due to long duration emissions of substances that are harmful to the ozone layer, such as gases containing chlorine and bromine (for example CFC, HCFC, halons).
Ecotoxicity - freshwater	Impact category regarding the toxic impacts on an ecosystem, which damage individual species and modify the structure and function of the ecosystem. Ecotoxicity derives from various toxicological mechanisms caused by the release of substances having a direct effect on the ecosystem health.
Human toxicity - cancer effects	Impact category of the environmental footprint representing the adverse health effects in human beings caused by the intake of toxic substances by inhalation of air, ingestion of food/water, skin penetration, insofar as these substances are carcinogenic.
Human toxicity – non cancer effects	Impact category representing the adverse health effects in human beings caused by the intake of toxic substances by inhalation of air, ingestion of food/water, skin penetration, insofar as these substances are not carcinogenic and not caused by particulate/smog deriving from emissions of inorganic substances or ionising radiation.
Particulate/smog caused by emissions of inorganic substances	Impact category of the environmental footprint representing the adverse effects on human health caused by emissions of particulate (PM) and its precursors (NO x , SO x , NH 3).
Ionising Radiation - effects on human health	Impact category representing the negative effects on human health caused by radioactive emissions.
Ionising Radiation - effects on the ecosystem	Impact category regarding the ionising radiation on ecosystems. It is expressed in CTUe, an estimate of the potentially affected fraction (PAF) of species involved by the phenomenon, integrated in the course of time and volume per unit mass of an emitted radionuclide (PAF m3 year / kg).

Photochemical ozone formation	Impact category representing the formation of ground-level ozone in the troposphere caused by photochemical oxidation of volatile organic compounds (VOC) and carbon monoxide (CO) in the presence of nitrogen oxides (NO x) and sunlight. High concentrations of tropospheric ozone at ground level are harmful to vegetation, to the human respiratory tract and to artificial materials through reaction with organic materials.
Acidification	Impact category regarding the repercussions of acidifying substances on the environment. The emissions of NOx and NH3 and SOx involve the release of hydrogen ions (H+) when the gases are mineralized. The protons favour the acidification of soil and water, if released on surfaces with low buffer capacity, with consequent deterioration of forests and acidification of lakes.
Eutrophication - terrestrial	The nutrients (primarily nitrogen and phosphorus) of sewage and agricultural fertilized land accelerate the growth of algae and other vegetation in waters. The deterioration of organic material consumes the oxygen, thus causing the lack of it and, in some cases, fish kills. Eutrophication translates the amount of emitted substances in a common measure expressed as the oxygen necessary for the decomposition of the dead biomass.
Eutrophication - freshwater	
Eutrophication - marine	
Depletion of resources - water	Impact category regarding the use of natural resources, renewable and non-renewable, biotic or abiotic.
Depletion of resources - minerals, fossils	
Use of land	Impact category regarding the use (occupation) and conversion (transformation) of land by activities such as agriculture, construction of roads, houses, mines, etc. The occupation of land takes into account the effects of the end use of the soil, the area of the territory concerned and the duration of its occupation (variations in quality multiplied by area and duration). The transformation of the soil takes into account the extent of soil properties variations and the area affected (variations in quality multiplied by the area).

CML-IA baseline	
Impact Category	Definition
Global Warming	Climate change is related to emissions of greenhouse gases in the atmosphere. The characterization factors, developed by the IPCC (*Intergovernmental Panel on Climate Change*), are expressed as "global warming potential" for a time frame of 100 years (GWP100), in kg CO2 equivalents/kg emission. The indicator is calculated on a global scale.
Photochemical oxidants formation	This category groups all the volatile organic substances that contribute to the photochemical formation (in the presence of solar radiation) of tropospheric ozone. The characterization factor is the "photochemical ozone creation potentials" (POCP) and the reference substance is ethylene: consequently, the factor is expressed in kg C2H4 equivalents/kg emission. The indicator

	varies along with the spatial scale of application.
Acidification	The acidification indicator is linked to the emissions into the air of particular acidifying substances such as nitrogen oxides and sulphur oxides. The characterization factors are expressed as "acidification potential (AP)" in kg SO_2 equivalents/kg emission. The spatial scale is variable.
Eutrophication	This category assesses the increase in the concentration of nutrients in water environments. Substances that contribute to this phenomenon are compounds based on nitrogen and phosphorus. The characterization factor is the "Eutrophication Potential (EP)" and the substance of reference is the phosphate ion; the factor is expressed in kg PO_4^{3-} equivalents/kg emission. The spatial scale is variable.

Appendix 2 - Results of uncertainty analysis with the Monte Carlo method

This appendix lists the results of uncertainty analyses carried out with the SimaPro software. The results regarding the dishes and cups categories are given separately.

A2.1 Uncertainty Analysis - DISHES

A2.1.1 PP Dish

Uncertainty Results - CML Method

Impact category	Unit	Average	Median	SD	CV (Coeff. Of Var.)	2.5%	97.5%	Average std. error
Acidification	kg SO_2 eq.	1.79E-01	1.79E-01	6.49E-03	3.62%	1.68E-01	1.95E-01	1.14E-03
Eutrophication	kg PO_4^{3-} eq.	8.54E-02	7.80E-02	2.90E-02	34%	5.25E-02	1.64E-01	1.07E-02
Global Warming	kg CO_2 eq.	6.43E+01	6.39E+01	4.20E+00	6.53%	5.72E+01	7.42E+01	2.07E-03
Photochemical Oxidants formation	kg C_2H_4 eq.	1.04E-02	1.03E-02	7.62E-04	7.31%	9.55E-03	1.21E-02	2.31E-03

Uncertainty results - ILCD Method

Impact category	Unit	Average	Median	SD	CV (Coeff. Of Var.)	2.5%	97.5%	Average std. error
Acidification	mole H+ eq.	2.45E-01	2.44E-01	7.87E-03	3.22%	0.232	2.63E-01	1.02E-03
Climate Change	kg CO_2 eq.	5.44E+01	5.43E+01	1.06E+00	1.95%	52.7	5.70E+01	6.15E-04
Ecotoxicity - freshwater	CTUe	1.48E+03	1.05E+03	1.40E+03	94.5%	442	4.74E+03	2.99E-02
Eutrophication - freshwater	kg P eq.	6.40E-03	6.03E-03	1.70E-03	26.6%	0.00452	1.04E-02	8.41E-03
Human toxicity - cancer effects	CTUh	1.76E-06	1.59E-06	1.07E-06	61.1%	9.76E-07	3.61E-06	1.93E-02
Human toxicity - non cancer effects.	CTUh	1.50E-05	1.38E-05	5.57E-05	373%	-8.9E-05	1.30E-04	1.18E-01
Ionising Radiation - effects on the ecosystem	CTUe	8.89E-05	8.85E-05	2.32E-06	2.61%	0.000086	9.54E-05	8.24E-04
Ionising Radiation - effects on human health	kg of U^{235} eq.	4.83E+00	4.28E+00	1.90E+00	39.3%	3.41	1.03E+01	1.24E-02
Use of land	kg C (deficit)	7.41E+01	7.20E+01	2.11E+01	28.5%	41.5	1.26E+02	9.00E-03
Eutrophication - marine	kg of N eq.	8.00E-02	7.79E-02	1.20E-02	15%	0.063	1.10E-01	4.75E-03
Depletion of resources - minerals, fossils	kg of Sb eq.	1.42E-03	1.27E-03	7.84E-04	55.1%	0.000656	3.18E-03	1.74E-02
Ozone depletion	kg CFC-11 eq.	4.14E-06	3.95E-06	8.17E-07	19.8%	3.13E-06	6.24E-06	6.25E-03
Particulate/smog, emissions of inorganic substances	kg $PM_{2,5}$ eq.	2.42E-02	2.40E-02	1.20E-03	4.94%	0.0223	2.73E-02	1.56E-03
Photochemical ozone formation	kg NMVOC eq.	1.87E-01	1.86E-01	5.08E-03	2.72%	0.178	1.98E-01	8.60E-04
Eutrophication - terrestrial	mole N eq.	5.03E-01	5.00E-01	1.87E-02	3.72%	0.472	5.45E-01	1.18E-03
Depletion of resources - water	m^3 of water	1.23E-01	1.57E-01	1.48E+00	1.21E3%	-2.79	3.01E+00	3.81E-01

A2.1.2 PS Dish

Uncertainty Results - CML Method								
Impact category	**Unit**	**Average**	**Median**	**SD**	**CV (Coeff. Of Var.)**	**2.5%**	**97.5%**	**Average std. error**
Acidification	kg SO_2 eq.	2.59E-01	2.59E-01	6.48E-03	2.5%	2.49E-01	2.74E-01	7.90E-04
Eutrophication	kg PO_4^{3-} eq.	1.44E-01	1.23E-01	7.77E-02	54.1%	6.99E-02	3.13E-01	1.71E-02
Global Warming	kg CO_2 eq.	6.92E+01	6.90E+01	1.25E+00	1.8%	6.73E+01	7.22E+01	5.70E-04
Photochemical Oxidants formation	kg C_2H_4 eq.	1.51E-02	1.50E-02	6.76E-04	4.47%	1.42E-02	1.67E-02	1.41E-03

Uncertainty results - ILCD Method								
Impact category	**Unit**	**Average**	**Median**	**SD**	**CV (Coeff. Of Var.)**	**2.5%**	**97.5%**	**Average std.error**
Acidification	mole H+ eq.	3.11E-01	3.10E-01	8.55E-03	2.75%	2.98E-01	3.29E-01	8.70E-04
Climate Change	kg CO_2 eq.	6.92E+01	6.91E+01	1.28E+00	1.85%	6.73E+01	7.25E+01	5.86E-04
Ecotoxicity - freshwater	CTUe	1.02E+03	8.74E+02	5.32E+02	51.9%	4.77E+02	2.48E+03	1.64E-02
Eutrophication - freshwater	kg P eq.	5.73E-03	5.33E-03	1.58E-03	27.7%	3.75E-03	9.97E-03	8.75E-03
Human toxicity - cancer effects	CTUh	2.12E-06	1.92E-06	8.84E-07	41.7%	1.16E-06	4.22E-06	1.32E-02
Human toxicity - non cancer effects.	CTUh	2.28E-05	2.33E-05	5.11E-05	224%	-8.02E-05	1.27E-04	7.09E-02
Ionising Radiation - effects on the ecosystem	CTUe	8.81E-05	8.75E-05	2.40E-06	2.72%	8.49E-05	9.44E-05	8.61E-04
Ionising Radiation - effects on human health	kg of U^{235} eq.	4.33E+00	3.81E+00	2.02E+00	46.6%	2.95E+00	8.49E+00	1.47E-02
Use of land	kg C (deficit)	7.09E+01	6.84E+01	1.94E+01	27.3%	4.10E+01	1.15E+02	8.64E-03
Eutrophication - marine	kg of N eq.	9.24E-02	8.91E-02	1.45E-02	15.7%	7.31E-02	1.27E-01	4.96E-03
Depletion of resources - minerals, fossils	kg of Sb eq.	1.41E-03	1.25E-03	6.60E-04	46.8%	6.62E-04	3.14E-03	1.48E-02
Ozone depletion	kg CFC-11 eq.	3.87E-06	3.68E-06	8.78E-07	22.7%	2.83E-06	6.30E-06	7.17E-03
Particulate/smog. emissions of inorganic substances	kg $PM_{2.5}$ eq.	3.01E-02	2.99E-02	1.26E-03	4.18%	2.82E-02	3.32E-02	1.32E-03
Photochemical Ozone formation	kg NMVOC eq.	2.12E-01	2.12E-01	5.13E-03	2.41%	2.03E-01	2.23E-01	7.64E-04
Eutrophication - terrestrial	mole N eq.	5.95E-01	5.93E-01	1.75E-02	2.94%	5.64E-01	6.32E-01	9.29E-04
Depletion of resources - water	m^3 of water	1.45E-01	2.15E-01	1.40E+00	965%	-2.85E+00	2.69E+00	3.05E-01

A2.1.3 PLA Dish

Uncertainty Results - CML Method								
Impact category	**Unit**	**Average**	**Median**	**SD**	**CV (Coeff. Of Var.)**	**2,5%**	**97,5%**	**Average std. error**
Acidification	kg SO_2 eq.	5.19E-01	5.16E-01	3.83E-02	7.37%	4.53E-01	6.01E-01	2.33E-03
Eutrophication	kg PO_4^{3-} eq.	2.27E-01	2.20E-01	4.03E-02	17.8%	1.72E-01	3.33E-01	5.63E-03

Global Warming	kg CO_2 eq.	9.61E+01	9.56E+01	5.11E+00	5.32%	8.73E+01	1.08E+02	1.68E-03
Photochemical Oxidants formation	kg C_2H_4 eq.	2.44E-02	2.42E-02	2.13E-03	8.73%	2.09E-02	2.89E-02	2.76E-03

Uncertainty results - ILCD Method

Impact category	Unit	Average	Median	SD	CV (Coeff. Of Var.)	2.5%	97.5%	Average std. error
Acidification	mole H+ eq.	6.43E-01	6.37E-01	5.00E-02	7.78%	5.58E-01	7.56E-01	2.46E-03
Climate Change	kg CO_2 eq.	9.62E+01	9.56E+01	5.07E+00	5.27%	8.78E+01	1.07E+02	1.67E-03
Ecotoxicity - freshwater	CTUe	2.66E+03	2.43E+03	1.19E+03	44.8%	1.25E+03	5.47E+03	1.42E-02
Eutrophication - freshwater	kg P eq.	2.43E-02	2.22E-02	9.49E-03	39%	1.41E-02	4.83E-02	1.23E-02
Human toxicity - cancer effects	CTUh	3.58E-06	2.79E-06	3.46E-06	96.8%	1.72E-06	1.09E-05	3.06E-02
Human toxicity - non cancer effects.	CTUh	3.69E-05	3.18E-05	8.05E-05	218%	-1.01E-04	1.97E-04	6.90E-02
Ionising Radiation - effects on the ecosystem	CTUe	3.00E-05	2.90E-05	6.04E-06	20.1%	2.16E-05	4.50E-05	6.36E-03
Ionising Radiation - effects on human health	kg of U^{235} eq.	1.06E+01	8.32E+00	8.52E+00	80.5%	5.39E+00	2.81E+01	2.55E-02
Use of land	kg C (deficit)	2.37E+02	2.64E+02	4.70E+03	1.98E3%	-8.91E+03	9.24E+03	6.26E-01
Eutrophication - marine	kg of N eq.	2.52E-01	2.50E-01	2.69E-02	10.7%	2.05E-01	3.12E-01	3.37E-03
Depletion of resources - minerals, fossils	kg of Sb eq.	3.40E-03	3.11E-03	1.37E-03	40.3%	1.66E-03	6.93E-03	1.27E-02
Ozone depletion	kg CFC-11 eq.	8.22E-06	7.88E-06	1.99E-06	24.2%	5.64E-06	1.27E-05	7.66E-03
Particulate/smog, emissions of inorganic substances	kg $PM_{2,5}$ eq.	6.05E-02	5.87E-02	8.74E-03	14.5%	4.80E-02	8.19E-02	4.57E-03
Photochemical ozone formation	kg NMVOC eq.	3.34E-01	3.33E-01	1.86E-02	5.59%	3.00E-01	3.73E-01	1.77E-03
Eutrophication - terrestrial	mole N eq.	1.33E+00	1.32E+00	1.01E-01	7.6%	1.16E+00	1.55E+00	2.40E-03
Depletion of resources – water	m^3 of water	2.53E+00	2.62E+00	1.13E+01	447%	-1.91E+01	2.39E+01	1.41E-01

A2.1.4 Cellulose Pulp Dish

Uncertainty Results - CML Method

Impact category	Unit	Average	Median	SD	CV (Coeff. Of Var.)	2.5%	97.5%	Average std. error
Acidification	kg SO_2 eq.	4.42E-01	4.38E-01	3.49E-02	7.91%	3.84E-01	5.23E-01	2.50E-03
Eutrophication	kg PO_4^{3-} eq.	3.58E-01	3.44E-01	8.78E-02	24.5%	2.29E-01	5.61E-01	7.74E-03
Global Warming	kg CO_2 eq.	1.21E+02	1.20E+02	1.14E+01	9.44%	1.02E+02	1.47E+02	2.99E-03
Photochemical Oxidants formation	kg C_2H_4 eq.	2.72E-02	2.68E-02	3.08E-03	11.3%	2.21E-02	3.43E-02	3.58E-03

Uncertainty results - ILCD Method

Impact category	Unit	Average	Median	SD	CV (Coeff. Of Var.)	2.5%	97.5%	Average std. error
Acidification	mole H+ eq.	5.27E-01	5.22E-01	4.16E-02	7.89%	4.61E-01	6.22E-01	2.49E-03

Climate Change	kg CO_2 eq.	1.22E+02	1.20E+02	1.18E+01	9.72%	1.02E+02	1.51E+02	3.07E-03
Ecotoxicity - freshwater	CTUe	7.59E+02	7.60E+02	2.22E+03	292%	-3.41E+03	5.42E+03	9.24E-02
Eutrophication - freshwater	kg P eq.	2.78E-02	2.50E-02	1.22E-02	44%	1.33E-02	5.96E-02	1.39E-02
Human toxicity - cancer effects	CTUh	3.73E-06	3.54E-06	1.30E-05	349%	-1.93E-05	3.00E-05	1.10E-01
Human toxicity – non cancer effects.	CTUh	6.11E-05	6.60E-05	1.42E-03	2.33E3%	-2.64E-03	3.01E-03	7.36E-01
Ionising Radiation - effects on the ecosystem	CTUe	4.92E-05	4.87E-05	6.89E-06	14%	3.77E-05	6.48E-05	4.43E-03
Ionising Radiation - effects on human health	kg of U^{235} eq.	2.26E+01	1.74E+01	1.69E+01	74.9%	8.36E+00	6.56E+01	2.37E-02
Use of land	kg C (deficit)	2.00E+02	1.93E+02	6.45E+01	32.3%	9.35E+01	3.41E+02	1.02E-02
Eutrophication - marine	kg of N eq.	5.35E-01	5.07E-01	1.57E-01	29.3%	3.10E-01	9.12E-01	9.28E-03
Depletion of resources - minerals, fossils	kg of Sb eq.	1.59E-03	1.46E-03	5.53E-04	34.9%	9.20E-04	2.96E-03	1.10E-02
Ozone depletion	kg CFC-11 eq.	1.33E-05	1.28E-05	2.81E-06	21.2%	8.77E-06	2.02E-05	6.70E-03
Particulate/smog, emissions of inorganic substances	kg $PM_{2,5}$ eq.	3.79E-02	3.76E-02	3.27E-03	8.62%	3.25E-02	4.57E-02	2.73E-03
Photochemical ozone formation	kg NMVOC eq.	2.86E-01	2.83E-01	2.69E-02	9.39%	2.43E-01	3.47E-01	2.97E-03
Eutrophication - terrestrial	mole N eq.	9.38E-01	9.26E-01	1.07E-01	11.4%	7.61E-01	1.19E+00	3.60E-03
Depletion of resources - water	m^3 of water	-3.21E+00	4.14E+00	8.28E+01	-2.58E3%	-1.83E+02	1.37E+02	-8.15E-01

A2.1.5 Porcelain Dish

Uncertainty Results - CML Method								
Impact category	**Unit**	**Average**	**Median**	**SD**	**CV (Coeff. Of Var.)**	**2.5%**	**97.5%**	**Average std error**
Acidification	kg SO_2 eq.	6.28E-02	6.25E-02	7.09E-03	11.3%	5.00E-02	7.80E-02	3.57E-03
Eutrophication	kg PO_4^{3-} eq.	2.00E-02	1.96E-02	8.42E-03	42%	4.82E-03	3.81E-02	1.33E-02
Global Warming	kg CO_2 eq.	1.76E+01	1.78E+01	7.26E+00	41.1%	2.73E+00	3.23E+01	1.30E-02
Photochemical Oxidants formation	kg C_2H_4 eq.	5.38E-03	5.30E-03	8.02E-04	14.9%	4.09E-03	7.23E-03	4.71E-03
Uncertainty results - ILCD Method								
Impact category	**Unit**	**Average**	**Median**	**SD**	**CV (Coeff. Of Var.)**	**2.5%**	**97.5%**	**Average std error**
Acidification	mole H+ eq.	7.85E-02	7.81E-02	8.14E-03	10.4%	6.43E-02	9.60E-02	3.28E-03
Climate Change	kg CO_2 eq.	1.75E+01	1.69E+01	7.13E+00	40.8%	3.30E+00	3.19E+01	1.29E-02
Ecotoxicity - freshwater	CTUe	1.57E+03	1.12E+03	2.39E+04	1.52E3%	-4.48E+04	4.94E+04	4.82E-01
Eutrophication - freshwater	kg P eq.	2.91E-03	2.55E-03	1.41E-03	48.6%	1.29E-03	6.48E-03	1.54E-02
Human toxicity - cancer effects	CTUh	3.30E-07	2.61E-07	2.66E-06	806%	-4.87E-06	5.55E-06	2.55E-01
Human toxicity – non cancer effects.	CTUh	2.07E-03	1.99E-03	2.92E-02	1.41E3%	-5.64E-02	5.98E-02	4.46E-01

Ionising Radiation - effects on the ecosystem	CTUe	4.23E-06	4.12E-06	8.23E-07	19.4%	2.97E-06	6.05E-06	6.15E-03
Ionising Radiation - effects on human health	kg of U^{235} eq.	1.85E+00	1.27E+00	1.77E+00	95.7%	5.66E-01	6.95E+00	3.02E-02
Use of land	kg C (deficit)	1.28E+02	1.25E+02	3.53E+01	27.6%	6.84E+01	2.11E+02	8.74E-03
Eutrophication - marine	kg of N eq.	2.19E-02	2.13E-02	6.73E-03	30.8%	1.02E-02	3.66E-02	9.73E-03
Depletion of resources - minerals, fossils	kg of Sb eq.	8.88E-04	7.80E-04	4.53E-04	51%	4.57E-04	1.98E-03	1.61E-02
Ozone depletion	kg CFC-11 eq.	1.66E-06	1.59E-06	3.87E-07	23.4%	1.07E-06	2.57E-06	7.39E-03
Particulate/smog, emissions of inorganic substances	kg $PM_{2,5}$ eq.	1.31E-02	1.28E-02	2.35E-03	17.9%	9.54E-03	1.86E-02	5.65E-03
Photochemical ozone formation	kg NMVOC eq.	3.69E-02	3.65E-02	5.70E-03	15.5%	2.67E-02	4.97E-02	4.89E-03
Eutrophication - terrestrial	mole N eq.	1.46E-01	1.45E-01	2.62E-02	18%	9.85E-02	2.01E-01	5.68E-03
Depletion of resources - water	m^3 of water	8.34E-01	2.04E+00	1.20E+01	1.44E3%	-2.56E+01	2.12E+01	4.54E-01

A2.2 Uncertainty Analysis - CUPS

A2.2.1 PP Cup

Uncertainty Results - CML Method								
Impact category	**Unit**	**Average**	**Median**	**SD**	**CV (Coeff. Of Var.)**	**2.5%**	**97.5%**	**Average std. error**
Acidification	kg SO_2 eq.	9.24E-02	9.22E-02	2.50E-03	2.71%	8.81E-02	9.85E-02	8.57E-04
Eutrophication	kg PO_4^{3-} eq.	5.02E-02	4.37E-02	2.49E-02	49.6%	2.59E-02	1.18E-01	1.57E-02
Global Warming	kg CO_2 eq.	2.51E+01	2.50E+01	4.53E-01	1.8%	2.44E+01	2.61E+01	5.71E-04
Formation of photochemical oxidants	kg C_2H_4 eq.	5.47E-03	5.43E-03	2.27E-04	4.14%	5.14E-03	6.01E-03	1.31E-03

Uncertainty results - ILCD Method								
Impact category	**Unit**	**Average**	**Median**	**SD**	**CV (Coeff. Of Var.)**	**2.5%**	**97.5%**	**Average std. error**
Acidification	mole H+ eq.	1.11E-01	1.10E-01	3.43E-03	3.1%	1.06E-01	1.19E-01	9.81E-04
Climate Change	kg CO_2 eq.	2.51E+01	2.50E+01	4.48E-01	1.78%	2.44E+01	2.61E+01	5.64E-04
Ecotoxicity - freshwater	CTUe	5.90E+02	4.39E+02	5.28E+02	89.4%	1.74E+02	1.90E+03	2.83E-02
Eutrophication - freshwater	kg P eq.	2.44E-03	2.36E-03	4.05E-04	16.6%	1.93E-03	3.50E-03	5.25E-03
Human toxicity - cancer effects	CTUh	7.41E-07	6.75E-07	3.12E-07	42%	4.30E-07	1.55E-06	1.33E-02
Human toxicity – non cancer effects.	CTUh	4.97E-06	4.56E-06	2.64E-05	530%	-4.71E-05	6.19E-05	1.68E-01
Ionising Radiation - effects on the ecosystem	CTUe	4.66E-06	4.46E-06	9.09E-07	19.5%	3.53E-06	7.02E-06	6.17E-03
Ionising Radiation - effects on human health	kg of U^{235} eq.	1.72E+00	1.62E+00	4.17E-01	24.2%	1.40E+00	2.56E+00	7.66E-03
Use of land	kg C (deficit)	2.96E+01	2.90E+01	8.73E+00	29.5%	1.47E+01	5.02E+01	9.32E-03

Eutrophication - marine	kg of N eq.	3.23E-02	3.15E-02	4.38E-03	13.6%	2.63E-02	4.36E-02	4.29E-03
Depletion of resources - minerals, fossils	kg of Sb eq.	5.39E-04	4.76E-04	2.54E-04	47.2%	2.62E-04	1.16E-03	1.49E-02
Ozone depletion	kg CFC-11 eq.	1.71E-06	1.63E-06	3.36E-07	19.6%	1.33E-06	2.56E-06	6.20E-03
Particulate/smog, emissions of inorganic substances	kg $PM_{2,5}$ eq.	1.09E-02	1.08E-02	4.64E-04	4.27%	1.01E-02	1.20E-02	1.35E-03
Photochemical ozone formation	kg NMVOC eq.	8.64E-02	8.62E-02	2.01E-03	2.33%	8.30E-02	9.05E-02	7.37E-04
Eutrophication - terrestrial	mole N eq.	2.23E-01	2.22E-01	7.03E-03	3.15%	2.11E-01	2.38E-01	9.95E-04
Depletion of resources - water	$m^3$of water	5.09E-02	5.38E-02	3.60E-01	707%	-6.79E-01	7.63E-01	2.24E-01

A2.2.2 PS Cups

Uncertainty Results - CML Method								
Impact category	**Unit**	**Average**	**Median**	**SD**	**CV (Coeff. Of Var.)**	**2.5%**	**97.5%**	**Average std. error**
Acidification	kg SO_2 eq.	1.18E-01	1.17E-01	2.49E-03	2.11%	1.13E-01	1.23E-01	6.68E-04
Eutrophication	kg PO_4^{3-} eq.	5.69E-02	4.96E-02	2.66E-02	46.7%	2.80E-02	1.29E-01	1.48E-02
Global Warming	kg CO_2 eq.	3.32E+01	3.31E+01	5.41E-01	1.63%	3.24E+01	3.45E+01	5.16E-04
Photochemical Oxidants formation	kg C_2H_4 eq.	7.26E-03	7.21E-03	2.64E-04	3.64%	6.90E-03	7.92E-03	1.15E-03

Uncertainty results - ILCD Method								
Impact category	**Unit**	**Average**	**Median**	**SD**	**CV (Coeff. Of Var.)**	**2.5%**	**97.5%**	**Average std.error**
Acidification	mole H+ eq.	1.41E-01	1.41E-01	2.91E-03	2.06%	1.37E-01	1.48E-01	6.50E-04
Climate Change	kg CO_2 eq.	3.32E+01	3.31E+01	5.08E-01	1.53%	3.24E+01	3.43E+01	4.85E-04
Ecotoxicity - freshwater	CTUe	4.13E+02	3.56E+02	2.31E+02	55.8%	1.77E+02	9.73E+02	1.77E-02
Eutrophication - freshwater	kg P eq.	2.09E-03	2.01E-03	4.42E-04	21.1%	1.52E-03	3.29E-03	6.67E-03
Human toxicity - cancer effects	CTUh	9.21E-07	8.28E-07	3.90E-07	42.4%	5.02E-07	1.89E-06	1.34E-02
Human toxicity non cancer effects.	CTUh	9.23E-06	8.13E-06	2.54E-05	275%	-3.96E-05	5.88E-05	8.71E-02
Ionising Radiation - effects on the ecosystem	CTUe	4.20E-06	3.98E-06	9.28E-07	22.1%	3.12E-06	6.52E-06	7.00E-03
Ionising Radiation - effects on human health	kg of U^{235} eq.	1.50E+00	1.42E+00	2.84E-01	19%	1.20E+00	2.24E+00	6.01E-03
Use of land	kg C (deficit)	2.84E+01	2.76E+01	8.70E+00	30.7%	1.39E+01	4.78E+01	9.70E-03
Eutrophication - marine	kg of N eq.	3.82E-02	3.72E-02	5.50E-03	14.4%	3.09E-02	5.22E-02	4.55E-03
Depletion of resources - minerals, fossils	kg of Sb eq.	5.37E-04	4.76E-04	2.62E-04	48.7%	2.52E-04	1.22E-03	1.54E-02
Ozone depletion	kg CFC-11 eq.	1.55E-06	1.49E-06	3.16E-07	20.3%	1.18E-06	2.35E-06	6.42E-03
Particulate/smog, emissions of inorganic substances	kg $PM_{2,5}$ eq.	1.35E-02	1.35E-02	4.75E-04	3.51%	1.28E-02	1.47E-02	1.11E-03
Photochemical ozone	kg NMVOC	9.60E-02	9.58E-02	2.01E-03	2.1%	9.27E-02	1.00E-01	6.63E-04

formation	eq.							
Eutrophication - terrestrial	mole N eq.	2.67E-01	2.66E-01	7.36E-03	2.76%	2.55E-01	2.81E-01	8.73E-04
Depletion of resources - water	$m^3$of water	6.23E-02	5.45E-02	3.83E-01	615%	-7.03E-01	8.09E-01	1.95E-01

A2.2.3 PLA Cups

Uncertainty Results - CML Method								
Impact category	**Unit**	**Average**	**Median**	**SD**	**CV (Coeff. Of Var.)**	**2.5%**	**97.5%**	**Average std. error**
Acidification	kg SO_2 eq.	2.00E-01	1.98E-01	1.50E-02	7.52%	1.76E-01	2.34E-01	2.38E-03
Eutrophication	kg PO_4^{3-} eq.	8.72E-02	8.48E-02	1.44E-02	16.5%	6.78E-02	1.22E-01	5.23E-03
Global Warming	kg CO_2 eq.	3.73E+01	3.71E+01	1.88E+00	5.03%	3.42E+01	4.14E+01	1.59E-03
Photochemical oxidants formation	kg C_2H_4 eq.	9.49E-03	9.39E-03	8.41E-04	8.87%	8.12E-03	1.14E-02	2.80E-03

Uncertainty results - ILCD Method								
Impact category	**Unit**	**Average**	**Median**	**SD**	**CV (Coeff. Of Var.)**	**2.5%**	**97.5%**	**Average std. error**
Acidification	mole H+ eq.	2.46E-01	2.45E-01	1.95E-02	7.91%	2.14E-01	2.89E-01	2.50E-03
Climate Change	kg CO_2 eq.	3.73E+01	3.71E+01	1.95E+00	5.23%	3.40E+01	4.15E+01	1.66E-03
Ecotoxicity - freshwater	CTUe	1.05E+03	9.31E+02	4.76E+02	45.1%	5.04E+02	2.29E+03	1.43E-02
Eutrophication - freshwater	kg P eq.	9.32E-03	8.65E-03	3.00E-03	32.2%	5.48E-03	1.64E-02	1.02E-02
Human toxicity - cancer effects	CTUh	1.38E-06	1.08E-06	1.55E-06	112%	6.86E-07	3.62E-06	3.56E-02
Human toxicity non cancer effects.	CTUh	1.62E-05	1.55E-05	2.67E-05	165%	-3.54E-05	7.04E-05	5.20E-02
Ionising Radiation - effects on the ecosystem	CTUe	1.18E-05	1.14E-05	2.38E-06	20.1%	8.57E-06	1.79E-05	6.35E-03
Ionising Radiation - effects on human health	kg of U^{235} eq.	4.22E+00	3.35E+00	2.84E+00	67.3%	2.20E+00	1.15E+01	2.13E-02
Use of land	kg C (deficit)	9.48E+01	1.11E+02	1.84E+03	1.94E3%	-3.59E+03	3.81E+03	6.15E-01
Eutrophication - marine	kg of N eq.	9.75E-02	9.68E-02	9.76E-03	10%	7.99E-02	1.18E-01	3.16E-03
Depletion of resources - minerals, fossils	kg of Sb eq.	1.32E-03	1.19E-03	5.19E-04	39.3%	7.18E-04	2.61E-03	1.24E-02
Ozone depletion	kg CFC-11 eq.	3.25E-06	3.08E-06	7.42E-07	22.8%	2.32E-06	5.33E-06	7.22E-03
Particulate/smog, emissions of inorganic substances	kg $PM_{2,5}$ eq.	2.32E-02	2.25E-02	3.44E-03	14.8%	1.84E-02	3.10E-02	4.68E-03
Photochemical ozone formation	kg NMVOC eq.	1.28E-01	1.27E-01	7.17E-03	5.6%	1.15E-01	1.43E-01	1.77E-03
Eutrophication - terrestrial	mole N eq.	5.05E-01	5.01E-01	3.63E-02	7.18%	4.41E-01	5.85E-01	2.27E-03
Depletion of resources – water	$m^3$of water	9.25E-01	8.84E-01	4.59E+00	495%	-7.42E+00	1.04E+01	1.57E-01

A2.2.4 Cardboard Cups

Uncertainty Results - CML Method								
Impact category	**Unit**	**Average**	**Median**	**SD**	**CV (Coeff. Of Var.)**	**2.5%**	**97.5%**	**Average std.error**
Acidification	kg SO_2 eq.	6.10E-02	6.00E-02	8.28E-03	13.6%	4.75E-02	7.99E-02	4.29E-03
Eutrophication	kg PO_4^{3-} eq.	3.74E-02	3.49E-02	1.12E-02	29.8%	2.36E-02	6.49E-02	9.43E-03
Global Warming	kg CO_2 eq.	1.79E+01	1.74E+01	3.48E+00	19.5%	1.26E+01	2.62E+01	6.16E-03
Formation of photochemical oxidants	kg C_2H_4 eq.	5.43E-03	5.33E-03	9.99E-04	18.4%	3.91E-03	7.76E-03	5.82E-03

Uncertainty results - ILCD Method								
Impact category	**Unit**	**Average**	**Median**	**SD**	**CV (Coeff. Of Var.)**	**2.5%**	**97.5%**	**Average std.error**
Acidification	mole H+ eq.	6.98E-02	6.92E-02	9.59E-03	13.7%	5.35E-02	9.08E-02	4.34E-03
Climate Change	kg CO_2 eq.	1.78E+01	1.73E+01	3.38E+00	19%	1.29E+01	2.59E+01	6.00E-03
Ecotoxicity - freshwater	CTUe	1.02E+02	9.59E+01	3.24E+01	31.8%	5.85E+01	1.82E+02	1.01E-02
Eutrophication - freshwater	kg P eq.	2.42E-03	2.39E-03	4.48E-04	18.5%	1.68E-03	3.39E-03	5.86E-03
Human toxicity - cancer effects	CTUh	4.76E-07	4.57E-07	1.36E-07	28.6%	3.14E-07	7.00E-07	9.03E-03
Human toxicity non cancer effects.	CTUh	3.60E-06	4.07E-06	1.50E-05	416%	-2.85E-05	3.26E-05	1.32E-01
Ionising Radiation - effects on the ecosystem	CTUe	3.70E-06	3.60E-06	7.17E-07	19.4%	2.57E-06	5.40E-06	6.13E-03
Ionising Radiation - effects on human health	kg of U^{235} eq.	1.16E+00	1.11E+00	2.64E-01	22.8%	7.82E-01	1.79E+00	7.22E-03
Use of land	kg C (deficit)	1.34E+02	1.32E+02	2.55E+01	19.1%	8.82E+01	1.90E+02	6.03E-03
Eutrophication - marine	kg of N eq.	3.83E-02	3.73E-02	6.30E-03	16.5%	2.77E-02	5.26E-02	5.21E-03
Depletion of resources - minerals, fossils	kg of Sb eq.	3.93E-04	3.56E-04	1.76E-04	44.7%	2.24E-04	8.23E-04	1.41E-02
Ozone depletion	kg CFC-11 eq.	3.87E-05	3.72E-05	9.39E-06	24.2%	2.30E-05	6.01E-05	7.66E-03
Particulate/smog, emissions of inorganic substances	kg $PM_{2,5}$ eq.	1.86E-02	1.84E-02	3.28E-03	17.6%	1.31E-02	2.62E-02	5.57E-03
Photochemical ozone formation	kg NMVOC eq.	5.88E-02	5.84E-02	6.41E-03	10.9%	4.71E-02	7.21E-02	3.45E-03
Eutrophication - terrestrial	mole N eq.	1.66E-01	1.65E-01	2.22E-02	13.4%	1.28E-01	2.15E-01	4.23E-03
Depletion of resources - water	m^3 of water	2.06E-02	1.90E-02	2.20E-01	1.07E3%	-4.45E-01	4.47E-01	3.37E-01

A2.2.5 Glass Cups

Uncertainty Results - CML Method								
Impact category	**Unit**	**Average**	**Median**	**SD**	**CV (Coeff. Of Var.)**	**2.5%**	**97.5%**	**Average std.error**
Acidification	kg SO_2 eq.	3.03E-02	3.03E-02	3.22E-03	10.6%	2.46E-02	3.77E-02	3.35E-03
Eutrophication	kg PO_4^{3-} eq.	9.51E-03	9.24E-03	4.00E-03	42.1%	2.15E-03	1.80E-02	1.33E-02
Global Warming	kg CO_2 eq.	8.26E+00	8.04E+00	3.70E+00	44.8%	1.35E+00	1.65E+01	1.42E-02

Photochemical Oxidants formation	kg C_2H_4 eq.	2.60E-03	2.54E-03	3.82E-04	14.7%	1.95E-03	3.49E-03	4.66E-03

Uncertainty results - ILCD Method

Impact category	Unit	Average	Median	SD	CV (Coeff. Of Var.)	2.5%	97.5%	Average std. error
Acidification	mole H+ eq.	3.84E-02	3.79E-02	4.17E-03	10.9%	3.13E-02	4.75E-02	3.44E-03
Climate Change	kg CO_2 eq.	8.54E+00	8.54E+00	3.76E+00	44.1%	1.20E+00	1.60E+01	1.39E-02
Ecotoxicity - freshwater	CTUe	5.15E+01	-2.68E+02	1.19E+04	2.32E4%	-2.32E+04	2.34E+04	7.34E+00
Eutrophication - freshwater	kg P eq.	1.33E-03	1.20E-03	5.73E-04	43%	6.05E-04	2.73E-03	1.36E-02
Human toxicity - cancer effects	CTUh	3.20E-07	3.55E-07	1.29E-06	401%	-2.16E-06	2.97E-06	1.27E-01
Human toxicity non cancer effects.	CTUh	3.81E-04	-4.19E-04	1.50E-02	3.92E3%	-2.76E-02	3.18E-02	1.24E+00
Ionising Radiation - effects on the ecosystem	CTUe	2.08E-06	2.01E-06	4.14E-07	19.9%	1.44E-06	3.06E-06	6.28E-03
Ionising Radiation - effects on human health	kg of U^{235} eq.	9.55E-01	6.27E-01	1.11E+00	117%	2.85E-01	3.90E+00	3.69E-02
Use of land	kg C (deficit)	6.25E+01	6.08E+01	1.88E+01	30%	2.96E+01	1.03E+02	9.49E-03
Eutrophication - marine	kg of N eq.	1.13E-02	1.09E-02	3.49E-03	31%	5.38E-03	2.00E-02	9.80E-03
Depletion of resources - minerals, fossils	kg of Sb eq.	4.35E-04	3.75E-04	2.24E-04	51.5%	2.19E-04	1.03E-03	1.63E-02
Ozone depletion	kg CFC-11 eq.	8.22E-07	7.91E-07	2.12E-07	25.8%	5.24E-07	1.31E-06	8.16E-03
Particulate/smog, emissions of inorganic substances	kg $PM_{2,5}$ eq.	4.53E-03	4.38E-03	8.77E-04	19.4%	3.25E-03	6.81E-03	6.12E-03
Photochemical ozone formation	kg NMVOC eq.	1.83E-02	1.80E-02	2.99E-03	16.4%	1.29E-02	2.49E-02	5.17E-03
Eutrophication - terrestrial	mole N eq.	7.31E-02	7.21E-02	1.37E-02	18.8%	4.94E-02	1.03E-01	5.95E-03
Depletion of resources - water	$m^3$of water	9.68E-02	7.51E-01	5.87E+00	6.06E3%	-1.24E+01	1.06E+01	1.92E+00

Appendix 3- PEF data quality matrix

Quality level	Quality indicator	Definition	Completeness	Methodological appropriateness and consistency	Temporal representativeness	Technological representativeness	Geographical representativeness	Parameters uncertainty
			To be assessed in relation to within each environmental impact category and in comparison to an hypothetical ideal data quality.	The life cycle inventory methods applied and the methodological choices (for instance the allowance, replacement and similar) are aligned to the objective and the data, especially as regards the applications envisaged as a support in decision making. The methods have been applied in a consistent manner to al data.	The degree to which the set of data reflects the specific conditions of the system under examination as regards time/age of data included the possible background data set. Comment: that is of the year involved (the possible annual or daily differences)	The degree to which the set of data reflects the actual "population" involved as regards the technology, including the possible background data set.	The degree to which the set of data reflects the actual "population" involved as regards the geography, including the possible background data set.	Quality judgment expressed by experts or deviation from standards as % if used a Monte Carlo simulation. Comment: the uncertainty evaluation involves only the data related to the profile of use of resources and emission; it does not involve the environmental footprint impact evaluation.
Very high		It highly satisfy the criterion, no improvement required	Very good completeness (> 90 %)	Full conformity to all requirement of the PEF guidelines.	Specific for the context	Specific for the context	Specific for the context	**Very low uncertainty** Very low uncertainty (< 10 %)
Good		It highly satisfy the criterion, little improvement required	Good completeness (trn 80% 90%)	Method based on an attributional process (2) E: The three requirements provided in the PEF guideline hereinafter given are fully satisfied - it is dealt with the multifunctionality aspect - end of life modelling -system boundary	Specific for the context	Specific for the context	Specific for the context	**Low uncertainty** Low uncertainty (between 10% and 20%)
Satisfactory		It acceptably satisfy the criterion, improvement required	Satisfactory completeness (tra 7 0% e SO%)	Method based on an attributional process E: Two of the three requirements provided in the PEF guideline hereinafter given are fully satisfied: - it is dealt with the multifunctionality aspect - end of life modelling -system boundary	Specific for the context	Specific for the context	Specific for the context	**Acceptable uncertainty** Acceptable uncertainty (between 20% and 30%)
Low		It does not satisfy the criterion, requires improvement	Low completeness (tra 50% 7 0%)	Method based on an attributional process E: One of the three requirements provided in the PEF guideline hereinafter given are fully satisfied: - it is dealt with the multifunctionality aspect - end of life modelling -system boundary	Specific for the context	Specific for the context	Specific for the context	**High uncertainty** High uncertainty (between 30% and 50%)
Very low		It does not satisfy the criterion, requires substantial improvement This criterion has not been deliberated/examined or the quality could not been checked/it is not known.	Very low completeness or not known (< 50 %)	Method based on an attributional process E: None of the three requirements provided in the PEF guideline hereinafter given are fully satisfied: - it is dealt with the multifunctionality aspect - end of life modelling - system boundary	Specific for the context	Specific for the context	Specific for the context	**Very high uncertainty** Very high uncertainty (> 50 %)

Appendix 4 - Requirements correlation matrix for the external communications report

The following table allows identifying the location of required information for the external communication report by the standard ISO 14044 (sections 5.2 and 5.3.1), by indicating the paragraph in which each requirement is taken into consideration in the present LCA report.

a) General aspects	
Requirement	**Paragraph**
1) who commissions and who performs the LCA (internal or external);	Frontispiece and 1st page
2) the date of the report;	Frontispiece
3) declaration attesting that the study was conducted according to the requirements of the present international standard.	Introduction
b) goal of the study	
Requirement	**Paragraph**
1) motivations to carry out the study;	1.1.1
2) envisaged applications;	1.1.2
3) intended audience;	1.1.2
4) indications specifying whether the study is intended to be used to support comparative assertions intended to be disclosed to the public.	1.1.2
c) scope of the study	
Requirement	**Paragraph**
1) the function, including: i) declaration of performance characteristics, and ii) any omission of additional functions in comparisons;	1.2.1
2) functional unit, including: i) consistency with the goal and scope, ii) definition, iii) result of performance measurement;	1.2.1
3) system boundary, including: i) omissions of required life cycle phases, processes or data, ii) quantification of energy flows, inputs and outputs, iii) hypothesis on energy production;	1.2.2
4) exclusion criteria for initial inclusion of inputs and outputs, including: i) description of exclusion criteria and hypothesis, ii) effect of choice on the results, iii) addition of mass, energy and environment exclusion criteria;	1.2.3
d) Life cycle inventory analysis	
Requirement	Paragraph
1) data collection procedure;	2.1, 2.2, 2.3
2) qualitative and quantitative description of unitary processes;	2.1, 2.2, 2.3
3) published literature sources;	2.1, 2.2, 2.3
4) calculation procedures;	2.1, 2.2, 2.3

5) data validation, including: i) data quality assessment, and ii) treatment of missing data;	2.4
6) sensitivity analysis to correct the system boundaries;	3.4.2
7) allocation principles and procedures, including: i) documentation and justification of allocation methods, and ii) even application of allocation methods.	1.2.4
e) Life cycle impact assessment, if applicable	
Requirement	**Paragraph**
1) LCIA procedures, calculations, and study results;	3 3.1
2) limitations of LCIA results in relation to the goal and scope defined by the LCA;	n.a
3) report of LCIA results in relation to the goal and scope;	3
4) report of LCIA results in relation to LCI results;	3
5) impact categories and category indicators taken into account, including a rationale for their selection and a reference to the source;	1.2.5, Appendix 1
6) descriptions or reference to all models of characterization, characterization factors and used methods, including all assumptions and limitations;	1.2.5, 3
7) descriptions or reference to all chosen values used in relation to impact categories, characterization models, characterization factors, standardisation, grouping, weighting and, in other LCIA points, a justification for their use and influence on results, conclusions and recommendations;	1.2.5, 3
8) a statement that the LCIA results are relative expressions and do not predict impacts on category endpoints, the exceeding of thresholds, safety margins or risks and, when part of the LCA, also:	3
i) a description and justification of the definition and description of all new impact categories, category indicators or characterization models used for LCIA,	1.2.5, Appendix 1
ii) a declaration and explanation of any groupings of impact categories,	n.a
iii) all additional procedures that transform indicators results and a justification of selected references, weighting factors, etc.,	n.a
iv) any of the indicators results analysis, for instance the sensitivity and uncertainty analyses or the use of environmental data, including the implications for the results, and	3.4.1, 3.4.2
v) data and results of the indicators achieved before normalization, grouping or weighting should be made available together with the results of standardization, the grouping or weighting.	n.a
f) Life cycle interpretation	
Requirement	**Paragraph**
1) results;	4.1
2) assumptions and limitations associated with the interpretation of the results and concerning methodology and related data;	4.3
3) data quality assessment;	4.3
4) complete transparency in the choice of values, rationales and experts reviews.	4.2.1

g) Critical Review	
Requirement	**Paragraph**
1) name and membership of reviewers;	5
2) Critical Review Reports;	5
3) responses to recommendations.	5
Further communication requirements for comparative assertions intended to be disclosed to the public	
Requirement	**Paragraph**
a) materials and energy flows analysis to justify their inclusion or exclusion;	2.1, 2.2, 2.3
b) the accuracy, completeness and representativeness assessment of the data used;	2.4
c) a description of equivalence of compared systems in accordance with point 4.2.3.7;	1.2.10
d) the description of the critical review process;	5
e) an LCIA completeness assessment;	4.2.1
f) a declaration regarding the existence or the absence of the international acceptance selected category indicators and a justification for their use;	1.2.5
g) an explanation of the scientific and technical validity and of the environmental relevance of category indicators used in the study;	1.2.5
h) results of the uncertainty and sensitivity analyses;	3.4.1, 3.4.2, Appendix 2
i) assessment of the significance of the observed differences.	4.3

Annex 1 - Application of additional calculation methods

[This annex has been omitted at the request of the study contractor since it contains sensitive information and strictly confidential data.
The LCA report has been the subjected to Critical Review and was found self-supporting in its content even in the absence of this annex (see section "External Communication" of Critical Review report, chapter 5)]

Annex 2 - Data validation

[This annex has been omitted at the request of the study contractor since it contains sensitive information and strictly confidential data.
The LCA report has been the subjected to Critical Review and was found self-supporting in its content even in the absence of this annex (see section "External Communication" of Critical Review report, chapter 5)]

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