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Life Cycle Assessment of Physical Books Vs. Electronic Books

A significant modern transition is the shift from physical books to electronic books, also known as e-books. With their increasing prevalence it is important to understand e-books' effect on Earth and organisms within it, a factor often overlooked by consumers. Does this shift bring society closer or further away from sustainability? To put this into perspective, a comparison of e-books and physical books that focuses on their respective environmental impacts throughout their life cycles must be made. To do this Life Cycle Assessment (LCA) effectively, guidelines must be placed on what exactly is being analyzed. For example, e-books can be accessed through multiple electronic devices. For this analysis Amazon's Kindle will be highlighted because contrary to other devices, like laptops or tablets, the kindle's sole purpose is for reading. Since its creation in 2007 the Kindle has become the lead e-reader, allowing consumers to have hundreds of books on one lightweight device. This attribute has hooked many consumers and made the $80-$300 price tag worthwhile. Additionally, this assessment will focus on paperback books rather than hardcover, as their environmental impacts slightly differ. While some people's personal preference for physical books keeps them from completely disappearing, the demand and popularity of e-books is continually expanding. This LCA will help determine if this increase in demand is better or worse for the environment by examining the impact of physical and electronic books from their production to their disposal.

Product #1: _Physical book (paperback)____	Product #2: __E-book (Kindle)_____	Winner for this Stage with Rationale
Materials Acquisition/ Resources • The US annually uses around 32 million trees to produce books, contributing to deforestation • Tree removal contributes to climate change by releasing stored carbon and negatively impacting carbon sequestration • Almost 75% of the publishing industry's carbon footprint is due to paper use • Ink can release "toxins such as toluene, xylene, methanol, and hexane" that pollute the land, water, and air (Ritch 2009) • According to a study, paper, ink, water and additives, plates, binding glue, and plastics used in book jackets equate to 0.6kg of CO2 emissions per book (Tahara et al. 2018)	**Materials Acquisition/ Resources** • **Requires heavy mining on non-renewable resources such as fossil fuels and minerals like cobalt and led (Veltman 2024)** • E-readers "require the extraction of nearly 33lbs of minerals" and use almost 79 gallons of water (Carpenter 2016) • Mining can lead to erosion, pollution, and habitat destruction as well as being damaging to workers' health by exposing them to particulates and dangerous working conditions • While not releasing their full material list, Amazon claims to make their newest model of Kindle from 29% recycled materials, including 90% recycled magnesium (Amazon 2024) • According to a study the electronic and other parts associated with e-readers amount to .137kg of CO2 emissions (Tahara et al. 2018)	**In this category the winner is the Kindle, assuming Amazon is being honest about the origins of their materials. This is because of the sheer number of trees used in book production and the large impact deforestation has on the environment, organisms, and carbon storage. While mining and fossil fuel use both contribute to emissions as well, the research shows that the materials needed to make physical books lead to a greater output of CO2. This greenhouse gas contributes to climate change, furthering the habitat and biodiversity loss already associated with deforestation. The materials in both products lead to environmental degradation and contamination but those involved in the making of physical books are on a larger scale due to the number of books produced.**

Product #1: _Physical book (paperback)____	Product #2: __E-book (Kindle)_____	Winner for this Stage with Rationale
Materials Processing/Manufacturing • Producing physical books requires 78 times the water needed to produce e-books (Ritch 2009) • The production of a single paper book has a carbon footprint of 7.5kg (Carpenter 2016) • To make paper wood must be turned to pulp, an energy intensive process (Muller 2024) • Use of recycled paper uses 11 ounces of minerals and 7.5 liters of water to produce a book (Towler 2022) • Chemicals are used, both to enhance paper quality and in glue used to bind the book together, that can double as pollutants (Towler 2022) • Those living near factories are subject to more air/water pollution and the associated health impacts	**Materials Processing/Manufacturing** • The device itself is made from petrochemical plastics and materials extracted from earth like lithium and copper to make the battery (Towler 2022) • The manufacturing of lithium-ion batteries and use of fossil fuels is energy intensive and contributes to CO2 emissions (Carpenter 20160 • Chemicals used during production are toxic and contribute to air pollution (Towler 2022) • The production of a kindle has a carbon footprint of 168kg (Ritch 2009) • Those living near factories are subject to more air/water pollution and the associated health impacts	**The winner in this stage is physical books because of the substantial amount of energy needed to produce Kindles. The manufacturing process burns fossil fuels, contributing to global warming and all its negative environmental and human health impacts. This process also relies on fossil fuel-based plastics to produce the Kindle. The excess use of nonrenewable fossil fuels contributes to the larger carbon footprint, higher pollution potential, and greater environmental impact during this stage. The main drawback with physical books, that is not also highlighted with e-books, is significant water use but that can be offset by using recycled paper.**

Product #1: _Physical book (paperback)____	Product #2: __E-book (Kindle)_____	Winner for this Stage with Rationale
Packaging/Transportation • Obtaining books from a local bookstore or ordering them online requires fossil fuel combustion (Towler 2022) • Packaging involved in physical book delivery is made from fossil-fuel based plastics	**Packaging/Transportation** • E-readers are manufactured in China, resulting in a large reliance on fossil fuels to transport them around the world (Towler 2022) • Transporting Kindle to a warehouse, then customer's house requires use of fossil fuels • Packaging involved in Kindle delivery is made of fossil-fuel based plastics	**The winner for this stage is the physical book because of the vast distance Kindles must travel to be imported from China. Transportation of Kindles could cause damage to both marine and terrestrial life due to the emissions from the vehicles utilized. The fossil fuel dependency associated with physical books during this stage is also seen in e-books, so the need to import Kindles makes them more environmentally damaging regarding transportation.**

Product #1: _Physical book (paperback)____	Product #2: __E-book (Kindle)_____	Winner for this Stage with Rationale
Usage • Physical books can last decades and be shared amongst people • Reading at night or poorly lit places requires energy usage to see	**Usage** • The average lifespan of a kindle varies by model and care but is typically 5-8 years • The longer one uses a Kindle, the greater the emissions from electricity use (Ritch 2009) • Fully charging a kindle equates to around 8.7kWh of electricity annually, equivalent to 3.8kg CO2 (Jarvis 2023) • Use data centers to store and send e-book files that contribute to energy, land, and water usage (Muller 2024) • Kindles have “backlight, which is a huge energy saver when reading at night or dimly lit places” (Towler 2022)	**The winner in this stage is the physical book because of the lesser lifespan and increased energy usage of the Kindle, once again contributing to emissions through fossil fuel use. The more a Kindle is used, the more energy it requires while reusing or sharing a physical book decreases its environmental cost. The only time an environmental drawback is presented with physical books during this stage is when light is needed to read, requiring use of fossil fuels, but that can easily be avoided by reading during the day using natural light.**

Product #1: _Physical book (paperback)____	Product #2: __E-book (Kindle)_____	Winner for this Stage with Rationale
Disposal • **Books that are not sold often get put into landfills, making up 26% of waste** • **25% of paperback books are returned to publishers after not selling at bookstores and are either recycled, sent to landfills, or burned** • **Many publishers have begun donating unsold copies or switching to on-demand printing to reduce their waste (Veltman 2024)**	**Disposal** • **Incorrect disposal of electronic waste can lead to "toxic fumes and corrosive battery fluids" being released into the ecosystem (Towler 2022)** • **Amazon has a trade-in program where they either restore and resell used devices or recycle them to reduce consumers' electronic waste (Chen 2024)**	**The winner during this stage is the Kindle, once again assuming that Amazon is being truthful about their efforts and consumers take advantage of them. This is due to the number of physical books that end up in landfills or incinerated, leaching harmful chemicals into the biosphere that were added during the earlier stages. While efforts have been made to decrease this practice and limit waste, it is nowhere near being fully eradicated.**

After going through the life cycles of both products it is clear that neither are truly sustainable, and both currently require practices that harm both human and environmental health. Neither physical books nor e-books are built in a cradle-to-cradle fashion and they have similar negative effects on the environment stemming from their chemical, water, and energy use. At face value, the more environmentally friendly option seems to be physical books, as e-books require significant fossil fuel usage at almost every stage. Additionally, the categories in which they are more sustainable than physical books are dependent upon Amazon being honest about their practices, an attribute many companies lack when it comes to environmentalism. However, the true environmental impact of each product largely depends on the reading habits of the consumer. How many books do they read? How much time do they spend reading? Do they reread, share, or throw away physical books after reading them? All these factors contribute to the question of whether e-books or physical books are the eco-friendlier option. For the average person, reading only around 12 books a year, physical

books are the best choice. To compensate for the environmental footprint of a Kindle, largely concentrated in the manufacturing stage, one would need to read around 22.5 books a year (Ritch 2009). Seeing that it is almost double the average, for most Kindles do more harm than good. When looking at the majority of people's reading habits, the trees saved during the material acquisition process are not enough to offset the emissions given off during the rest of the product's life cycle. However, for those that consider reading as a frequent hobby and annually read a significant number of books, investing in a Kindle and taking advantage of Amazon's trade-in program when it comes time is a great way to lower one's ecological footprint.

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