Quantis

Life Cycle Assessment of the HP Pro x2 612 G2 Tablet in the United States

Life cycle inventories and impact assessment of the HP Pro x2 612 G2 Tablet – Final Summary Report

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Context and objectives

The overarching goal of this work is to provide an ISO-compliant environmental life cycle assessment (LCA) of a tablet PC product. This LCA report will be suitable for both internal use and to support broader communication. Achieving these goals will allow HP to:

- Understand the environmental impacts of the full product life cycle of one of its products;
- Identify key environmental hotspots within the product life cycle and evaluate strategies for improving performance;
- Understand how it might communicate this information;
- Capture the EPEAT points available for conducting an ISO compliant LCA; and
- Gain recognition through environmental leadership.

To these ends, HP has commissioned Quantis to carry out an LCA of the HP Pro x2 612 G2 Tablet. The LCI and LCA conform to the International Organization for Standardization (ISO) 14040:2006 (ISO 2006a) and 14044:2006 (ISO 2006b) standards and includes a critical review by an external LCA expert. The results of this study apply only to the product within its own context. It is not intended to reach comparative conclusions between the product examined and other products.

This report is intended to provide information about the potential environmental impacts of one product in a clear and useful manner. HP may elect to share this report with external audiences such as partners, suppliers, customers, and the public.

Methodology

LCA is a leading tool for assessing environmental performance. The International Organization for Standardization (ISO) provides standards with which to perform it, namely the 14040-14044 standards (ISO 2006a; ISO 2006b). LCA is an internationally-recognized approach that evaluates the relative potential environmental and human health impacts of products and services throughout their life cycle, beginning with raw material extraction and including all aspects of transportation, production, use, and end-of-life treatment. Among other uses, LCAs can identify opportunities to improve the environmental performance of products, inform decision-making, and support marketing, communication, and educational efforts.

The functional unit for this study is **the HP Pro x2 612 G2 tablet over a useful lifetime of 5 years, by a heavy user/office use profile of 10.1 hours per day, five days a week, in the United States**. This study includes all life cycle stages of HP Pro x2 612 G2 Tablet, from cradle to grave (extraction and processing of raw materials through the end-of-life of all components). All of the systems are assumed to be transported from assembly in Taiwan for use and disposal in the United States. The tablet was evaluated in terms of the following principal life cycle stages:

Materials processing (and component production): extraction and processing of material inputs for the tablet as well as production of electronic components. See Section 6 for a complete bill of materials and components included based on tear down data.

The packaging considered in this study includes primary packaging data as supplied from a tear-down analysis. Secondary and tertiary packaging, such as boxes to aggregate tablets and wooden pallets, are not considered in this study as the impacts of such packaging across each tablet is assumed to be negligible.

Assembly: processing and assembly of materials into finished products. Energy and ancillary materials are included. Assembly takes place in Taipei, Taiwan. A region-specific electricity grid mix along with relevant emission factors will be applied to the production of electricity used in assembly. Included infrastructure data (factory and equipment) is based on the production volume.

Transport: is comprised of two parts:

- *Delivery*: transportation by various modes from raw material production sites to the assembly site in Taipei.
- *Distribution*: This study assumes all tablets are sold directly to end consumer; therefore, retail is not relevant. This stage includes transportation by plane from assembly in Taipei to the final consumer in the United States.

Purchase: Purchase is assumed to be done directly by the final consumer online. The energy use for the online purchase is expected to be negligible compared to the other categories and therefore not included.

Use: electricity required for operation, which is assumed to take place in the United States. Although HP markets its products in numerous countries, the present assessment focuses on the sale to the US consumer market only.

End-of-life (EoL): transportation and waste management, including landfilling, recycling, and waste-to-energy.

A bill of materials from an iFixit (2016/2017) teardown are used to support the modeling of the tablet's electronic and material components, and data gaps are supplied by HP direct measurement (2017). Data for other assumptions, such as transportation distances, modes, and efficiency, are supplied from HP and a variety of publications. Particularly, published studies from the US Environmental Protection Agency (US EPA) provide rates for EoL treatment options.

All life cycle inventory are drawn from the *ecoinvent* v3.3 database (SCLCI 2016) with only a few modifications by the modelers to better represent current electronics and processing. The peer-reviewed impact assessment methods RECIPE H 2016 Midpoint (H) (Huijbregts et al. 2016), IPCC 2013 GWP 100a (v1.02), and Cumulative Energy Demand (v1.09) (Frischknecht R. Jungbluth, et al. 2003) are used for the impact assessment phase of the study, evaluating a variety of midpoint indicators. To meet the requirements for IEEE 1680.1, the following four indicators must be reported:

- Global warming potential (represented with the "IPCC GWP 100a" result (IPCC 2013))
- Acidification potential (represented with the "Terrestrial acidification" result (Frischknecht R. Jungbluth, et al. 2003))

- Water consumption (Frischknecht R. Jungbluth, et al. 2003), and
- Primary energy demand (represented with the "Cumulative energy demand" result (Frischknecht R. Jungbluth, et al. 2003))

Results and conclusions

The baseline results (shown in Figure 1) reveal that for the HP Pro x2 612 G2 tablet, used over five years in the United States by an office user, most potential environmental impact occurs in the Materials processing stage for all indicators except Ionizing radiation. The Use stage is the second most contributing, although it is more important than the Materials processing stage in terms of Ionizing radiation.

For some indicators, such as Global warming potential (GWP), Fossil resource scarcity, and Ozone formation, Distribution is a meaningful contributor. For other indicators, such as Water consumption and Marine and Freshwater ecotoxicity, Assembly is important. The stages of Delivery and EoL are relatively small contributors to impact for all indicators.

The GWP indicator result is approximately 295 kgCO_2-e, which is equivalent to the emissions of driving 723 miles in an average passenger vehicle[1].

The acronyms used in Figure 1 are defined as the following:

- kg CO_2 eq: kilograms of carbon dioxide equivalents
- GJ: gigajoules
- m^3: cubic meters of freshwater
- kg oil eq: kilograms of oil equivalents
- kg Cu eq: kilograms of copper equivalents
- m^2a crop eq: square meters x years of agricultural land use equivalents
- kg 1,4-DBC e: kilograms of 1,4 dichlorobenzene equivalents
- kg P eq: kilograms of phosphorus equivalents
- kg SO_2 eq: kilograms of sulfur dioxide equivalents
- kg NOx eq: kilograms of oxides of nitrogen equivalents
- kg $PM_{2.5}$ eq: kilograms of particulate matter 2.5 micrometer equivalents
- kBq Co-60 eq: kilobecquerels of cobalt-60 equivalents
- kg CFC-11 eq: kilograms of trichlorofluoromethane equivalents

[1] US EPA Greenhouse Gas Equivalencies Calculator: https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator

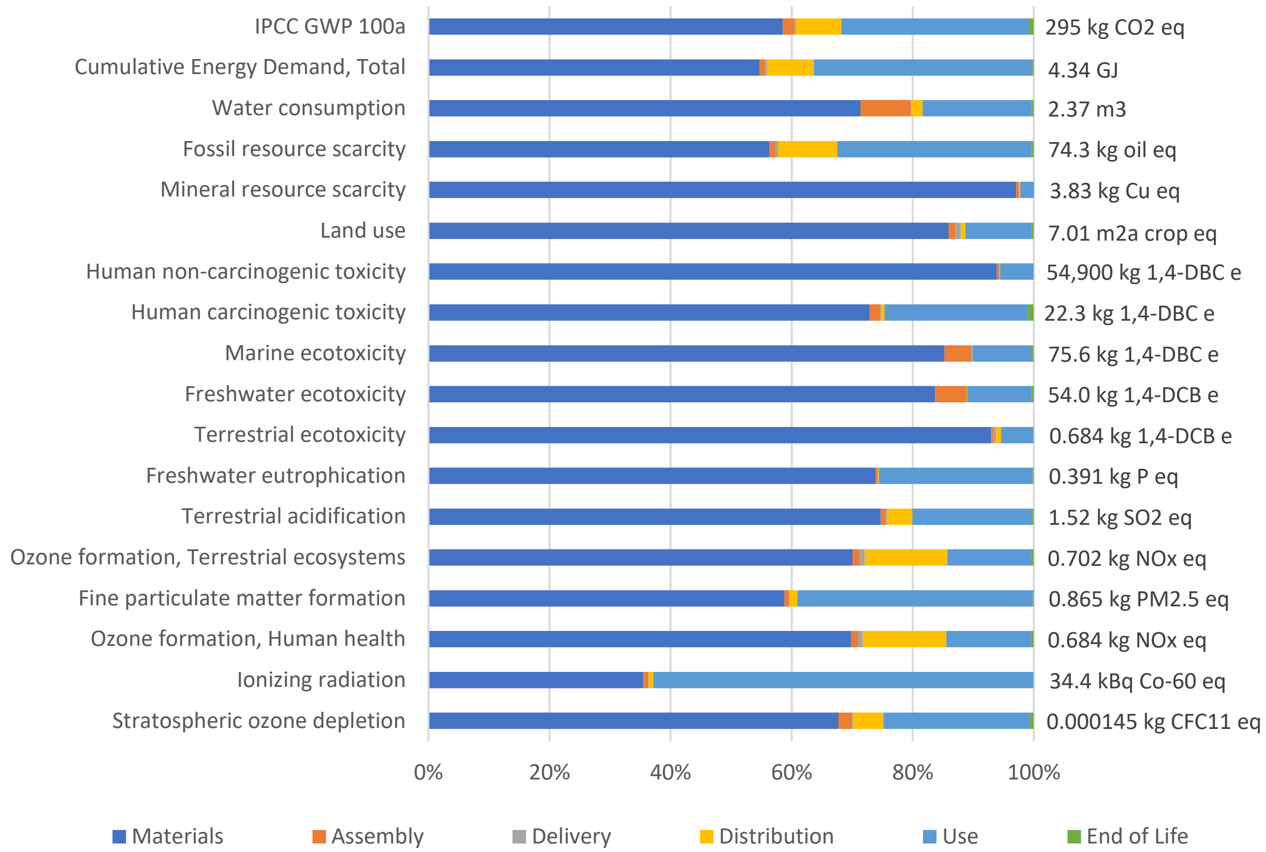

Figure 1. Contribution to overall impact of the life cycle stages, as a percentage of each indicator score (ReCiPe 2016 Midpoint (H), IPCC 2013GWP100a V1.00 and Cumulative Energy Demand v1.09)

As a benchmarking exercise, the results of this full LCA were compared to those of the Product-Attributes-to-Impact-Algorithm (PAIA) streamlining tool for tablets, which was designed to rapidly estimate the GWP of tablet computers (MIT 2017). The results of this study align closely with results of the PAIA tablet tool using similar inputs (mean results fall within 17% of one another), helping to validate these results as well as those of PAIA. Although meaningful, direct comparisons with similar tablet LCAs cannot be made due to differences in functional unit and goal and scope assumptions, the results of this study are reasonable in the context of those other studies.

To improve the accuracy of the LCA results, more representative LCI data could be sought out. The datasets applied here for transistors and other electronic components tend to represent older technology (from the early 2000's) and therefore may overestimate impacts. If transistors, capacitors and resistors were to have 50% lower impact relative to the outdated data used here, this would have the effect of reducing their contributions from 4.9% to 2.5% of the overall impact for Ionizing radiation, from 16.7% to 9.1% of the overall impact for Terrestrial acidification, and from 5.8% to 3.0% of overall results for GWP for the tablet over its life cycle. The overall GWP result would drop from 295 to 286 kgCO2-e.

Given the importance of the use stage to the overall impact of the tablet's life cycle, it is important to understand how the results might vary under different assumptions. The assumptions of interest are the yearly typical energy consumption (TEC) and the useful lifetime. If we were to assume more moderate daily use, instead of a heavy, office use profile, the short idle time per day might be closer to 5.6 hours per day than 10.1 hours per day, five days per week. If we were to assume a shorter useful lifetime, we might reduce it from five years to three. Combining these would have the effect of reducing the tablet's life cycle indicator results from a minimum of 1.3% for Mineral resource scarcity to a maximum of 36.5% for Ionizing radiation. The effect on GWP would be a reduction to 241 kgCO2-e.

Furthermore, given the importance of material and electronic component choices to the overall potential environmental impacts of a tablet PC, the lessons learned from this study would be valuable to product designers. Tools might be developed to enable designers to know the sensitivity of potential impacts to various design decisions, including material choices, PWB size, IC integration and the correlation of component manufacturing with use of renewable energies for that manufacturing. The key in designing such tools would be to ensure they are easily available and useable.

There is also an opportunity to leverage the outcomes of this work to provide educational materials to consumers on the importance of maximizing their productive use of the equipment. Specifically, communications might focus on minimizing the number of devices used, maximizing the utilization of those devices, and maximizing the useful lifetime of each device. Additionally, given the importance of the use stage to the overall potential impacts, consumers should continue to be educated on the importance of optimizing use by reducing time spent idling.