LIFE CYCLE ASSESSMENT OF GREEN PRACTICES FOR SUSTAINABLE TOURISM: GLASS VS. PLASTIC ONBOARD A CRUISE SHIP

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ABSTRACT

The aim of this paper is to analyze different scenarios for primary packaging management onboard a cruise ship through Life Cycle Assessment (LCA). In particular, the potential environmental impacts due to strategic choices for packaging materials related to water distribution have been evaluated along their life cycle, i.e. from extraction of raw materials to final disposal and/or recycling. The substitution of the total amount of water bottles distributed in the cruise restaurants, shifting from glass to plastic, has been evaluated, in comparison with the reference scenario. Moreover, this study evaluated the possibility of introducing a process onboard in order to treat the polyethylene terephthalate (PET) waste stream deriving from water bottles with a recycling perspective. This measure has been configured as an enhancement of the management scenario where the substitution of water bottles is set up.

The results of this study allow concluding that strategic choices for packaging materials and waste materials management are able to yield evident benefits on the environmental balance. The partial substitution of glass bottles with plastic bottles has been demonstrated to yield not only benefits from waste prevention and minimization point of view, but also in terms of consumption of material and energy resources and potential environmental impacts along the bottles life cycle. In particular, the analysis of Global Warming Potential (GWP) showed that a shift in material supply represents a waste minimization measure that is able to halve the impact on such a crucial indicator for cleaner production and environmental sustainability. Besides, the introduction of a process technology onboard that is able to regranulate PET waste material has been demonstrated to be able to enhance (or not worsen, depending on the impact category) the environmental performance of the system, with the additional benefit of yielding an output flow from the cruise ship that is not a waste but a product, able to enter as a raw material in new life cycles by a recycling perspective.

Keywords: Life Cycle Assessment, Packaging, Bottles, Cruise Ship, Sustainable Tourism

1. Introduction

The increasing pressure about environmental issues related to tourism sector is nowadays pushing cruise operators towards the investigation of environmentally friendly measures within their activities. In this context, cruise managers should evaluate the inflows and outflows of packaging materials within their purchase activities, in order to reduce waste generation to a minimum, with attention on the entire supply chain and evaluation of alternative methods of waste disposal and waste management systems onboard ships, with investments in new technologies. Although cruise ships represent less than 1% of the global merchant fleet, they are responsible for 25% of all waste generated by merchant vessels, with a figure of 3.5 kg/passenger/day per cruise quoted by the International Maritime Organization (Herz, 2002). In fact packaging materials contribute with a high share to waste generation; therefore they need to be object of an accurate management planning by prioritizing waste minimization (Johnson, 2002). Packaging waste can be disposed in a variety of ways, by incineration onboard, dumping offshore or delivery onshore to structures for disposal or recovery. Management choices, besides the requirements of the international convention MARPOL 73/78 (IMO, 1973), depend

on the itinerary of the vessel, the state of the facilities on board, the owner's environmental commitment and the possibilities offered by the landing ports in terms of receptive structures (UNEP, 2002). The waste hierarchy worked well in the past, particularly through increased levels of re-use, recovery and recycling, but there is a growing need to take into account the environmental, social and economic impacts of sourcing strategies based on the hierarchy, 'prevention is better than the cure' principle may represent the key step towards sustainability (Gertsakis and Lewis, 2003).

Life Cycle Thinking (LCT) is a core concept in Sustainable Consumption and Production (SCP) for business and policy, aimed to embrace the whole supply chain when measuring the environmental sustainability of management choices. The environmental pillar of LCT is supported by Life Cycle Assessment (LCA), an internationally standardized tool (ISO, 2006a; ISO, 2006b) for the integrated environmental assessment of products, i.e. goods and services. The results from such assessment studies can provide useful input for commercial procurement decisions, product design and stewardship, and waste management (Cleary, 2013). A reduction in the environmental burden of the entire life cycle of the product-package system can be achieved through the design of an optimal relationship between the type and weight of the packaging material (Albrecht *et al*., 2013; Kang *et al*., 2013). A recent comparative LCA for milk packaging in fact demonstrated that the environmental impacts from raw materials extraction represented the highest share of the total environmental impacts in the packaging life cycle, except for the disposal stage (Xie *et al*., 2011). Recycling strategies for plastic-based packaging can significantly reduce the quantity of waste to landfill and the overall environmental burden, consequently (Ross and Evans, 2003; Nessi *et al*., 2012).

The aim of this paper is to evaluate the environmental sustainability of a practice onboard a cruise ship, entailing the substitution of the total amount of water bottles distributed in the cruise restaurants, i.e. shifting from glass to plastic. For this purpose, the management scenario of primary packaging for water distribution on a cruise ship is here assessed through the analysis of the life cycle of the bottles served onboard. The implementation of the green sourcing practice has been thus evaluated in comparison with the reference scenario for a case study ship. Moreover, this research evaluated the possibility of introducing a process onboard in order to treat the PET waste stream deriving from water bottles with a recycling perspective. This measure has been configured as an enhancement of the management scenario where the substitution of water bottles is set up.

2. Methodology

This comparative study has been configured as a difference analysis, i.e. a type of LCA focusing in the differences among three alternative scenarios, thus ignoring those unit processes that are qualitatively and quantitatively identical. The three different scenarios analyzed for a case-study ship are built. SCENARIO A is the baseline situation before the introduction of the substitution measure onboard the ship, where the management of water distribution in the restaurants entails an equal use of glass and plastic bottles. In SCENARIO B all the glass water bottles distributed in the restaurants have been replaced with plastic bottles. In SCENARIO C, starting from supplying figures of SCENARIO B, a technology able to regranulate the PET material (polyethylene terephthalate) is introduced on board.

In order to provide two alternative possibilities for the evaluation of the results, two alternative functional units have been defined in this study, i.e. one day of cruise (day) and one passenger per day of cruise (p-day). In life cycle inventory procedures, the amounts of bottles in input to the cruise have been collected on one month basis (31 days), for the different scenarios. The considered scenarios involve the product system of a cruise with different packaging management strategies, thus – from a difference analysis perspective – the system boundaries describe the processes that distinguish the management options only.

Therefore in this study the product system of distribution of water through bottles has been analyzed. The end-of-life of the packaging materials has been differently modeled for, respectively, glass and plastics. As concerns glass material, in all the scenarios considered the

total amount of waste is stored onboard and discharged in an equipped port, destined to recycling. In Scenario A and Scenario B the shares between landfill, incineration and recycle destinations have been derived from the calendar of the unloading for the case study during the period of reference, on the basis of the national scenarios for waste in the respective countries. Scenario C instead entails: absence of plastic incineration onboard, regranulation of the total amount of PET material, and ashore disposal for caps and labels. In the assessment of waste treatment and output flows that are reused or recycled, the “Polluter-Pays (PP) allocation method” has been followed.

In life cycle impact assessment procedures, SimaPro software has been used, and the potential environmental impacts associated with the various types of use of resources and pollutant emissions have been reported into the following categories: Global Warming Potential (GWP), Photochemical Ozone Creation Potential (POCP), Acidification Potential (AP), Eutrophication Potential (EP), use of non-renewable/renewable energy and material resources.

3. Results and discussion

The production of plastic bottles is responsible of a lower environmental load with respect to glass bottles from a life cycle perspective. In fact the shift from glass material to plastic material yields a remarkable reduction of the potential environmental impacts, except from POCP, with respect to the reference case. In particular, the reductions range from 95% (AP) to 47% (EP). As concerns GWP, the reduction is estimated to be 52%, equal to a reduction of 120 g CO_2 eq per passenger-day, or 342 kg CO_2 eq per day.

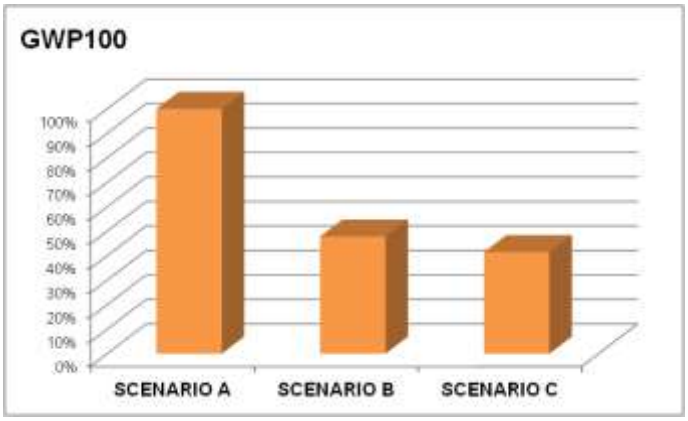

Figure 1: GWP100 for the analyzed scenarios.

In Scenario C, PET bottles – without caps and labels - undergo a washing process, then a drying process and finally the grinding of flakes in the thermal system of regranulation, where the material recover its original properties and characteristics, in order to be ready for a new utilization in new manufacturing processes. The chance of using existing drying technologies on board for the drying phase has been here considered. The operating conditions for the regranulation process are planned in order to maximize the input loads and therefore minimize the number of starts. This strategy choice results to be feasible onboard since plastic waste do not create any degradation problems during their storage. According to PP methodological premises, the assessment of this additional management measure includes the environmental burdens of PET regranulation process, calculated on the basis of the electricity consumption, generated on a diesel-electric propulsion ship, with six diesel engines (12,600 kW) and six generators (14,000 kVA). The environmental profile of Scenario C comprises a share of impacts deriving from PET regranulation process, that increases its total environmental load. Nevertheless, the environmental performance of this management option results to be enhanced (or not worsened, depending on the category), with the additional benefit of yielding an output flow from the cruise ship that is not a waste but a product able to be commercialized as raw material for new manufacturing processes. The additional energy consumption is

counterbalanced by the disappearance of the onboard incineration for plastics waste, so that the end-of-life stage of the life cycle results to be enhanced in terms of potential environmental impacts and consumption of resources.

In fact the impacts of Scenario C result to be lower or nearly equal to Scenario B for every impact category considered. In terms of GWP, Scenario C entails a reduction of 13% with respect to Scenario B and of 58% with respect to Scenario A. The regranulation process is in fact responsible for only 1% of the total impact, while the offshore treatment of labels and caps is associable to a 5% share. When integrating a measure of waste minimization and a measure of waste recycling, the sum of the two contributions to end-of-life stage results to be well below the case of minimization only, that shows a more than three times higher quota on the total.

4. Conclusions

Through the application of LCA methodology with a difference analysis approach, the effects related to the implementation of green sourcing practices onboard a cruise ship have been evaluated. The partial substitution of glass bottles with plastic bottles has been demonstrated to yield not only benefits from waste prevention and minimization point of view, but also in terms of consumption of material and energy resources and potential environmental impacts along the bottles life cycle. In particular the analysis of GWP showed that a shift in material supply represents a waste minimization measure that is able to halve the impact on such a crucial indicator for environmental sustainability.

Besides, the introduction of a process technology that is able to regranulate PET waste material onboard has been demonstrated to be able to enhance (or not worsen, depending on the impact category) the environmental performance of the system, with the additional benefit of yielding an output flow from the cruise ship that is not a waste but a product able to enter as raw material in new life cycles with a recycling perspective. The analysis of GWP for this scenario has revealed an additional reduction of the impact with respect to the scenario where the material substitution is adopted.

In conclusion, a comparison of scenarios by a life cycle perspective has been proved to be a useful tool for investigating the environmental sustainability of strategic choices for packaging materials and waste materials management in line with the current guidelines promoted by EU regulation. In particular this study has allowed to quantify the benefits in terms of resources consumption and potential environmental impacts for assessing innovative practices in the cruise sector, a branch of the tourist industry where nowadays waste management shows relevant leeway for improvement.

ACKNOWLEDGEMENTS

This work has been co-funded by the European Commission LIFE+ Programme through the project SUSTAINABLE CRUISE. The content of this work reflects exclusively the authors' view, the European Commission is not liable for any use of the information contained here. The authors wish to here thank the partners of the project.

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