aguaro & resilio

SUMMARY NOTE

Environmental impacts of IT equipment

A comparative analysis - Resilio Database and 'Product Carbon Footprint' sheets

October 2024

Abstract

This document presents a summary of the work carried out to **compare the environmental impacts** for about twenty **laptop models**, published by the manufacturers in their **'Product Carbon Footprint'** (PCF) sheets and estimated by Resilio based on a **Life Cycle Assessment (LCA) methodology**. The aim is to identify the reasons for differences in impacts between different sources providing environmental impact values for digital products and services (public and private databases, manufacturers' declarations, etc.).

The analysis is based on PCF sheets from **Dell** and **HP**, as well as modelling of the impacts of the same models in **Resilio Database**. The comparison is based on overall impacts and a breakdown by component (chassis, mainboard, storage), to analyse differences and correlations.

This study shows that the analysed impacts of the PCF and Resilio-DB files are in the **same order of magnitude**. According to these two sources, the impact on the climate change indicator for a standard office laptop is between 175 and 300 kg eq. CO_2, depending on its technical configuration.

However, an in-depth analysis of the impacts given in the PCF sheets from the two manufacturers, along with the quantities deemed crucial for modelling (screen size, amount of SSD storage, etc.), shows no clear correlation on these parameters. This **lack of clear correlation** can be explained by a number of limitations identified in this study: **discrepancies between the equipment configurations** in the PCF sheets and the Resilio Database modelling, **different versions of calculator** for the PCF sheets making them **inhomogeneous** with each other. The lack of information on the modelling of the PCF sheets prevents us from taking the analysis further to understand the origin of these differences in impact.

From this analysis, we see that **transparency of methodology** is a crucial condition for the disclosure of environmental impacts. Indeed, it makes it possible to analyse the modelling in depth, without which a true comparison is not possible.

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Summary

1. Introduction

This document is the synthesis of the comparison of environmental impacts for around twenty laptops, published by the manufacturers in their 'Product Carbon Footprint' (PCF*[1]) files, and modelled by Resilio.

This work was prompted by the recurring question of how to compare the various sources providing environmental impact values for digital products and services. The generic databases (Base Empreinte ADEME, NegaOctet, ResilioDatabase, BoaviztAPI, etc.) come with documentation (of varying degrees of detail) that allows methodologies to be compared. However, this is not the case with the PCF files, which are not transparent about the methodology used.

The analysis carried out here focuses solely on the laptop category[2]. We are unable to explain certain differences in results between the two methodologies due to the lack of transparency on PCFs.

2. Methodology

2.1 Data

Aguaro has compiled PCF sheets from several manufacturers and extracted data from them. The results available on the PCF sheets are as follows:

- Total impact on climate change indicator* (kg CO_2 eq.)
- Uncertainty on total impact
- Impact broken down by life cycle stage (Manufacturing, Distribution, Use, End of life)
- For the manufacturing phase, impact broken down by component (chassis, battery, screen, motherboard + electronic components, storage)

Resilio extracted the impacts from the Resilio Database (ResilioDB) corresponding to the models in the PCF sheets supplied by Aguaro. The exact configurations used in the PCF sheets are not given. As an example, we have presented below the assumptions used for the Dell Latitude 5530 in the PCF sheet.

Assumptions for calculation a carbon footprint

Product Weight	1,78 Kg	**Screen Size**	15.6"	**Assembly Location**	China
Product Lifetime	4 years	**Use Location**	EU	**Energy Demand (Yearly TEC)**	25.21 kWh

1 Words followed by a star are defined in the glossary.

2 This work could be extended to cover a wider range of equipment. Resilio Database contains more than 15 categories of equipment, and Aguaro has collected around 2500 PCF files.

Therefore, for each model, an average configuration representative of the configurations offered on manufacturer or retailer websites is used for modelling in ResilioDB. The results available for analysis are as follows:

- Total impact on the climate change indicator (kg CO_2 eq.)
- Impact broken down by life cycle stage (Manufacturing, Distribution, Use, End of life)
- For the manufacturing phase, impact broken down by components (fixed part, motherboard, CPU, RAM, integrated graphics card, storage)
- This study focuses on laptops and initially on the following subset:
- 8 Dell models
- 11 HP models

This subset of PCF sheets was chosen from among those displaying a sufficiently detailed breakdown of impacts. In fact, some PCF sheets only show a breakdown of impacts by life cycle stage, as shown in the figure opposite. In addition, the models were chosen from among those available in ResilioDB in order to be able to carry out the comparison.

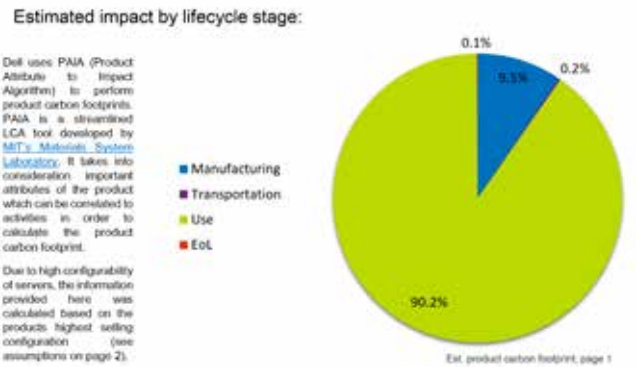


Figure : Example of the results of a PCF sheet showing only the breakdown of impacts by life cycle stage[3]

Details of the models are available in Appendix 1.

2.2 Analysis methodology

The comparative analysis of impacts covers the overall impacts as well as the impacts of the various components. Concerning the use phase, no information is provided on the electricity mix used in the PCF sheets. The use phase is therefore excluded from the analysis. The following data are compared:

- **Overall** manufacturing + distribution + end-of-life impacts
- **Impacts of the manufacturing** phase on the various components

As the impact analysis used to supply the PCF sheets is not carried out using the same tools from one manufacturer to another, the comparison distinguishes between the two manufacturers.

The analysis by component is divided into the following categories:

- **'Fixed part':** Corresponding to the screen, battery and chassis
- **'Mainboard':** Corresponding to the motherboard, processor (or CPU), RAM and integrated graphics card
- **'Storage':** Corresponding to the SSD and HDD storage disks.

As the climate change indicator is the only one available on the PCF sheets, it is the only environmental indicator presented in this document. It is abbreviated GWP (Global Warming Potential) in the rest of the document.

3 Source : https://i.dell.com/sites/csdocuments/CorpComm_Docs/en/carbon-footprint-poweredge-c4130.pdf

2.3 Modelling methodology for PCF sheets

A Product Carbon Footprint (PCF) is a carbon footprint statement published by manufacturers and not subject to verification. The environmental impact results are provided using simplified Life Cycle Assessment* (LCA) tools such as PAIA (Product Attributes to Impact Algorithm)[4] in the field of Information and Communication Technologies (ICT). Here, in the case of HP and Dell, the two manufacturers are using the same PAIA tool.

PAIA works by establishing a correspondence between the major components of a product (according to their environmental impact and/or their importance) and their environmental impact at each stage of the life cycle. The calculation can then be automated based on pre-existing scenarios and the attributes associated with the product. The Figure below shows an example of how this works for a laptop.

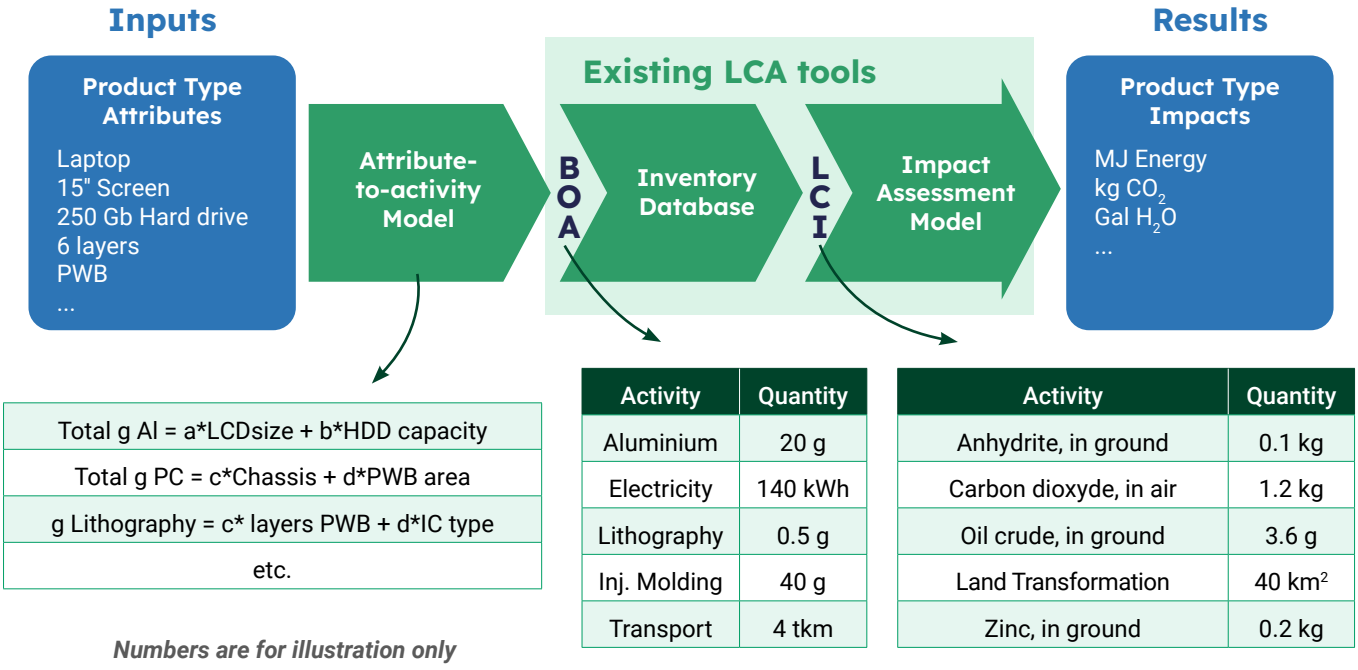


Figure: Diagram of PAIA methodology with the example of a laptop[5]

It is therefore clear that without an explanation of the overall methodology used (scope, assumptions, etc.), the comparison of different products in the same category from different manufacturers is very limited.

As far as emission factors are concerned, we know that generic databases are used. However, we do not have any further information (original database, version, year, nature of the emissions factors, uncertainties, etc.) that would enable us to understand how these PCFs are constructed.

4 https://quantis.com/who-we-guide/our-impact/sustainability-initiatives/paia/

5 Figure based on : http://msl.mit.edu/projects/paia/paia-research-approach

2.4 Modelling methodology in Resilio Database

Resilio Database is a dynamic environmental footprint database for digital products. It follows the LCA methodology[6].

The environmental impacts displayed do not come from equipment manufacturers. Nor is it a complete LCA of a specific manufacturer's model. The models proposed (laptop, server, screen, etc.) are parametric representations of the environmental impacts for each category of equipment. They are intended to be representative of most of the equipment in this category. For each specific piece of equipment (Laptop X from manufacturer Y), the corresponding model is 'fed' with the technical specifications of the equipment to be assessed.

The advantage of this dynamic or parametric approach is that it strikes the right balance between impact accuracy and LCA scaling. It also makes it easier to update the models, which is vital in the fast-moving field of digital technology.

The modelling of a category of IT equipment always follows the same bottom-up approach:

- **Manufacturing and end-of-life:**

How it works	Types of parameters	Types of sources
• Breakdown of the equipment into subcomponents • Parametric modelling of the environmental impacts of each component • Sum of the impacts of each component	• Mass or surface area of material, type of material • Technical configuration of equipment (CPU/GPU model, amount of RAM/storage, screen size, etc.)	• Scientific literature • Benchmarks carried out on samples of marketed equipment • Databases • Own research

- **Distribution:**

How it works	Types of parameters	Types of sources
• Definition of a typical transport profile based on equipment categories (aeroplane, boat, train, truck)	• Weight of equipment • Distance covered	• Scientific literature • LCA and public reports • Databases

- **Use:**

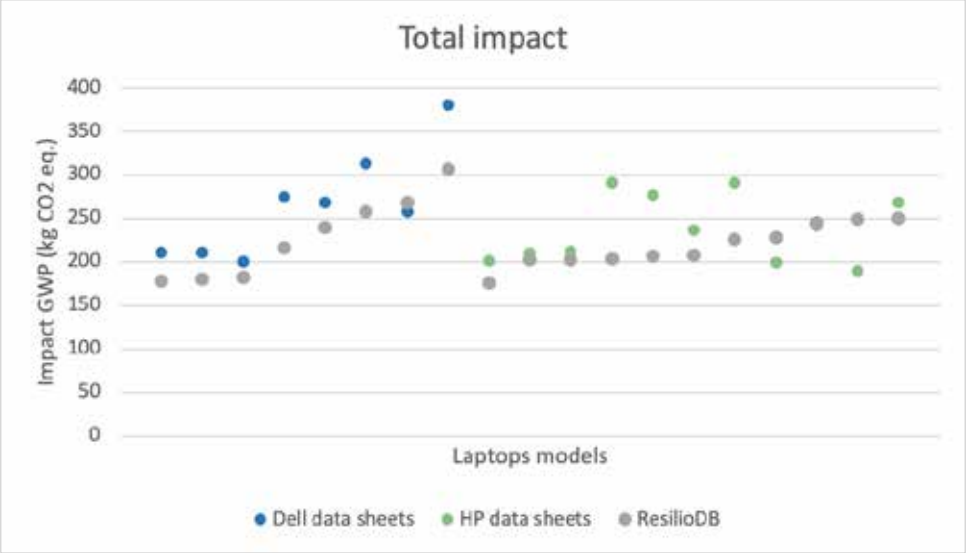
How it works	Types of parameters	Types of sources
• Proposed average generic consumption value	• Usage profile • Load rate	• Scientific literature • LCA and public reports • Databases

6 Source : https://db.resilio.tech/docs

3. Main results for laptops

3.1 Total results

The graph below shows the comparative impact on the climate change indicator (in kg eq. CO_2) of the manufacturing, distribution and end-of-life phases of laptop models.



Overall, the impacts of the PCF and ResilioDB records are of the same order of magnitude. The impact on the climate change indicator for a standard office laptop is between 175 and 300 kg eq. CO_2, depending on its configuration, for both data sources.

The impact given by ResilioDB is generally lower than that of the PCF data sheets, for both Dell and HP. The difference between the ResilioDB data and the manufacturer data is twice as high in the case of Dell compared with HP. The average difference between these two values is summarised in the table below:

	Dell	HPE
Average absolute deviation (kg CO_2 eq.)	35,8	19,7
Average percentage deviation (%)	14%	8%

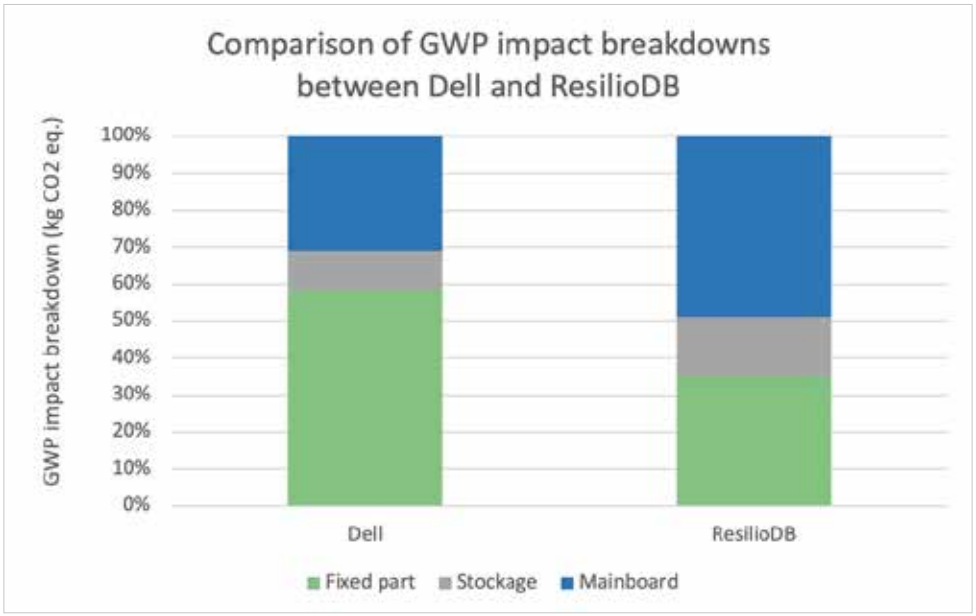
Beyond this average value, the difference observed between the impacts is not constant from one model to another. Some PCF sheets report an impact of 70 to 80 kg eq. CO_2 higher than the ResilioDB values, as can be seen in the graphs above.

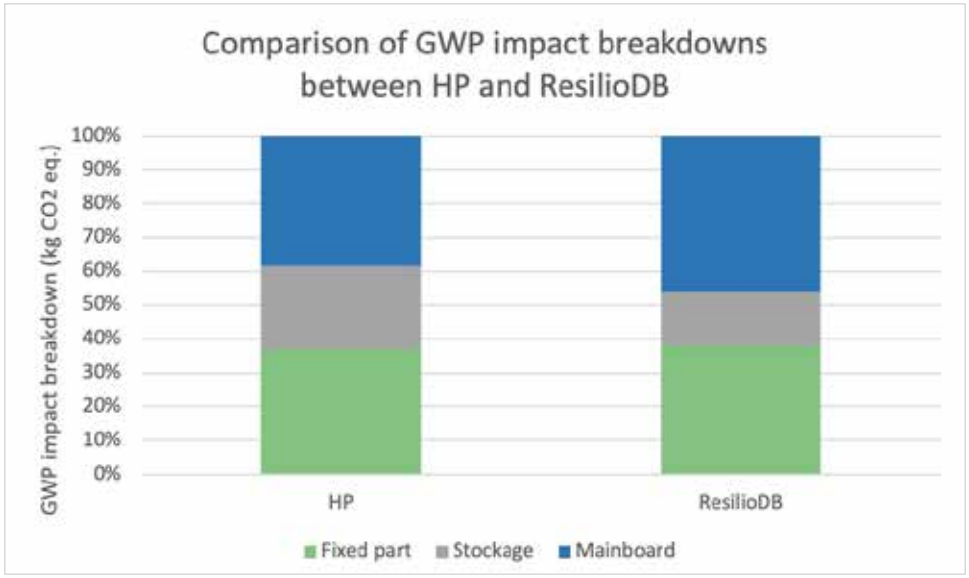
We can also see that the variance of the ResilioDB results is lower, i.e. the differences in impacts from one model to another are smaller in ResilioDB than in the PCF sheets.

In order to investigate the nature of these differences more precisely, it is necessary to compare the results at component level.

3.2 Breakdown of impacts by component

The graphs below show the average breakdown of impacts by component, compared between the manufacturers' PCF sheets and ResilioDB.



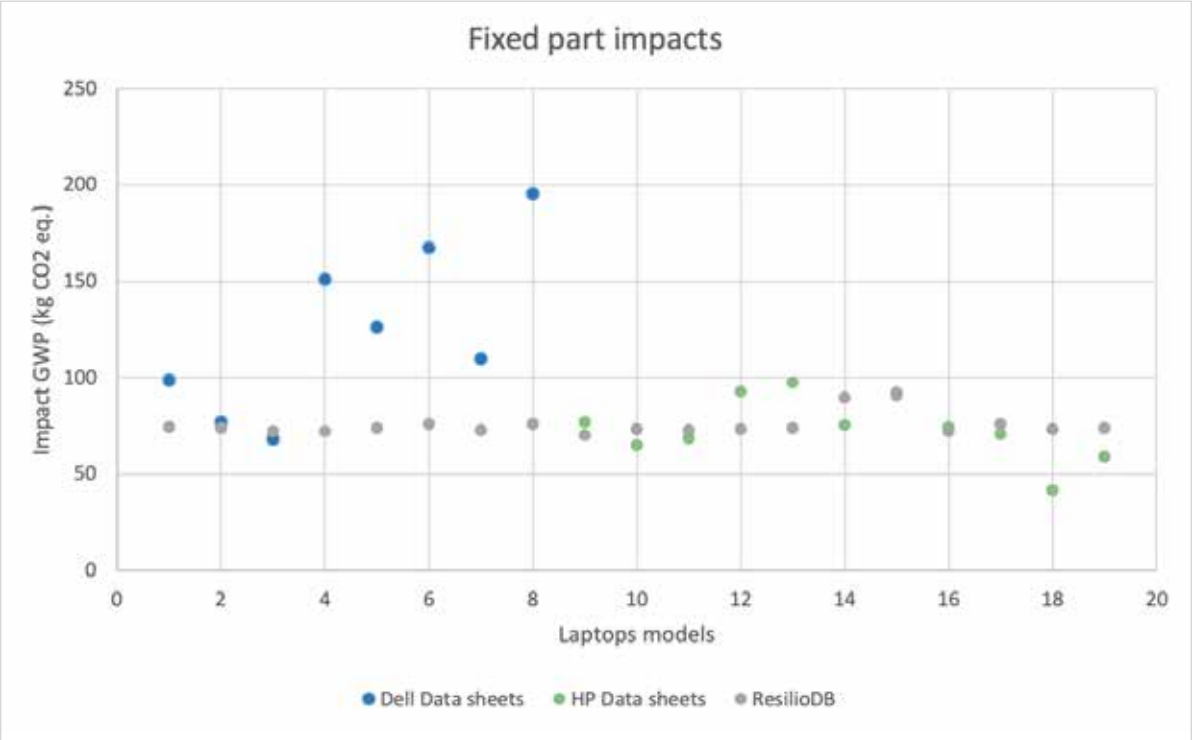


We can see that the distribution of ResilioDB impacts is fairly similar to that of HP's PCF sheets. For Dell, the 'fixed part' (chassis, screen and battery) takes up a lot of the impact. This is mainly due to the screen, which has a very large footprint, as detailed below.

3.3 Results per components

3.2.1 Analysis of 'Fixed part' impacts

The graph below shows the impact of the 'Fixed part' category, compared between the PCF and RDB sheets, for the different models.



The 'Fixed part' category considers the impact of the chassis, screen and battery. The impacts are quite constant from one model to another. They fluctuate between 70 and 90 kg CO_2 eq. In comparison, Dell's impacts vary much more, between 70 and 200 kg eq. CO_2. HP's impacts are close to those of ResilioDB, varying slightly more depending on the model.

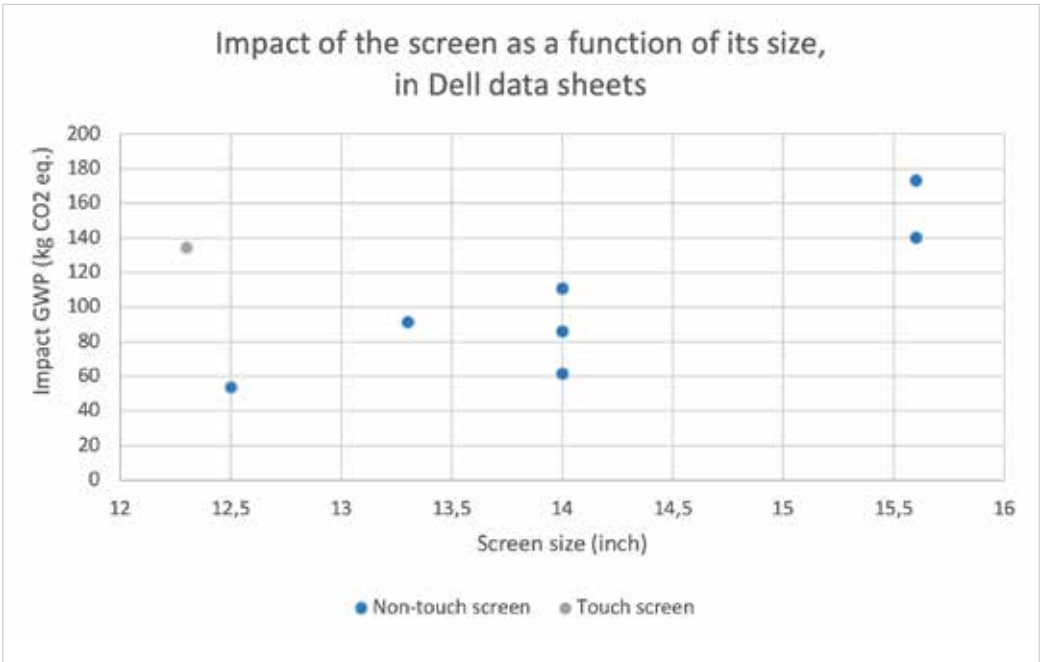
In the PCF sheets, the average breakdown of impacts in the 'Fixed part' category is as follows:

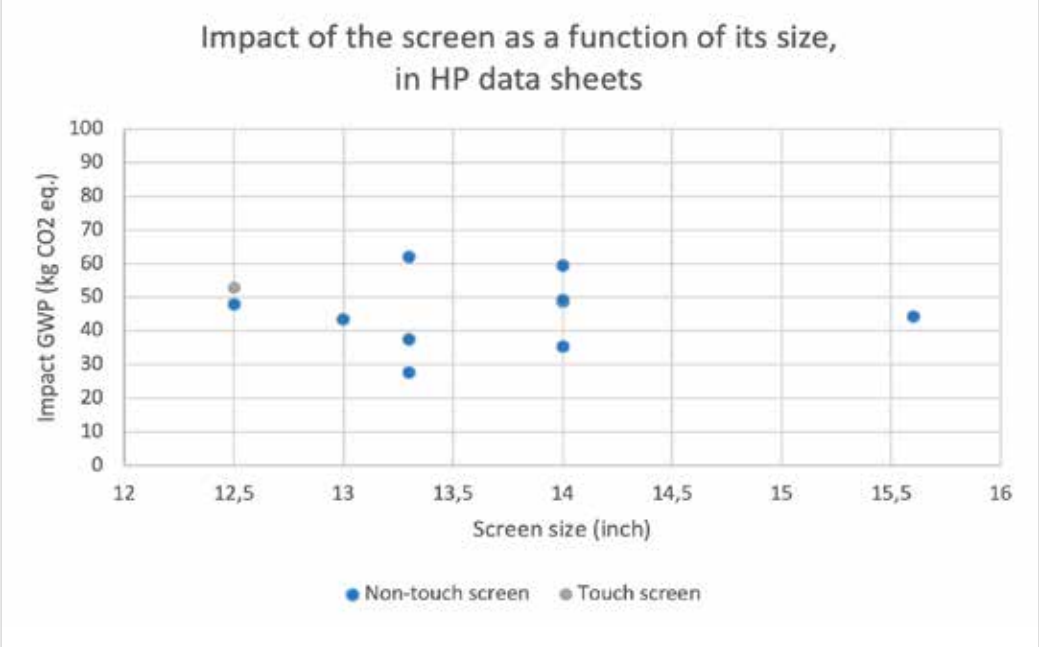
	Percentage of screen impact (%)	Percentage of battery impact (%)	Percentage of chassis impact (%)
Dell	71	5	7
HP	48	12	16

The majority of impacts in the 'Fixed part' category come from the screen for both manufacturers. This is much more pronounced for Dell, where the screen accounts for almost ¾ of the impacts. The variability of the 'Fixed part' impacts for Dell are therefore due to the variability of the impacts of the screen, analysed in more detail in the next section.

3.2.2 Specific analysis of the impact of screens in PCF sheets

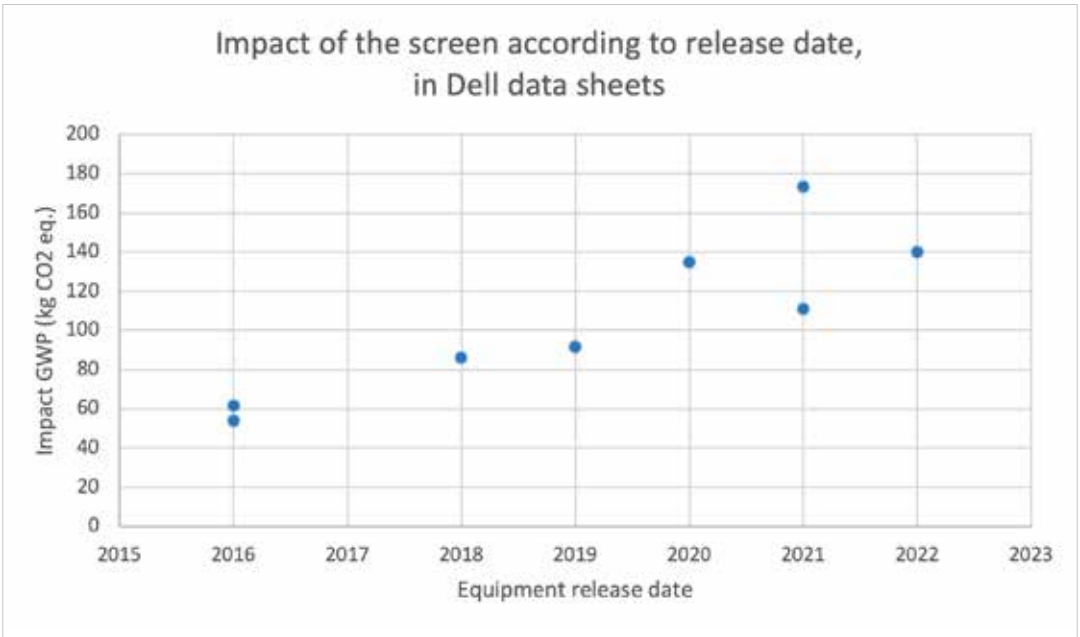
The graphs below represent the impact of screens according to their size for the PCF sheets from Dell and HP. In the case of touch screens, a different colour code is used as variations in impact are expected. All the screens considered here are LCD*.





There is no clear correlation between screen size and environmental impact in the manufacturer data. However, the state of the art in academic research shows a very strong correlation between the two within a single technology. In PCFs, several screens of the same size have different impacts, which can be as much as double. This observation applies to both manufacturers.

One hypothesis that could explain this lack of correlation is the fact that the models were released in different years, and therefore the PAIA versions used to calculate the impacts of the PCF sheets are different. From one version of the tool to the next, the impact factors and modelling assumptions may vary, thus explaining the inconsistent values for the same screen size.



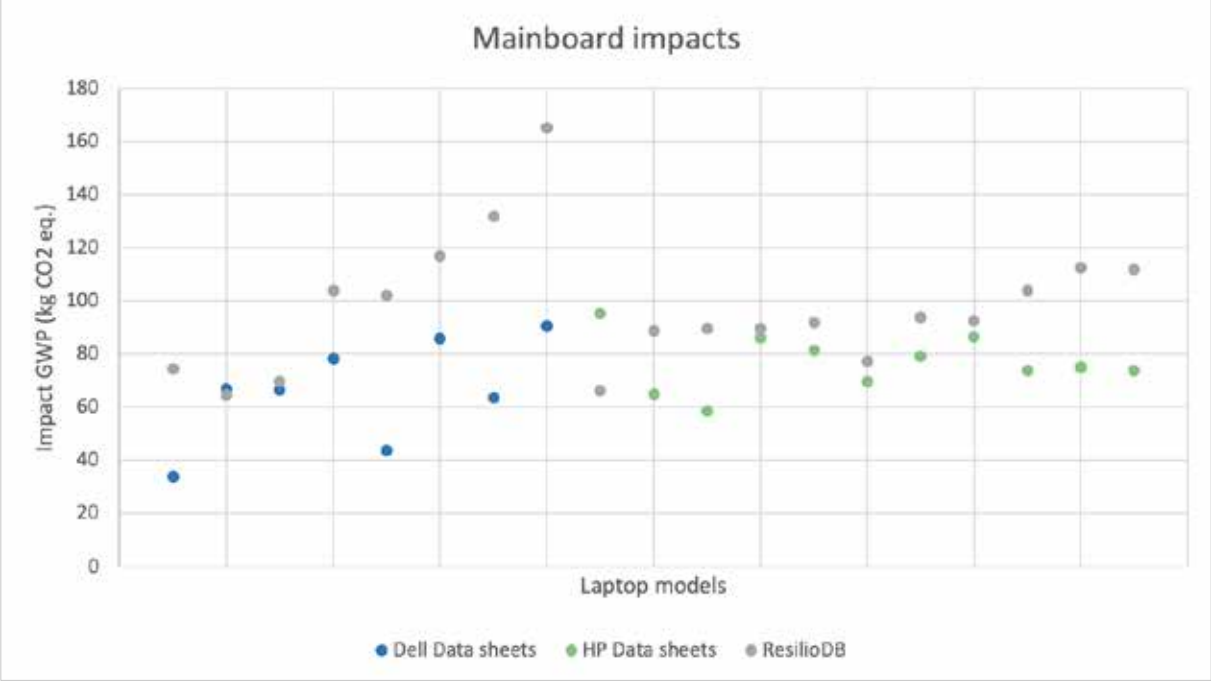
Out of curiosity, we plotted a graph of the impact of the screen according to the release date of the equipment for the Dell PCF sheets. We can see that the correlation is stronger in this case. One hypothesis would therefore be that the impact of the screen increased with each version of PAIA. This increase was greater than the variations in impact due to screen size, thus 'erasing' this correlation.

Furthermore, the impacts between Dell and HP are not at all the same. We can see that the impact of the screen at Dell ranges from around 60 to 180 kg eq. CO_2, whereas for HP it ranges from 30 to 60 kg eq. CO_2. Given that HP and Dell use the same tool, PAIA, to obtain the impacts of their PCF sheets, we can wonder about the differences that explain such a wide gap. All the screens use LCD technology and the models from the two manufacturers have similar size ranges (12.5 to 15.6 inches). We have no hypothesis to explain this discrepancy, without having more detailed access to the methodology used.

3.2.3 Analysis of "Mainboard" impacts

The 'Mainboard' category considers the motherboard, processor, RAM and integrated graphics card. This is a consolidated impact for PCFs, i.e. no details on sub-components are available, nor is there any description of assumptions.

Here are the various impact graphs for the 'Mainboard' category, showing a comparison between the PCF and ResilioDB sheets, for the various models.

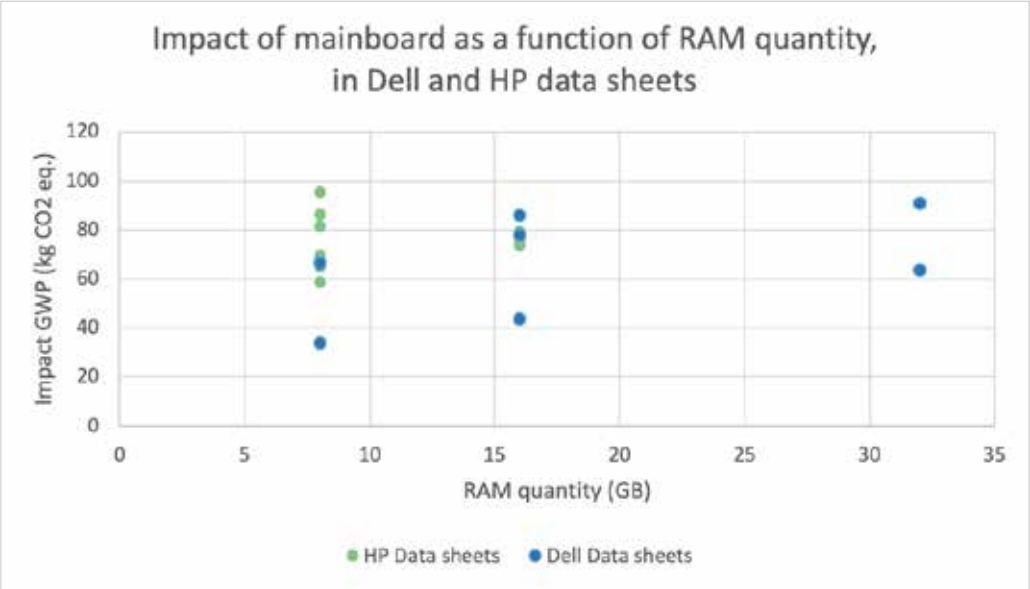


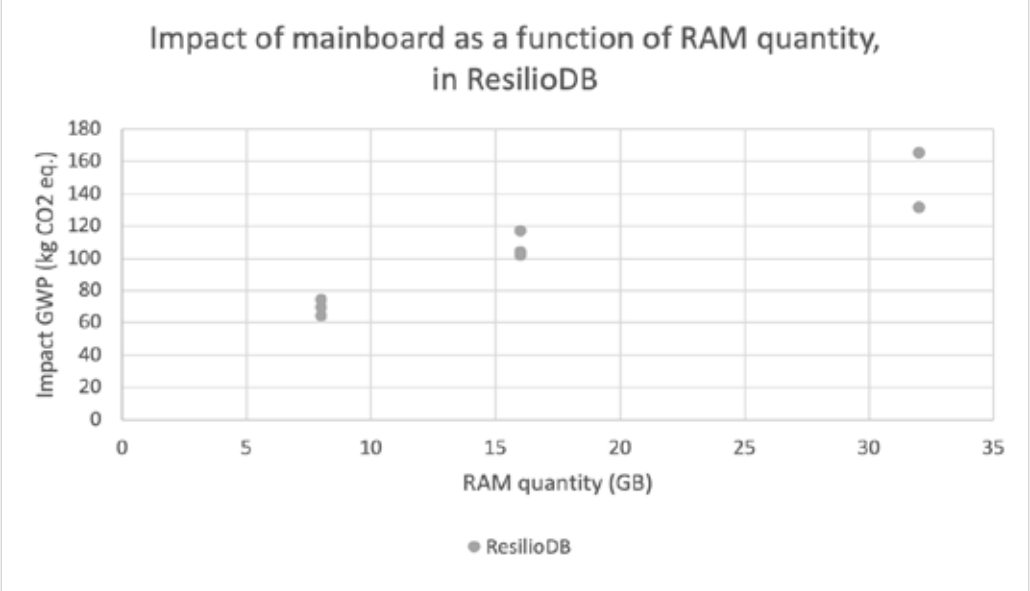
The impacts are variable and generally higher for ResilioDB, as can be seen in the graph above.

The average breakdown of impacts for the 'Mainboard' category for ResilioDB is as follows:

- RAM: 36%
- CPU: 18%
- GPU: 22%
- Motherboard: 24%

This breakdown is not known for PCFs, as mentioned above. Let's take a closer look at RAM, which accounts for most of the impact.

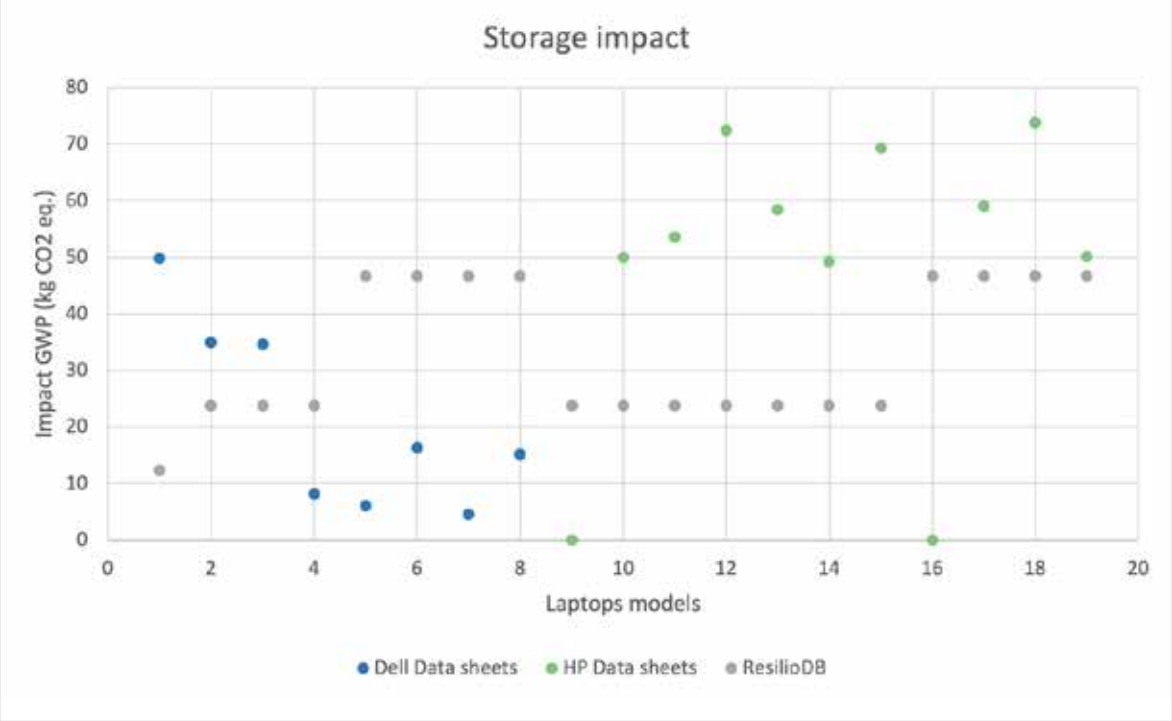




We can see that for PCFs, the correlation is not clear, since the impact for the same amount of RAM can be as much as double. For ResilioDB, the correlation is clearer, although the impacts also vary for the same amount of RAM. This is due to the different CPU and GPU models, which have varying impacts.

3.2.4 Analysis of Storage impacts

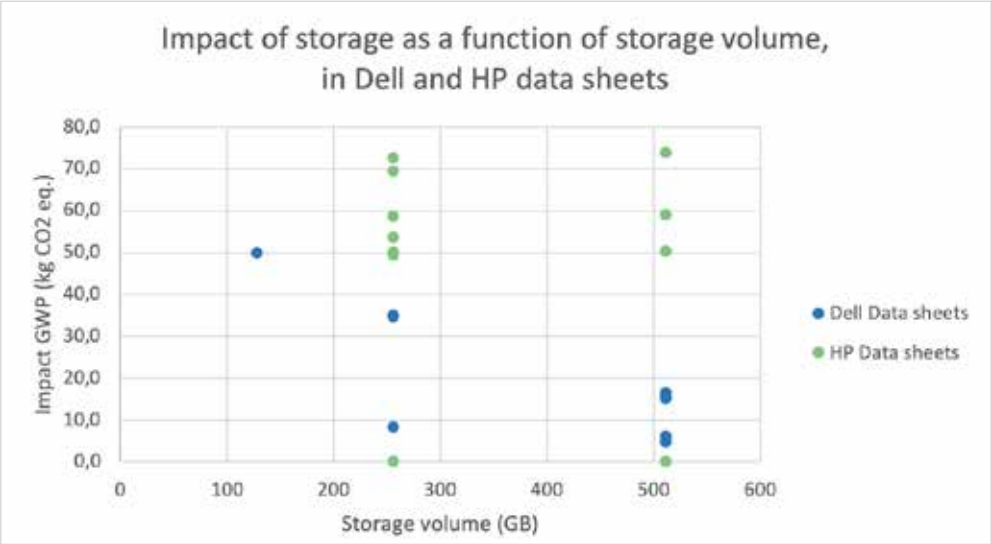
The graph below shows the impacts of the 'Storage' category, compared between the PCF and RDB sheets, for the different models.



Impacts vary widely, particularly for PCFs. For 17 of the 19 PCF equipment items, only 2 have an impact from an HDD component. In addition, we do not know the storage capacity assumption used, which limits our interpretation of the results.

The 'Storage' category includes SSD and HDD disks. We can see that the impacts of the three data sources vary considerably. The impacts from ResilioDB are sometimes higher and sometimes lower than the impacts from the PCF sheets. We would expect the impacts to vary greatly depending on the amount of storage, which varies greatly from one model to another (between 128 and 512 GB). For this reason, it is interesting to study the impact as a function of the amount of storage.

In addition, here is a graph showing the impact of SDSs as a function of the amount of storage, in the PCF sheets from Dell and HP.



We can see that the impact of SSDs in the Dell and HP PCF sheets is not directly correlated with the amount of storage. What's more, there are major differences in impact between Dell and HP. The impacts on the Dell side range from 7 to 50 kg eq. CO_2, while the impacts on the HP side range from 49 to 72 kg eq. CO_2, i.e. almost double. The two models are therefore not homogeneous.

Other parameters such as SSD technology (SLC, MLC, TLC, etc.) and format (M2, 2.5', etc.) can influence environmental impacts, but here we should clearly see a correlation between storage volume and impact. One hypothesis to explain this lack of correlation is uncertainty about the amount of storage. Indeed, as explained in the Methodology section, the storage quantity of the model is not given in the PCF sheets. An average configuration representative of the configurations offered on manufacturers' or retailers' websites is therefore used. It is possible that a discrepancy between our assumptions and those of the data sheets could influence the results and generate these inconsistencies on the graph and therefore also generate discrepancies between the PCF sheets and ResilioDB data.

4. Limits of the study

This study was carried out using the data available and has certain limitations that are worth mentioning.

The limitations of the PCF sheets are as follows:

- The **exact configuration** of the equipment is **not given in the PCF sheets**. It is therefore possible that there are differences between the configuration used in the PCF sheets and the modelling produced by ResilioDB. This creates uncertainty about the differences between the impacts of the PCF sheets and those of ResilioDB.
- Some PCF sheets show impact **distribution graphs** without absolute figures. In this case, a **visual reading** of the distribution of impacts on the graphs was necessary, leading to uncertainty in the results.
- This study did not allow a detailed comparison of the **methodologies** behind the PCF and ResilioDB sheets, due to the **lack of transparency in the manufacturers' PCF sheets**. It is not possible to know how the components have been modelled. This limits the depth of the analysis.

- Each PCF sheet is calculated with a **different version of PAIA**, depending on the year of release of the laptop model. (You can look at the PAIA version number on the PCF sheet to identify identical versions). Between each version of PAIA, the modelling assumptions may vary. So, by comparing several files, we are comparing several different models, which will give different results. This creates additional variance in the results and makes the analysis more complex.

Other limitations include

- **The size of the sample:** This is a study of a small subset of models (19 in total) and it is not possible to deduce general conclusions.
- **The limitation to one category of equipment,** laptops.

5. Conclusion

The impacts analysed in the PCF sheets and ResilioDB data are of the **same order of magnitude**. According to these two sources, the impact on the climate change indicator for a standard office laptop is between 175 and 300 kg eq. CO_2, depending on its configuration.

In-depth analysis shows that the differences between the impacts generated by ResilioDB and those generated by HP are smaller than those generated by Dell, both in terms of absolute values and the distribution of impacts across the various components.

However, the analysis of the impacts given by the PCF sheets of the two manufacturers, with the variables that we consider crucial for modelling (screen size, amount of SSD storage, etc.), does not show any clear correlation on these parameters. This **lack of clear correlation** may be due in part to **differences in equipment configurations**, as well as to the other limitations mentioned in section 4. The lack of information on PAIA's modelling prevents us from taking the analysis further to understand the origin of these differences in impacts.

From this analysis, it is clear that **transparency of methodology** is a crucial condition for the disclosure of environmental impact data. It allows modelling to be analysed in depth, without which a true comparison is not possible.

After using PAIA for several years, Dell is now switching to an in-house calculator based on Sphera data. Initially launched on laptops, desktops and monitors, Dell intends to extend the tool to all its products. With the launch of this tool, Dell has published a report detailing the methodology[7] on several case studies, which is a step in the right direction. Let's hope that this change will be accompanied by greater transparency about the methodologies used.

7 *Source :* https://www.delltechnologies.com/asset/en-us/solutions/business-solutions/briefs-summaries/dell-pcf-calculator-whitepaper.pdf

6. Glossary

- **Life Cycle Assessment (LCA)**: A methodology for assessing the environmental impact of a product or service. It considers all stages of the life cycle, from the extraction of raw materials through production, transport and use to end-of-life. It is a global approach that takes into account various environmental indicators such as energy consumption, global warming potential, water use, fine particle emissions, acidification, etc.

- **Climate change indicator:** An environmental impact indicator that quantifies induced climate change, including increases in global average temperatures and sudden regional climate changes, due to emissions into the atmosphere of greenhouse gases such as carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). It is measured in kilograms of CO_2 equivalent (kg CO_2 eq.).

- **LCD:** Liquid Crystal Display. A type of flat screen display that has replaced cathode ray tube screens. It uses liquid crystals to switch the pixels on and off and display a specific colour.

- **PCF:** Product Carbon Footprint. This is the application of the Carbon Footprint method to a specific product. At the end of the analysis, the results and methodology are generally presented in a summary sheet, a Product Carbon Footprint sheet, which is made available to customers.

7. Appendix

Appendix 1:

List of laptop models used in the study, with their technical configuration

Manufac-turer	Commercial reference	Technical configuration
Dell	Latitude 3420	16GB RAM ; 512GB SSD ; CPU : Intel Core i7-965 ; GPU : Intel Integrated iris xe graphics ; LCD 14 inches screen
Dell	Latitude 5300	32GB RAM ; 512GB SSD ; CPU : Intel Core i5-8365U ; GPU : Intel UHD Graphics 620 ; LCD 13,3 inches screen
Dell	Latitude 5530	16GB RAM ; 512GB SSD ; CPU : Intel Core i5-1235U ; GPU : Intel Iris XE Graphics ; LCD 15,6 inches screen
Dell	Latitude 7210 2-in-1	16GB RAM ; 256GB SSD ; CPU : Intel Core i7-10610U ; GPU : Intel UHD Graphics 620 ; LCD 12,3 inches screen
Dell	Latitude 7490	8GB RAM ; 128GB SSD ; CPU : Intel Core i5-7300U ; GPU : Intel UHD Graphics 620 ; LCD 14 inches screen
Dell	Latitude E7270	8GB RAM ; 256GB SSD ; CPU : Intel Core i5-7300U ; GPU : Intel HD Graphics 5500 ; LCD 12,5 inches screen
Dell	Latitude E7470	8GB RAM ; 256GB SSD ; CPU : Intel Core i5-6300U ; GPU : Intel HD Graphics 520 ; LCD 14 inches screen
Dell	Precision 5560	32GB RAM ; 512GB SSD ; CPU : Intel Core I7-11850H 8C ; GPU : NVIDIA RTX A2000 ; LCD 15,6 inches screen
HP	EliteBook x360 1040, G9	8GB RAM ; 256GB SSD ; CPU : Intel Core i5-1235U ; GPU : Intel Iris Xe Graphics ; LCD 14 inches screen
HP	EliteBook 725 G4 Notebook	8GB RAM ; 256GB SSD ; CPU : AMD PRO A12-8800B ; GPU : AMD Radeon R7 ; LCD 12,5 inches screen
HP	EliteBook 735 G5 Notebook	8GB RAM ; 256GB SSD ; CPU : AMD Ryzen 5 2500U ; GPU : AMD Radeon Vega 8 Graphics ; LCD 13 inches screen
HP	EliteBook 735 G6 Notebook	8GB RAM ; 256GB SSD ; CPU : AMD Ryzen 5 Pro 3500U ; GPU : AMD Radeon Vega 8 Graphics ; LCD 13,3 inches screen
HP	EliteBook 745 G5 Notebook	8GB RAM ; 256GB SSD ; CPU : AMD Ryzen 7 2700U ; GPU : AMD Radeon RX Vega 10 ; LCD 14 inches screen
HP	EliteBook 745 G6 Notebook	16GB RAM ; 512GB SSD ; CPU : AMD Ryzen 3 PRO 2300U ; GPU : Radeon Vega Mobile Gfx ; LCD 14 inches screen
HP	EliteBook 820 G4 Notebook	16GB RAM ; 512GB SSD ; CPU : Intel Core i7-7500U ; GPU : Intel HD Graphics 620 ; LCD 12,5 inches screen
HP	EliteBook 830 G8 Notebook	8GB RAM ; 256GB SSD ; CPU : Intel Core i5-1135G7 ; GPU : Intel Iris Xe Graphics ; LCD 13,3 inches screen
HP	EliteBook 830 G10 Notebook	16GB RAM ; 512GB SSD ; CPU : Intel Core i7 1355U ; GPU : Intel UHD Graphics ; LCD 13,3 inches screen
HP	EliteBook 845 G8 Notebook	16GB RAM ; 256GB SSD ; CPU : AMD Ryzen 3 5400U ; GPU : AMD Radeon Graphics ; LCD 14 inches screen
HP	EliteBook 850 G5 Notebook	16GB RAM ; 512GB SSD ; CPU : Intel Core i7-8550U ; GPU : Intel HD Graphics 620 ; LCD 15,6 inches screen

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Environmental impacts of IT equipment — A comparative analysis - Resilio Database and 'Product Carbon Footprint' sheets

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