University of Padua

Chemical Processes in Engineering Department

Quality of the Environment Studies Centre

A comparative study of the life cycles of fresh and UHT milk containers: Tetra Rex – PET and Tetra Brik Aseptic – HDPE

Summary

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Preface

Life Cycle Assessment (LCA) is a method used in assessing the environmental aspects and potential environmental impact of various stages in the life cycle of a product, service or activity.
LCA aims at evaluating all resources and emissions (into the atmosphere, water and land), in terms of the flows of material and energy into and out of the system under investigation. It is these flows that have the potential to impact on the natural world, in the form of such consequences as global warming and the depletion of non-renewable resources.

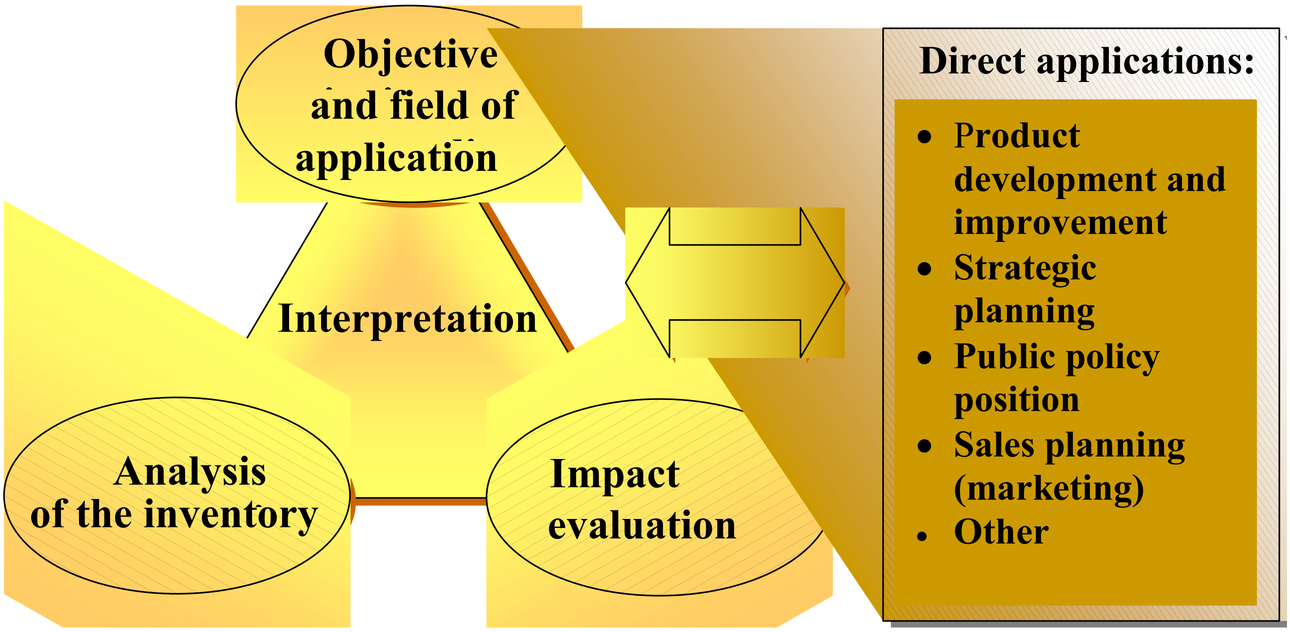

Fig.1: structure and aims of a Life Cycle Assessment.

Such an analysis covers the product's whole system, from the extraction of raw materials, through the manufacturing process to disposal/recycling/ final energy recovery. The study takes the form of a repetitive procedure that goes through a series of systematically interpreted and repeated stages. These stages consist in the statement of objectives, of the requisites of the study and the characteristics of the system under examination, as well as the compilation of an inventory of what goes into and what comes out of the product system (*life cycle inventory*, LCI), an evaluation of environmental impact on the basis of the inventory data (*life cycle impact assessment*, LCIA) and the interpretation of the final results.
The LCA's conclusion addresses the questions posed at the beginning when objectives are defined (see figure 1)

In the wake of the objectives laid down by the European directive 94/62/CE, the packaging sector has for some years now been applying the LCA method to support external communication and optimise production process choices and product planning, as well for the identification of the most advantageous end-of-cycle solutions including materials recycling, energy recovery, disposal in dumps etc.

The work considered in this summary regards two LCA comparisons between different types of milk packaging and distribution.

The study was carried in 2002 out as a result of a research contract made between the University of Padua's Quality of the Environment Studies Centre and Tetra Pak Italiana S.p.A. The organisation of the work was in accordance with ISO 14040 standards.

1 Introduction

This study's aim was to analyse the life cycle of two types of packaging normally used for packing and distributing milk. In particular, the research carried out a direct comparison between:

- PET bottles and the TETRA REX® paperboard container manufactured by Tetra Pak, in the case of fresh milk;
- HDPE bottles and the TETRA BRIK ASEPTIC® paperboard container made by Tetra Pak, in the case of UHT milk.

The study set itself the following objectives:

1) To compare the environmental impact and energy/environmental loads associated with the life cycles of the above four types of packaging;
2) To gather objective information that could be used by Tetra Pak to initiate environmental awareness campaigns aimed at its own customers and consumers;
3) To use the study, in implementing the new packaging directive, as a tool for obtaining a better understanding of the most environmentally friendly solutions, particularly as regards the end of the containers' life cycles.

2 A description of the product systems analysed

2.1 Functional unit and characteristics of the investigated products.

In an LCA study, the functional unit is the unit of measurement used to quantify all inflows and outflows from the system as identified in the life cycle inventory analysis stage. In this work product function refers to the product's capacity to contain a certain volume of milk.

The reference volume for the containing function is 1 litre of milk (fresh or UHT), and is also the functional unit selected when comparing containers.

Table 1 shows the composition of the container Tetra Rex for the functional unit considered.

Tetra Rex (1 Lt)	Weight (%)
Paper	23.76 g (87.04 %)
PE	3.45 g (12.65%)
Ink	0.08 g (0.31 %)
TOTAL (1 litre)	27.3 g

Table 1: the composition of Tetra Rex for the chosen functional unit.

Table 2 shows the composition of the PET bottle for the functional unit considered. In this case the weights are also given of auxiliary components used in fresh milk packaging.

PET bottle (1 Lt)	Material	Weight (%)
Bottle	PET	26 g (86 %)
Cap	HDPE	3.5 g (11,5%)
Label	PP	0.77 g (2,5 %)
TOTAL (1 litre)		30.27 g

Table 2: the composition of the PET bottle for the chosen functional unit.

Similarly, tables 3 and 4 respectively show the characteristics of the Tetra Brik Aseptic containers and the HDPE bottles, for the functional unit considered.

Tetra Brik Aseptic (1 Lt)	Weight (%)
Paper	19.10 g (73,89 %)
PE	5.28 g (20,46%)
Aluminium	1.34 g (5,19 %)
Ink	0.12 g (0,12 %)
TOTAL (1 litre)	25.84 g

Table 3: the composition of the Brik Aseptic for the chosen functional unit.

HDPE bottle (1 Lt)	Material	Weight (%)
Bottle	HDPE	29.88 g (82,6%)
Cap	HDPE	4.15 g (11,4%)
Label	PP	1.84 g (5 %)

Seal	**Al**	**0.31 g (1 %)**
TOTAL (1 litre)		**36.18 g**

Table 4: the composition of the HDPE bottle for the chosen functional unit.

2.2 Stages of the systems analysed

The stages in the life cycle of the containers, considered for both comparative analyses, were the following (see figure 2):

1. Production
2. Packaging
3. Distribution (primary)
4. End of life cycle

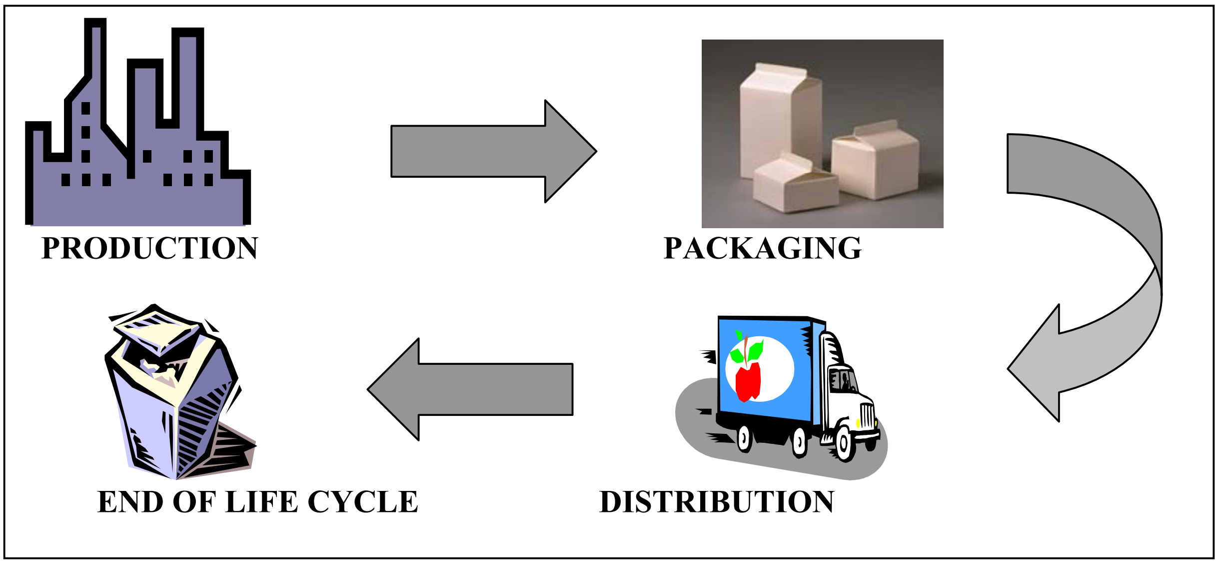

Figure 2: life cycle stages considered.

The studied system stages comprise in the following:

Production	• The production of raw materials (this stage relates to the extraction of the raw materials and the first work of processing or refining carried out on them). • The production of semi-finished goods and basic materials, i.e. the stage involved in the production of materials used by factories manufacturing the Tetra Rex and Tetra Brik Aseptic paperboards, and also the PET and HDPE bottles: examples include the inks, the production of photopolymers and printing blocks, as well as the production in Santarcangelo of Havana paper for Tetra Rex packaging. • Actual manufacturing as such, particularly: the production of Tetra Rex paperboard at the factory of Cartotecnica Pontina di Latina, of PET preforms at the Tetra Pak PET Italia factory in Bergamo, of Tetra Brik Aseptic paperboard the Tetra Pak premises in Rubiera and on site HDPE bottle production at the packaging works
Packaging	Consisting in: • Bottle-forming in the case of PET bottles (carried out on site at the Centrale del Latte dairy), as well as the actual packaging itself. The data relating to this phase were gathered at the Granarolo factory (Bologna). • Packaging, only in the case of Tetra Rex andTetra Brik Aseptic. (Tera Rex data are from Granarolo production and the Tetra Brik Aseptic data are taken from the Boustead database) • The manufacture and filling of HDPE bottles. Data were gathered from the manufacturers of the extrusion-blowing and filling machinery.
End of cycle	Includes landfill disposal, energy recovery and composting, as well as actual recycling of the material itself. The aimed-for end of cycle scenario has been the following for Tetra Pak containers (data from Comieco): Landfills 69.4%, Energy recovery 23.9%, Joint recycling 6.3%, Specific recycling 0.3%, Composting 0.1%. On the basis of Corepla estimates, the figures for the plastic bottles are as follows: Landfills 61.6%, Mechanical recycling 19.5%, Energy recovery18.9%.
Transportation	Transportation regards the delivery of raw materials, basic materials, packaging materials and the packed milk itself to the branches for primary distribution.

The above included stages in the containers' life cycles, do not include, being a comparative LCA[1], the following stages:

1) The production of milk and corresponding treatment of the milk;
2) Secondary distribution of packed milk;
3) Use (refrigeration and consumption).

2.3 Inventory analysis

An Inventory Analysis was carried out for each of the products and systems indicated in the above section in order to determine the energy and environmental loads associated with the various stages of the life cycle under examination. The data were collected directly site, as primary data, or taken from national and international databases specialised in this type of analysis (secondary data).

The results of the Inventory for each life cycle stage (i.e. Production, Packaging, Distribution and End of cycle) were grouped together into the following categories:

1) Energy analysis
2) Water consumption
3) Raw materials
4) Emissions into the atmosphere
5) Emissions into water
6) Solid waste

For each of the production systems or subsystems investigated, these categories took the following into account:

- The production of fuels: all operations connected with fuel or energy (e.g. electricity) producing companies, such as the extraction of primary fuel from underground, their processing and the channelling to the final user.
- The use of fuels: direct emissions from the burning of fuels.
- Transportation: the emissions and direct energy consumption involved in the transportation of products or sub-products to manufacturing plant and factories producing materials (such as steel) used in the manufacture of the necessary means.

[1] In a comparative LCA study, the stages which are practically identical (in terms of energy and environmental loads) for the products being compared are normally overlooked.

- Processes: emissions and consumption of resources in this case reflect direct environmental aspects, i.e. direct emissions resulting from production in the various factories and the processing units within these.

3 Environmental assessment of the products

The Assessment stage consists in taking the environmental results and substances identified in the Inventory, to determine what the potential impact is of the systems, and the various stages in the product life cycle, on the regional or global environment. The environmental effects selected for the purposes of this study, were the following:

1) Global warming potential. (GWP)
2) Acidification potential (AP)
3) Nutrification potential. (NP)
4) Photochemical Ozone Creation Potential (photochemical smog) (POCP)
5) Non-renewable resources depletion

3.1 Global warming

The global warming indicator is calculated by considering those substances emitted into the atmosphere that contribute to potential global warming.

The mass of each relevant substance, calculated over the product's whole life cycle, is multiplied by a weight coefficient known as the GWP (Global Warming Potential). The total value of the indicator is obtained by adding together the contributions of the various substances.

The main substances that contribute to global warming are: CO_2, CH_4, N_2O and CFC/HCFC. Carbon dioxide is the reference substance for this indicator, that is to say that its weight coefficient is equal to 1 and the values of the indicator are expressed in terms of grams of CO_2 equivalent (g CO_2 eq).

The structure of the calculation models for all the other selected indicator models is similar to that above for global warming.

3.2 Acidification

The acidification index is linked to the emission into the atmosphere of certain acidifying substances such as the oxides of nitrogen (NO_x) and sulphur (SO_x).

The reference substance for this index is the hydrogen ion H+ (g. eq. ions of H+) and the weight coefficient is called the AP (Acidification Potential).

3.3 Nutrification

The nutrification potential evaluation assesses increases in concentrations of nutrients in water environments. The substances that contribute most markedly to this nutrification phenomenon are compounds containing phosphorous and nitrogen.

The reference substance is phosphate (g eq. PO_4^{3-}) and the weight coefficient is called the NP (Nutrification Potential).

3.4 Photochemical smog

The term photochemical smog groups together all those airborne organic substances that lead to the production of photochemical formation (in the presence of sunlight) of tropospheric ozone.

The factor is known as POCP, (Photochemical Ozone Creation Potential) and the reference substance is ethylene (g eq. C_2H_4).

3.5 Non-renewable resources depletion

The depletion of non-renewable resources is defined as the reduction of the availability of natural reserves. This index places the focus on depletion of the various resources themselves rather than on the environmental impact caused by their extraction (e.g. methane emissions that takes place during coal mining). The potential (expressed in years $^{-1}$), represents the number of years current mineral or fossil reserves of a particular substance can last at current rates of production (extraction).

4 Study conclusions

4.1 Tetra Rex – PET

Summarising what emerged from the Assessment and Interpretation of eco-balances, the main results obtained for the purposes of comparing the energy and environmental characteristics of Tetra Rex and PET bottles, in accordance with the stated aims and objectives of the study, were as follows:

- the life cycle of PET bottles was associated with a total energy need 3.3 greater than that of the Tetra Rex container;
- the life cycle of the Tetra Rex required 1.5 times more water than the PET bottle;
- the indicator measuring global warming potential was 2.3 times higher for PET bottles than is the case for Tetra Rex;
- the acidification potential associated with the PET bottle life cycle was found to be 4.8 times higher than that for Tetra Rex;
- the nutrification potential associated with the life cycle of the PET bottle showed itself to be 3 times greater than that found for Tetra Rex;
- the photochemical oxidants creation potential associated with the life cycle of a PET bottle was found to be 7.1 times higher than that associated with Tetra Rex;
- the non-renewable resources depletion potential associated with the life cycle of a PET bottle was 5.4 times greater than that of Tetra Rex

Note: figures 3, 4, 5 and 6 show graphs summarising the study's results. For comparative purpose it was chosen to:

- add up the total of the indices for each category for a stage in the life cycle (production, packaging, distribution, cycle end) of the two containers;
- considering the above sum as 100, assess the contribution to it of one container as against the other.

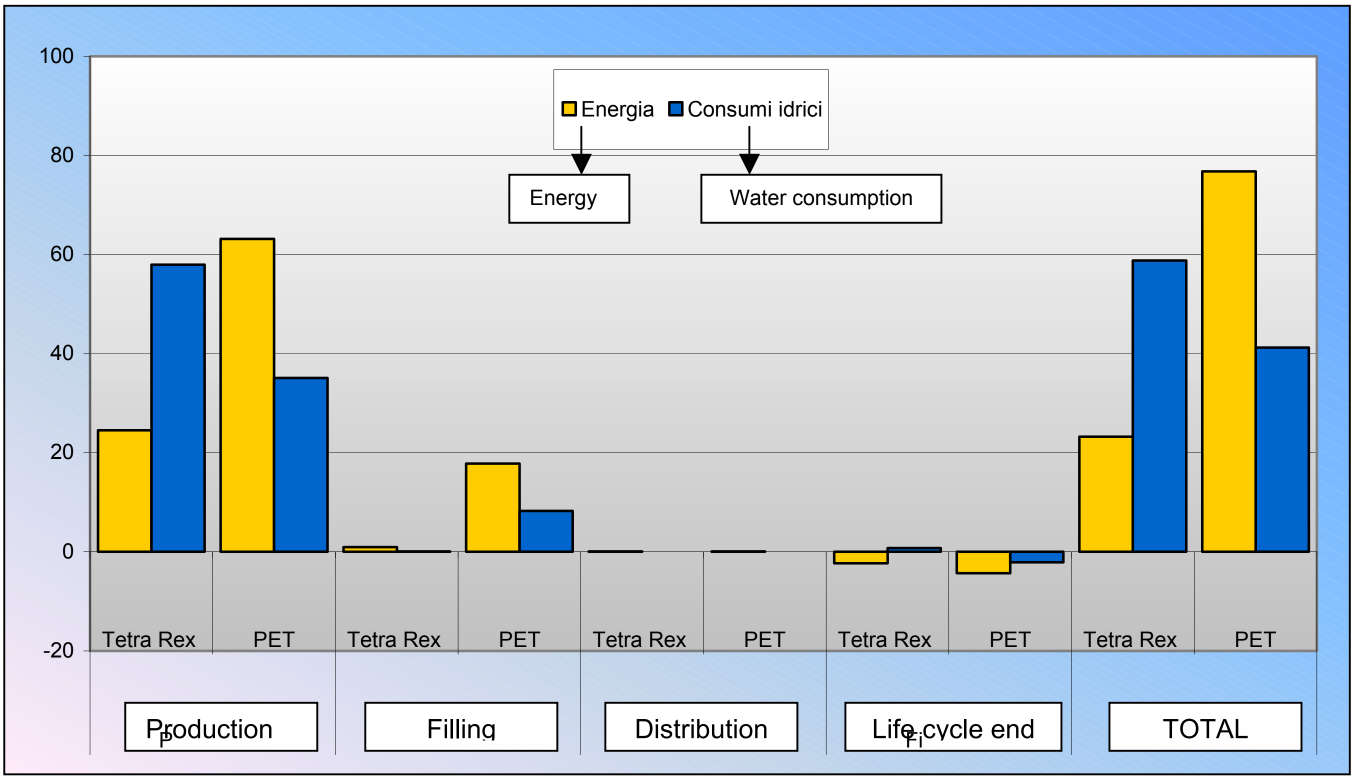

Figure 3: relative Tetra Brik Aseptic and HDPE water consumption contribution during life cycle.

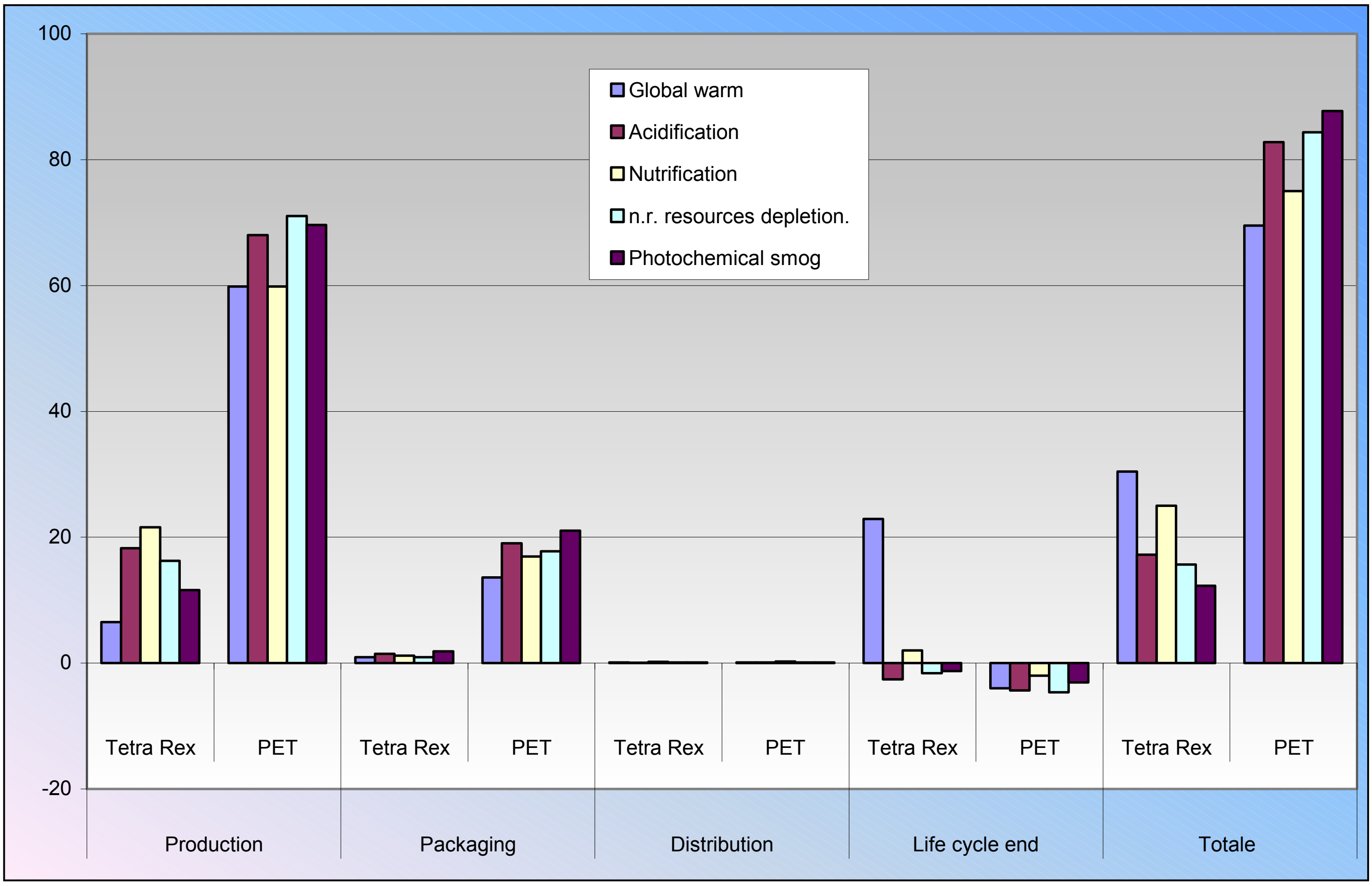

Figure 4: relative contributions of Tetra Rex and PET to life cycle category indicators

4.2 Tetra Brik Aseptic – HDPE

As regards the comparison between the energy and environment characteristics of HDPE bottles and Tetra Brik Aseptic containers, the results showed:

- the HDPE bottle's life cycle was associated with a total energy need that 3 times higher than that of the Tetra Brik Aseptic container;
- the life cycle of the HDPE bottle was associated with a need for water 4.3 times greater than that of the Tetra Brik Aseptic container;

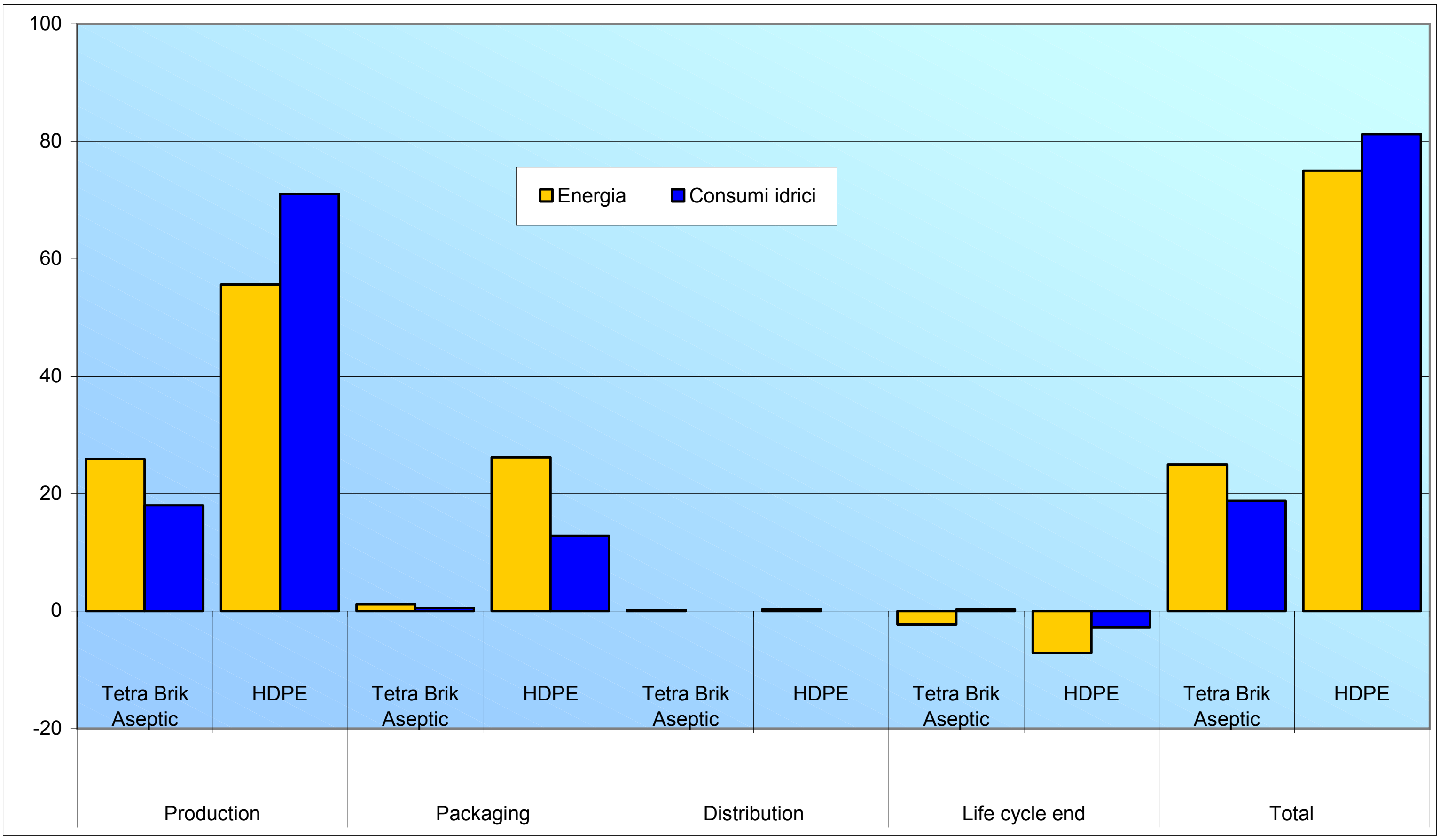

Figure 5: the relative contributions of the Tetra Brik Aseptic container and the HDPE bottle to water and energy consumption in their life cycles.

- the potential global warming effect indicator measured the potential global warming effect associated with the life cycle of the HDPE bottle to be 1.8 times higher than that of the Tetra Brik Aseptic;
- the acidification indicator showed the HDPE bottle to have a level 3.2 times that of the Tetra Brik Aseptic;

- the indicator measuring the nutrification potential associated with the bottle's life cycle showed the HDPE bottle had a 2.9 times greater impact than that of Tetra Brik Aseptic;
- the indicator measuring photochemical oxidation creation associated with the life cycle of the HDPE bottle showed its effect to be 2.7 times greater than that of the Tetra Brik Aseptic.
- The indicator measuring potential non-renewable resources depletion associated with the life cycle of the HDPE bottle showed this indicator to be 4.2 time higher than was the case for the Tetra Brik Aseptic;

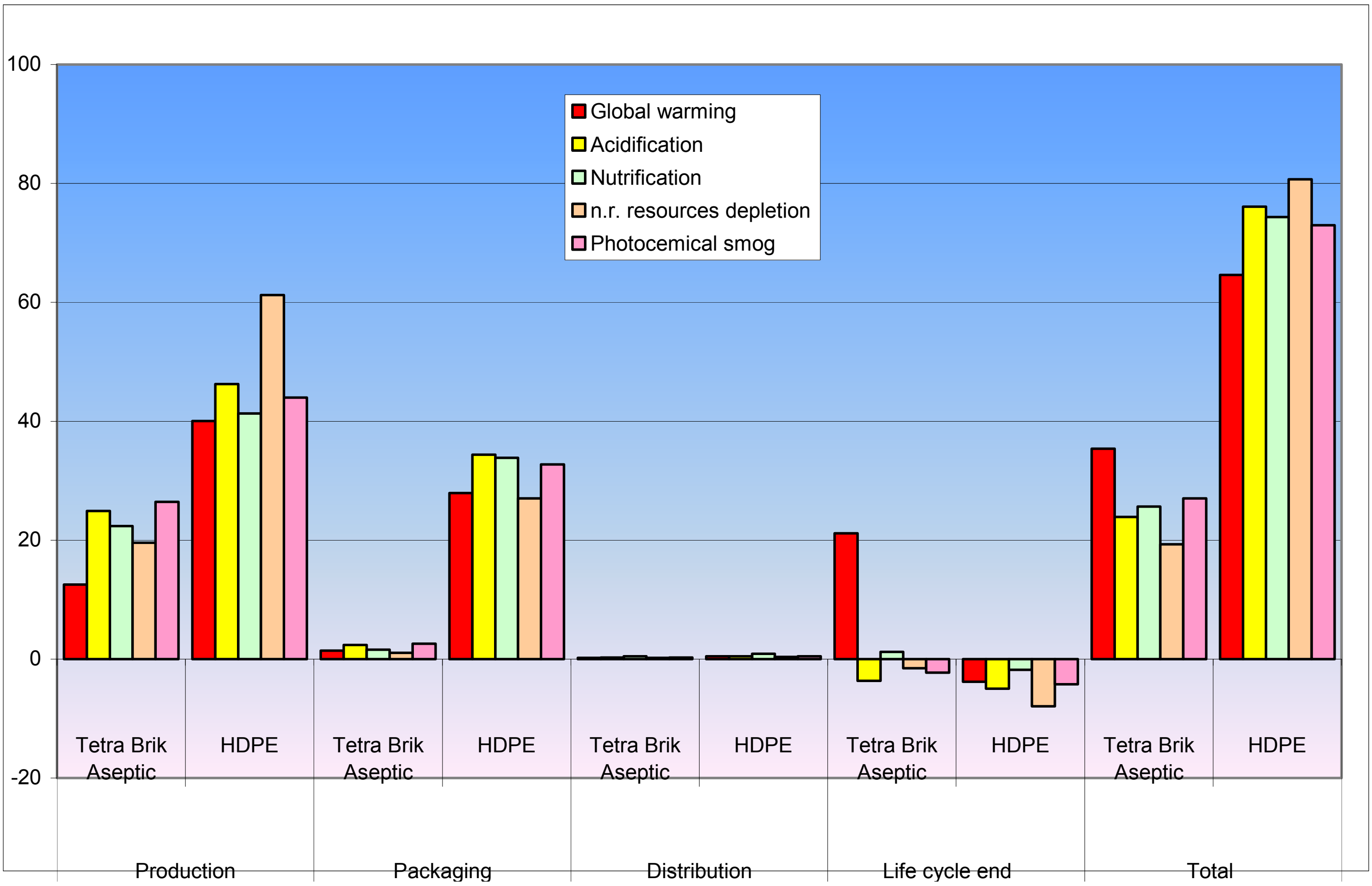

Figure 6: relative contributions of Tetra Brik Aseptic and HDPE to the category indicators in their life cycles.

4.3 Conclusions

- The Tetra Rex and Tetra Brik Aseptic containers have a lower impact potential than the PET and HDPE bottles in all the categories analysed. On average the Tetra Rex energy consumption is 3 times lower and their potential impact 4 times lower than PET bottles. The only environmental aspect for which Tetra Rex was shown to be at a disadvantage with respect to PET is in the area of water consumption.

On average the Tetra Brik's energy consumption and environmental impact potential is 3 times lower than that of the HDPE bottle.

- In all the life cycles examined, the Production stage was that which contributed most to the total category indicators selected for environmental impact (in the case of PET and HDPE there was also a contribution in the packaging stage).

- In the product's end-of-life-cycle stage there is no option between energy recovery, landfills and recycling that can be said to be valid in absolute terms with respect to all the environmental impact potentials selected, even if the benefits resulting from incineration with an energy recovery component appear to more significant, for many of the impact potentials, than those from actual recycling.

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