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Life Cycle Comparison Report on a Ballpoint Pen

Contents:

1. Introduction

The product we are assessing is a cheap bic pen - the type you would receive for free at an event – and our goal is to create a greener version of it. By greener, we mean a version that significantly cuts back emissions for the total lifecycle of the pen. We set out to find the most reliable, affordable, and executable solution. Our basic assumption are that the pen will be used in Finland and that they are common cheap pens used mainly for writing. In this report we'll show which improvements have been made in the product, why these targets for the improvement were chosen, and how much lower an impact is gained by the improvements.

The functional unit for a bic pen is defined to be its lifetime. A bic pen can write a line up to 1,92km in length (~1mm in width) (1) in a best case scenario, however we chose the functional unit of a lifetime instead of meters written or drawn, as we estimated it to be likely that the pen is lost or the ink dries out before its computational maximum amount of text is reached. Average lifetime is thus estimated to be shorter than it would be in the ideal case scenario.

2. Life Cycles of Actual Product and Our Improved Version in Comparison

The work starts with identifying the parts of the lifecycle that have the biggest impacts. Furthermore, we looked into the most significant effects of each part of the life cycle separately. System limitations are defined in each sub part. The used assessment method is BEES+, and the assessed categories are eutrophication, global warming potential, water intake, ecotoxicity and acidification. In all of these categories, the most important impact is the plastic parts, as it can be seen from figure 2. Plastic forms the majority of the pen. Glass containers are also identified as a significant source of pollution, but as they are part of the transport containers the pens are shipped in, it is not a meaningful focus of our study as it has nothing to do with the product composition.

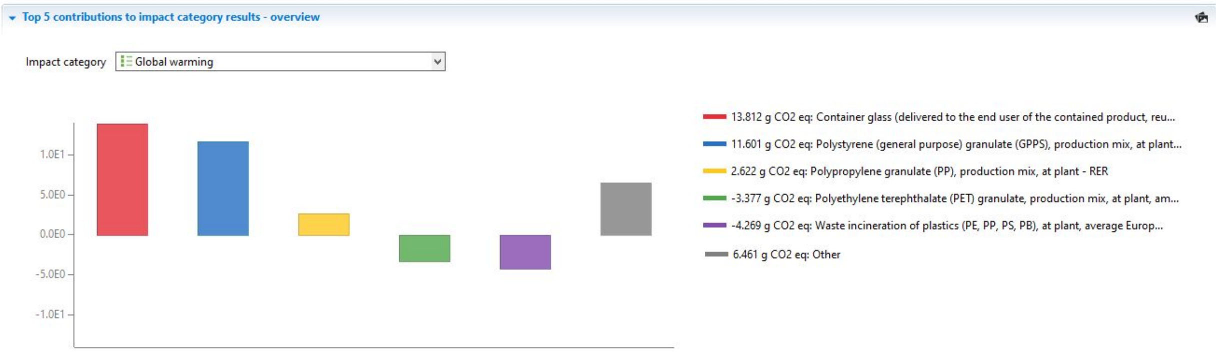

Figure 1: Biggest contributors to life cycle emissions of the pen.

2.1 Raw Materials and Their Preparation

The materials of the ballpoint pen are 1.35g of polypropylene, 3.4g of polystyrene, 0.2g of ethanol as the main ink component, 0.05g of tungsten carbide (tungsten 0.047g and carbon 0.003g) (3) and 0.2g of brass (assumed to be 35% zinc, 65% copper translating to 0.13g of copper and 0.07g of zinc. The zinc ratio is assumed as the precise ratio of the two in our product is hard to know without chemically testing it, and 39-40% is around the limit where brass becomes less ductile.(2) . The materials can be seen from figure 2.

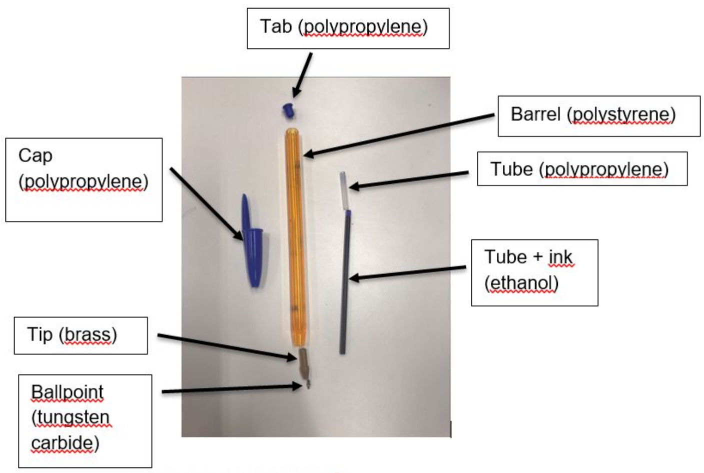

Figure 2: Explosion picture of the BIC pen

In OpenLCA, due to the limitations of databases, ethanol emissions were estimated with ethene and tungsten with steel. Ethene was chosen because it is the closest available type of alcohol. Steel consists of carbon and iron, and is a metal like tungsten, so it gives us at least an estimation of environmental effects of metals. Zinc was excluded as the source in openLCA would give ridiculously high impacts, scale 1000x of the effect of aluminium, which we deemed as impossible by comparing it to average energy intensiveness and thus a fault with the dataset. By manual calculation the little amount of zinc was not deemed to be a significant source of environmental impacts, so its exclusion is fair (18).

In addition to these, the packaging material was taken into consideration. These types of pens are individually sold and are delivered to the store in packages containing an estimated 500 pens. An average cardboard box (weighed by a team member) weighs 200 grams and thus the amount of package material per pen is 0,4 grams. The effect was small, so the packaging remained the same for the eco version.

The most notable source of emissions in the original LCA was Polystyrene(barrel). Since it's not usually recycled, its effect is hard to be improved. By comparing different options, we opted to change the material to aluminium. We scaled the weight needed for the barrel made of aluminium by aluminium's (2.7g/cm^3) and polystyrene's (1.05g/cm^3) density values so that the shape of the pen would stay the same although with increased weight. Aluminium can be almost fully recycled, it maintains a good quality after recycling and it is durable. The price difference isn't too high either with polystyrene being 1017 Euro per ton while Aluminium is around 1826 Euro per ton.(8)(9) Recycling uses up to 95% less energy and creates 95% less emissions in comparison to using virgin aluminium.(7) The other material plastic, polypropylene, can be recycled with up to 50% energy efficiency. Our greener product only uses these recycled sources.

In figures 3 and 4 we look into CO2 emissions and environmental impacts (water use) caused by the raw materials. SO2 emissions and NOx emission were investigated as well, but as the pattern follows the same trends as CO2, the graphs are not included. In each diagram the first bar represents the original product. The second bar represents the product with the barrel replaced with aluminium. The third and fourth bars represent the impact of using recycled materials of aluminium and polypropylene respectively. The 5th bar shows the impact of using both recycled materials in the same product.

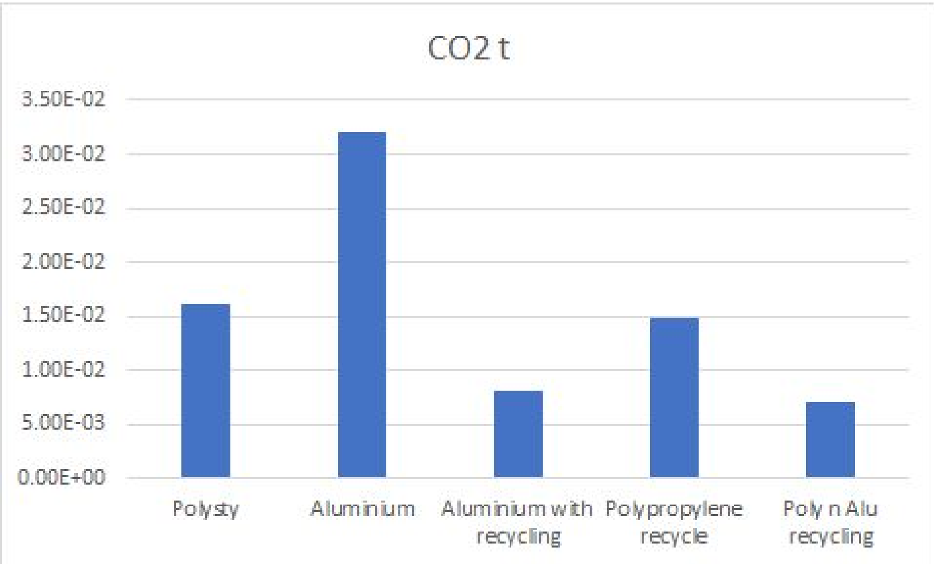

Figure 3: LCA comparison of different material for CO2

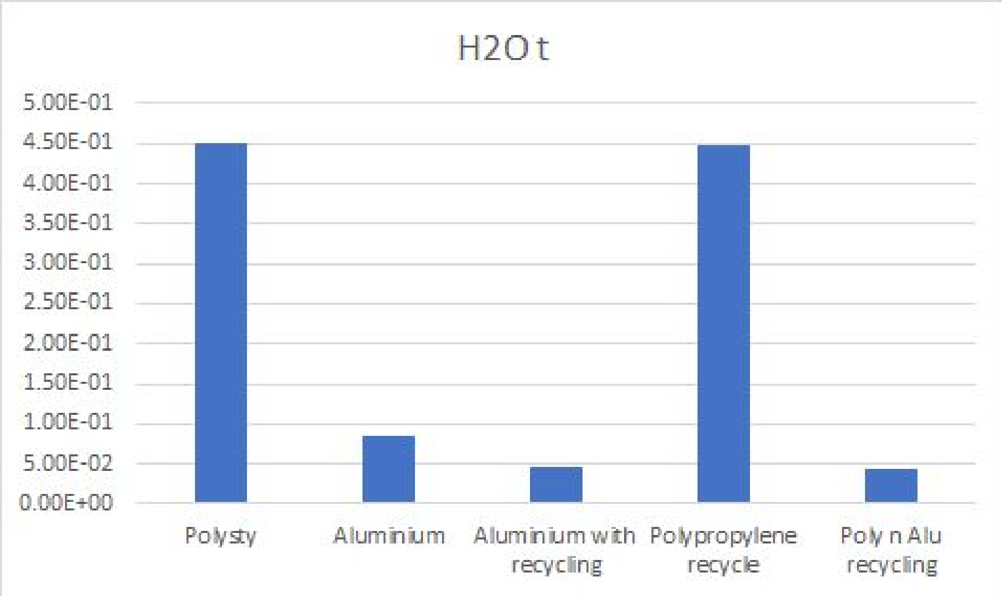

Figure 4: LCA comparison of different material for water

As seen in the graphs although virgin aluminium has a higher impact in terms of greenhouse gases released, but when recycled this is decreased so much that it becomes the best option, this combined with the minor benefits of recycling polypropylene make our pen have a lower environmental impact across the 4 most relevant categories.

We looked into replacing the metal parts to aluminum as well, but the brass and tungsten components need to be strong as most of the force is placed on them and given their small cross sectional area this force can be relatively high. Given this and the fact that the modulus of elasticity for the the metals aluminium, brass and tungsten are 68.3Gpa(4), 117Gpa(5) and 400Gpa(6) respectively we found that aluminium might be too weak for such a task. Thus, the metal parts will be kept.

The environmental effect of the ink was also assessed in LCA. The ink includes a wide variety of hazardous and environmentally taxing components such as carbon black and cobalt. We investigated the ink. The first option is an inkless pen. It is made of metal and metal instead of ink. The tip never needs to be sharpened, and will never run out. It is thus a real replacement for throwaway plastic pens. (12) Price for this kind of eco-friendly pen is significantly expensive compared to the original product, up to 3,5 more expensive. We thus concluded that this would not be reasonable for our market. Another option is soy-based ink. It is made from soybeans as opposed to petroleum-based ethanol ink. It was important that the basic qualities of the ink were kept, so that the pens would still be used and would not dry out too quickly. Although it is transported from further, Our LCA analysis concluded that it is a more environmentally friendly option than conventional ink, while maintaining a reasonable budget (13). We looked into making the ink tube replaceable, but concluded it not to be a good fit for our target market of marketing pens, as we estimated people would receive these types of pens enough and thus not prefer to pay to replace their ink.

2.2 Transportation

Sea and road freights are used for transportation of BIC pens (19). All distances were calculated with the online application searoute.com. OpenLCA takes into consideration the transport of raw material to be defined in the emissions of that material. The transportation of the pen material to be manufactured into a pen, and the transport of the ready product to Finland had to be taken into consideration separately.

Plastics and ethanol are commonly oil-based products (although they can be made of other materials as well), and America is the largest oil producer(10)). Distance was calculated from Dallas (Exxon Mobil headquarters) to Paris (BIC factory headquarters) and corresponds to 2417 NM by ship and 4459 km by truck. Metals are mostly mined and refined in China, and distance from Xiangyang (average city between large copper and zinc mines) to Paris was calculated to be 10289 km by truck.

Once the product is manufactured, it is assumed that consumers are in Finland and, once again, trucks are used for transport between Paris and Helsinki, for a total distance of 2957 km. The emissions produced by users obtaining the product, such as driving to the store or ordering office supplies to their company are excluded, as these cannot generally be affected by the pen manufacturer: BIC only sells to retailers. Once used, pens are sent to Vantaan Energia where they are burnt (11) after a 20 km truck transportation.

Note: 40 t lorry was used for this LCA, which corresponds to a payload of 27 t. Simple calculations enable us to estimate a number of 3000000 pens per truck. This number, converted in mass when needed (knowing that one pen weights 5.2 g), was used for calculations.

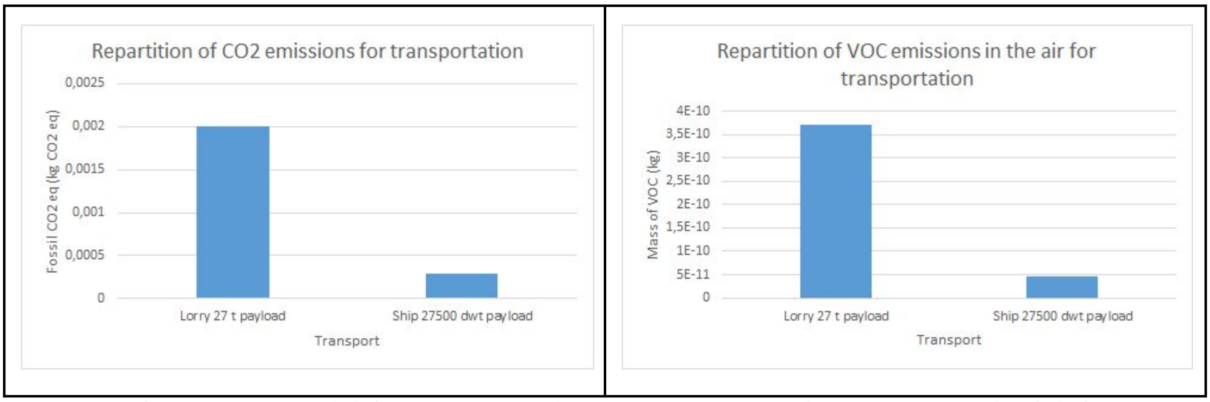

Figure 5: a) Repartition of CO2 emissions for transportation; b) Repartition of VOC (Volatile Organic Compounds) in the air for transportation.

LCA clearly shows that CO2 emissions are the highest environmental impact for transportation. Since lorries are used for the longer distances, they are responsible for most emissions. LCA analysis shows that all other environmental impacts are negligible regarding transportation. An example is given by Figure 5 b, with emissions of Volatile Organic Compounds below 10^10.

Transportation impact is low compared to the raw materials impact. But there are still possibilities to reduce it.

- Use trains instead of trucks.

- Use materials that are produced close to the manufacturing place. Plastic can be sourced from recycling and refining factory, situated close to Lyon, in France. They have the know-how to recycle polypropylene and refine it into granules and pellets. This avoids ship transportation and largely reduces the CO2 emissions.
- Since polystyrene is replaced by aluminium, a French aluminium supplier is considered, called Trimet Aluminium.
- Once used, pens are sent to a plastic recycling and refining factory in Riihimäki, Finland, (20) located at 70 km of Helsinki.
- Mine metals in Europe, for environmental, social, economic and strategic reasons (Europe competitiveness):
    - Copper mine: Kevitsa mine, Finland.
    - Zinc mine: Boliden Tara, Ireland.
    - Tungsten mine: Los Santos Mine, Spain.

By taking all of these changes into account, the transport emissions of CO2 are decreased by 63% for our green BIC pen, as seen in figure 6.

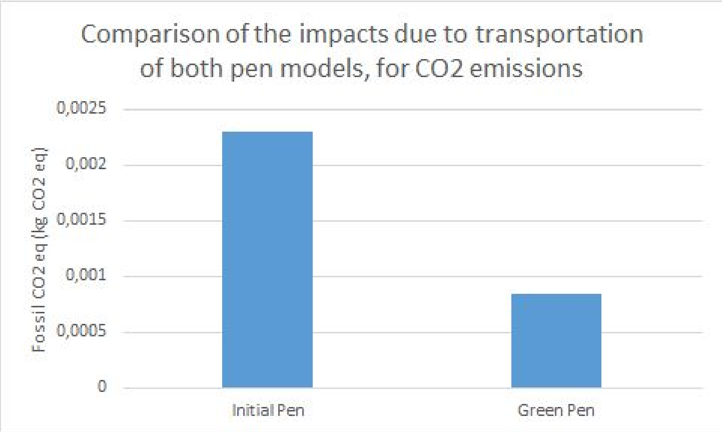

Figure 6: Comparison of LCA of transportation

2.3 Manufacture and assembly

Manufacture and assembly effects were estimated with energy use, as estimations of the life cycle emissions were not included in the OpenLCA free databases. It was estimated that manufacturing and assembling the product takes 40 MJ per kg for the metal parts and 10 MJ per kg for the plastic parts. (16,17). These were not significant compared to other effects in the original or in n the eco version.

2.4 Use Phase

While using, the only substance released is the ink. According to our measurements, there is only 0,2 g of ink in the pen. The paper that has been drawn on will in Finland be either burned or recycled. If recycled, the ink will have to be de-inked from the produced pulp. Either case, 0,2 g of ink can be assumed not to have a measurable effect. Also, paper end-of-life is out of the scope of our study, and use-phase emissions are thus excluded from the evaluation. The use phase thus in our scope produces no emissions, so there are no changes for the greener version either.

2.5 End of Life

In Finland all municipal waste is burned with only a couple exceptions. All plastic is thus either recycled or burned. For the current product we are assuming that the pen ends up in the mixed waste, because the different materials of the pen are not easily removable and sorting is thus unlikely. According to the LCA, the burning processes, especially the burning of the plastic, has significant ecotoxicity, eutrophication and acidification effects. The process also produces energy, but more energy would be saved by recycling than by burning the plastic (14). In general, even considering the energy the recycling process takes, the global warming impact of recycling plastic is 25-75 % compared to virgin plastic (15) and upt to 95% for aluminum.(7). Recyclability of the pen is thus very important for our ecopen. Aluminum to be more durable through multiple recycling cycles and is more likely to be recycled due to common recycling systems of metal. All parts of the pen are easy to be separated, and metal parts are assumed to be recycled. The saved energy by the recycling process is considered in the raw materials part: 95% percent of emissions can be saved by using recycled compared to virgin aluminum even taking into consideration the energy the recycling process takes. (7).

3. Interpretation & Conclusion

To sum up, our greener pen will be significantly more environmentally friendly. By adding up all the improvement, our greener version of the bic pen is able to cut emissions back by half. As analyzed and described above, it's polystyrene parts will be replaced with recycled aluminium, and it's polypropylene parts will be replaced by recycled polypropylene. The ink is replaced with a soy based ink formula. Transportation methods will also be altered. The product will be made easily recyclable by making the part easily separable. The product's use phase and appearance to the end user remain similar, apart from a little added weight, which means that making it greener will not affect user experience, except for the added brand value of greenness.

The eco version is a testament to recycling – the reuse of processed materials already in use all over the world instead of always starting anew and exhausting resources. Our solution is based on definitive facts and calculations on how to improve the existing form of the pen. The solution is more executable and affordable than any other solution, which means this solution can be implemented without delay and therefore helps our environment most effectively.

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