Laurine Gerlier
Alizée Sanouillet
Tram Nguyen
Jesse Räisänen
Titouan Nozais
Madina Muratova

Team 5

Task 3: Product Life Cycle Report

1. Introduction

This report presents an improved version of the typical flashlights which can be found in stores. First, the life cycle assessment of the original flashlight is performed. Then, a greener version is suggested, taking into account the most important impacts to reduce. Finally, a comparison between the two life cycle assessments was conducted, thus enabling us to show that the part of the flashlight we have to modify.

1.1. Product introduction

The Maglite Mini AA flashlight is made from an aircraft aluminium. The overall product weight is about 105.8 without packaging. The length of the flashlight is 14.6 cm. Performance according to ANSI FL1 standard: light intensity of the product is 2305 candelas, light range 96m and luminous flux 14 lumens. The runtime using the original bulb constitutes for 5h 15mins.

Figure 1: The original flashlight

1.2. Functional Unit Definition

In order to compare the two flashlights, a functional unit has to be defined. When buying a flashlight, the main feature taken into account is the electrical output. The Maglite mini AA flashlight has a ANSI FL1 rated output of 14lm [1]. When replacing the lightbulb, we will therefore have to be careful about not diminishing this light output.

2. Life cycle impact assessments

This chapter presents the life cycle impact assessments of both the original product and the improved version. First, the parts of the dismantled product are grouped by materials. After analysing the impact of different parts, an improved version is presented. After that, the two versions are compared by their CO2 equivalent values.

2.1. Inventory analysis

In order to study the product materials, the flashlight was disassembled (see Figure 2). Table 1 presents its components as well as their material composition, net weights and functions. Each component and material was examined for sustainability improvements. The product contains mainly several components which weighed below 0.5 grams, which is less than 0.5% of the total product mass. Due to the insignificant weights, those components (in grey) were excluded from the life cycle impact assessment of the product. The reason is even if improvements were made to those small components, the improved impact would be considerably little.

Figure 2: Product disassembly

Part	Material	Mass (g)	Function	Sustainability
Case	aluminum	54.5	Withstand rain, Resist if it falls	Use recycled aluminum (need to compare the energy used to produce and recycle)

2 batteries	Multiple materials	47	Provide energy	Look at rechargeable batteries,RoHS 2 compliant
Glass	PC	.4	Lets the light go through	Can be recycled
Reflector	Polystyrene, vacuum coated with aluminum	1.1	Focuses the light for more usable beam	Recycled plastic can be used
4 o-rings	Silicone	.5	Helps keep water and dirt from entering the product	Use more sustainable material, like bio-based rubber
Spring	Steel	.5	Makes and keeps electrical contact between the battery and the case	Recycled metal can be used
bulbholders metal contacts	Brass	<.1	Ensure that current goes from the battery to the light bulb	Recycled metal can be used
Light bulb	Glass, tungsten, metals	1.5	Turns electricity into light and heat	Energy Independence and Security Act compliant, look at more effective one as LED, lamp of class A++
Replacement bulb holder	Plastic	.2	Holds replacement bulb in place inside the case	
Total		**105.8**		

Table 1. Inventory analysis of the flashlight

2.2. Life cycle impact assessment of the original product

The purpose of a life cycle impact assessment (LCA) is to examine environmental impacts of a product. The life cycle impact assessment was conducted using the OpenLCA software. IPCC 2013 GWP 100a was chosen as the impact assessment method because the study aims to examine the global warming potentials of the product.

Table 2 summarizes the inventory inputs of the product components and the impact assessment results in the global warming potential value.

Part	Input (amount and unit)	Global warming potential impact result (kg CO2eq)
Case	-Aluminum -Transportation by truck [1] (20,000 km) -Electricity needed to produce aluminum	0.642
2 batteries	2 pcs AA alkaline 47g 3.7kg of CO2 per kg of product [2].	0.180
Reflector	- Polystyrene - Transportation by truck (200 km) - Energy production mix (131,8 MJ/kg)	2,617 E-3
O-rings	- Silicon (0.0005 kg) - Transportation by truck (200 km) - Energy production mix (0,071 MJ)	3.269E-3
Spring	-Ferro metal (0.5) -Transportation(9500km) -Energy production mix	3.04E-6
Light bulb	Filling gas - argon (0.0080g) Aluminum (0.0675g) Brass (0.0029g) Resin glue (0.0910g) Glass bulb (1.3240g) Lead wire (0.0059g) Filament - tungsten (0.0006g) Electricity (0.021kWh) Corrugated cardboard box (1.5g) Road transport, lorry (3g*200km)	7.46E-3

[1] We decided to consider the lamp manufacture in Germany. We had to pick a country in Europe as most data in OpenLCA are given for european countries (e.g electricity production mix). For transportation, it is assumed that the bauxite used to produce aluminum comes from Australia (Australia and China being the main bauxite producer[4]). As no data for ship transportation is available on OpenLCA, we approximate the impact by considering transportation by truck on 20,000 km which is a low approximation of the distance travelled by ships from Australia to Europe. For now, we do not need more accuracy on the impact of transportation as it is negligible compared to the aluminum production's one.

Table 2: Input and impact results of the life cycle impact analysis of the original flashlight

2.3. Improved version

The bulb of the original flashlight was deemed outdated. It was concluded that changing the bulb for a one with better efficiency was going to yield most significant improvements.

The flashlight had a run time of 5h 15min with the original bulb. [1] We assume that a typical AA alkaline battery has 2.5Wh of usable energy at these power levels. With this energy and our runtime we can calculate an electrical power of approximately 1W for the original bulb. This means an output to power ratio of 14lm/W. We chose a modern LED that can achieve an output to power ratio of up to 96lm/W. [3] This means that for the same output we would have close to **7 times** the runtime. In reality the runtime would be even longer because batteries have higher capacity when less power is drawn. Also the lifetime of LEDs is typically 50000h which means no spare LEDs needed after manufacturing. [5]

2.4. Comparisons of life cycle impact assessments

Comparison of Incandescent and LED lamps

Ample of research has been conducted to compare the environmental impacts of incandescent and LED lamps. Due to this reason, it was decided in this study not to conduct separate LCAs to compare the two options. Instead, the chosen approach was to review results from LCA research which has been conducted previously.

Several LCA studies (U.S. Department of Energy, 2012; Sangwan et al., 2014; Bertin, 2020) showed that the energy consumption of a lamp is the factor that dominates the majority of its environmental impacts over its lifetime, from manufacturing to end-of-life. Three studies included in this review made the same conclusion that a LED lamp has a significantly lower global warming potential as compared to an incandescent lamp.

Lamp type	Total lifetime light output	Power consumption (W)	Functional unit (Mlm-hr)	Global warming potential (kg CO2eq)	Summary of comparative result	Literature
Incandescent	1.35 Mlm-hr	60	20	1031.640	A LED lamp offers 88% savings in kg CO2eq as compared to an INC	U.S. Department of Energy (2012)
LED	33 Mlm-hr	6.1	20	122.772		
Incandescent	720 lm-hr	60	-	1.86E-2	The impact of manufacturing of	Sangwan et al. (2014)

manufacturing use end of life				9.98E+0 6.41E-5	a LED lamp is dominant. The energy consumption of an INC is 5-6 times higher. The end of life of an INC is higher.	
LED manufacturing use end of life	6000 lm-hr	5	-	 5.10E-2 2.00E+0 2.01E-3		
Incandescent	1.35 Mlm-hr	60	26.8	210.57	An INC consumes 9 times more energy and generates 5.8 times more CO2eq emissions.	Bertin (2020)
LED	26.8 Mlm-hr	8	26.8	27.2		

Table 3: Literature review of comparative results of incandescent (INC) and LED lamps

In table 4 we have calculated examples of battery usage during the lifetime of the flashlight. From the table we can see that the bulb makes significant improvement especially if the flashlight gets used a lot. The table only counts for the manufacturing of the alkaline batteries. Involving the recycling of batteries in the calculations would further prove the importance of efficient bulbs. We can also see that during the lifetime of the flashlight the usage of batteries has the highest impact.

Table 4: Example case of environmental impact during the use of flashlight.

Type of bulb	Usage in hours	Sets of two AA batteries used	kg of CO2 equivalent emissions of the batteries used.
Original incandescent	100	20	3.6
LED	100	3	0.54
Original incandescent	1000	200	36
LED	1000	30	5.4

3. Conclusion

All in all, the greener version of the flashlight will be considerably more environmentally friendly. The general assessment is mainly about climate change potential and therefore the ICCP assessment method was used during the LCA analysis. As described above, the main change is replacing the incandescent bulb for a LED one, so that we can reach 88% of savings in kg CO_2eq as compared to INC. During the analysis, manufacturing, use and end-of-life phases were taken into account. Therefore, we can conclude that even though the manufacturing phase of LED represents more impact to the environment, considering both use and end-of-life stages, it is more eco-friendly to replace INC to LED in order to reduce the CO_2 emissions and other impacts that can lead to global warming. When considering the number of batteries used, LED gets interesting as on the overall life of the lamp we manage to reduce considerably the number of batteries used and so the product impact. It was shown by calculations that for 1000hours of usage of the lamp with a LED, there is roughly seven times less emissions of equivalent CO_2, which depicts that the solution we are proposing is efficient. In conclusion, we can state that improved flashlight might emit up to approximately 7 times less CO2 equivalent emissions that will definitely make it a more sustainable product to use in the long term. Our solution is based on reliable sources and calculations we made during the research and overall alterations we integrated are executable.

4.References

[1]https://maglite.com/collections/compact-size/products/mini-maglite-xenon-flashlight-national-breast-cancer-foundation-xenon
[2] E.Olivetti, J.Gregory, R.Kirchain. 2010. life cycle impacts of alkaline batteries with a focus on end - of - life. Massachusetts Institute of Technology. Materials Systems Lab. Available online: https://www.epbaeurope.net/wp-content/uploads/2016/12/NEMA_alkalinelca2011.pdf
[3] https://www.digikey.com/en/products/detail/cree-inc/XPEBWT-L1-0000-00BE8/3641932
[4] Y. W. Rolando, 'The World's Leading Bauxite Producing Countries', WorldAtlas, Jun. 2019. https://www.worldatlas.com/articles/the-world-s-leading-bauxite-producing-countries.html (accessed Oct. 13, 2020).
Sangwan, K.S., Bhakara, V., Naika, S., Andratb, S.N., 2014. Life Cycle Assessment of Incandescent, Fluorescent, Compact Fluorescent and Light Emitting Diode Lamps in an Indian Scenario. Procedia CIRP 15 (2014) 467 – 472. https://core.ac.uk/download/pdf/82207343.pdf (accessed Oct. 20, 2020).
U.S. Department of Energy. 2012. Life-Cycle Assessment of Energy and Environmental Impacts of LED Lighting Products Part 2: LED Manufacturing and Performance. https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-21443.pdf (accessed Oct. 13, 2020).
Bertin, K. 2020. Life Cycle Assessment of Indoor Residential Lighting. https://www.eeca.govt.nz/assets/EECA-Resources/Research-papers-guides/Life-Cycle-Assessment-of-Indoor-Residential-Lightning-AU-NZ.pdf (accessed Oct. 20, 2020).
[5] https://www.creelighting-europe.com/en/resources/faq/