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# Comparative Analysis of Carbon Footprint and Environmental Impact of Laptops

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The widespread use and mass production of desktop and laptop computers contributes to global warming. Due to the demand for increased performance and faster processing capabilities, new models of laptop computers become outdated rather quickly: a laptop's typical lifespan is between three and four years. To understand the environmental impact of different laptops from major brands, A comparative analysis is done by taking same categories (size, weight and type) laptops from different brands (Apple, HP, Dell , Microsoft, Acer, Lenovo and Asus) and compared the amount of carbon release throughout their life cycle. All the data are taken from the respective brands carbon footprint report.
**Keywords:** Life cycle assessment, Laptops, Carbon Footprint, Environmental impact.

## 1. Introduction

Background and Motivation

The use of computers, smartphones, and other consumer electronic devices (CEDs) has revolutionised communication, entertainment, and personal productivity in daily life over the past 40 years. According to estimates from the US EPA (2011), more than 900 million desktop and laptop computers as well as 700 million cathode ray tube (CRT) and flat-screen monitors have been sold in the country since 1980.

Between 2013 and 2015, the global market for personal computing devices is anticipated to grow 11%, with tablets, smartphones, and other ultramobile accounting for the majority of that growth (Gartner, 2014). Consumer electronics have many negative environmental effects, ranging from the risk of adverse effects on human and ecological health that may result from the release of toxic materials (heavy metals, flame retardants, etc.) during end-of-

life management (Wager et al., 2011) to the climate change impacts resulting from the significant embodied energy related to manufacturing and use (Teehan and Kandlikar, 2013). Given the rise in popularity of these products, manufacturers, policymakers, and consumers are searching for ways to reduce the environmental impact of electronics over their entire life cycle by promoting greener design, the use of safer materials, and increased recycling and reusing. The term "environmentally preferable" refers to "products or services that have a lesser or reduced effect on human health and the environment when compared with competing products or services that serve the same purpose." Institutional buyers in the public and private sectors are attempting to allocate their purchasing budgets towards "environmentally preferable" electronics goods. The use of raw materials, production, packaging, distribution, use, reuse, operation, maintenance, and disposal are all included in this comparison (Dodd and Wolf, 2013).

According to Moraga et al., (2022) materials should be kept in use for as long as possible to reduce waste and its effects on the environment.

The emergence of environmental standards and eco-labels for personal computers and other electronics globally reflects the demand for environmentally preferable (US EPA, 2014a) electronics. More than 16 private or public standards and eco-labels are found in a database maintained by the Global Eco-labelling Network (Global Ecolabelling Network, 2014) with regard to common CEDs like computers, printers, copiers, televisions, and cell phones. The Energy Star program, which is implemented in the US and 34 other countries, is one example of an additional standard that applies to specific CED features, such as energy use.

A laptop computer requires a lot of time and materials to construct. According to a study by the United Nations University, an average desktop computer with a monitor requires about 1.8 tons of raw materials and other natural resources to produce. A desktop computer and a 17-inch CRT monitor require 240 kilograms of fossil fuels, 22 kilograms of chemicals, and 1,500 kilograms of water to produce (Hoang, A et al., 2009). This is comparable to a mid-size car (Wilson 2004).

In order to obtain data to help the selection of environmentally friendly consumer electronics items, the objective of this study is to carry out a screening-level life cycle evaluation of a laptop. It attempts to improve knowledge of potential environmental trade-offs during the lifespans of well-known laptops from various brands, including Apple, HP, Dell, Microsoft, Acer, Lenovo, and Asus.

## 2. Literature Review

According to Canalys research (2021), the PC market in India is predicted to grow by 45% in 2021, with shipments of desktop, notebook, and tablet computers reaching 18.6 million units. This makes 2021 the Indian PC market's best year for growth since 2013, when shipment growth was 29%. Most of the market growth was driven by notebook PCs (Laptops), which accounted for 63% of all shipments with 11.8 million units, up 49% year over year (Tech Desk, 2022).

The second pandemic wave and the lockdowns hampered company operations, but they also raised demand for PCs because professionals and students were compelled to spend more

time working and studying at home. The majority of the market growth was driven by notebook PC shipments, which accounted for 63% of all shipments and increased by 49% year over year to 11.8 million units(Tech Desk, 2022).

Lenovo shipped 4.2 million units with a market share of 23% (Lenovo, 2023), trailing HP in the market (including tablets), which it led with 4.6 million units shipped in 2021(HP, 2023). After shipping 2.5 million units with a 14% market share, Dell placed a far-off third (Dell, 2023). Samsung and Acer placed fourth and fifth, respectively, with 7.2 and 6.8 percent of the market (Tech Desk, 2022).

With market shares of 25,1%, 23%, and 14%, respectively, for just notebook and desktop computers (as opposed to laptops), HP Lenovo and Dell are still in the lead. Acer comes in at fourth place with an 8.4% market share, while Apple trails in distant fifth place with a 4.7% market share due to Samsung's protracted absence from the Indian PC market (Tech Desk, 2022).

Desktop, laptop, and netbook computers are all included in the annual worldwide market share of personal computer vendors, but mobile devices, such as tablet computers that do not fit into the category of 2-in-1 PCs, are not (Rimol & Howley, 2023).

Table 1: Ranking of different laptop brands on the basis of Market Share (Q1 2022)

| Ranking | Laptop Brands | Share |
|---|---|---|
| 1 | Lenovo | 23.8% |
| 2 | HP | 20.4% |
| 3 | Dell | 17.7% |
| 4 | Apple | 9.0% |
| 5 | Acer | 7.2% |
| 6 | Asus | 7.1% |
| | Others | 14.8% |

How do laptops effect the environments?

A laptop's estimated average carbon footprint is 422.5 kg, which takes into account emissions from manufacturing, shipping, and the first four years of use (Haughton, 2021).

The amount of CO2 released by a laptop varies considerably depending on the maker, the size of the device, and the frequency of usage, which should be noted. Due to the uncertainty of their calculations, all manufacturers' estimates suggest that the CO2 could vary by +/- 15 to 20% (Haughton, 2021).

What is a carbon footprint?

A carbon footprint is the total amount of greenhouse gases—like carbon dioxide and methane—that are produced as a result of our actions.

Usually, the first thing we look at when calculating a laptop's carbon footprint is how much energy it consumes. According to Lars Meiritz, vice-president of Gartner, just 20% of the environmental impact of a laptop is attributable to its use, even if a laptop used for 8 hours a day generates between 44 and 88 kg of CO2 yearly. Then what about the other 80%? (Meiritz, 2021).

The carbon footprint of laptops has become a significant concern, and researchers are exploring ways to reduce their environmental impact. For example, Li et al. (2020) propose a

circular economy framework for laptop design and manufacturing, which considers the entire lifecycle of the device and aims to reduce resource consumption, waste generation, and carbon emissions. The framework includes three phases: design for durability and repair, design for disassembly and recycling, and design for circularity.

Furthermore, there is a growing trend towards sustainable laptops made from recycled materials. Dell, for example, has developed a laptop made from recycled ocean plastic, while HP has launched a laptop made from recycled aluminum (Hsu, 2021). However, sustainable laptops are currently more expensive than traditional laptops, which may limit their widespread adoption.

In conclusion, the increased demand for laptops has a negative impact on the environment, and it is essential to consider the entire lifecycle of the device when analyzing its environmental impact. Researchers are exploring ways to reduce the carbon footprint of laptops, such as circular economy frameworks and sustainable materials. However, these solutions are currently more expensive than traditional laptops, which may limit their adoption. It is crucial to continue research and innovation to reduce the environmental impact of laptops while also meeting the growing demand for these devices.

## 3. Methodology

In this study, carbon emission was calculated on the basis of carbon footprint reports of different brands of similar specification laptop models which is collected from their respective official website and after that a comparison of these details is performed so that one can easily understand and differentiate between them on the basis of their carbon emission.

These are the models of the laptops of respective brands are taken for comparisons:

1. Apple MacBook Air Laptop with M2 chip: 13.6-inch Liquid Retina Display, 8GB RAM, 256GB SSD, 1.2 Kg.

2. HP Envy 11th Gen Intel Core i5: 14-inch, 16GB RAM, 1TB SSD, 1.59Kg.

3. Dell XPS 13 9370 Core i5: 13.3-inch, 8GB RAM, 128GB SSD, 1.27 Kg.

4. Microsoft Surface Laptop 5: 13.5" Intel® Evo™12th Gen Core™ i7, 16GB RAM, 256GB SSD, 1.288Kg.

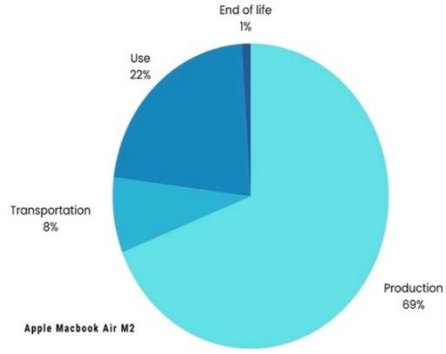
5. Acer TravelMate TMP614-52-73EJ 14-inch, Intel Core i7, 16 GB RAM, 512GB SSD, 1.1Kg.

6. Lenovo ThinkBook 13s G3 ACN: 13.3-inch, AMD Ryzen 7, 16 GB RAM, 512 GB SSD, 1.26Kg.

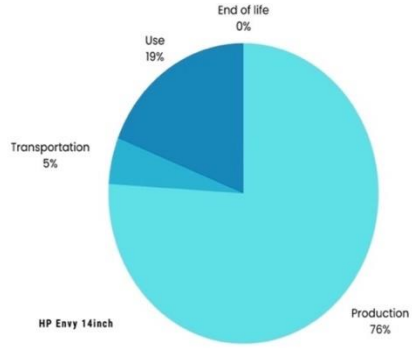
7. Asus ZenBook 14X OLED (UX5401Z): 14-inch, Intel Core i5, 16GB, 512GB SSD, 1.4Kg.

And their carbon footprint are show below which is extracted from their respective official website and percentage contribution of all phases during whole life cycle of laptops are also shown with the help of pie chart respectively as show below:

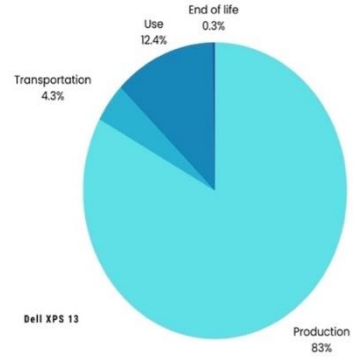
1. Apple **MacBook Air** Laptop with **M2** chip: According to Carbon Footprint report of Apple MacBook Air, its produce total 147 kg carbon emissions, which is classified as (Apple, 2022):
    - 69% Production
    - 8% Transport
    - 22% Use
    - <1% End-of-life processing



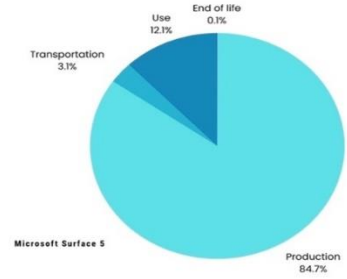

2. **HP Envy** 11th Gen Intel Core i5: **14-inch**: According to Carbon Footprint report, its produce total 206 kg carbon emissions, which is classified as (HP, 2021):
    - 76% Production
    - 5% Transport
    - 19% Use
    - 0% End-of-life processing




3. **Dell** XPS 13 9370 Core i5: **13.3-inch**: According to Carbon Footprint report, its produce total 297 kg carbon emissions, which is classified as (Dell, 2018):
    - 83% Production
    - 4.3% Transport
    - 12.4% Use
    - 0.3% End-of-life processing




4. **Microsoft Surface Laptop 5: 13.5 inch**: According to Carbon Footprint report, its produce total 255 kg carbon emissions, which is classified as (Microsoft, 2022):
    - 84.7% Production
    - 3.1% Transport
    - 12.1% Use
    - 0.1% End-of-life processing



7. **Asus ZenBook 14X OLED (UX5401Z): 14-inch**:
According to Carbon Footprint report, produce total 281 kg carbon emissions, which is classified as (Asus, 2022):
    - 70.3% Production
    - 2.7% Transport
    - 26.9% Use
    - 0.1% End-of-life processing

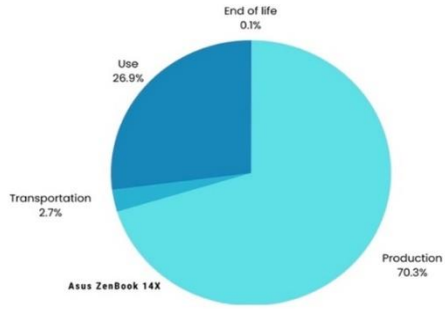



Figure 1, demonstrates the system boundary of LCA study of laptops, in which manufacturing stages includes raw material acquisition, production, packaging, and transportation. At the phase of use it includes the energy consumption and part replacements for maintenance. Lastly during end of life phase in includes waste management such as landfill or incineration, reuse, recycling.

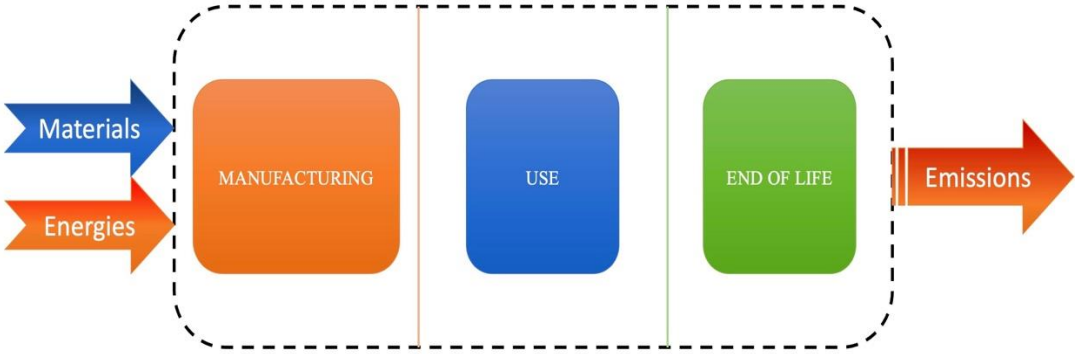



Fig. 1: System boundary of LCA study of Laptops

## 4. Results and Discussion

The study compared the carbon emissions of seven similar categories laptop models from different brands, based on their carbon footprint reports. The laptops included in the study were: Apple MacBook Air M2, HP Envy, Dell XPS 13, Microsoft Surface 5 Laptop, Acer TravelMate, Lenovo ThinkBook 13s G3, and Asus ZenBook 14X OLED.

Table 2: Product's estimated Carbon Footprint for whole Life Cycle:

| Carbon Footprint | Apple MacBook Air M2 (Kg CO2) | HP ENVY Laptop 14-eb0020TX (Kg CO2) | Dell XPS 13 9370 (Kg CO2) | Microsoft Surface Laptop 5 (Kg CO2) | Acer TMP614-52 Business Notebook (Kg CO2) | Lenovo ThinkBook 13s G3 ACN (Kg CO2) | Asus ZenBook 14X OLED (Kg CO2) |
|---|---|---|---|---|---|---|---|
| Manufacturing | 101.43 | 156.56 | 246.51 | 215.5 | 46.50 | 379.68 | 197.54 |
| Transportation | 11.76 | 10.30 | 12.77 | 8 | 2.31 | 13.56 | 7.58 |
| Product Use | 32.34 | 39.14 | 36.83 | 30.5 | 92.18 | 58.76 | 75.58 |
| End of Life | 1.47 | 0 | 0.89 | 1 | 0.01 | 0 | 0.3 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Total | 147 | 206 | 297 | 255 | 141 | 452 | 281 |

The results show in Table 2 that the carbon emissions produced by the laptops vary significantly, with the lowest carbon emissions of 141 kg produced by Acer TravelMate and the highest carbon emissions of 452 kg produced by Lenovo ThinkBook. The breakdown of carbon emissions by production, transport, use, and end-of-life processing also varies among the laptop models. For example, the carbon emissions from production ranged from 46.50kg for Acer TravelMate to 379.68kg for Lenovo ThinkBook. The carbon emissions from use ranged from 30.5kg for Microsoft Surface Laptop to 92.18kg for Acer TravelMate. This variation in different phases are shown in Figure 2.

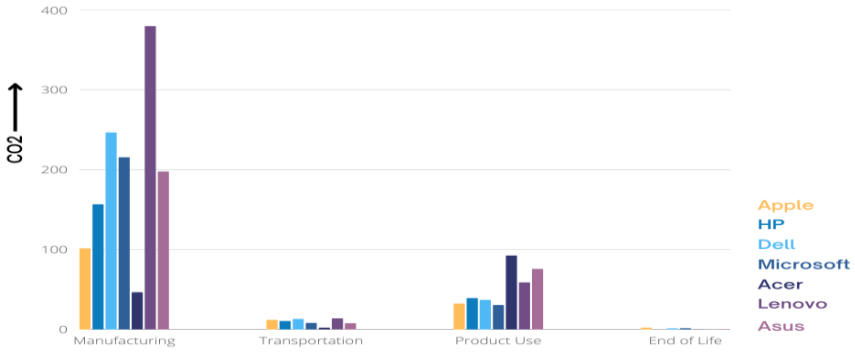



Fig 2. Variation of carbon emission at different phases of life cycle.

The results indicate that the carbon emissions of a laptop are influenced by various factors, such as the materials used in production, the manufacturing process, energy efficiency during use, and waste management practices. The findings of this study can help consumers make more informed decisions about the environmental impact of their purchasing choices and also encourage manufacturers to adopt more sustainable practices in their production processes.

If we calculate carbon emission of these selected laptops on the scale of 0 to 500 Kg $CO_2$ emission, the environmental performance percentage of these laptops can easily become more understandable as show below in Table 3 and a graphical represented also show below for ease of visualisation in Figure 3:

Table 3: On scale from 0 to 500 kg $CO_2$ emission

| Laptops | Percentage |
|---|---|
| Acer | 28.2% |
| Apple | 29.4% |
| HP | 41.2% |
| Dell | 59.4% |
| Asus | 56.2% |
| Microsoft | 51% |
| lenovo | 90.4% |

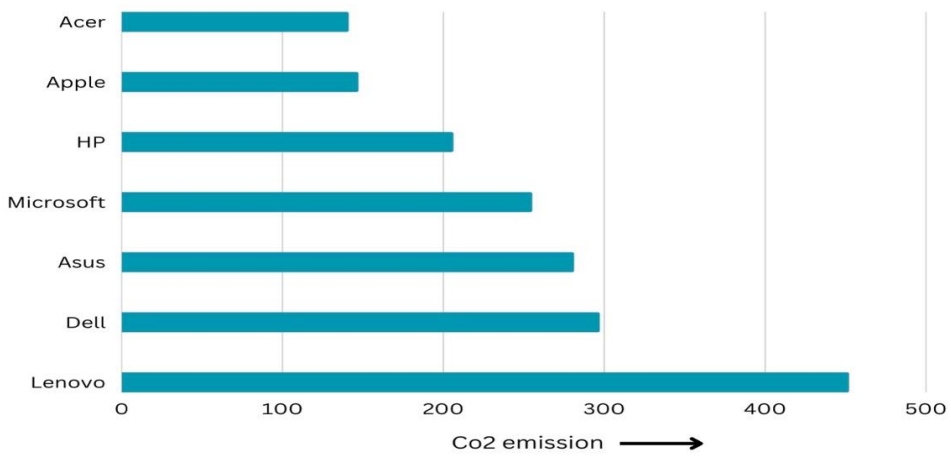



Fig 3. Graphical representation of carbon emission of selected brands on the scale of 0 to 500 kg $CO_2$ emission

## 5. Conclusion

In this study, the carbon emissions of seven laptop models were compared based on their carbon footprint reports.

The laptops included in the study were Apple MacBook Air, HP Envy, Dell XPS, Microsoft Surface Laptop, Acer TravelMate, Lenovo ThinkBook, and Asus ZenBook.

The results show that the carbon emissions produced by the laptops vary significantly, with the lowest carbon emissions of 141 kg produced by Acer TravelMate and the highest carbon emissions of 452 kg produced by Lenovo ThinkBook.

The breakdown of carbon emissions by production, transport, use, and end-of-life processing also varies among the laptop models.

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