A Carbon Footprint Study and a Life Cycle Assessment of an identical Refrigerated Display Cabinet: comparative analysis of the respective ratios of embodied and operational impacts.

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Environmental footprinting is widely used in the academic, industrial and political circles alike. But it is in the product centric category of environmental footprinting techniques that Product Carbon Footprint (PCF) and Life Cycle Assessment (LCA) emerged as pivotal instruments in response to the climate change and sustainability imperatives. In addition, these techniques have been the object of several international assessment guidelines and according to Carbonostics (2011) and Fishwick (2012) they can be evaluated in terms of international acceptance, time/cost involvement and comparability. In contrast, little literature discusses the dissimilarities inherent in the use of different environmental measurements for an identical product. That is the reason why this paper presents a comparison between the results obtained from a Product Carbon Footprint (PCF) against that of Life Cycle Assessment (LCA) for an identical Refrigerated Display Cabinets (RDC). Results of the study show that the proportions (embodied/operational) derived from a PCF and that an LCA for an identical RDC are dissimilar; and the implications of those results warrant the need for further research but strengthens the case for LCA over PCF because the former offers a more holistic environmental assessment. Moreover, initial results show that the ratio of embodied and operational impact are 5% and 95% while that of the LCA are 20% and 80% respectively. This paper will present in turn an overview of the RDC studied, the set of assumptions made, and breakdowns of the results for PCF and LCA as well as avenues for further research.

1 Introduction

As stated by NASA (2014), ninety-seven percent of climate scientists agree that climate-warming trends over the past century are very likely due to human activities. Therefore, in response to the threat posed by the global warming challenge, environmental footprinting emerged as the major quantitative technique used in academia, policy making or industry alike. As explained by Finnveden (2005) such footprinting can be used to assess countries, organisations or products. But it is in the latter category that the main tools are PCF and LCA. Despite the fact that both tools are the objects of several international assessment standards there is little literature discussing the dissimilarities inherent in the use of different environmental measurements for an identical product. That is the reason why this paper presents a comparison between the results obtained from a PCF against that of an LCA for an identical Refrigerated Display Cabinet (RDC). To this end, the first section will present the product to be assessed, the second one, the methods and assumptions, whilst the third section will present the results and the fourth will offer a discussion which will precede the conclusion.

2 The assessed Refrigerated Display Cabinet

Both environmental assessments are carried out on an identical RDC. These products are widely used in the retail industry (800,000 in the UK) where they cool and display foodstuff. This study concentrates on the open front plug-in cabinet shown in Figure 1, which is manufactured by the Bond Group in the UK. This model is a Chicago of size 1.8m with a mass of 450 kg. (For detailed bill of materials consult Bibalou *et al.* 2011 or Bibalou *et al.* 2012)

Figure 1 Chicago 1.8m integral multi-deck

3 Methods and assumptions

Table 1 presents a set of selective assumptions used for both assessments. Moreover, a more comprehensive list was published by Bibalou *et al.* (2011) or Bibalou *et al*. (2012) for the PCF. As to the LCA, a more comprehensive list will be published in future publication.

Table 1 Selective assumptions for PCF and LCA of an RDC

	PCF	**LCA**	**Comments**
Materials extraction	Identical		N/A
Manufacturing	Identical		N/A
Use phase and life span	6 years	6 years	This duration was determined by the results of a survey involving the refrigeration managers of the major UK retailers by market size (see upcoming Bibalou, 2013)
Software	CES selector 2014	Simapro 7.3.3 plus Ecoinvent v2.2	N/A
End of Life	Recycling	Recycling	N/A
Functional unit	$\frac{kwh}{\frac{m^2}{day}}$		As per Watkins *et al.* (2006) and Youbi-Idrissi *et al.* (2007)
System boundary	These studies are concerned with the second order which includes all processes during the life but the capital goods are left out (Goedkoop, 2010).		See Figure 4 p.4 for system boundary of the Chicago RDC

3 Results

The exhibits shown below present respectively the results of the PCF and that of the LCA of the Chicago. The results of the PCF shown in Table 2 demonstrate that the use phase accounts for 97.5% of the impact of the RDC. In contrast, Figure 2 presents the result of the LCA and in that case, the use phase accounts for 80% of the weighted results for the same Chicago RDC.

Table 2 Carbon footprint of a recycled Chicago RDCs

Phase	Energy			CO_{2e} (kg)	Proportion (%)
	MJ	KWh	toe		
Materials	13,018	3,616	0.3	797	2.9
Manufacturing	1,470	408	0.04	112	0.4
Transport	1,285	357	0.03	91	0.3
Use	436,194	121,175	10.4	27,180	97.5
End of life	-6,971	-1,937	-0.2	-309	-1
Total	**444,996**	**123,620**	**10.6**	**27,872**	**100**

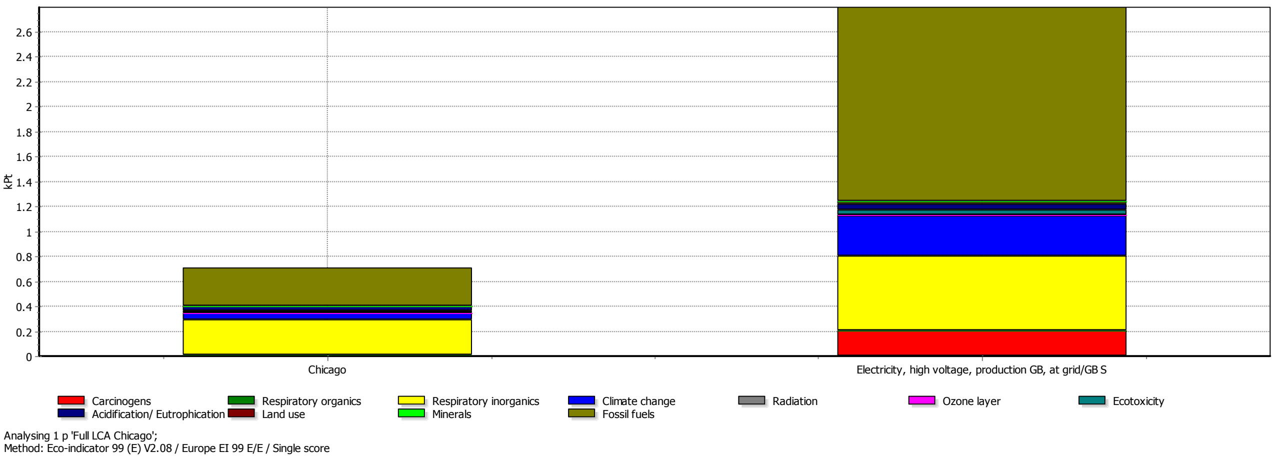

Figure 2 Results of a screening LCA of a Chicago RDC

To highlight the dichotomous nature of the results of the PCF and that of the LCA of an identical RDC, the resulting embodied/use impact proportions are presented in Figure 3.

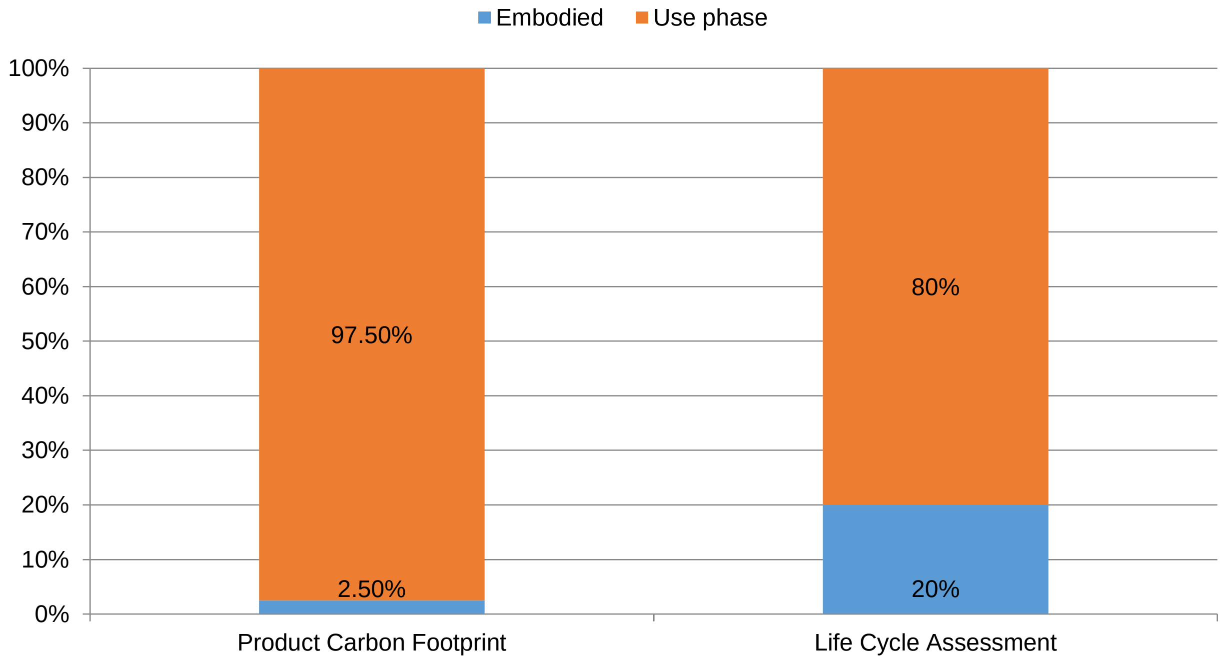

Figure 3 Respective embodied and operational proportions derived from the assessments of an identical RDC using a PCF and that of an LCA for

4 Discussion

The magnitude of the differences resulting from those assessments raises several questions for the PCF and LCA practitioners as well as the recipients of their results, whether they are private companies or policy makers alike. RDCs are energy using products (EuP) and as such their use phase consistently dominates the environmental impacts of the products. However, there exists a discrepancy between an LCA and a PCF, an LCA is by definition a multi-impact assessment method as opposed to PCF. Equally, PCF is a cheaper assessment method than LCA and both of these assertions raise the following interrogations. Do practitioners make an informed trade-off between cost and comprehensiveness of results? If yes, is that documented?

The difference between the proportions derived from those results questions the environmental soundness of the current model of consumption for RDCs. According to CRR (2009) only 12.5% of the RDCs reaching EoL are refurbished or remanufactured. In effect, the results of this study support the proven environmental benefits of refurbishing and remanufacturing of RDCs (Bibalou, 2011; Bibalou, 2012).

On should however note that the PCF and LCA presented herewith are by definition screening studies and as such their preliminary results need to be confirmed through full environmental LCA with a sensitivity analysis. Equally, there is a need to confirm or to infirm the existence of such a pattern for different product through further research. Another question to be addressed is that of the conventional aggregate impacts converted in kPt and whether it constitutes a contravention to the principle of like for like comparison.

5 Conclusions

This paper discussed the results of a PCF and that of an LCA of an identical Chicago RDC. Both sets of results showed that there was a discrepancy between the proportions embodied/use for both environmental assessment methods. As a consequence, this paper highlighted the need for practitioners and end users alike to make and to document their trade-offs when choosing between an LCA and a PCF. Equally, this paper stressed the need for the research community to further investigate the presence of similar patterns in other EuP.

Figure 4 System boundary of the Chicago RDC

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