STRATEGIES TO MAKE FOOTWEAR SUSTAINABLE AND CIRCULAR: A NEW WALK TOWARDS THE EUROPEAN GREEN RULES

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To stay on pace with Paris Agreement goals on climate change, the 1.5°C pathway and Green Deal objectives, the footwear sector must speed up its efforts to reduce greenhouse gas (GHG) emissions to contribute to an absolute reduction of 50% by 2030 (or equivalent science-based targets) and achieve Net Zero by 2050. Footwear needs to move away from a linear pattern of growing consumption of planet resources towards a sustainable and more circular living where we use less resources and reduce emissions and climate change. To do so, the industry, whole value chain and consumers need to commit and take concrete actions. The objective of this article is to inspire footwear companies to measure their products environmental footprint, using the European Product Environmental Footprint methodology, and present the actions with higher potential of increasing sustainability and reduce the aggregate GHG footprint of new products.

Keywords: footwear, product environmental footprint, recycling, circular economy

INTRODUCTION

GHG emissions continue to rise and there is a growing likelihood that temperatures will temporarily exceed the threshold of 1.5°C above pre-industrial levels in the next five years. Rising temperatures are fuelling a variety of social, environmental, and economic impacts, from heatwaves and fires, to flooding. To contribute to limit global warming to 1.5°C is fundamental that footwear businesses measure footwear environmental footprint, define specific actions, and act.

The European Product Environmental Footprint (PEF) methodology/tool supports companies to measure the environmental performance of their products. The PEF tool introduces several improvements compared to other existing Life Cycle Analysis (LCA) methods including, clear identification of the environment impact categories to be considered, data sets to be used, minimum data quality requirements and detailed procedure to estimate the PEF.

Within project LIFE17 ENV/PT/000337 nine partners including AMF, APICCAPS, ATLANTA, CEC, CTCP (coordinator), EVATHINK, ICPI, INESCOP, FICE and PESTOS (https://www.greenshoes4all.eu/), were engaged in experimenting the EU draft PEF method and deploying new recycled materials. This paper presents works done by AMF shoe manufacturer and CTCP R&D centre with the objective of estimating and reducing footwear products environmental footprint.

To complement this works in the frame of national project GreenShoes4.0, CTCP studied and established a set of sustainable actions with high potential to contribute to the goal of reducing the global carbon footprint of footwear products by 50%. These actions will be synthetically presented to inspire companies to plan and give firm steps to reduce the environmental footprint of new products.

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EXPERIMENTAL

Materials

Three shoe models were selected by AMF and CTCP and LCA studies conducted to evaluate the magnitude and significance of potential environmental impacts throughout their life cycle. The work included identifying the most relevant impact categories, life cycle stages and processes. The systems boundaries integrate the entire life cycle (cradle to cradle), including the following: the raw material acquisition and pre-processing, manufacturing, distribution, and end-of-life. Additional, more greener solutions (e.g., incorporating recycled and lighter materials) were studied, and their environmental performance compared. Table 1 presents the models and a general description of main materials and components.

Table 1. Footwear environmental footprint impact categories assessed

Model	Description	
	Original	Sustainable
XFAST 	Upper: Microfiber (PA/PU) Lining: PA/PE Insole: Synthetic fibre/resin/PP Insock: PU/PE/PVP foam Outsole: EVA	Upper: Recycled cotton/PE Lining: Recycled PES/Corn fibres Insole (lighter: PE + Synthetic resins Lighter insock: (PU/PE/PVP foam) Outsole: EVA
TUBELESS 	Upper: Microfiber (PA/PU) Lining: PA/PE Insole: Kevlar Insock: PU/PE/PVP foam Outsole: Rubber	Upper: Recycled cotton/PE Lining: Recycled PES/Corn fibres Insole: Lighter Kevlar Lighter insock: (PU/PE/PVP foam) Outsole: Rubber
REDBRICK 	Upper: Leather Lining: PA/PE Insole: Kevlar Insock: PU/PE Outsole: PU/TPU	Version 1 Upper: Leather Lining: PA/PE Insole: Lighter Kevlar Insock: Lighter (PU/PE/PVP foam) Outsole: PU/TPU Version 2 Upper: Polyamide microfiber Lining: PA/PE Lighter insock: (PU/PE/PVP foam) Lighter Insole: PE + Synthetic resins Outsole: Recycled PU/TPU

Legend: EVA – Ethylene Vinyl Acetate; PA – Polyamide; PE – Polyester; PU – Polyurethane; TPU – Thermoplastic polyurethane; PP – Polypropylene; PVP – Poly(vinyl phosphate)

Methods

A Product Environmental Footprint (PEF) study is a standardised LCA study aiming to ensure that environmental information is comparable and reliable. The PEF calculation gives quantitative information on the impacts of products, taking into consideration the entire value chain (from the extraction to the end life stages). Estimating a PEF involves, namely: defining the goal and scope (e.g., functional unit, reference flow), life cycle inventory (e. g. primary data collection), impact assessment,

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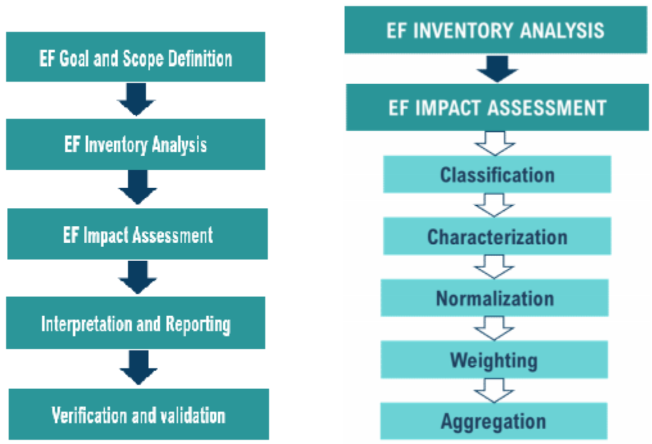
interpretation and reporting, and final verification and validation (Fig. 1a). Measuring the product sustainability/environmental impacts involves (Fig. 1b):

1. Classification: assignment of all input and output flows collected in the inventory to the relevant impact categories.
2. Characterization: process to model environmental mechanisms linking the environmental pressures represented by inventory data to each EF impact category, and to quantify the impact magnitude.
3. Normalization: understand better the relative contribution of the studied system to the reference system for each indicator result, and which impact categories are more critical for the product system under study.
4. Weighting: process of converting normalized results of the different impact categories by using numerical factors based on the expressed relative importance of the impact categories considered.
5. Interpretation: can be used for hotspot analysis to identify the most relevant impact categories, life cycle stages, processes, and elementary flows.



(a) (b)

Figure 1. Steps of EF methods (a) and of the impact assessment phase (b).

In this work specific primary data was collected at AMF company. Since the use phase of footwear is usually insignificant its impact was not considered. Regarding secondary data, Ecoinvent database v3.7 and other data sets were used. The software used to model the data was OpenLCA 1.9. The impact categories were calculated using the EU EF updated method (adapted).

RESULTS AND DISCUSSION

The PEF method assesses 16 impact categories (Table 2), covering, namely, climate change, acid rain, human toxicity, and particulate matter as well as impacts due to the use of water, land, and resources. Table 3 presents an example of the characterised, normalised, and weighted results obtained. Table 4 details the results for 3 of the 7 most relevant impact categories. These 3 categories, "Climate change"; "Fossil resources use"; and "Minerals/metals resources use", represent about 57% of the total impact.

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Table 4 details also the environmental impact associated to the product “Life cycle stage” and “Materials, components and/or processes”, giving indications to make changes to reduce the products PEF/environmental impact.

Among these, “Climate Change” is the most relevant impact category and was chosen to present and discuss the environmental impact of the shoe models. Fig. 2 presents the results of the Climate Change impact category, Global Warming Potential indicator (GWP100), in kg CO_2 eq, calculated for each pair of footwear before and after redesign (sustainable). Within this study was possible to reduce AMF shoes carbon footprint (kg $CO_{2\ eq}$) up to between 14 to 32% considering the more sustainable versions.

Table 2. Footwear environmental footprint impact categories assessed

EF Impact Category	Impact category Indicator	Unit
Climate change, total + fossil + biogenic + land use and land use change	Radiative forcing as global warming potential (GWP100)	kg CO2-eq
Ozone depletion	Ozone Depletion Potential (ODP)	kg CFC-11-eq
Human toxicity, cancer	Comparative Toxic Units for humans (CTUh)	CTUh
Human toxicity, non-cancer	Comparative Toxic Units for humans (CTUh)	CTUh
Particulate matter	Impact on human health	disease incidence
Ionising radiation, human health	Human exposure efficiency relative to U235	kBq U235-eq
Photochemical ozone formation, human health	Tropospheric ozone concentration increase	kg NMVOC-eq
Acidification	Accumulated Exceedance (AE)	mol H+-eq
Eutrophication, terrestrial	Accumulated Exceedance (AE)	mol N -eq
Eutrophication, freshwater	Fraction of nutrients reaching freshwater end compartment (P)	kg P-eq
Eutrophication, marine	Fraction of nutrients reaching marine end compartment (N)	kg N-eq
Ecotoxicity, freshwater	Comparative Toxic Unit for ecosystems (CTUe)	CTUe
Land use	Soil quality index and others	Dimensionless (pt)
Water use	User deprivation potential (deprivation-weighted water consumption)	m3 world eq
Resource use, minerals and metals	Abiotic resource depletion (ADP ultimate reserves)	kg Sb eq
Resource use, fossils	Abiotic resource depletion – fossil fuels, ADP	MJ

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Table 3. PEF example of results: characterised, normalised and weighted results

Impact category	Characterised results		Normalised	Weighted
	Reference unit	Total impacts	Total impacts (Person-years)	Total impacts (Points)
Acidification	mol H+ eq	4,46E-02	8,02E-04	4,97E-05
Climate change	kg CO2 eq	8,7	1,07E-03	2,26E-04
Ecotoxicity, freshwater	CTUe	1,60E+02	3,74E-03	7,19E-05
Eutrophication, freshwater	kg P eq	3,54E-03	2,20E-03	6,17E-05
Eutrophication, marine	kg N eq	9,57E-03	4,90E-04	1,45E-05
Eutrophication, terrestrial	mol N eq	7,98E-02	4,51E-04	1,67E-05
Human toxicity, cancer	CTUh	3,85E-09	2,28E-04	4,86E-06
Human toxicity, non-cancer	CTUh	1,12E-07	4,87E-04	8,96E-06
Ionising radiation	kBq U-235 eq	6,42E-01	1,52E-04	7,62E-06
Land use	Pt	7,81E+01	9,53E-05	7,56E-06
Ozone depletion	kg CFC11 eq	4,59E-06	8,56E-05	5,40E-06
Particulate matter	disease inc.	4,04E-07	6,79E-04	6,08E-05
Photochemical ozone formation	kg NMVOC eq	2,89E-02	7,11E-04	3,40E-05
Resource use, fossils	MJ	1,24E+02	1,90E-03	1,58E-04
Resource use, minerals and metals	kg Sb eq	1,28E-04	2,01E-03	1,52E-04
Water use	m3 depriv.	8,20E+00	7,15E-04	6,08E-05
Total (single score)	n/a	n/a	n/a	9,41E-04

Table 4. Footwear most relevant impact categories, stages and process (example)

Impact category	% Contribution	Life cycle stage	% Contribution	Material / component / process	% Contribution
Climate change	24,0%	Raw materials in final product	55,5%	Outsole	22,3%
				Insole	8,0%
				Interlayer	7,8%
				Insock	6,9%
				Upper	3,5%
		Raw materials that go to waste	3,0%	Interlayer	1,4%
		Waste	19,8%	Urban waste	15,7%
		End of Life	7,3%	Transport passenger car	3,8%
				Municipal solid waste	3,2%
Resource use, fossils	16,8%	Raw materials in final product	68,0%	Outsole	35,1%
				Insole	9,9%
				Insock	7,5%
				Interlayer	5,6%
		Waste	15,4%	Urban waste	12,0%
		Raw materials that go to waste	2,8%	Interlayer	1,3%
Resource use, minerals and metals	16,1%	Waste	90,9%	Urban waste	84,0%

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Fig. 3 details the main contributors to Climate Change (Global Warming Potential indicator, GWP100, in kg CO_2 eq) for each pair of footwear before and after redesign. These results indicate that "Materials selection (and their pre-processing)", including, raw materials, components, adhesives, and packaging, is the most relevant life cycle stage, representing around (65 to 90) % of the total GWP100 in kg CO_2 eq. The heavier components, e.g., upper, insole and outsole, are the main EF contributors. Manufacturing, including namely electricity and waste; and EoL represent, respectively, around (4 to 26) % and (6 to 7) % kg CO_2 eq of the total GWP100. These range of results are related with the production processes and type of models. Distribution account around 2 % of the total GWP100 in kg CO_2 eq. Therefore, reducing the weight of the materials incorporated and wastes generated, and selecting materials that are recycled and recyclable increases sustainability / decreases environmental impact.

FUTURE STEPS

GreenShoes4.0 Project

The Portuguese footwear sector has evolved from being an industry driven, resource-based activity to a market led knowledge-based industry, taking advantage of design and technology to preserve Portugal's shoemaking capability.

To remain competitive, it needs to concentrate on the creative phase, master the whole product and process life cycle and add value to each phase, embracing societal, environmental, digital and market trends and opportunities.

GreenShoes4.0 (Footwear, Leather Goods and Advanced Material, Equipment and Software Technologies) is a Portugal 2020 R&D collaborative project, promoted by a consortium of 15 companies covering the whole footwear value chain. It includes leather, insoles/soles, software, production equipment, logistics and leather goods and footwear leadership, as well as 8 R&D bodies with multidisciplinary and complementary capabilities (Fig. 4).

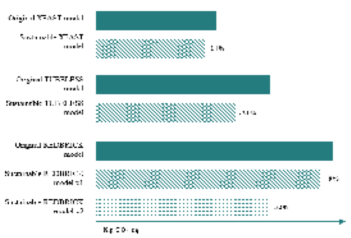

Figure 2. AMF shoes: Results of climate change impact category before and after sustainable

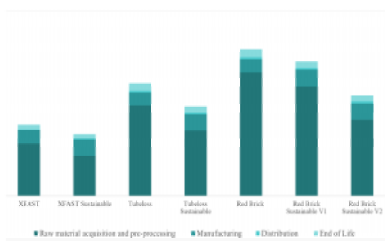

Figure 3. AMF shoes: Detailed contributor to Climate Change, GWP100), kg CO_2 eq.

GreenShoes4.0 seeks to mobilise the whole sector with the aim of researching, developing and creating in the following three areas:

1. New footwear and leather goods concepts aiming the circular and digital green economy, incorporating the materials developed, and produced and commercialised by new agile technologies.
2. Leathers, polymers and components for the footwear and leather goods of the future.

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3. New production technologies and digitalization of the entire value chain of the cluster and solutions to valorise the waste materials generated during the sector industry's productive phase and by used products.

Figure 4. The GreenShoes4.0 consortium

ACTIONS TO INCREASE SUSTAINABILITY AND REDUCE FOOTWEAR ENVIRONMENTAL FOOTPRINT

Based in life cycle analysis studies and experience of working with footwear and allied trade companies in Portugal and Europe, CTCP proposes a set of sustainable actions with potential of contributing towards the target of reducing 50% in the overall carbon footprint of products:

1. Design: Product ecodesign for longer life, repairability and circular use/recyclability.
2. Materials & Components: Upper, lining, and bottom materials and components that have low environmental, carbon and water footprint, are lighter, and recycled.
3. Materials Efficiency: Using materials more efficiently and reducing wastes.
4. Go Circular: Increasing production waste and products at the end-of-life circularity.
5. Research: Developing materials, components, and processes with lower environmental, carbon and water footprint (impact).
6. Energy: Increasing efficiency and adopting lower carbon and renewable energy.
7. Business Models: Increasing collaboration in the value chain from supply to retail and creating circular, digital enable, or traceable business models.
8. Processes: Deploying lower impact production processes.
9. Chemicals: Reducing chemical critical substances according REACH and other regulations.
10. Packaging: Rethink packaging to promote reuse and recycling and reduce weight.

Fig. 5 illustrates these actions estimated relative contribution to reduce the footwear footprint. The Figure shows that acting on the design phase, material and components selection and circularity will give a relevant contribution. The quantified reductions will depend on the company and products baseline, the specific objectives established, and the concrete measures undertaken. Ongoing work in GreenShoes4. establishes is fundamental to radically change the design and production approach and train designers and all the collaborators about the implications of their choices and procedures, namely sensibilizing for the following aspects:

1. Minimize the number and weight of all materials, components, adhesives, chemicals, and choosing light weight sustainable materials.
2. Incorporate materials and components that promote the product durability, longer use and repairability, namely upper in leather, removable insocks, soles

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that can be substituted or easily repaired by roughing and gluing a new bottom material.
3. Use recycled and recyclable materials and components.
4. Reduce the material required per pair / item and increasing material usage, namely upper shapes that allow maximum cut efficiency and minimize cutting and sewing wastes.
5. Minimise the number of production steps, finishing operations and chemicals used along the processes, selecting water-based solutions when needed.
6. Increase energy efficiency, reduce energy consumption, and use renewable green energy for production and transportation.
7. At the end-of-life increase the circular use of footwear, namely are made with one material, or materials that don't need to be separated before recycling or are modular and can be more easily disassembled before upcycling.

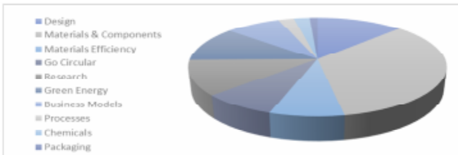

Figure 5. Where to act to reduce footwear and bags environmental footprint

CONCLUSIONS

This study involved the estimation of the environmental footprint of three footwear models based on PEF method. The reduction of footwear environmental footprint can be achieved by careful selection of materials and components, namely recycled and recyclable materials, reduction of materials amount (mass), reduction of waste generation by implementing more efficient production processes (e.g., more efficient cutting process), among others. Within this study was possible to reduce AMF shoes carbon footprint (kg CO2 eq) up to between 14 to 32%. To reduce the products environmental footprint companies, need to prioritize actions and bet in the ones with higher potential of achieving the reduction desired in a sustainable way, with social, environmental and economical balance. Based in life cycle analysis studies done within these projects and experience of working with footwear and allied trade companies in Portugal and Europe, CTCP identified and set of sustainable actions with potential of contributing towards the target of reducing 50% in the overall carbon footprint of footwear products.

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