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Life cycle comparison report

The Athletic Footwear segment amounts to US$1,530m in 2020 and is expected to grow annually by 5.3% [1]. Due to a growing industry and production, the environmental impact will grow as well. To lower the impact of that industrial sector, it is important to assess the sustainable potential of manufacturing and materials. Assessment tools like LCA can be used to determine the actual impact of production, transport and recycling of shoes, and can help to guide the environmental policies [2]. In this report, the environmental and health impacts of a pair of running shoes will be evaluated. Additionally, alternatives for the most environmental hazardous materials will be suggested.

1. Functional Unit Definition

The functional unit we choose is:

"Running 1000 km"

The verb running refers to the application of the shoes, we focus on sporting shoes. This means that some materials are not appropriate and the shoes must answer to some specific criteria (comfort, shock absorption,...) to avoid injury.
Instead of using the time parameter (e.g. the shoes durability during 1 year), we use a distance parameter. In that respect, we don't take into account the level of the runner. The choice of 1000 km refers generally to the maximal life time of a running shoe. Runners prescribe to change shoes when you reach this cumulated distance, otherwise the structure of the shoe is deformed and the sole loses its shock absorber (especially for foam sole).

2. Goal and Scope Definition

The goal is to reduce the environmental impacts during the manufacturing of the shoes and to present a new packaging solution. Minor adjustments were also made to their structure to improve recyclability. Table 1 shows several points of improvement which were studied.

Table 1: Reasons, improvements and reduction of impact for the main parts of the shoe.

Targets for improvement	Reasons	Improvements made	Prediction of the reduced impact
Outer & Mid Sole	- roughly 80% of the total mass - Polyurethane is used	- change material from Polyurethane to EVA foam	- Reduction of almost all impacts is expected to be between 30-70%
Packaging	- source of 12.7% energy consumption despite not being part of the product itself	- Reduce the amount of material used such as using thinner cardboard or an air-filled plastic pouch.	- Reduction of energy consumption - Lower weight improves transportation optimization

End of life	- most emissions come from the production of materials rather than the manufacturing of the product itself - in an ideal case up to 80% of the emissions could be cut	- reduce material variety - make the shoe easier to dismantle	- Most consumers probably won't bother to recycle the materials and probably not all of it can be made recyclable, so the ideal case won't happen, but emissions could still probably be cut by 20%
Use of glue	- unnecessary	- weaving can be used as a more environmentally friendly alternative	- Minor, since there isn't much glue used - Makes dismantling easier for material recycling purposes

Changing the polyurethane of the sole of the shoe to a more sustainable material would probably be the most effective way of improving their eco-friendliness. Not only is the sole 80% of the mass of the shoe itself, but through LCA analysis we discovered that the production of polyurethane is by far the biggest contributor to the product's various negative effects on the environment. Our plan is to use EVA foam as a replacement for polyurethane to achieve this outcome [3].

In contrast, it was discovered that the textile parts of the sneakers had such minimal impacts by comparison, that they are neglectable due to a less relevant impact in the big picture.

The impact of the packaging of the product is also something that was analyzed. The original packaging was a cardboard box which at first glance might appear to be eco-friendly, but it was found out that the packaging alone contributes to 12.7% of the energy consumption of the product on top of also making the whole noticeably heavier, increasing transportation emissions. An alternative that we came up with was to use air-filled plastic bags. The use of plastic seems counter-intuitive from a sustainability standpoint, but due to their low mass, the overall impact on the environment ends up being less in spite of the suboptimal material. And since the weight is greatly reduced, an additional benefit rises in the form of cutting down transportation emissions.

Another option that was considered was the recyclability of the shoe. Sneakers require a variety of materials, which makes dismantling them a necessary step in the recycling process. This would be achieved by replacing glue with weaving as a means of connecting the different parts together. Not only would this make the shoe easier to dismantle, but also by getting rid of the glue, one material with harmful impacts will have been eliminated. Weaving is done using machines which run on electricity, but this is a negligible amount compared to the impact of the glue it replaces.

3. Inventory Analysis

For analysing the sustainability and life cycle assessment the open source softwares openLCA (Environmental Footprint (EF) database) and GRANTA EduPack are used. The footwear life cycle stages are presented in Figure 1. The corresponding input materials and processes are listed in Table 2.

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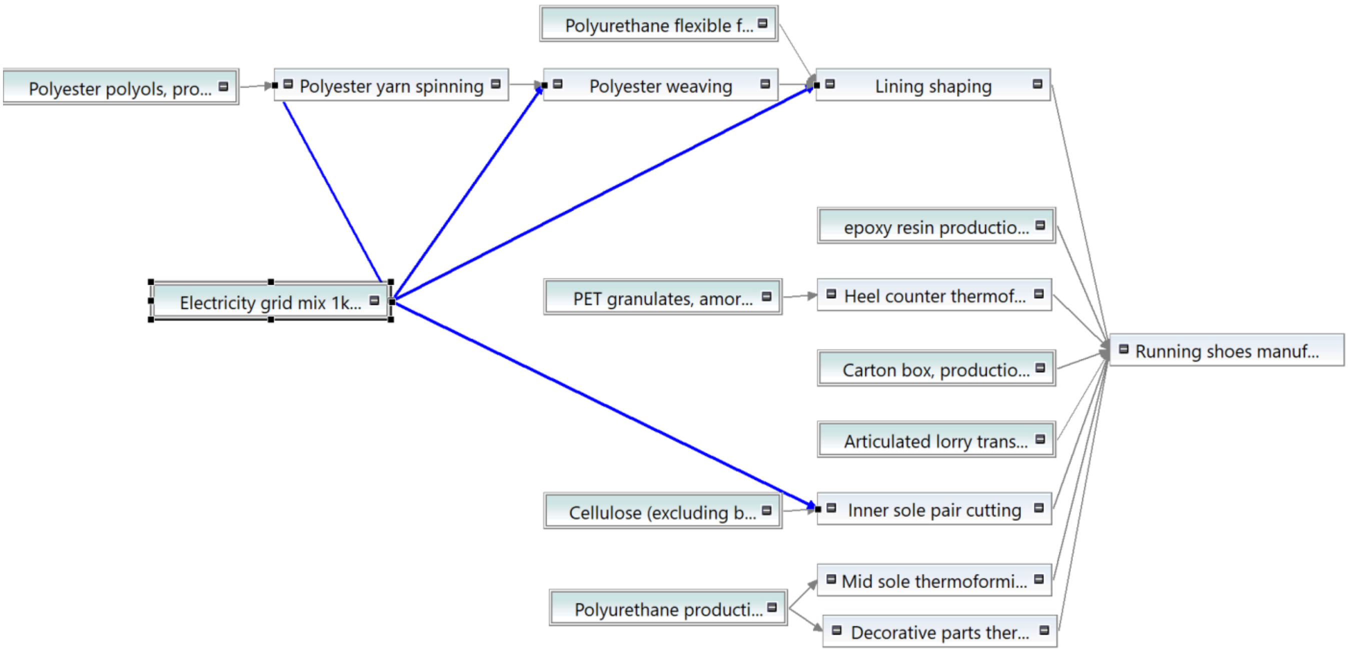

Figure 1: Life cycle stages of the shoe with openLCA.

Table 2: Inventory of the materials and processes for producing the different parts of the initial shoe (openLCA).

Shoe parts	Inputs materials and processes	Amount	Unit
Lining & tongue	Polyester polyols, production mix, at plant, polycondensation, Hydroxyl value: 150-360, aromatic content: 5-50% - EU-28+EFTA	0.10200	kg
	Polyester yarn spinning	0.10200	kg
	Polyester weaving	0.10200	kg
	Lining shaping	0.10200	kg
	Polyurethane flexible foam, production mix, at plant, Reaction of toluene diisocyanate (TDI) with long-chain polyether polyol and foaming, 18- 53 kg/m3 - EU-28+EFTA	0.02040	kg
Heel counter	PET granulates, amorphous, production mix, at plant, Polymerisation of ethylene, 0.91- 0.96 g/cm3, 28 g/mol per repeating unit - EU-28+EFTA	0.01471	kg
Inner Sole	Cellulose (excluding blowing) production, production mix, at plant, technology mix, 100% active substance - RER	0.01960	kg

	Inner sole paire cutting	0.01960	kg
Mid sole & Outer sole, decorative parts	Polyurethane production, production mix, at plant, technology mix, 100% active substance	0.44481	kg
Global	Electricity grid mix 1kV-60kV, consumption mix, to consumer, AC, technology mix, 1kV - 60kV	2.4236	MJ
	Thermoforming, production mix, at plant, plastic thermoforming, 25% loss, 2.5 MJ electricity, 0.5 MJ thermal energy	0.45954	kg
Paperboard	Carton box, production mix, at plant, Kraft Pulping Process, pulp pressing and drying, box manufacturing, 280 g/m2, R1=47% - EU-28+EFTA	0.24000	kg
Transport	Articulated lorry transport, Total weight 28-32 t, mix Euro 0-5, consumption mix, to consumer, diesel driven, Euro 0 - 5 mix, cargo, 28 - 32t gross weight / 22t payload capacity - RAF	3.24000	kgkm

4. Assumptions

For the sake of using data from OpenLCA, some hypotheses must have been made. The following list refer to our assumptions according to each LCA steps:

Materials:

- For the laces, the elastane has been replaced by polyurethane
- For the inner sole, the cellulose based materials have been replaced by pure cellulose. The real chemical formulation is unknown. We supposed that choosing pure cellulose instead the real cellulose based material has a negligible impact.
- The open cell foam polyurethane used to increase the conform inside the shoe isn't available in the EF database. We used instead a flexible foam polyurethane. The impact of this foam might be very close to the real one.
- For the lining, we assume that polyester has been used as it is an affordable material. Nylon or a mix of polyester-nylon could be the real material but the impact is roughly the same. [4]
- For the glue, there is no such flow in the EF database. We choose the epoxy resin flow, as such chemicals are mainly used as glue.

Manufacture:

Energy consumption:

- The energy consumption due to the application of the glue has been neglected.
- We didn't manage to find proper information on the cellulose board manufacturing energy consumption, then the manufacture of this cellulose board (before cutting) was neglected.
- The energy consumption for the cutting tool (for inner sole, lining, and tongue) was calculated from an industrial cutting tool [5]
- The energy consumption for spinning and weaving polyester was calculated from the Specific Energy Consumption (SEC, unit kWh/kg) according to both studies [6,7]
- The energy consumption of the final assembly has been neglected as it is only glueing and sewing parts together.

Other:

- Several parts have been dyed (lining, outer sole and decorative parts) but we didn't take into account the dyeing process. There is no such process in the EF database. This big assumption helps us to simplify the overall LCA.
- We suppose that the decorative parts, the heel counter, and the sole may be manufactured by a thermoforming process from plastic granulates.
- The production of yarn used for sewing everything has been neglected. The reason is that its impact can easily be included in the polyester production for the lining.

Transport:

- We suppose that every single part of the shoe is manufactured in China
- The shoes and the packaging may be assembly in China
- In our scenario, the final product is sent to Finland. The transportation is made by lorry 32t.

Use:

- We didn't take into account this step of the Life Cycle Analysis as there is no real impact during the use of running shoes.

End of life:

- In the first scenario, the user doesn't know how to recycle the shoe. Then the shoe is thrown in the landfill.

5. Impact Assessment

For the impact assessment six main impact categories were determined and these can be seen in Figure 2. These clearly fall into 2 clear types. First there are human hazards: human toxicity, both carcinogenic and non-carcinogenic, as well as particulate matter, microscopic solid and liquid particles that cause health problems when inhaled. Secondly, there are environmental hazards, mainly climate change caused by the use of fossil fuels in the production and manufacturing phases of the sneakers. Ocean acidification is also a notable impact, but of lesser magnitude than the others.

From figure 3, it becomes evident that polyurethane is the overwhelming source of almost all impacts that our product has, regardless of impact type. This is the primary reason why replacing it with an alternative material was our highest priority.

Impact category	Amount
Human toxicity, cancer	0.00109
Resource use, fossils	0.00105
Particulate Matter	0.00097
Human toxicity, non-cancer	0.00069
Climate change	0.00051
Acidification	0.00035

Figure 2.
Normalized and weighted impact categories.

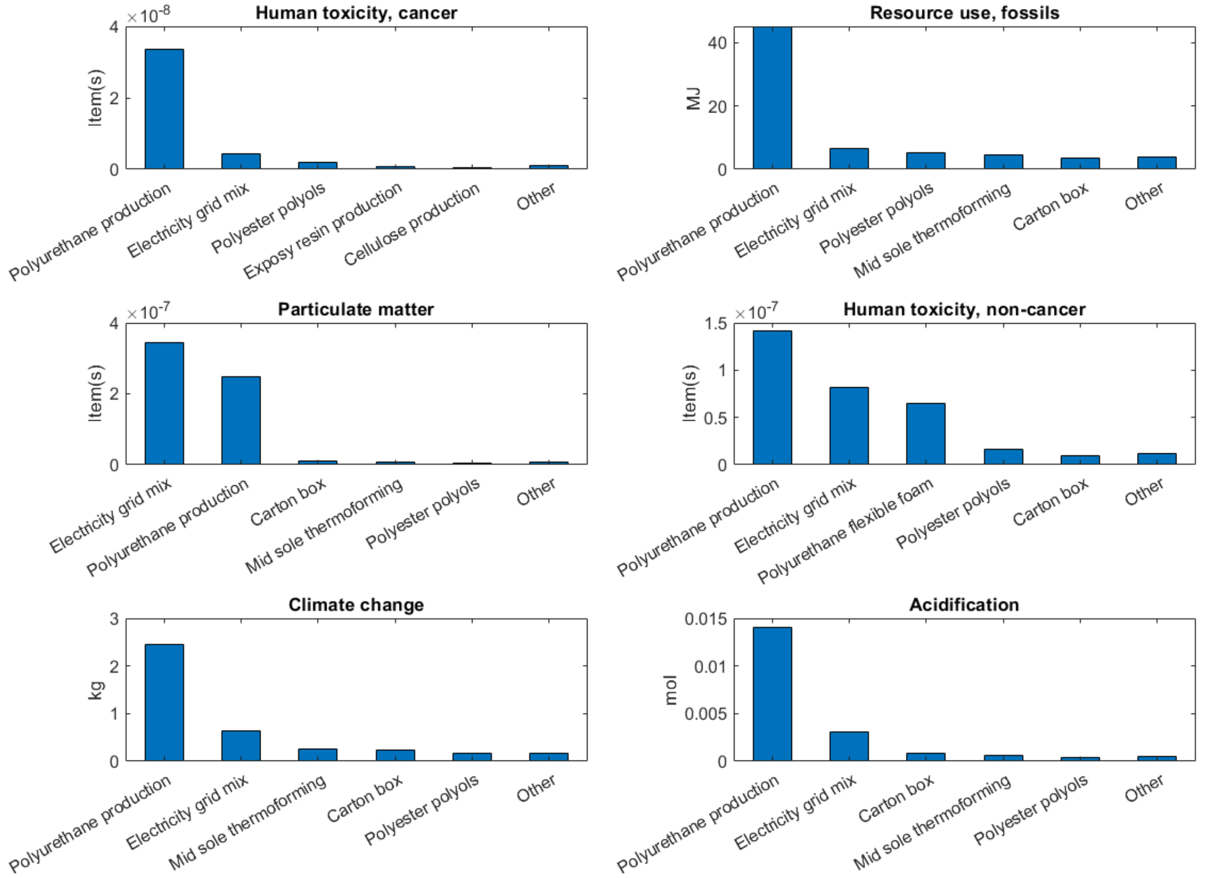

Figure 3.
Comparison of the impact of the different materials and processes. The most harmful materials are represented for each of the impact categories.

6. Interpretation

As it can be seen from the comparison of the two options in Figure 4, the usage of EVA foam can drastically lower the hazardous and environmental impact of the shoe. The human toxicity has been reduced by more than 50%. The particle matter impact reduces up to 40%. The fossil resource use and climate change impacts have decreased more than 40%.
One of the reasons is that the use of EVA foam allows us to save weight.

We can see that the Land use impact and the Climate change related to land use impact have barely decreased. This is due to the fact that the main contribution comes from the packaging, not the polyurethane production.

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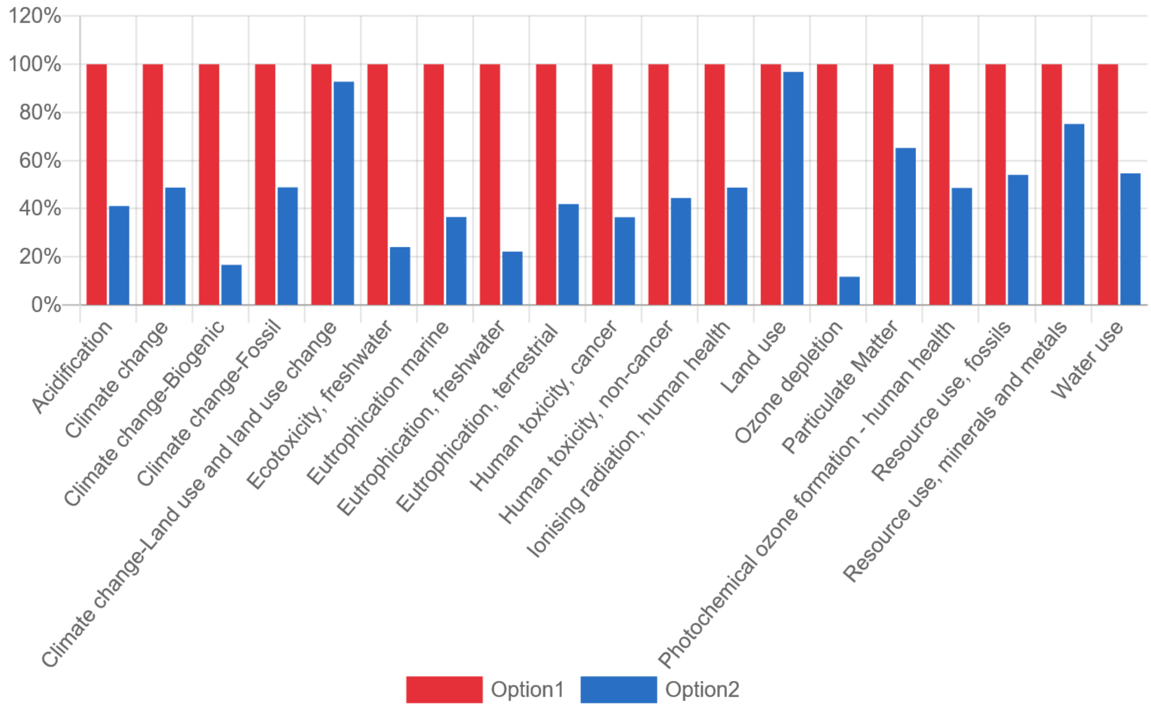

Figure 4:
Comparison of the impacts of the original shoe (option 1) and the shoe when substituting polyurethane as the main factor by 100g EVA foam (option 2).

This result has been confirmed by Granta Edupack calculations. In addition, this scenario includes new packaging and a more realistic way of transportation. The results have been summarized in Figure 5.

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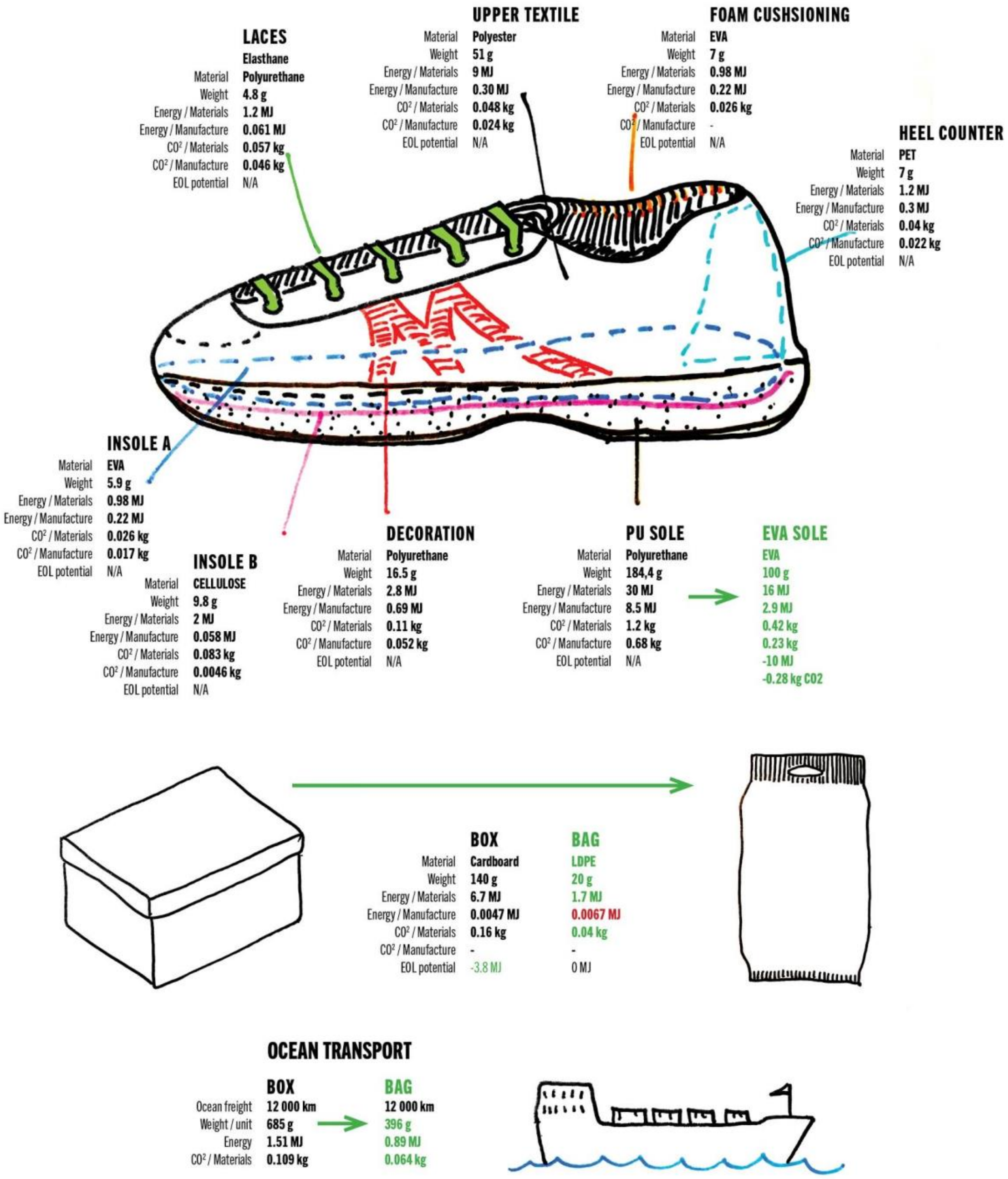

	ORIGINAL	GREEN VERSION	DIFFERENCE
Total energy used	67.2 MJ	40,3 MJ	-40%
CO2 emissions	3.11 kg	1,69 kg	-46%
EOL energy saving potential	-3.82 MJ	-10,4 MJ	270%
EOL CO2 saving potential*	-0,005 kg	-0,28 kg	N/A

Figure 5.
A summary of sneaker manufacturing materials, energy use and CO2 emissions during manufacture and transport. Comparison between original shoe and an option where outer sole and packaging are changed. Calculations done with Granta Edupack.

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References

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