Life Cycle Assessment of an Umbrella

From a high-environmental impact product to a greener alternative

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INTRODUCTION

Our goal is to make an umbrella more sustainable by reducing its biggest environmental impact throughout its whole life cycle, from raw materials extractions to waste disposal.
To do the Life Cycle Assessment, three softwares were used: OpenLCA, Granta EduPack (CES) and Base Impacts. Base Impacts is a software created by ADEME, the ecological transition agency from the french government [1]. We used this open resource because OpenLCA did not provide us with information about polymers, and because the CES software only gave information about CO2 footprint and embodied energy.

FUNCTIONAL UNIT DEFINITION

An umbrella is a hand-held device that protects a person or item against rain (here we only consider the function of an umbrella against rain and not against sunlight because in Europe, an umbrella is commonly used against rain).
In Europe, depending on the country, it can rain from 90 days to more than 210 days per year [2]. Let's consider it rains 150 days per year in Europe.
Finally, we want our umbrella to be durable, so it should last during a human lifetime.

Functional unit considered

Protecting one person from rain, while walking outside, approximately 2 hours/day during 150 days in a year, with the durability of a human lifetime.

GOAL AND SCOPE DEFINITION

While doing the life cycle assessment of our umbrella, we noticed that the manufacturing phase (including raw materials extraction and production) and more specifically, the 16 ribs of the umbrella, had the biggest environmental impact (see Impact Assessment section). As a consequence, we focused on improving and reducing the impacts of the ribs made out of steel.

According to Global Umbrella Survey Results [3], world-widely, one person …

- owns 2 umbrellas
- buys one new umbrella per year

This leads to an average of 70 umbrellas per person in a lifetime.

An umbrella user keeps his or her umbrella until it breaks. Umbrellas can be classified as a"bulk item" in terms of recycling, which is the category of product people find the hardest to recycle (Source: survey created during a Startup Experience course in Aalto). Because an umbrella has many parts, made from various materials, the users don't know how to recycle it, and the whole umbrella is thrown away as a waste. So, in order to reduce the environmental impact of our umbrella we chose to make it easier to recycle.

The main reason why people throw away their umbrella is because it is broken. So we wanted to make our umbrella repairable. According to our own experience, umbrellas mainly break when they are bent by the wind, and when either the canopy is torn apart, or the ribs (metallic parts that support the canopy) are broken or bent. Moreover, the ribs are the most important sections of an umbrella and “the biggest stress points are along the ribs” [4].

In this perspective, we had the idea to make the canopy detachable and the ribs replaceable. This way, if the canopy is torn apart, the user can buy another one and replace it, and if the ribs are bent, the user will use the extra ribs sold with our umbrella and replace the broken one. The system fixing the ribs to the pole will be simple and solid, so that anyone can replace broken ribs by reading instructions.

With these improvements, the broken ribs made of steel (now detached from the rest of the umbrella) will be easy to recycle, for the simple reason that they are composed of a single material. Thus, umbrellas will not be thrown away completely for a torn up canopy or a bent rib. This improvement will drastically reduce the number of functional ribs wasted, which are the part of the umbrella that have the biggest environmental impact (see Impact Assessment section). Instead of producing 70*16 or 1120 ribs per user [3], we will produce 16+(70*1) or 86 ribs so 13 times less (if we assume that umbrellas break because of a broken rib).

INVENTORY ANALYSIS & ASSUMPTIONS

Original umbrella

Raw Materials extraction

All the materials, and only those materials, referenced in *Table 1* were taken into account to make the life cycle assessment of the considered umbrella.

Material	Amount
Low alloy steel	16 ribs: 172.4g Bottom & top springs: 4.3g 2 screws: 1.4g **Total=178.1g**
Polyester	Handle: 76.8g Canopy: 47.1g 16 tips : 7.1g **Total=131g**
Aluminum	Pole: 59g Open cap: 1.0g **Total=60g**
Polypropylène	Runner and top notch: 8.9g

	Plastic skirt<0.1g **Total=8.9g**
PET polyester foam	Small piece between the top notch and the canopy<0.1g
Galvanized steel	Steel wire: 0.1 g **Total = 0.1 g**
Nylon	Hook and loop fastener: <0.1g

Table 1: Materials used in the umbrella and their amount

The umbrella was very cheap, comes from China according to its tag and there was no mention of use of recycled materials in it.

The raw materials are certainly not extracted right aside from the factory, where the different parts are manufactured and assembled. The raw materials must often be transported over large distances, sometimes even overseas [5]. On average, we can make the assumption that the raw materials are transported over a distance of 1000km by truck. It is a big approximation but depending on the location of the factory and mining, and because we have no information about the origin of our product, such an approximation is needed. The most important thing is to take into account this transport phase in the life cycle.

→ We made the hypothesis that:

- The raw materials were transported from their location of extraction to the factory by a truck over a distance of 1000km.
- No recycled material was used.

Manufacturing

- The umbrella was made in China according to its tag and is not of good quality so the pessimistic scenario is well-adapted.
- No information about the origin of the different parts of the product is available. So, we believe that adopting a global point of view is the best approximation we can make.

→ For the manufacturing phase:

- when selecting the production steps, a **scenario at a global level** (GLO) was considered with the Base Impacts software.

Distribution

According to its tag, the considered umbrella was manufactured in China. In addition, it was very cheap (less than ten euros). So, since train transportation is 2.5 times more expensive than transportation by ship [6], we think ship transport was used. The software sea-distances.org [7] was used to approximate the distance traveled by such a ship between China and Europe. Although this software is not perfect, it is sufficient to have a good idea of the distance.

For transportation, as the umbrella is not fragile and because it was very cheap (as mentioned before), it was certainly stored in cardboard boxes, since it is the simplest and cheapest way to store goods. According to an industrial packaging company, the adapted cardboard box for our umbrella could be one that weighs 500g [8].

The umbrella was sold without packaging.

Umbrellas do not have to be stored in warehouses that are cooled down. Thus, the storage does not require much energy, and apart from the place it takes to store umbrellas, it has no environmental impact. We chose to make the hypothesis that no energy was required to store umbrellas.

→ For the distribution phase, we assumed that:

- The umbrella was transported by ship over a distance of 15 919 km (or 8596 nautical miles) from China to Europe,
- The umbrella was stored in 500g-cardboard boxes (with other umbrellas) during transportation,
- No energy is required to store umbrellas in warehouses.

Use phase

At this stage of the life cycle, no raw material has to be added, or only in very little quantity if the umbrella needs some maintenance. In this case, glue, tape, and metal wires can be used.

No energy is consumed while using an umbrella, except for human energy.

During the use phase of the umbrella life-cycle, no waste is produced.

→ We made the hypothesis that the use phase had no environmental impact.

End of life

From our experience, we know that the umbrella cannot be easily dismantled. Moreover, a well-known fact is that umbrellas produce 150,000 tons of wasted metal (i.e, the metal is not recycled) per year, which corresponds to the amount of what is needed to build 25 Eiffel Towers [9]. Thus, it is very likely that it will be put directly in the bin without being recycled by its owner, and it will end its life in a landfill, or incinerated.

→ We made the hypothesis that, at the end of life of the umbrella:

- it is transported by a garbage truck, filled up at 100% with other household garbage, for 10km to a landfill/incineration center,
- 50% is incinerated and 50% is put in a landfill.

Greener Umbrella

For the greener version of the product, not many assumptions changed as compared to the original version. As the 16 ribs can now be easily dismantled (see Goal and Scope definition section), the steel used can be a recycled one and can be recycled if a rib breaks. In Finland, 90% of the steel craps are recycled [10]. Only two assumptions differ:

- In the raw materials phase: we assumed the steel used for the 16 ribs is a recycled one.
- In the end of life, 90% of the steel used for the 16 ribs is recycled.

IMPACT ASSESSMENT

To assess the life cycle of the original umbrella, 2 softwares were used: the Granta EduPack (or CES) software and the Base Impacts software. Thanks to Base Impacts we were able to take into account a wide variety of environmental impacts. And CES confirmed that we were focusing on the right problem.

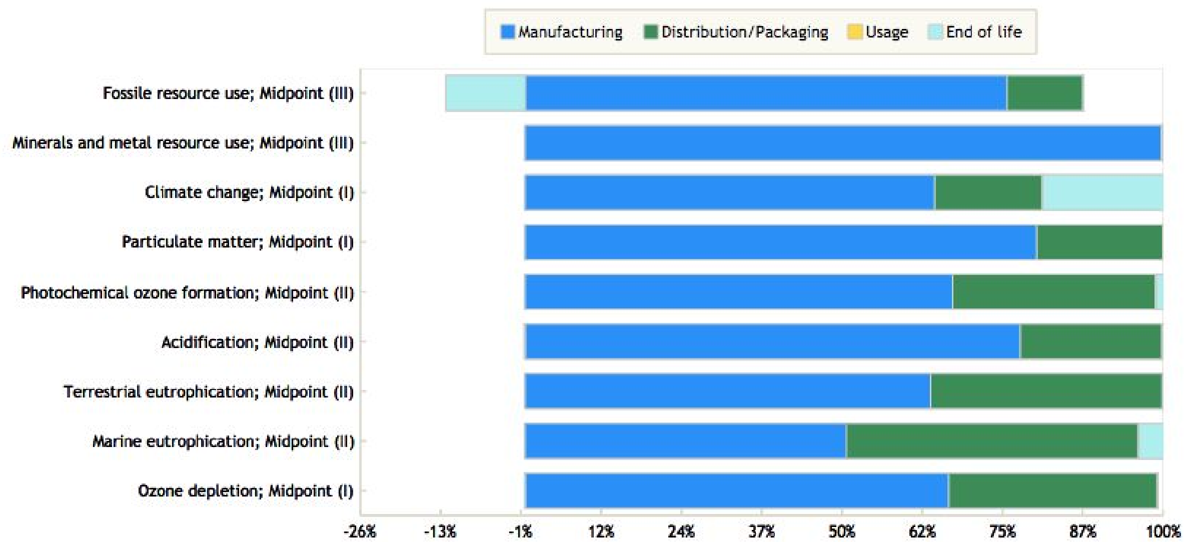

Figure 1: Environmental impacts of the umbrella throughout its lifecycle, Base Impacts software

NB: we see that the end of life has a positive impact in terms of fossil resources (units: MJ). According to the GrantaEduPack software, this is due to the assumption that the energy produced thanks to incineration can be utilized for something else.

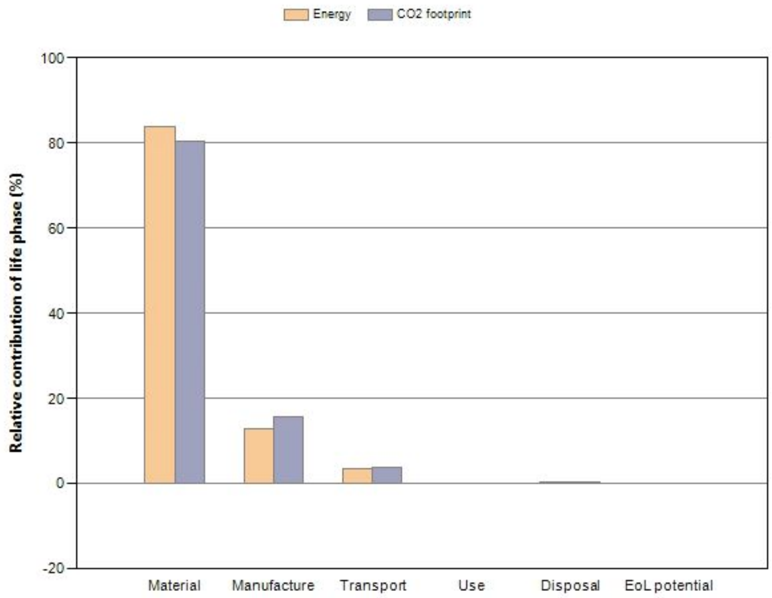

Figure 2: Environmental impacts of the umbrella throughout its lifecycle, CES

Figure 1 shows that the manufacturing phase has the worst environmental impact for each category of impact. The CES confirms this assertion and *Figure 2* reveals that the Raw Material extraction phase has the worst environmental impact.

Then, when taking a look into the details, we see that the 16 ribs made out of steel are the parts which have the worst impacts. *Figure 3*, extracted from Base Impacts, confirms this assertion. Here, only eutrophication and ozone formation impacts are displayed but all the data for the different impacts can be found in Appendix A.

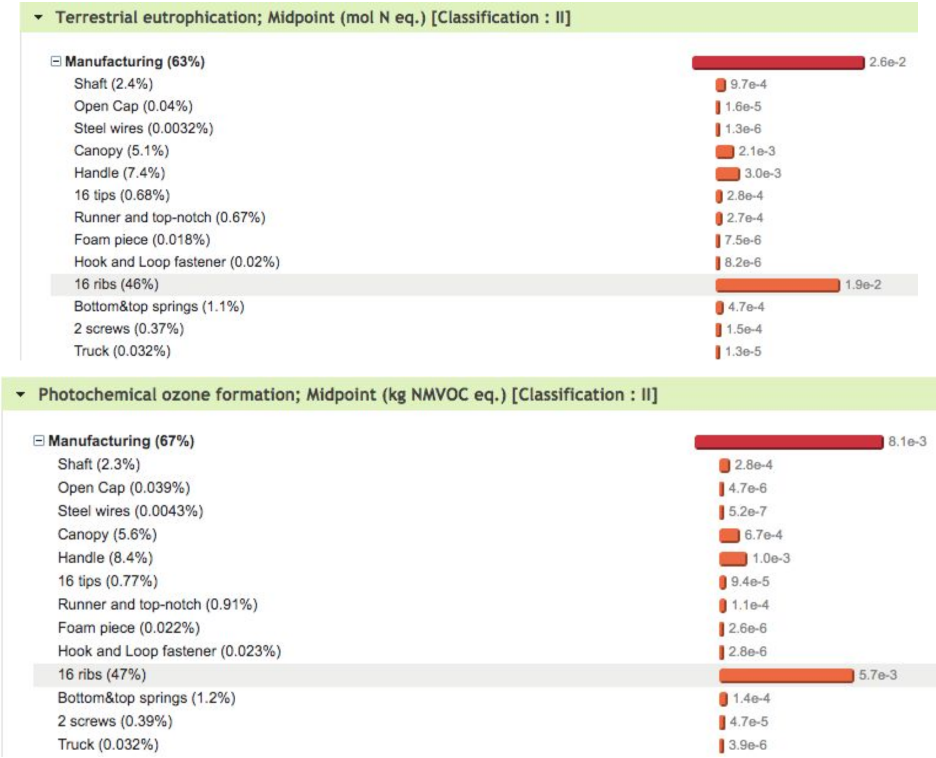

Figure 3: the 16 ribs are the most impactful parts of the umbrella, Base Impacts

INTERPRETATION

Impact category	Evaluation #1	Evaluation #2
Fossile resource use (MJ)	3.1e+1	2.4e+1
Minerals and metal resource use (kg Sb eq.)	3.6e-5	2.1e-5
Climate change (kg CO2 eq.)	3.5e+0	2.8e+0
Particulate matter (disease incidence)	2.0e-7	1.3e-7
Photochemical ozone formation (kg NMVOC eq.)	1.2e-2	1.0e-2
Acidification (mol H+ eq.)	2.5e-2	1.5e-2
Terrestrial eutrophication (mol N eq.)	4.1e-2	3.5e-2
Marine eutrophication (kg N eq.)	3.0e-3	3.6e-3
Ozone depletion (kg CFC 11 eq.)	6.4e-8	2.6e-8

Table 2: Comparison of the environmental impacts of the original umbrella (evaluation 1) and a greener version (evaluation 2), Base Impacts

According to *Table 2*, apart from the marine eutrophication, every environmental impact is lowered by our improvement.

Nitrogen is one of the most common oversupplied nutrients to cause marine eutrophication, which leads to overgrowth of plants and algae in aquatic ecosystems.

Nitrogen is used as an impurity element in steelmaking and is removed from the source iron melt during processing. All steels contain nitrogen, which affects steel internals depending on the amount of the nitrogen inside. According to *Table 2* the emission of nitrogen is higher for the recycled steel. It is logical, if we consider that for recycled steel the process of removing the nitrogen has happened at least twice, which leads to the rising impact of marine eutrophication.
However, the recycled steel is still more sustainable and eco-friendly, since it is more economic to produce, causes less damage to the environment and saves raw materials [11].

CONCLUSION

The greener version of the umbrella we imagined has indeed lower environmental impacts than the original one, according to the Base Impacts software. Moreover, our initial goal was also to make it more durable by extending its lifetime. With the solution we suggested (manufacturing an easily dismantable and repairable umbrella), this is indeed possible.

REFERENCES

Some of the sources may not be professional and/or be written by experts. However, to this day, they are the best sources we could find to make this life cycle assessment.

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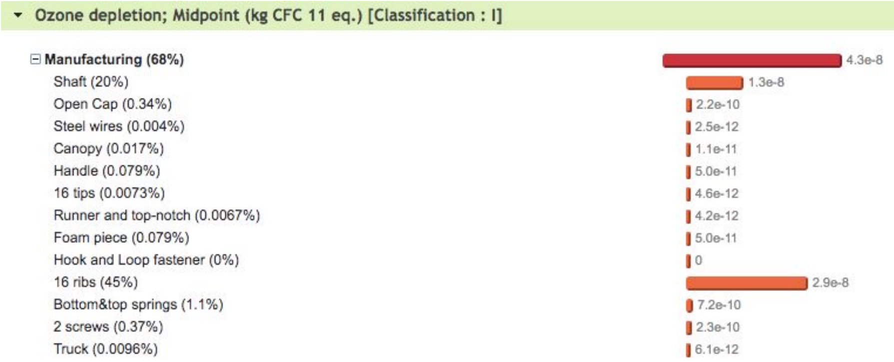
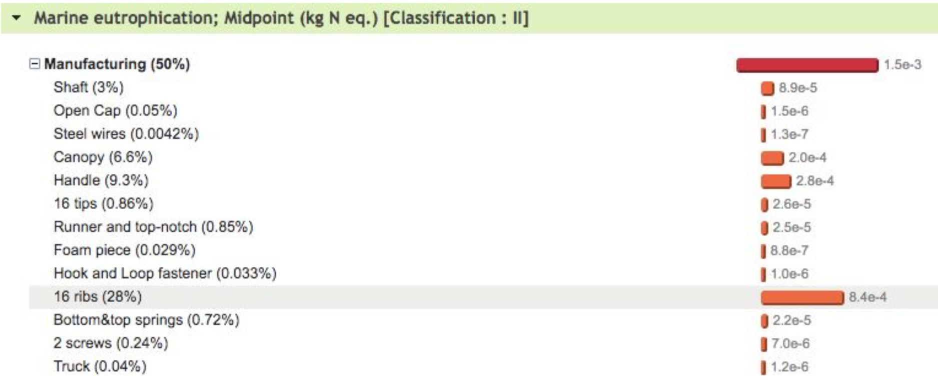
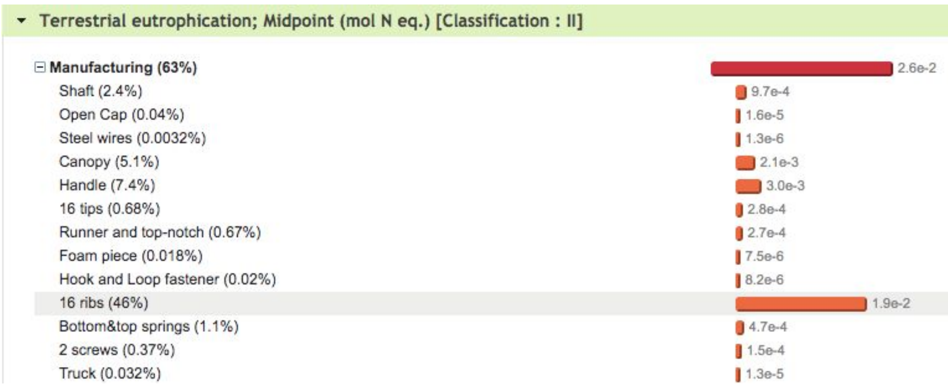
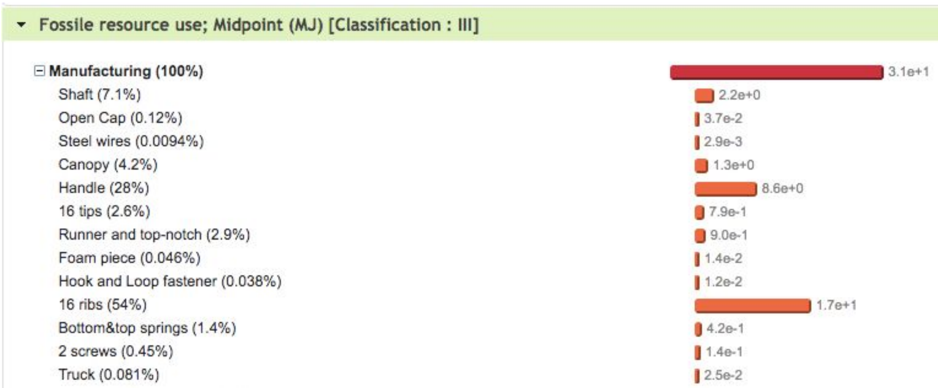
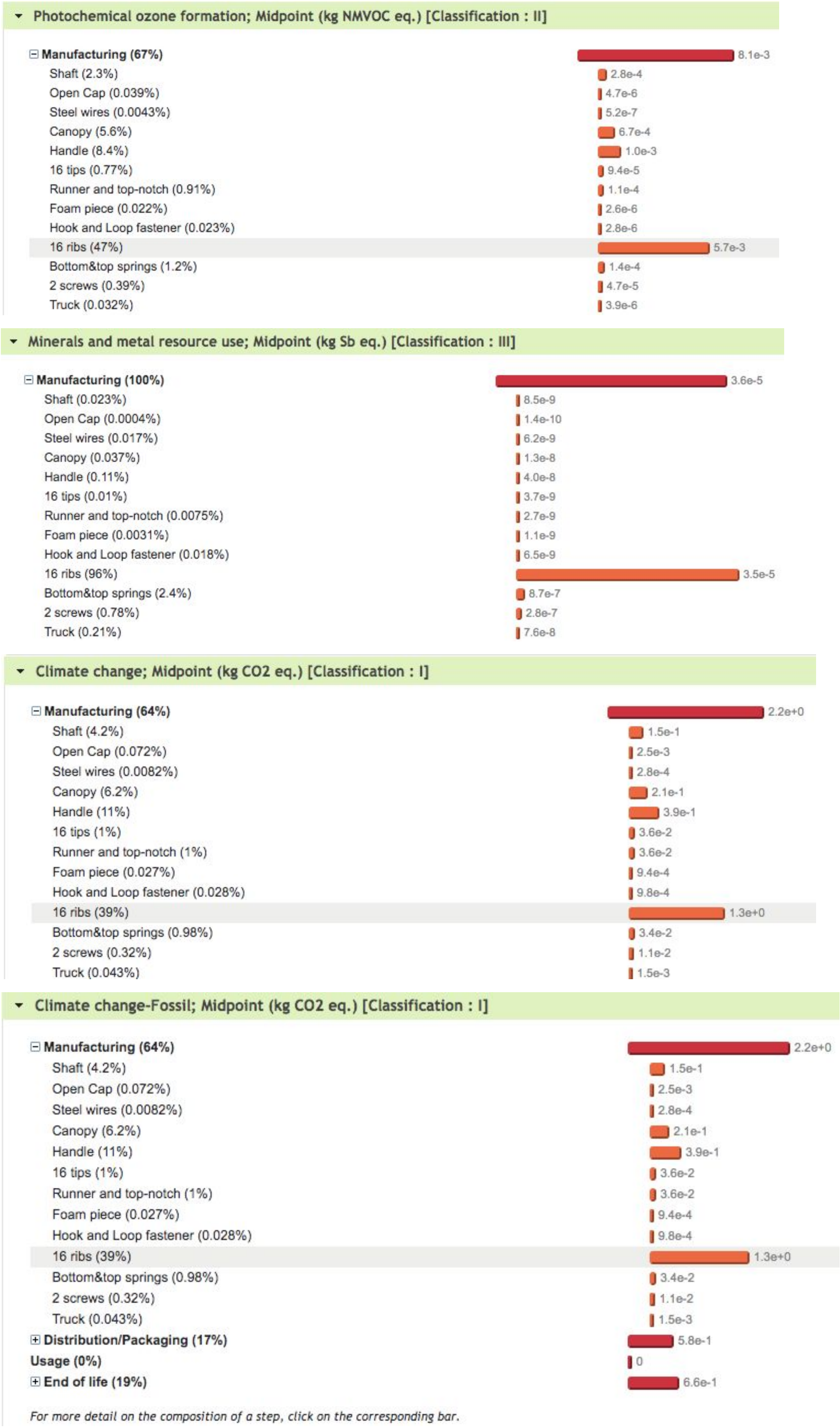
APPENDIX 1 : Environmental impacts of the original umbrella










Photochemical ozone formation; Midpoint (kg NMVOC eq.) [Classification : II]
Manufacturing (67%) 8.1e-3
Shaft (2.3%) 2.8e-4
Open Cap (0.039%) 4.7e-6
Steel wires (0.0043%) 5.2e-7
Canopy (5.6%) 6.7e-4
Handle (8.4%) 1.0e-3
16 tips (0.77%) 9.4e-5
Runner and top-notch (0.91%) 1.1e-4
Foam piece (0.022%) 2.6e-6
Hook and Loop fastener (0.023%) 2.8e-6
16 ribs (47%) 5.7e-3
Bottom&top springs (1.2%) 1.4e-4
2 screws (0.39%) 4.7e-5
Truck (0.032%) 3.9e-6
Minerals and metal resource use; Midpoint (kg Sb eq.) [Classification : III]
Manufacturing (100%) 3.6e-5
Shaft (0.023%) 8.5e-9
Open Cap (0.0004%) 1.4e-10
Steel wires (0.017%) 6.2e-9
Canopy (0.037%) 1.3e-8
Handle (0.11%) 4.0e-8
16 tips (0.01%) 3.7e-9
Runner and top-notch (0.0075%) 2.7e-9
Foam piece (0.0031%) 1.1e-9
Hook and Loop fastener (0.018%) 6.5e-9
16 ribs (96%) 3.5e-5
Bottom&top springs (2.4%) 8.7e-7
2 screws (0.78%) 2.8e-7
Truck (0.21%) 7.6e-8
Climate change; Midpoint (kg CO2 eq.) [Classification : I]
Manufacturing (64%) 2.2e+0
Shaft (4.2%) 1.5e-1
Open Cap (0.072%) 2.5e-3
Steel wires (0.0082%) 2.8e-4
Canopy (6.2%) 2.1e-1
Handle (11%) 3.9e-1
16 tips (1%) 3.6e-2
Runner and top-notch (1%) 3.6e-2
Foam piece (0.027%) 9.4e-4
Hook and Loop fastener (0.028%) 9.8e-4
16 ribs (39%) 1.3e+0
Bottom&top springs (0.98%) 3.4e-2
2 screws (0.32%) 1.1e-2
Truck (0.043%) 1.5e-3
Climate change-Fossil; Midpoint (kg CO2 eq.) [Classification : I]
Manufacturing (64%) 2.2e+0
Shaft (4.2%) 1.5e-1
Open Cap (0.072%) 2.5e-3
Steel wires (0.0082%) 2.8e-4
Canopy (6.2%) 2.1e-1
Handle (11%) 3.9e-1
16 tips (1%) 3.6e-2
Runner and top-notch (1%) 3.6e-2
Foam piece (0.027%) 9.4e-4
Hook and Loop fastener (0.028%) 9.8e-4
16 ribs (39%) 1.3e+0
Bottom&top springs (0.98%) 3.4e-2
2 screws (0.32%) 1.1e-2
Truck (0.043%) 1.5e-3
Distribution/Packaging (17%) 5.8e-1
Usage (0%) 0
End of life (19%) 6.6e-1
For more detail on the composition of a step, click on the corresponding bar.