**A11 - Ethical and Environmental Analysis**

**Year: 2025 Semester: Spring Team: 15 Project: AlphaCassaeopieae**

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**Assignment Evaluation: See the Rubric in the Brightspace Assignment**

* **Environmental Impact Analysis**

**Manufacturing Processes**

The two major manufacturing processes required to manufacture our design are PCB manufacturing and extruded aluminum manufacturing for our enclosure. PCB manufacturing is inherently a pretty harmful process, as it involves a lot of raw materials such as metals, polymers, and chemicals. The plants needed to process all of these raw materials emit a lot of gases into the air, contributing to air pollution, and since chemicals are involved, any chemical runoff from these plants can contribute to water pollution [2]. Additionally, as with any time that mining metal/silicon is involved, ecosystems can be disturbed or even destroyed in the effort to obtain these natural resources. The acutal manufacturing process also generates a lot of waste and hazardous materials (etching solutions, scrap metals, and laminates), which can be tough to recycle. Furthermore, PCB manufacturing facilities are power-hungry, so the power needed to operate the manufacturing facility results in fossil fuels being released into the atmosphere. Since our design uses 4 PCBs (three unique design), manufacturing these in large quantities would have a fairly measurable impact on the environment.

In terms of the manufacturing or our enclosure, we are using an enclosure made from extruded aluminum. This process is a fairly inefficient one, according to academic literature and experts on the matter "around 40% of all aluminum cast into extrusion billets is scrapped before completion in a fabricated product, which increases the cost of the fabricated profile by approximately 16% and the greenhouse gas emissions and cumulative energy demand by approximately 40%" [3]. As with PCB manufacturing, acquisition of the raw materials needed to manufacture an aluminum enclosure can harm ecosystems during the mining process. Manufacturing facilities also contribute to emissions (as with any manufacturing process), so manufcaturing these enclosures in large quantity would have a significant environmental impact. Since we are not doing any of these processes ourselves, there is very little that we can do to reduce our environmental footprint.

**Normal Use**

The only environmental impact that our product has during normal operation is the fossil fuels burned to generate the electical power that it uses. Since our machine is wall-powered, we step the voltage down from 120V AC to 5V DC, then from 5V DC to 3.3V DC to supply to all of our components. According to the U.S. Energy Information Association, "about 62% of ttotal electricity generation in 2022 was produced from fossil fuels" [1]. Since burning fossil fuels to generate electricity releases harmful gases such as carbon monoxide/dioxide, nitrogen oxides, and sulfur dioxide into the atmosphere, we need to investigate our power footprint to determine if operation of our machine would contibute to this in a significant way. If we assume a wall adapter efficiency of 100%, our wall adapter is only drawing 5 W of power. However, once we account for the current draw from all of our components (microcontrollers, LEDs, external clock, etc.), we expect our machine to draw about 4.8A of current, and thus 15.84 W of power when operating at the 3.3V level. Seeing as a typical incandescent light bulb consumes between 40 and 150 W depending on the brightness, our machine is fairly insignificant in terms of power draw. Therefore, the electricity generated to power our machine will have little to no environmental impact during normal operation.

**Disposal & Recycling**

The disposal stage of our design is probably where the environmental impact of our design is the most felt. Since neither the aluminum enclosure or the PCBs housed within are biodegradable, careful steps must be taken by the user to reduce the impact of disposing of our product. For the enclosure, it can be recycled as scrap, at which point the paint will be stripped, and it will be shredded and melted for use in the future [4]. However, it is the responsibility of the user to dispose of this properly. If they just through it away in a normal trash can, the product will go to a landfill, where it will not biodegrade.

Likewise, if the PCBs in our design ended up in a landfill, they will not biodegrade. Additionally, "circuit boards are made from materials like mercury, lead, silver, lithium, and so on" [5]. Therefore, any PCBs in our design need to be either reused or taken to an e-waste disposal facility, which are equipped to safely dispose of old electronics with minimal environmental impact. All of these disposal instructions would be included in the instruction manual that we provide with the product if we were to bring this to market. Assuming the worst case, where users just throw it in the trash and it ends up in a landfill, the computer would simply sit in a landfill for eternity, which results in the presence of toxic chemicals (in the PCBs) in the landfill, which is not ideal.

* **Ethical Challenges**

Our design is extrememly safe overall and there is very little to worry about when bringing this product to market. Our design is very lightweight and the edges of our enclosure are rounded with no sharp edges, so anybody picking up the machine and moving it around would have no serious risks to themselves. Additionally, there are no exposed electronics other than the buttons and switches on the front panel, so there is no concern of anyone shocking themselves with our design. The only thing to consider is the connection to wall power. As mentioned earlier, our design does not draw a whole lot of power, so plugging it into the wall poses little risk when compared to something like a space heater, where plugging multiple power-hungry devices into the same receptacle poses a higher fire risk. Our design is most likely to be used on a desk or table, so it is unlikely that users would run the power cord under carpet or doorways, which would create a fire risk. On our end, as long as we were to provide a high-quality wall adapter, there would be little to no safety risks associated with our power system. Doing this would cost us a bit more to produce in mass, but it would be a worthy investment in the interest of safety and the reduction of fire risks. Another concern is that since users are interacting directly with the front panel, electro-static discharge (ESD) could potentially damage sensitive components on the front panel. While we do have some ESD protection integrated in our PCB designs, it would still be a good idea to put a warning label on the enclosure stating the electrostatic sensitivity, encouraging users to only use our design at a static-free workstation. This would ensure that if directions are followed, there is practically zero risk of users accidentally damaging the product through ESD.

**3.0 Sources Cited**

[1] U.S Energy Information Administration, “Electricity and the environment - U.S. Energy Information Administration (EIA),” Eia.gov, Dec. 06, 2021. <https://www.eia.gov/energyexplained/electricity/electricity-and-the-environment.php> (accessed Apr. 12, 2025).

[2] T. Team, “Environmental Impact of PCB Manufacturing: Building a Sustainable Future,” Tapren, Feb. 06, 2025. <https://www.tapren.com/post/environmental_impact_of_pcb_manufacturing#viewer-936r116> (accessed Apr. 12, 2025).

[3] G. Oberhausen, Y. Zhu, and D. R. Cooper, “Reducing the environmental impacts of aluminum extrusion,” Resources, Conservation and Recycling, vol. 179, p. 106120, Apr. 2022, doi: <https://doi.org/10.1016/j.resconrec.2021.106120> (accessed Apr. 12, 2025).

[4] T. Buechel, “What Is Aluminum Extrusion Scrap? A Guide to Grades, Recycling, and Value,” iScrap App, Jan. 22, 2025. <https://iscrapapp.com/blog/what-is-aluminum-extrusion-scrap/> (accessed Apr. 12, 2025).

[5] “Are Circuit Boards Recyclable? (And 6 Ways To Reuse Them) - Conserve Energy Future,” Conserve Energy Future, May 27, 2021. <https://www.conserve-energy-future.com/are-circuit-boards-recyclable.php> (accessed Apr. 12, 2025).

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