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Organizational Life Cycle Assessment: the introduction of the production allocation burden

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Abstract

In this study, Organizational Life Cycle Assessment (OLCA) was applied to a multisite beverage company along with a product LCA to one of its representative beverage product. Results proved that, given a certain production mix and volume, different allocations of production of the specific beverage product among different sites could improve the product environmental performances but worsen the overall organizational environmental performances. Therefore, it is important to use both LCA and OLCA results to effectively plan environmental performance improvement of a company and that production allocation strategies should be considered to avoid environmental burden shifting.

Keywords: LCA; beverage; production allocation; burden shifting; packaging; climate change; water scarcity; fossil depletion

1. Introduction

With the adoption of the 17 Sustainable Development Goals (SDG) in September 2015, the United Nations reaffirmed the need to take urgent actions for the protection of the environment and natural resources. The main reason for this attention is that issues like climate change, water scarcity and resource depletion, are affecting lives and disrupting national economies worldwide therefore limiting the opportunity for a global sustainable development [1].

In this context, a growing number of organizations recognized the need to adopt tools and methods to make appropriate decisions towards the reduction of environmental impacts of their products and activities [2]. To support this decisional process, the Life Cycle Assessment (LCA) methodology has been developed to quantitatively assess the environmental impacts of goods and processes from “cradle to grave” [3]. LCA has been widely used in a great variety of industrial sectors and proved to be effective in avoiding environmental burden shift and guiding the development of products with reduced environmental impacts [4].

Nomenclature

OLCA	Organizational Life Cycle Assessment
LCA	Life Cycle Assessment
SDG	Sustainable Development Goals
PET	Poly Ethylene Terephthalate
ISO	International Organization for Standardization
TS	Technical Specification
FU	Functional Unit
RU	Reporting Unit

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Its potential benefits have been recognized also at institutional level. The European Union, for example, adopted LCA as basis for the development of regulations to support the marketing of greener products that ranges from the food [5] to the electronic sector [6].

Recent scientific developments demonstrated that the benefits of LCA can be extended also to the environmental assessment of organizations, considering their activities and their value chain [4]. The interest for this application increased over time so that the International Organization for Standardization (ISO) has published in 2014 a technical specification with requirements for the application of Organizational LCA (OLCA), namely ISO/TS 14072 [7]. The European Commission [8] also launched an initiative called organization environmental footprint (OEF) where a method to address environmental impacts of organizations is presented. Due to the recent introduction of this methodology, only a limited number of studies reports on OLCA applications and related challenges [9,10,11,12]. Recently the United Nations Environmental Programme (UNEP) has published a report on 12 case studies concluding that OLCA is a valuable tool that can reveal environmental hotspots where the organization should focus energies and intervention [13]. However, further scientific work is needed to guide its application and verify its validity in different contexts and applications [14,15]. One of the challenges for future developments set by the scientific community, goes in the direction to further explore its potential benefits and synergies with traditional product LCAs [13,15]. The present research aims to contribute filling this gap by applying OLCA and LCA to a multi-site company located in Italy and Poland, and one of its representative product, respectively. It has to be noted that the company under study had already made changes in production according to product LCA acting on the allocation of production aiming the two sites. The objective of the research was to verify whether the standalone application of LCA to reduce the environmental impacts of a single product can also drive the overall performance improvement of the manufacturing company or whether it is necessary to use the results of LCA and OLCA in a joint manner. Considering the specific case study, another objective of the research is to verify if the production allocation can be an environmental burden. With production allocation, in this paper, we refer to the decisions related to the way that the production mix is distributed among different production sites.

2. Material and Methods

2.1. LCA and OLCA methodologies

LCA and OLCA methodologies are based on the same principles and life cycle thinking framework. The main difference is the object of analysis that is respectively, a product or the activities associated with the organization as a whole or portion thereof [16,17].

The two methodologies have the same structure consisting of 4 main phases: goal and scope definition, inventory analysis, impact assessment and interpretation (Fig.1).

The first phase consists of the definition of the objective of the study, the unit of analysis and the system boundaries and is the one that presents the main differences between the two methods. In the case of LCA, the product, is represented by a functional unit (FU) and a reference flow, meanwhile in OLCA, the organization, is represented by its reporting unit (RU), defined as the quantified performance expression of the organization under study to be used as a reference. A second difference is that in OLCA a consolidation approach (i.e. financial control, operational control, equity share) [7] is introduced to support the aggregation of results, which is necessary when complex organizational structures are concerned (e.g. multinational companies). Another difference is related to system boundaries which address one-perspective in product LCA, where only the life cycle of products is considered, and two-perspectives in OLCA, whereas the second one is represented by the structure of the organization [7].

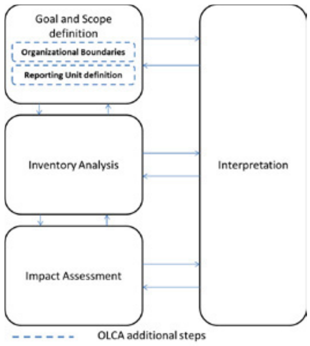

Fig. 1. OLCA and LCA study structure

The second phase consists in the collection of all the environmental input and output that are related respectively to the different process unit, in the case of LCA, and activities, in the case of OLCA. The third and the forth phases are the same for the two methods and respectively consists of the quantification of the potential environmental impacts, and the interpretation and analysis of results to draw consistent conclusions and remarks. This last step can be generally used to support decisions for the reduction of the environmental impacts of the entity under study [4].

2.2. Research Structure

To conduct the research, a bottled-water company that owns two different production sites was considered: one site is located in the north–east of Italy and the other one in Poland. This company was chosen for several reasons; first of all, it has experience in the application of LCA to several products and proved interest in applying OLCA to verify its overall environmental performances over time. Secondly, the organization started a program for the reduction of the environmental impacts of one of its products and it had already applied made changes in production according to product LCA results. Therefore, the necessary data at product and organizational level over a two-year period (2015-2016) were provided to verify the improvements achieved. For confidentiality reasons, all references to the company that delivered the data are not reported. When specified, particularly at the inventory level, sensitive data are qualitatively described but not quantitatively reported.

To fulfill the research-objectives the activities were structured as follows:

- Step 1, *product LCA for the base year*: application of LCA to a representative product of the organization under study with the objective to identify its environmental hotspots and identify strategies to reduce its environmental impacts for the base year 2015;
- Step 2, *product LCA performance tracking*: application of LCA to the same representative product for a second year (2016) in order to monitor its environmental performances;
- Step 3, *OLCA for the base year:* application of LCA to the two sites of the organization under study to quantify their environmental impacts for the base year 2015;
- Step 4, *OLCA performance tracking*: application of OLCA to the overall organization and its sites for the second year with the objective to monitor the overall environmental performance and verify the effects of the decisions based on LCA results at product level with specific reference to the allocation of production among the two sites.

Results will be reported and discussed (in sections 3 and 4) following the steps presented above.

2.3. Goal and scope definition

The goals of the product LCA study were: (i) to identify the environmental hotspot of a 2 l Poly Ethylene Terephthalate (PET) bottled still water produced in the Polish site and distributed in Europe in order to identify strategies for the reduction of its environmental impacts and (ii) to monitor its performances over 2015 and 2016. The functional unit is "to provide 2 l of still water from a 2 l PET container ready to be drunk at the mouth contributing to hydration". This product was chosen because it saturates 50% of the production capacity of the site located in Poland and therefore is central to the company improvement strategies.

The goal of the OLCA was to monitor the overall environmental performances of the company under study and its sites over the period 2015-2016 to verify if the decision taken at product level with specific reference to the allocation of production, benefit also the overall organizational environmental performances. The company fully owns the operations and activities located in the sites under study; the consolidation method of the financial control was thus chosen to determine the organizational boundaries, which include all of the operations and activities of the two sites. The reporting unit is defined as the overall volume of water withdrawn by the company and bottled in PET containers detailed at site level in the years 2015 and 2016. Information on the product portfolio, that did not change over the period under study, are reported in table 1. Over the same period the production capacity resulted to be fully saturated for both of the sites (circa 93 million l in Poland, circa 125 million l in Italy). The base year for the performance tracking is 2015. The volume withdrawn and bottled for single product format remained constant over the same period.

The system boundaries (fig. 2) were defined consistently in the LCA and OLCA studies and included: the extraction, transformation and transport of raw and ancillary material from different suppliers, the processes that directly take place in the company, the distribution of finished products, the use stage and the end of life operations. Activities such as administration, employee commuting were excluded in this study because considered to be not significant if compared to other processes.

Table 1. Product portfolio of the company under study.

	Italy and Poland
	Format (l)
PET bottled water	0,5
	1
	1,5
	2

The same impact categories were considered in the LCA and OLCA study, i.e. the most relevant for the water bottle sector in line with the specific European Product Environmental Footprint Category Rules (PEFCR) [18]: climate change [19], water availability [20] and fossil depletion [21].

2.4. Inventory

In the LCA and OLCA the following primary data were collected within the two sites: water withdrawals, PET consumption, secondary and tertiary packaging materials consumption, chemical compounds consumption for the sanitization, cleaning of the installations and for the wastewater treatment, waste production and production allocation mix of the two sites. Energy inputs are related to electricity and methane gas consumption considering the local national energy mix (Italy and Poland). Where possible, upstream processes data were collected directly from the suppliers, otherwise, secondary data from the Ecoinvent database (version 3.2) were adapted (e.g. considering energy mix of the region of the suppliers) and used. Downstream processes were modelled considering: primary data on distribution, use stage requirements from the relevant PEFCR [18], national statistics on the end of life processes [22] and using secondary data from Ecoinvent. End of life was modelled adopting a cut-off approach.

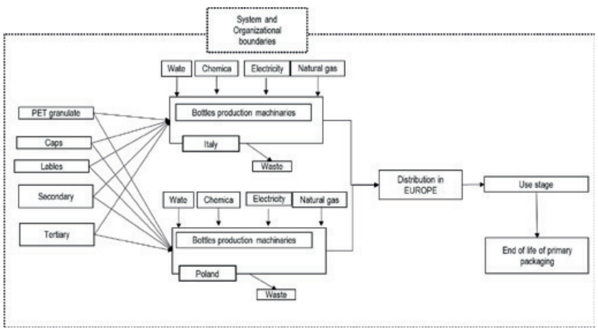

Fig. 2. LCA and OLCA System Boundaries

At organizational level, the data collection was performed adopting a hybrid approach combining bottom-up (for product allocation) and top-down (for environmental data) procedures according to ISO/TS 14072 [7].

3. Results

3.1. Results of the product LCA for the base year and product LCA performance tracking

Table 2 and Fig. 3 reports on the results of the impact assessment and contribution analysis for the product under study in the base year. Results allowed the identification of two main hotspots, i.e. raw material production with specific reference to PET production (with a contribution to overall impacts that ranges from 30% to 40% in each impact category) and production processes (with a contribution to overall impacts that ranges from 20% to 50% in each impact category).

Considering that the results of previous product LCA studies proved that the Italian site is more energy efficient, has a shorter supply chain and a slightly better local water availability profile, the company decided to change the production allocation of 50 million l of the product under study from Poland to Italy for the year 2016. As a consequence, considering the market demand, the full saturation of the production capacity, and production line constraints (e.g. limited capacity to work on a different formats), it was decided to shift the production of 24 million l of 0,5 l PET, 12.000 million of 1 l and 4.000 million of 1,5 l PET still water bottles from Italy to Poland.

Table 2. Results of product LCA per functional unit (FU) in the period considered (2015-2016).

Impact Category	Unit	2015	2016
Climate change	kg CO2 eq/FU	3,68 E-01	3,07 E-01
Water availability	m3 eq/FU	3,92 E-03	3,85 E-03
Fossil depletion	kg oil eq/FU	1,19 E-01	9,99 E-02

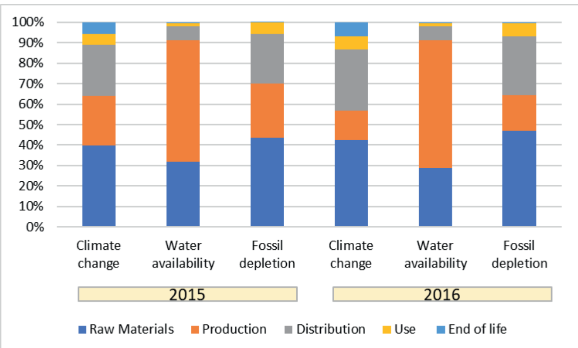

Fig. 3. Contribution of life cycle stages to overall product impacts in the period considered (2015-2016)

Table 2 reports on the results of the performance tracking for the product under study over the two-years period at site and company level. All of the performances at product levels resulted to be improved, confirming the results of previous product LCA studies. In particular, the less fossil based energy mix in Italy and the shorter supply chain related to the plastic raw material acquisition, allowed a significant improvement in the climate change and fossil depletion categories (i.e. -16,5%, - 16,3%, respectively). With reference to water availability the potential impact improvement resulted to be more limited (-1,9%).

The contribution of the production process changed significantly reflecting the better performances of the Italian site with reference to the energy efficient and energy mix (climate change and fossil fuel categories).

3.2. Results of OLCA for the base year and OLCA performance tracking

Table 3 reports on the OLCA results and its performance tracking over the two-year period for the selected impact categories. Results are reported at site and company level and expressed per reporting unit as the entire production of bottled water for the specific year under study.

Focusing on the Polish production site, the overall performances resulted to worsen in all of the impact categories (+22% climate change, +17% water scarcity +31% fossil depletion). The analysis of the products that were reallocated into the Polish sites allowed to justify such increase. It emerged that, if compared to the 2 l PET bottled still water, the consumption of PET per l increases when smaller formats are produced (Table 4). As a consequence, the energy and water use of the production stage resulted to be increased in Poland where the energy mix and the water scarcity are worsening if compared to Italy as well as the impacts of the supply chain.

On the other hand, focusing on the Italian production site, the overall performances improved in all of the impact categories (-15% climate change, -11% water scarcity -20% fossil depletion). Such improvement is justified by the fact that a significant amount of the more efficient 2l PET water bottle was allocated to this production site.

Table 3. OLCA results per reporting unit (RU)

Impact category	Unit	Poland		Italy		Company	
		2015	2016	2015	2016	2015	2016
Climate change	kg CO2 eq/RU	1,85 E+07	2,25 E+07	2,32 E+07	1,97 E+07	4,17 E+07	4,22 E+07
Water availability	m3 eq/RU	1,98 E+05	2,32 E+05	2,71 E+05	2,41 E+05	4,69 E+05	4,73 E+05
Fossil depletion	kg oil eq/RU	6,29 E+06	8,27 E+06	8,65 E+06	6,94 E+06	1,49 E+07	1,52 E+07

Table 4. PET consumption per l of bottled water

Format	g of PET per bottle	g of PET per litre
0,5	12,79	25,59
1	20,00	20,00
1,5	28,00	18,67
2	31,00	15,50

Focusing on the company comprehensive environmental performances, an overall increase of the environmental impacts was registered over the two-year monitoring (+1,2% for climate change, +0,9 % for water scarcity, +1,8% for fossil depletion).

4. Discussion

The standalone application of product LCA suggested the company to allocate the production of the 2l PET bottled still water to the Italian production site due its better environmental performances with reference to energy use and water availability. However, such choice was made without considering the overall organizational performances or the consequences on the impacts of other products realized by the company.

The performance tracking performed at product level over the two-years confirmed an improvement of the performances of the product under study suggesting the validity of the choice to allocate the production of the 2 l bottled water to Italy.

Despite this solution allowed to improve the specific product performances, the performance tracking conducted through the use of OLCA, revealed the worsening of the overall company environmental performances. This situation depended on the production allocation between the two sites that shifted products with higher resource use (0,5 l, 1l, 1,5l) to Poland. In this case study, the production allocation resulted to be an environmental burden. Therefore, to verify if the improvement of the environmental performances of one product can also drive the improvement of the environmental performances of the company, it is necessary to investigate the consequences on the performances of the other products and activities of the organizations through OLCA.

To confirm the influence of production allocation and production constraints on the environmental impacts of the company, the overall environmental performances of the organization were further quantified by scenario analysis. An alternative scenario was defined, by simulating an increase of the production capacity in Italy in 2016 equal to the volume of production of the 2 l bottled in Poland in 2015, thus avoiding any shifts in the production allocation of the different formats. Results of the scenario analysis are reported in table 5 and expressed per reporting unit over the two-year period. In this simulation an improvement in the single product resulted in an improvement of the overall company performances confirming the influence of product allocation within production constraints. The influence that these aspects have on the environmental performances of products and organizations should therefore be investigated before taking decisions on performance improvement strategies.

It has to be noted that in this specific case study the production mix and the reporting unit of the company did not change significantly and did not influence the environmental impacts. The results of the study should be further investigated when also change in the production mix or in the reporting unit occurs to answer market needs and constraints (e.g. as in the case of increasing for the demand of a product at the expense of another).

Table 5. Simulation of OLCA results per RU without production constraints

		Poland		Italy		Company	
Impact category	Unit	2015	2016	2015	2016	2015	2016
Climate change	kg CO2 eq/RU	1,85E +07	4,59E +06	2,32E +07	3,11E +07	4,17E +07	3,57E +07
Water availability	m3 eq/RU	1,99E +05	5,04E +04	2,70E +05	3,70E +05	4,69E +05	4,20E +05
Fossil depletion	kg oil eq/RU	6,30E +06	1,78E +06	8,65E +06	1,12E +07	1,49E +07	1,30E +07

5. Conclusion

LCA and OLCA are recognized to be important tools for the improvement of environmental performances of products and organizations. Despite this, a limited number of applications of the two tools to the same company exists [13]. The objective of this study was to verify if LCA results used to guide product performance improvement can drive also the organizational environmental performances. To provide an answer, LCA and OLCA were applied respectively to a product and the organization that realize it.

Results of this combined application proved that an improvement in the environmental performances of a product can have a negative effect on the overall environmental performances of the company. The reasons for this, were identified in the decisions taken for the allocation of production under specific production constraints that favored the production of more energy demand products in a production site with lower energy efficiency.

It can be concluded that an organization, when planning actions to reduce the environmental impacts of one of its products, should also investigate the consequences of this choice at organizational level. To verify this, LCA and OLCA results can be used together and can help to drive performance improvement both at product and organizational level.

From this specific case study, it also emerged that choices on production allocation can result in an environmental burden shift (from the product to other products of the organization) that should be thoroughly considered when planning the improvement of a single product in a life cycle perspective by verifying, for example, the energy efficiency of the production sites.

Considering the outcomes of this study, future research on the synergies among LCA and OLCA can be outlined. First, it would be interesting to verify if “the production allocation burden” emerges from the application of LCA and OLCA in other sector and more complex organizational structure. Second, investigate how external constraints and factors such as market demand can influence the company environmental impacts (e.g. a sensitivity analysis to investigate the effects of the market trend to have sell bottles). Third, another interesting development could be the optimization of production allocation under internal and market constraints to minimize the overall environmental impacts of the organization adopting Multi Criteria Decision Making analysis tools [23]. Moreover, considering the latest development of LCA and OLCA [2, 24], it would be interesting to investigate the results of this study considering also economic and social aspects towards a more comprehensive life cycle sustainability assessment.

Interesting development could be to introduce a quantitative risk analysis. This analysis takes account of specific local factors in assessing local risks to specific groups of people due to incidents [25, 26]. While LCA analysis considers many types of impacts on human health and the environment due to thousands of substances may not be able to reflect consequences at local level. Therefore, it would be interesting to evaluate the feasibility and effectiveness of a joint approach of QRA and LCA.

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