KU LEUVEN

Ecodesign & Life Cycle Engineering

Comparative Environmental Impact Assessment of ICT Tools for Education:
KU Leuven as case study

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CHAPTER 1
Introduction

This study quantifies and analyzes the environmental impact of 1 semester at KU Leuven. We will conduct an Life Cycle Assessment (LCA) to highlight and showcase the processes and goods that are the most harmful from an environmental standpoint. In this LCA, we will investigate various scenarios and conduct a sensitivity analysis to add depth to this work. Finally, we will reflect upon our findings and propose ideas and solutions to tackle the challenges of the modern education system..

We analyze the situation from two main points of view.

1. **Student:** we will quantify and measure the impact at the scale of one student and then generalize our findings.
2. **KU Leuven:** we will take KU Leuven as our case study and measure the impact of their infrastructure, hardware, ...

Then, we will analyze and compare our findings and take 3 distinct periods: before COVID, during COVID and after COVID. We want to see if the rapid expansion of Massive Open Online Course (MOOC) and other learning technology has been beneficial or detrimental to the environment.

1.1 USAGE OF GENERATIVE AI

None of the critical tasks (data collection, scoping, research, etc.) relied on generative Artificial Intelligence (AI). However, AI has been used to help in formatting the document, converting images to table (OCR) and as a proofreader.

CHAPTER 2
Life Cycle Assessment

2.1 QUESTIONS & FUNCTIONAL UNIT

Question: What is the impact of 1 semester of classes and content throughout the various digital and non-digital tools used at KU Leuven ? Did education's carbon footprint increased during and after COVID compared to the model before COVID ?

We assume a semesters comprises 30 European Credit Transfer and Accumulation System (ECTS) credits and each account for approximately 25 hours of work [1]. From our experience we can assume that a class of 3 ECTS takes around 3 hours per week with 2 hours of lecture and 1 of exercise sessions, laboratory, etc. This results in approximately 30 hours of classes per week, with a maximum of 8 distinct courses per semester. Each semester is composed of 12 weeks of active learning, 3 weeks of "*blok*" and 3 weeks of exams. We estimate around $30 \cdot 25[hours] - 8 \cdot 3[hours] \cdot 12 = 462$ hours of work at home [2].
To compare those 3 distinctive time periods, some hypotheses and simplifications were made:

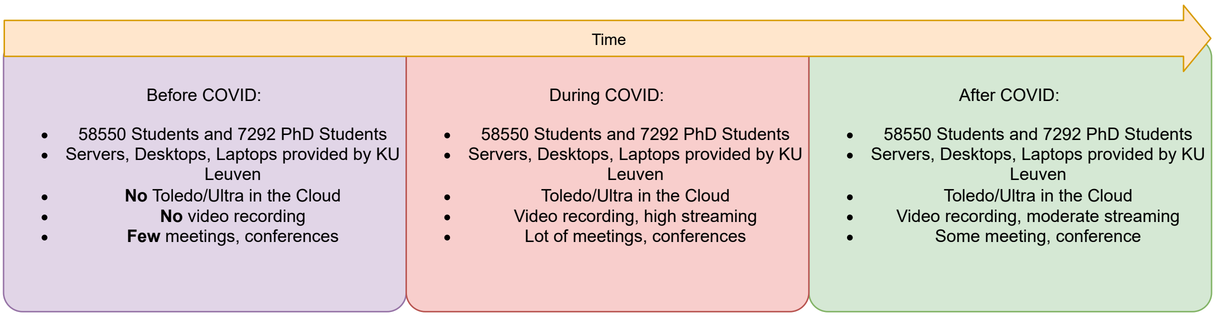


Figure 2.1: Timeline of the Information Technologies (IT) Infrastructure and its evolution at KUL

So, 1 *functional unit* represents 1 semester of education at KU Leuven through the various mean employed at the university.

2.2 SCOPE

2.2.1 Students

Up to 2025, there has been a wide variety of products supporting digital learning. The most popular among these include laptops, tablets with digital styli, Electronic Paper Displays (EPDs), and writing pads integrated with tablets. Their adoption rates depend on software maturity, performance, and pricing. Based on our observations within the Department of Electrical Engineering, supplemented by informal insights from students across other campuses, laptops and tablets remain the most favored tools, given their ability to support both academic tasks and recreational use beyond study routines. Accordingly, we focus primarily on the use of personal laptops, tablets, and stylus pens. The goal is to provide reference data for students who are concerned about the environmental impact of digitalizing their learning process, aiming to help them make informed choices that align personal preferences with sustainability objectives.

Bills Of Materials

Regarding the use of tablets, we have identified several dominant brands through market reports, which will be discussed in detail in subsequent sections. Therefore, our analysis is based on an average Bill Of Materials (BOM) derived from these leading brands. However, due to Intellectual Property (IP) constraints, publicly available data on the composition of digital styli remains limited. Given their relatively simple functionality and the fact that a few manufacturers dominate the market, we provide an estimation based on teardown analyses from third-party platforms. This estimation will be detailed later in the report. As for personal computers, the variation in their configurations is substantial, owing to their broad spectrum of functionalities. Nevertheless, since our focus is primarily on academic usage, we refer to an average PC BOM similar to the models supported by KU Leuven's Information and Communication Technologies (ICTS) department.

2.2.2 KU Leuven

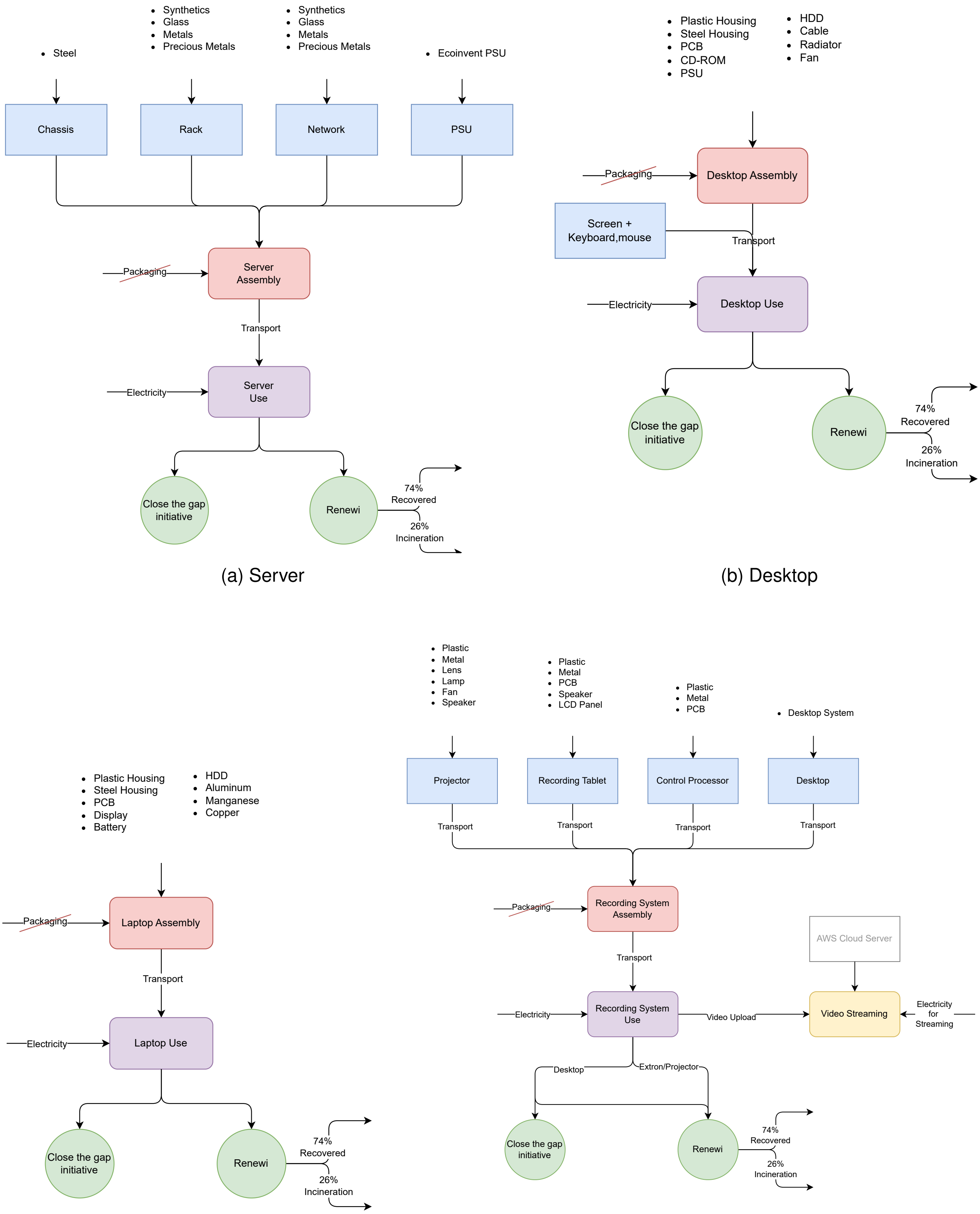
There are many tools and services proposed by the ICTS team but we will take only into account the most relevant one for students and staff. So we will primarily focus on the MOOC, course environment, hardware and servers provided at KU Leuven. Specifically, our research will be focused on:

- Hardware provided to staff and researchers: desktop, laptops, ...
- Learning infrastructure: Ultra (Toledo), Blackboard, Kaltura, ...
- Conferencing & Recording tools: equipments, video storage, teams, ...

Bills Of Materials

Hardware: Since IT is an ever changing domain where new manufacturing techniques are developed and used every month, it is hard to find reliable data regarding the environmental cost. Moreover, most of those manufacturing techniques are kept secret under Non Disclosure Agreement (NDA) and other IP contracts. So for this reason, we are going to solely base our production cost and impact on the available BOM that can be found in literature for typical equipment.
The only mature assembly processes considered were injection molding for polycarbonate plastics housing and steel processing for the enclosure.
For the servers (fig. 2.2a), the cooling has been ignored as the exact infrastructure is not exactly known and the heat generated is reused for heating the building of ICTS [3].
In most cases, the packaging is ignored as it doesn't contribute significantly to the impact and can be minimized.

Cloud: For cloud servers, only the data stored and sent was considered and not the hardware as it is hard to quantify precisely due to their flexible. So, the cost of a cloud service provider will be modeled by GigaBytes (GB) transferred.
It is a reasonable assumption since the operational impact has been proven to be 4 times higher than the embodied impact for datacenters [4].



(a) Server (b) Desktop (c) Laptop (d) Video recording

Figure 2.2: Scope for various Hardware of KU Leuven

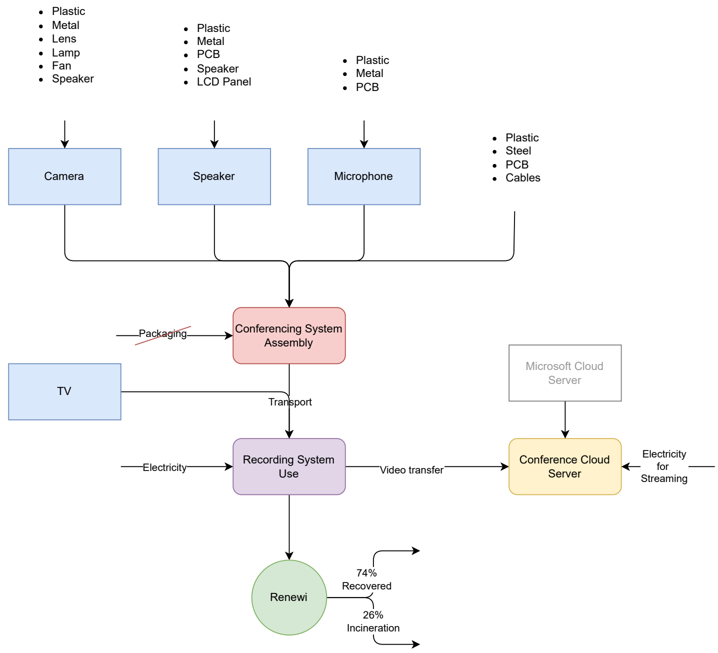


Figure 2.3: Scope for Conference Devices

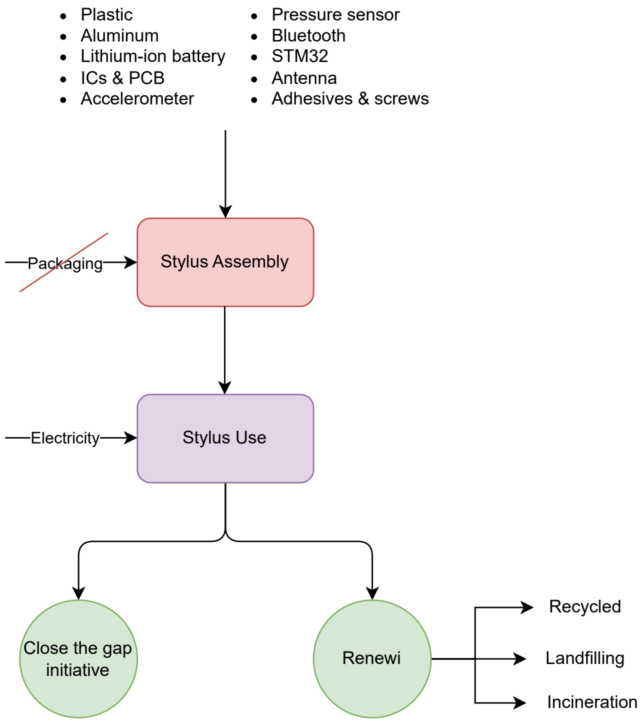


Figure 2.4: Scope for Stylus

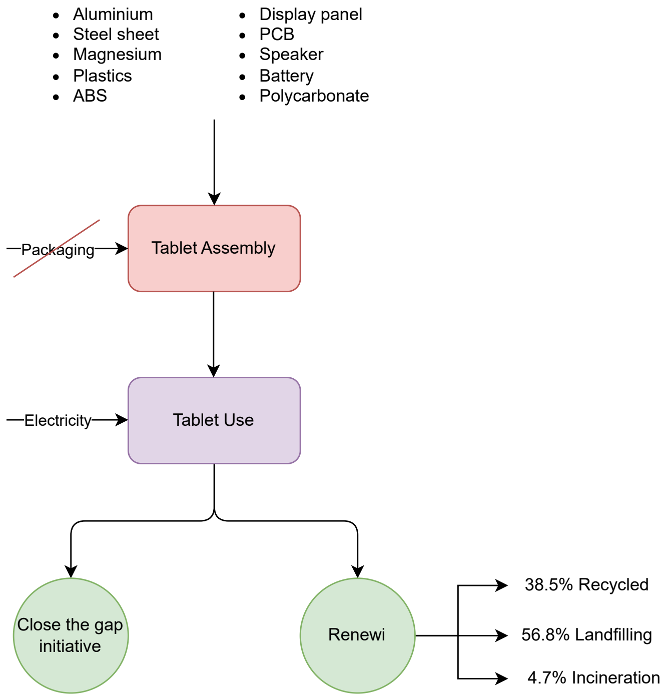


Figure 2.5: Scope for Tablets

2.3 DATA COLLECTION

2.3.1 Students

Currently, no specific reports targeting ownership and usage of the electronic devices by KU Leuven students. However, there have been reports focusing on the digital device usage of European students, as well as the impact of COVID-19 and its influence on digitization. According to their *official website* [5] KUL is located in Europe and has 24.2% foreign students, we will make an educated assumption about KUL student behavior based on those reports.

We also kept in mind that different study majors could have varied levels of adaptability to digital education. According to KUL's *info page* , the majority of students belong to the Humanities and Social Sciences Group, the Science, Engineering and Technology Group, and the Biomedical Sciences Group. Some specific programs involve more in-person training sessions than others. After looking into their program guides, we observed that most programs involve theoretical study, which is supported by the university's digital learning platform Toledo. The supporting infrastructure of this platform will also be analyzed later in the paper. Hence, we believe that grouping university students as a whole for this analysis still provides a sufficiently representative result.

We will also compare the market growth of electronic devices within Europe in recent years, spanning years prior to and after the COVID-19 outbreak. We have observed that PC market revenue has remained stable, as even before COVID, PCs and smartphones already had high ownership rates. There has been a slight increase in the revenue of tablets in Europe, which correlates with the impact of COVID-19 on education. After the pandemic, the revenue tends to fall back to its pre-COVID level, though it saw a slight increase.

2.3.2 KU Leuven

A real in depth and transparent work has been conducted by the IT department and they report all their findings and policies on a website [6]. We also contacted Mr. Hendrickx, an assistant for this course, for data. We based our data partially on this and we also investigated beyond the data reported here to conduct rigorous research. We base our study on data publicly available, on literature, statistics and our own expertise in the field of electronics as EE students. For the parts where literature or information were lacking, some estimation and educated guesses about the infrastructure, type of hardware, ... were made.

2.4 QUANTIFICATION

2.4.1 Students

For the categorization of students, we have split it up into 2 categories:

- Regular Student: degree-seeking students and exchange students
- PhD Student

We do not take into account the other type of students in our calculation. Which brings the total amount of regular students to 58550 and of PhD students to 7292. We keep those 2025-2026 statistics for our analysis of 2021 and COVID era as we have observed an increase of students around 0.5% and the distribution of students remained stable across categories [5].

Learning Medium

Throughout COVID, our usage of e-learning tools has spiked up and consequently the ownership of other devices such as laptop, tablet, phones, etc. One medium has risen significantly: tablets [7]. Many students purchased a tablet for the ease of portability, cost, etc. For note taking, pen and paper remains the number 1 chosen methods for $\sim 70\%$ of students while the rest use either both or only a tablet.

Since most of the classes are recorded, some students only watch the lecture online. Based on our observations, $\sim$ 60% of students rely solely on recordings and do not attend the lectures physically.

In 2020, a survey was conducted to assess university students' attitudes toward tablet use, specifically focusing on how undergraduate students utilize tablets for educational purposes [8]. The survey included 234 students across various study programs. Among them, 48% reported frequent usage of tablets after acquiring them, and over 90% indicated that they used the device for academic purposes and found it beneficial for their studies. From these results, it can be reasonably inferred that tablets serve as an effective medium to support digitized education [9]. While highlighting their benefits—such as reduced costs associated with printed course books and handouts, and increased convenience due to portability—it is also important to acknowledge that tablets are generally less central to university students than laptops. The latter already had high ownership rates before the COVID-19 pandemic. Given the broader and less easily replaceable functionality of laptops, students with limited budgets are more likely to prioritize the purchase of laptops over tablets. Therefore, it can be estimated that laptops will continue to be the primary device for engaging in digital education, although an increasing shift from handwritten notes to digital tablet-based note-taking may be expected.

Furthermore, the COVID-19 pandemic significantly accelerated the digitization of education [10]. According to market data [11], there was an approximate 10% increase in revenue for both tablets and laptops in Europe during the peak pandemic year. However, this was followed by a noticeable decline in sales as quarantine measures eased across most European Union (EU) countries—dropping to levels even lower than those before the pandemic. This trend demonstrates a strong correlation between the pandemic and increased demand for digital devices, driven by remote work, remote learning, and leisure activities. While the pandemic served as a short-term catalyst for these purchases, it also initiated a longer-term transformation toward digital learning practices. As a result, it is plausible to anticipate continued growth in tablet adoption for educational purposes in the future.

Scope of Research

Considering the factors outlined above, and acknowledging that tablet purchases are typically more discretionary and flexible compared to long-term assets such as conferencing equipment or personal computers, we choose not to estimate the total environmental impact of all student-owned tablets. Instead, this report conducts an LCA of the usage of a single tablet over the duration of one academic semester. This case-based approach provides a representative benchmark, enabling students to better understand the ecological implications of integrating tablets into their academic practices. Based on this assessment, students may make more informed decisions regarding the adoption of digital tools, balancing environmental concerns with personal preferences and study requirements. In contrast, for personal computers and conference devices—whose usage does not vary significantly among individuals—we propose a more detailed group-level analysis based on the estimated total number in use at KU Leuven.

Personal Computers for Individual Use

Some facilities, such as AGORA, provide access to shared computing resources, including rental PCs, and many university campuses are equipped with dedicated computer rooms. Nevertheless, the majority of students still own a personal laptop. According to a 2024 Eurostat survey [12], approximately 77% of students within the European Union own a laptop, while 34% own a tablet. Considering the vast market of laptop brands and the high variability in their configurations—for instance, gaming laptops typically contain significantly more components than lightweight models such as Chromebooks—we can expect a high degree of deviation in environmental impact results. To ensure consistency, we estimate an average BOM for a standard laptop.

Tablet for Individual Academic Use

Between 2021 and 2023, a market report [11] indicates that Apple has consistently held the largest share of the tablet market, accounting for approximately 50% of total sales during this period. Samsung followed as the second-largest vendor, maintaining a steady growth trend and capturing around 20% of the market. Historical data from earlier years shows a similar distribution of market share. Therefore, we consider it appropriate to reference a BOM report on tablets published in 2018 [13]. Given the consistent market structure and dominance of the same manufacturers, we anticipate no significant deviations that would compromise the relevance or validity of this data for our analysis.

While reviewing previous literature [14], we noticed that the screen accounts for a very high proportion of the device composition—up to 38% for aluminum-housed tablets and 46.1% for those with plastic housing. This is concerning because screens are not easily recycled. Most components are tightly bonded and difficult to separate into simpler, recyclable parts. Moreover, screens cannot be recycled like regular glass since many display technologies incorporate heavy metals or toxic substances. Other materials, such as aluminum shielding or steel sheets, involve heavy mining during their production stages. However, their recyclability is comparatively easier, which can mitigate their environmental impact if recycling is properly managed.

Considering the composition alone, the idea of refurbishing products as a whole rather than disassembling and recycling individual parts appears to be a promising alternative. Refurbished products are often sold at more affordable prices, making them accessible for students while maintaining adequate functionality. However, this approach often necessitates the replacement of parts with third-party batteries or screens, thereby introducing additional environmental impacts. The fate of the replaced old parts depends largely on the practices of the second-hand vendors. Later in this report, we will briefly analyze whether refurbishment is indeed a more environmentally friendly approach compared to traditional recycling.

Tablet-Compatible Stylus

The use of tablets for educational purposes is frequently accompanied by tablet-compatible styli, primarily for digital note-taking. This technology has seen increasing adoption, with Apple remaining the dominant brand in the market. According to [15], as of 2020, the environmental sustainability of such devices remained inferior to that of traditional paper notebooks, particularly in terms of production impact. However, following the COVID-19 pandemic and the growing emphasis on digital education, it is reasonable to expect improvements in the environmental performance of these devices, driven by more mature manufacturing processes and extended product lifespans. It is also worth noting that the dominant stylus models are typically integrated with wireless charging capabilities or embedded charging ports; thus, it is reasonable to exclude the environmental impact of additional charging equipment from the analysis.

Due to confidentiality concerns, the most dominant manufacturer of digital styli has not publicly disclosed a complete BOM for their products. However, a detailed teardown of the Apple Pencil—one of the most established and widely adopted stylus models—has been published by an independent source [16]. Given the Apple Pencil's market prevalence and technological maturity, we consider it a representative case. Thus, we adopt this teardown as a basis to approximate the material composition and to perform an LCA by evaluating the environmental impacts of its individual components.

While examining the product listings for tablet-compatible styli from major manufacturers such as Apple and Samsung, as well as third-party vendors like Amazon and Coolblue, we observed limited generational development or significant product iteration. Given their simple functionality and limited demand for upgrades nor do they present strong market demand for enhanced versions—we assume that this category has reached a point of diminishing returns, where further investment is unlikely to generate substantial additional revenue. Consequently, we do not anticipate considerable technological evolution in stylus design in the near future. Due to their simplicity, we also expect styli to exhibit extended lifespans. However, their replacement cycles may be closely tied to that of their associated devices—the tablets—as the stylus typically functions as a peripheral in a host-device relationship.

Materials	Mass [g]		
	All Tablets	Al Housing	Plastic Housing
Aluminium	41.5	103.7	0.0
Steel sheet	3.9	0.0	6.6
Magnesium	14.8	4.2	21.8
Plastics (unmarked)	4.0	0.0	6.7
ABS	1.0	2.5	0.0
Polycarbonate	13.1	0.0	21.8
Polycarbonate + GF	9.0	0.0	0.0
ABS + PC	24.6	21.9	26.4
Display panel	226.8	226.8	226.7
PCB + EMI shielding	44.0	52.0	38.6
Speaker	3.3	3.4	3.2
Battery	124.6	150.1	107.6
Components: avg weight	510.5	564.6	474.5
Tablet: avg total weight	528.7	583.1	492.3
Other components	18.1	18.5	17.9

Table 2.1: BOM for 20 tablets [13]

Component	Estimated Mass [g]
Plastic casing	2.5
Metal casing (Aluminum)	4.0
Lithium-ion battery (0.329 Wh)	0.6
Logic board (incl. ICs & PCB)	1.0
Sensors (accelerometer, pressure)	0.3
Bluetooth module	0.2
Microcontrollers (e.g., STM32)	0.4
Lightning connector	0.7
Antenna	0.2
Nib (with tip + emitters)	0.3
Misc. adhesives & screws	0.3
Total estimated mass	10.5

Table 2.2: Teardown Apple Pencil (1st generation) [16]

2.4.2 KU Leuven

Learning Infrastructure & Cloud

The main learning platform of KU Leuven is Toledo (recently renamed Ultra as of December 2024). On this web application, the students can access the handouts, slides, exercises and video recordings of each and every lecture. This infrastructure is hosted remotely on Amazon Web Service (AWS) servers in Germany.
Regarding Toledo and the cloud access, we approximate that for each 2 hours of lecture, there is a video recording of 2 hours and a presentation in pdf format. For 1 hour of lecture, around 800 MegaBytes (MB) are required according to the ICTS team and a presentation is usually around 5 MB. For the exercise sessions, we can roughly estimate the handout to be around 2 MB each and we make abstractions of other possible media formats as the needs vary drastically from field to field. We will focus primarily on the pdf and videos (conference and recording) as they constitute the vast majority of data exchange in web traffic [17].
According to [14], "*During the lockdown, 14,000 viewers watched more than 1 million minutes of video daily*", which is 8 times more than prior to COVID. The amount of conference increased by a factor of 12 from the baseline of 249 conferences a day. Assuming each meeting lasts one hour with at least two participants.

Before COVID: *recording:* $18 \cdot 7 \cdot 800[MB/hour] \cdot 10^6[min.]/60/8 = 210[TB]$ (2.1)

conferencing: $18 \cdot 7 \cdot 249 \cdot 12 \cdot 800[MB/hour] \cdot 2 \cdot 1[hour] = 50.2[TB]$ (2.2)

During COVID: *recording:* $18 \cdot 7 \cdot 800[MB/hour] \cdot 10^6[min.]/60 = 1.68[PB]$ (2.3)

conferencing: $18 \cdot 7 \cdot 249 \cdot 800 \cdot [MB/hour] \cdot 2 \cdot 1[hour] \cdot 12 = 602.24[TB]$ (2.4)

For the after COVID scenario, KU Leuven didn't disclose any specific number but almost all lectures are recorded and around 50% of students do not attend lectures physically based on our own observation. During COVID, 14000 students were watching lectures everyday. If around 25000 are following from home, after COVID, it is a reasonable hypothesis to keep the same numbers of viewers. For conferencing, the emerging trends has been *hybrid* conference. We searched for papers and statistics describing the change of video conference without much success. We then assume the amount of video-conference data got reduced by a factor 4.

After COVID: *recording:* $18 \cdot 7 \cdot 800[MB/hour] \cdot 10^6[min.]/60 = 1.68[PB]$ (2.5)

conferencing: $18 \cdot 7 \cdot 249 \cdot 12 \cdot 800[MB/hour] \cdot 2 \cdot 1[hour] \cdot 3 = 100.6[TB]$ (2.6)

Slides and Handouts: Assuming that all students will access the learning material, they may access it multiple times on Toledo as *Anthology* allows student to stream handout[1]. On average they access the same content 3 times. Moreover, Toledo is not a well optimized applications and around 7 MB of data are transferred just to access a simple static webpage according to our tests. So if a student access a pdf or recording, it takes a student around 5 clicks and 2 different pages to get to its desired content.
Since Anthology was not introduced before COVID, we can assume that students had to download the file and couldn't *stream* it [14].

Before COVID: $58550 \cdot 12 \cdot 8 \cdot (1[access] \cdot (2[pages] \cdot 7[MB] + (5 + 2[MB]))) = 118.04[TB]$ (2.7)

During, after COVID: $58550 \cdot 12 \cdot 8 \cdot (3[access] \cdot (2[pages] \cdot 7[MB] + (5 + 2[MB]))) = 354.1[TB]$ (2.8)

Finally, cloud storage is provided by Microsoft. Recently, Microsoft changed its policy, and only 50 GB is allocated to new students (representing approximately 20% of students), while 250 GB are allocated for existing students and PhD students. Not everyone is actively relying on it so 50 GB is used for academic work. Before and during COVID, Microsoft proposed $1TB$ of cloud storage.

Before & during COVID: $(58550 + 7292) \cdot (0.1 \cdot 1000[GB]) = 6.58[PB]$ (2.9)

After COVID: $(58550 + 7292) \cdot (0.1 \cdot (0.2 \cdot 50[GB] + 0.8 \cdot 250[GB])) = 1.38[PB]$ (2.10)

Hardware on Premises

Servers: Besides cloud computing that is massively used by the university to optimize resources and to scale when it's needed, it also relies on physical servers distributed around the campus. There are around 390 physical servers as of 2019 [3]. We assume this number remained stable during and after COVID, as there was no significant increase in demand for computing power besides scaling for the educational tools such as Ultra. The IT department has made significant investments to reach lower-emitting data centers by using some heat exchange pumps to heat their building and using green Uninterruptible Power Supply (UPS). All of this is an effort to reduce the carbon footprint.
If we take the example of the server `vierre64.esat.kuleuven.be`, a server available to students of ESAT, we can find that it is most likely running an *AMD EPYC 7251* or *7281*. This Central Processing Unit (CPU) consumes

[1] not forcing download, possible to view in the browser

at maximum 120 W according to its Thermal Design Power (TDP) [18]. In a typical server, the CPU and cooling infrastructures are the most power hungry component so we will only take them it into consideration for the power usage [19]. We assume optimal space usage and that all servers are grouped in standard 42U servers. In a typical 42U rack, only 20 spots are used for actual servers [20]. An additional 2U is required for Power Delivery Unit (PDU)/Power Supply Unit (PSU) [21] and 2U for networking equipment. The 18U remaining are either left empty for cooling or filled in with other equipment we neglect (storage, Keyboard, Video (monitor), Mouse (KVM), router, WiFi, ...) . According to [3], there is currently 390 distinctive server equipment or *rack*.

$$\text{390 racks} \qquad \left\lceil \frac{390}{20} \right\rceil = 20 \text{ chassis} \qquad 20 \cdot 2 = 40 \text{ PSU and network equipment} \tag{2.11}$$

We derived the power delivery system from *ecoinvent* and its PSU system, and multiplied it by 5 to represent the power system of one server [22]. We multiplied by 5 as the PSU of a server can easily reach power up to 1600 Watts compared to a 300 Watts PSU of a work computer [23].

Desktop and Laptops: As of 2019, ICTS states that there are 6367 desktops and laptops in use. We can assume this number to remain stable throughout the years.

There is 2930 desktop across 8 sites on KUL's campus and 2802 laptops for staff member and 66 laptops lent to library [24].

For each desktop available, there is a screen, keyboard and mouse paired with. Those components will be modeled as system process in *Simapro*. For the laptop charger, we use the system process available in *Simapro*.

Materials	Chassis [kg]	Rack [kg]	Network [kg]
Synthetics			
Epoxy	/	0.6707	0.5111
PVC	/	0.5203	0.4000
Other Synthetics	/	2.1940	1.5556
Glass/ceramics/inert materials			
E-glass	/	1.0343	0.7833
SiO	/	0.2241	0.1667
Ceramics	/	0.9168	0.7056
Si	/	0.0172	0.0133
Metals			
Steel	141	/	/
Fe	/	7.7449	5.8500
Cu	/	2.2473	1.6889
Al	/	2.2254	1.4722
Ni	/	0.0674	0.0500
Sn	/	0.1238	0.0944
Zn	/	0.0298	0.0228
Pb	/	0.0768	0.0583
Precious metals			
Au	/	0.0010	0.0008
Pt	/	< 0.0001	< 0.0001
Pd	/	0.0004	0.0003
Ag	/	0.0042	0.0032
Ru	/	< 0.0001	< 0.0001
Other Precious materials	/	0.0027	0.0020

Table 2.3: BOM for a datacenter [25, 26]

Materials	Mass [kg]
Plastics	0.515
Batteries	0.2626
Display	0.16
Storage	0.0712
PCB	0.265
Steel	0.2251
Al	0.2117
Mg	0.177
Cu	0.0121
Total:	1.93

Table 2.4: BOM for a laptop computer [13]

Materials	Mass [kg]
Steel housing	4.95
Plastic housing	0.16
PCB	0.66
CD-ROM/DVD ROM	0.75
Power-supply unit	1.62
Hard disk	0.55
Cable	0.14
Radiator (Al)	0.57
Fan	0.07
Total:	9.47

Table 2.5: BOM for a desktop computer [13, 27]

Conference & Recording devices

Conference devices: According to [28, 14], there exists 3 main solutions for conference: rooms, hardware and mobile[2]. There are 73, 94 and 78 of each devices respectively. On top of this, for each conference room and conference hardware comes a 65" TV.
As no precise BOM exists, we will use the system process named *Electronic component* to represent the camera, speaker and microphone. To model the impact of each device and take its shape and size in consideration, we decided to subtract 20% kg from the total advertised weight and use the rest of the weight allocating 60% for

[2]the fourth not being mention in the first source which seems to have been phased out

plastic housing, 20% for steel housing, 10% for PCB and 10% for cables as this type of mass distribution is similar to what was observed for laptops and other electronic devices.
For the conference room, we used the *Logitech rally* as reference [28] which is made with 40% recycled plastic according to Logitech [29]. For the hardware, KU Leuven use the *Logitech Meetup* and for the mobile, they use the *Logitech ConferenceCam Connect* [28].

Materials	Conference Room [kg]	Conference Hardware [kg]	Conference Mobile [kg]
Plastic	3.348	0.4992	0.383
Steel	1.116	0.1664	0.128
PCB	0.558	0.0832	0.0638
Cables	0.558	0.0832	0.0638
Materials	quantities	quantities	quantities
Camera(s)	1	1	1
Microphone(s)	6	3	2
Speaker(s)	2	1	1
Paired components	quantities	quantities	quantities
65” Screen	1	1	0

Table 2.6: BOM for the conferencing devices [29, 30, 31]

Recording system: According to [32], the *Extron* system is vastly used at KU Leuven. It is composed of a 10” *TouchLink Pro 1025T* [33] that must be paired with a compatible control processor. The *IPCP Pro 250 xi* is taken as reference and is the first recommended device by the manufacturer [34]. Paired with this recording system, there is the video projector. The NEC P554U beamer is actively used at KU Leuven and we generalized this information for all classroom.
The BOM of a projectors was found in literature and the other devices was estimated based on their total weight and comparable devices [35].

Materials	Projector [kg]	Recording tablet [kg]	Control processor [kg]
Plastics	1.405	~ 0.64	~ 0.1
Al	0.162	~ 0.1	~ 0.05
Steel	0.069	~ 0.05	~ 0.01
Lens	0.194	/	/
Gas discharge lamp	0.068	/	/
PWB	0.495	~ 0.3	~ 0.1
Fans	0.255	/	/
Screws	0.048	~ 0.03	~ 0.03
Speaker	0.044	~ 0.03	/
Cables	0.047	~ 0.01	~ 0.01
Liquid Crystal Display (LCD) panel	/	~ 0.2	/

Table 2.7: BOM for the recording devices

On top of this, there must be a computer that controls the projection and recording. Note that the lamp of the projectors last for 6 months of intensive usage according to the manufacturer [36] and they are covered for 3 years. So over the course of its lifetime (4 years), we need 8 lamps.
We can estimate the amount of room equipped with this material at around 300. Indeed, a class is composed of around 150 students and if most of the students have classes at the same time, 300 rooms should be available at the same time.

2.5 LIFE CYCLE & ENERGY CONSUMPTION

2.5.1 Students

Life Cycle of tablets

Prior research [37] indicates students retain their tablet devices for approximately four years. The digital stylus, an associated accessory, is likely to exhibit a similar life cycle, as it is typically replaced concurrently with the tablet. Regarding personal laptops used for academic purposes, there remains insufficient research with statistically significant sample sizes to determine a precise replacement frequency among students. Multiple influencing factors may be considered: for instance, intensive usage and the frequent transportation of devices during academic activities may increase the risk of physical damage and accelerate wear. On the other hand, factors such as graduation or income from student employment may encourage device replacement, whereas students without extracurricular income may continue to use aging devices despite minor malfunctions. Based on these generalized scenarios, we propose adopting a four-year estimated lifespan for personal laptops, consistent with the replacement schedule followed by KU Leuven's ICTS infrastructure, which will be elaborated on in a subsequent section.

Energy Consumption

According to the 2024 Eurostat survey [12], approximately 77% of students within the European Union own a laptop, while 34% own a tablet. However, it would be inaccurate to assume that these percentages directly reflect the number of devices used for academic purposes. The extent to which students digitize their learning is often influenced by the teaching and assessment formats adopted by individual courses. For instance, in course units with open-book examinations, students may prefer to take notes on paper, as electronic notes might ultimately require printing in order to be used effectively during the exam.
Therefore, rather than attempting to estimate the actual energy consumption of all students using electronic devices for education—which would vary significantly—we propose a reference-based approach. Specifically, we will estimate the energy consumption under two hypothetical scenarios: (1) where a student relies entirely on electronic devices for their studies, and (2) where all students who own such devices use them exclusively for educational purposes. These estimations will be presented separately for laptops and tablets. Subsequently, we will refer to existing literature on the environmental impact of paper-based learning to provide a preliminary comparison. Regarding the use of a stylus pen, most models are designed for extremely low power consumption and can operate for extended periods on a single charge [38]. Compared to the energy demands of a tablet, the energy consumption of a stylus is practically negligible. Therefore, for the purpose of this analysis, we have chosen to consider the tablet and stylus as a single combined unit. Our data is gathered from various prior studies.[18, 21, 39] While conducting research on device usage within KU Leuven-provided facilities—detailed further in the subsequent section—we estimated the personal energy consumption of individual devices by assuming 8 hours of use per working day over a period of 18 weeks. Based on this usage pattern, the estimated energy consumption per student is as follows:

- *Laptop:* $18 \cdot 7 \cdot 8[Hours] * 50[Watt] = 50.4[kWh]$
- *Tablets:* $18 \cdot 7 \cdot 8[Hours] * 20[Watt] = 20.16[kWh]$

Now, if we take into account the ownership ratio of these two electronic platforms—77% of students within the European Union owning a laptop and 34% owning a tablet—alongside KU Leuven's student population consisting of 58,550 regular students and 7,292 PhD students, we can estimate the total academic energy consumption for these devices under full utilization conditions:

- *Laptop (ownership 77%):* $0.77 \cdot (58550 + 7292) * 50.4[kWh] \approx 2558214.8[kWh]$
- *Tablet (ownership 34%):* $0.34 \cdot (58550 + 7292) * 20.16[kWh] \approx 451883.8[kWh]$

Although the figures may seem large, a study by Muhammad Imran [40] reported that the production of one ton of paper for paper-based education requires approximately 5-17 GJ of energy. Additionally, many handouts are often discarded after only a short period of use. The study found that computer-based methods emit slightly less CO_2 compared to paper-based ones. However, the actual environmental impact depends significantly on students' eco-conscious behavior—such as how efficiently they utilize paper handouts or the usage patterns of their electronic devices.

2.5.2 KU Leuven

Life Cycle of the hardware on premises

According to [24], there are 2930 desktops in use and they are replaced every 4 years[3]. The screens, mouse and keyboards remain in place [24] and it is estimated it can last up to 8 years for screens [41] until the backlight fails, same lifetime can be expected from input devices. On top of those, they are some desktops available at learning center and others places where the use is less intensive. Those computers are kept for an undetermined amount of time. They are replaced until they no longer function properly, which is approximately 8 years [24].

Energy Consumption

Since a semester is 18 weeks, it can be assumed that each electronic device is used daily and they are employed around 8 hours per day and 24 hours for servers. Power consumption estimates for each device are based on data from :[42, 18, 43, 36, 21].

- *Server:* $18 \cdot 7 \cdot 24[Hours] * 1000[Watt] = 3024[kWh]$
- *Desktop:* $18 \cdot 7 \cdot 8[Hours] * 370[Watt] = 372.96[kWh]$ (desktop and screen)
- *Laptop:* $18 \cdot 7 \cdot 8[Hours] * 50[Watt] = 50.4[kWh]$
- *Tablets:* $18 \cdot 7 \cdot 8[Hours] * 20[Watt] = 20.16[kWh]$
- *Conferencing devices:* $12 \cdot 5 \cdot 3[Hours] * (Mic \cdot 2.5 + Speaker \cdot 4.1 + Cam \cdot 9.5 + (20 + 172 \cdot ScreenSize[m^2]))$
  These values require adjustment per device type [44]. For a 65" TV, the surface is around $1.2m^2$.
  1. *Room*: $P = 2.5 * 6 + 4.1 * 2 + 9.5 + 20 + 172 * 1.2 = 259.1[W] \rightarrow 46.638[kWh]$
  2. *Hardware*: $P = 2.5 * 3 + 4.1 + 9.5 + 20 + 172 * 1.2 = 247.5[W] \rightarrow 44.55[kWh]$
  3. *Portable*: $P = 2.5 * 2 + 4.1 + 9.5 = 18.6[W] \rightarrow 3.35[kWh]$
- *Recording devices:* $12 \cdot 5 \cdot 8[Hours] * (11.5 + 9.6 + 457) = 229.488[kWh]$ (control panel + recording device + projector consumption) [33, 34, 36]

Toledo and Cloud: Regarding the power usage for AWS, Germany has been developing extensively their data centers and they are using over 10 TWh of their energy just for cloud computing [45, 46, 47].
According to a report by AWS in 2024, they should be using 100% of renewable energy for their datacenter by 2025. While some independent investigations reveal that the carbon footprint of those data centers may be up to 6.62 times higher than reported by the major IT companies [48].
However, Amazon cannot control the entire data transport chain and so the traffic may go to less sustainable backbones routers. Studies show data transfer costs up to $2.5 \cdot 10^{-3} gCO_2e/GB \cdot km \approx 78.125 \cdot 10^{-6} kWh/GB \cdot km$ in France [49, 50, 51].
As the cloud infrastructure is complex to model, the choice has been made to model data storage and streaming as a *system process* instead of a unit process. According to a study by Carnegie Mellon University [52], around 3 to 7 kWh per year are required to store and stream a GB of data. Some other studies have indicated an energy

[3] This lifetime of 4 years will be used for every product which is extensively used (laptop, projector, ...)

consumption closer to 0.1 kWh [20] but was focusing on Cloud storage and not streaming. It was decided to take 1 kWh per GB per year as the reference for streaming and 0.1 kWh per GB per year for cloud storage [53, 54, 55]. By combining equations 2.5, 2.8 and 2.10 and comparing the various scenarios, we obtained the following result:

Service	Data Before COVID [kWh]	Data During COVID [kWh]	Data After COVID [kWh]
Video stream	72.7E+3	581.5E+3	581.5E+3
PDF stream	40.9E+3	122.6E+3	122.6E+3
Cloud storage	114.0E+3	114.0E+3	114.0E+3
Conferencing	17.4E+3	208.5E+3	34.8E+3
Total Cloud	244.9E+3	1.0E+6	852.9E+3

Table 2.8: Energy Consumption of the cloud for a semester

2.5.3 Global metrics

Transport

The vast majority of IT products come directly from China. The most employed trade route from China to Europe goes through the Suez Canal, this route is approximately 19600 km long on board of container ship [56, 57].

Material	Transport [tkm]
Desktop	185.612
Laptop	37.828
Server	8957.2
Conference: Room	138.768
Conference: Hardware	20.384
Conference: Mobile	15.0136
Recording	78.4

Table 2.9: Transport for each material

2.6 DISPOSAL SCENARIO AND REUSE

2.6.1 Students

The city office of Leuven offers recycling services for electronic devices through designated recycling parks, as stated on the local government website. In the case of laptop and tablet devices, an additional End Of Life (EOL) scenario worth mentioning is resale to second-hand vendors for refurbishment and eventual resale to new users. However, regarding conventional recycling routes, it has been reported in [58] that even under the most optimistic scenarios, the recycling efficiency of tablets in Europe falls short of the targets established by the European Directive for IT and telecommunications equipment. This is partly attributed to the difficulty in disassembling and separating tightly integrated components, such as LCD screens.
A similar challenge applies to digital styli. Refurbished styli are typically only offered by the original manufacturers, suggesting that refurbishment often involves replacing or repairing proprietary internal components that are not easily accessible.

2.6.2 KU Leuven

For the Hardware used at KU Leuven, the IT department has been involved in a few programs to give desktops and laptops a second chance through *Close the gap* and *Worldloop* [24, 59, 60]. Close the gap is a program that donates used computers to emerging countries in Africa. The Worldloop program *was*[4] a program that ensured

[4]Seems to have gone out of business as of 2025 [61]

KU Leuven that their Waste from Electrical and Electronic Equipment (WEEE) will be disposed in a sustainable manner [60]. Nowadays, the rest of material that cannot be donated or is broken goes to RENEWI who disposes the WEEE. According to [62, 63], 74% of material is recovered from their input SDA/LHA - ICTS mix.

KU Leuven doesn't provide the exact share of donated and disposed hardware and no figure is known in the literature [64, 65]. So we will analyze 3 disposed-donated scenarios: 30-70, 50-50, 70-30.
They also mention giving away and disposing screens after 8 years, but according to manufacturers, screens last up to 30000 hours [41] which is equivalent to 8 years of regular use. This means that most screens are unusable when they arrive in their EOL so they are almost all disposed by RENEWI.

Due to their specialized nature, we model video conferencing, recording devices, and servers as disposed by RENEWI. This type ICTS hardware are not the primary target of the Close the gap initiative [66].

CHAPTER 3

Comparative Life Cycle Assessment

3.1 ACTUAL SITUATION

3.1.1 Student

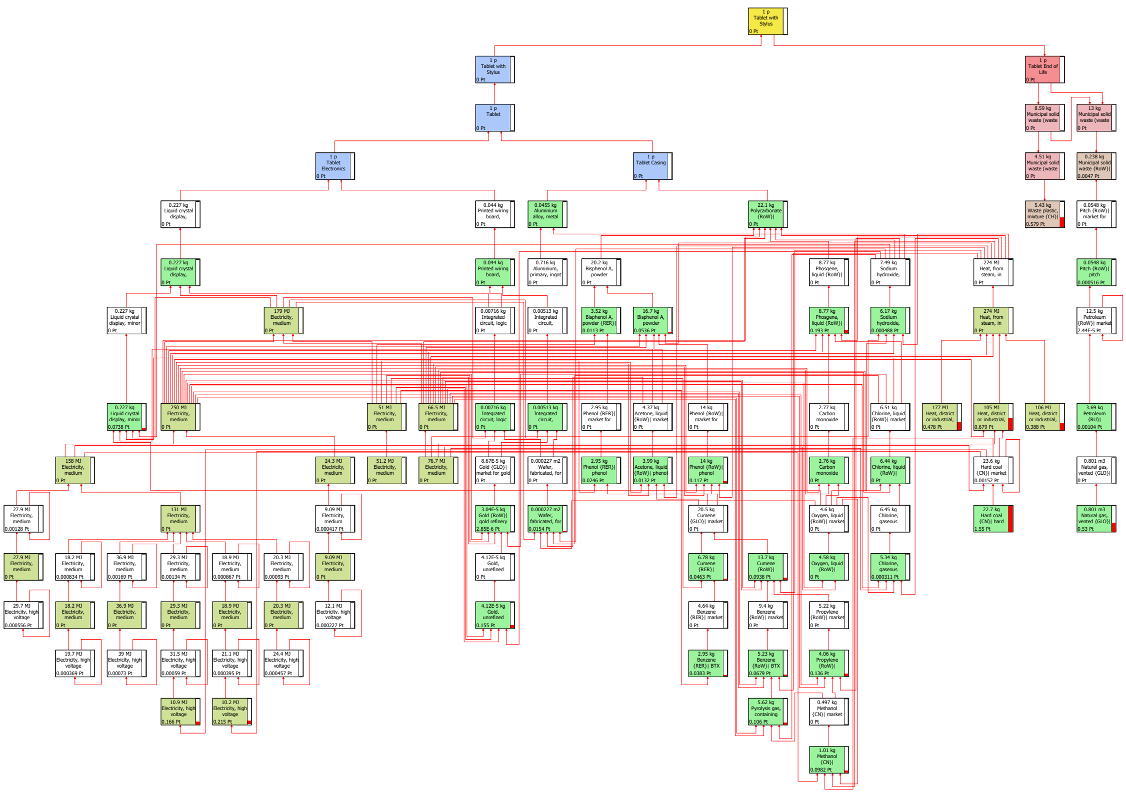


Figure 3.1: Network (2% cut-off) of tablet and stylus usage, single student

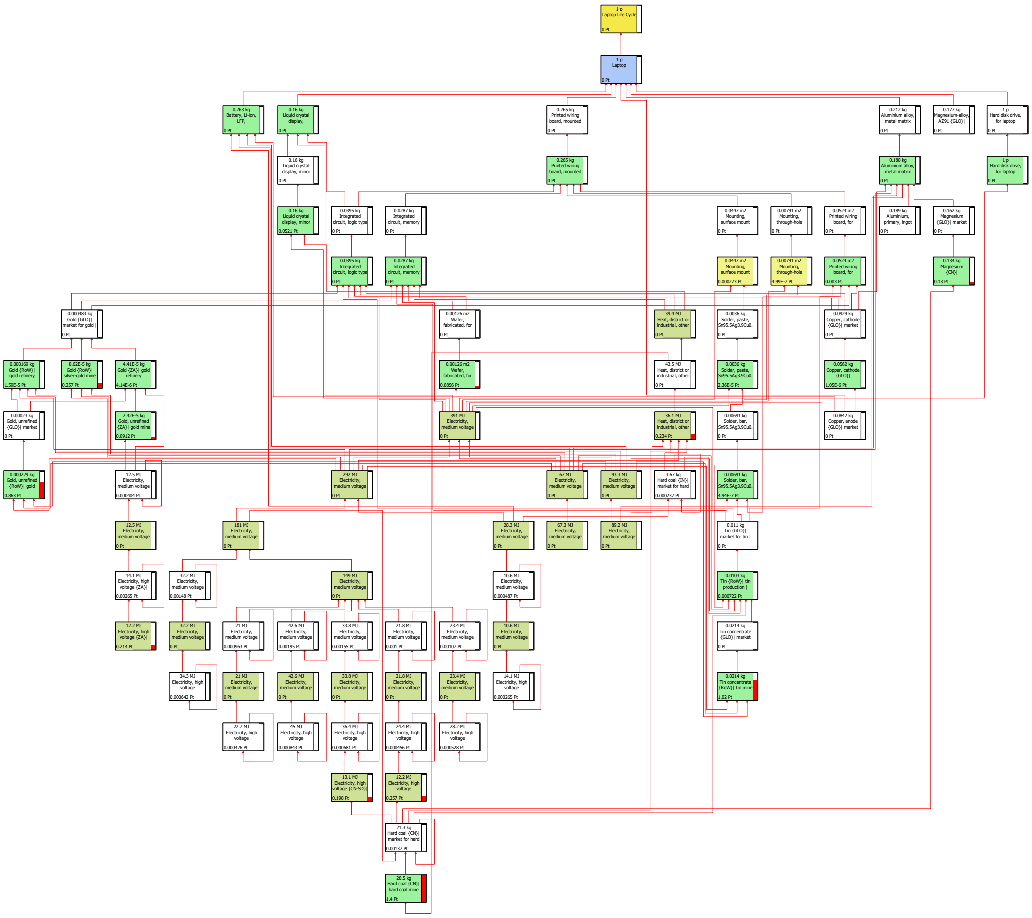
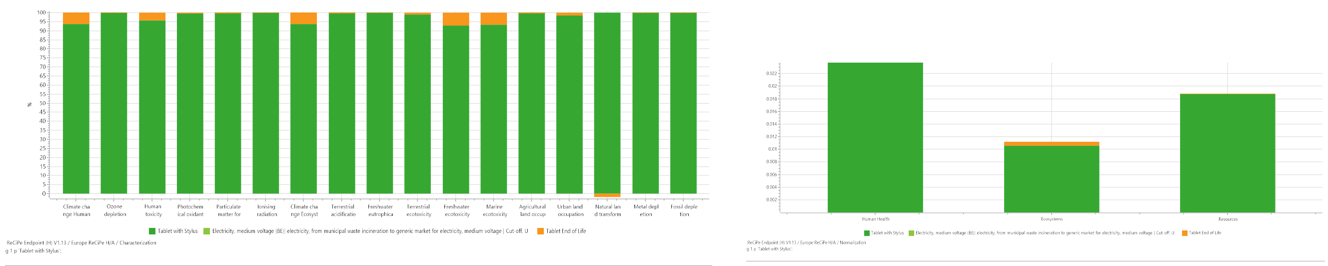


Figure 3.2: Network (2% cut-off) of laptop, single student

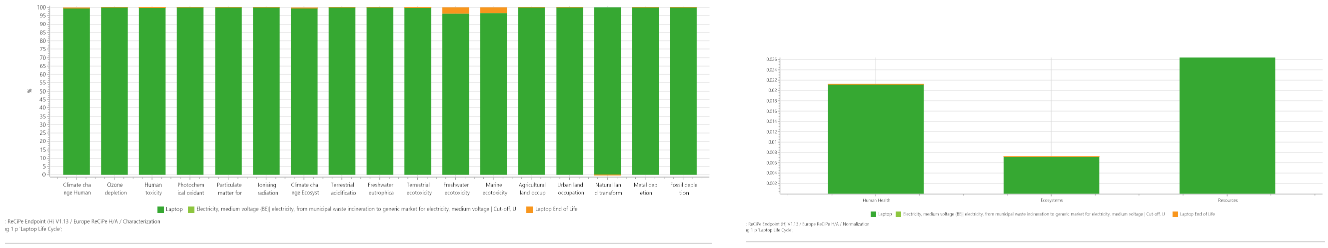


(a) Midpoint

(b) Weighted following ReCipe 2016 Hierarchist

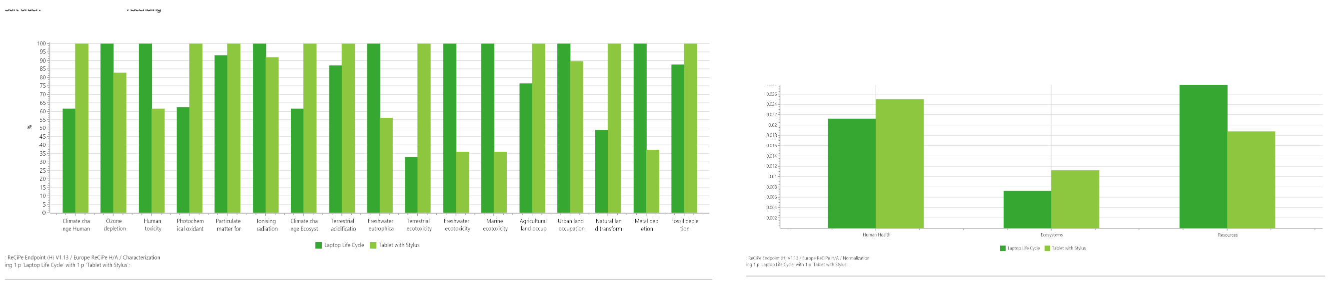
Figure 3.3: Analysis of tablet and stylus based study, single student

In this study, we conducted an LCA of tablets combined with stylus pens, as well as laptops. We adopted the EOL scenarios outlined in [58], which include reselling as second-hand devices, incineration, and landfill disposal. The assessment revealed that the production phase and the extraction of raw materials contribute significantly to the overall environmental impact. When comparing tablet-based and laptop-based educational approaches, we observed that laptops have a higher environmental burden during the production phase, whereas tablets tend to consume more energy during the usage phase.



(a) Midpoint (b) Weighted following ReCipe 2016 Hierarchist

Figure 3.4: Analysis of laptop based study, single student



(a) Midpoint (b) Weighted following ReCipe 2016 Hierarchist

Figure 3.5: Comparison of tablet and laptop-based study, single student

3.1.2 KU Leuven

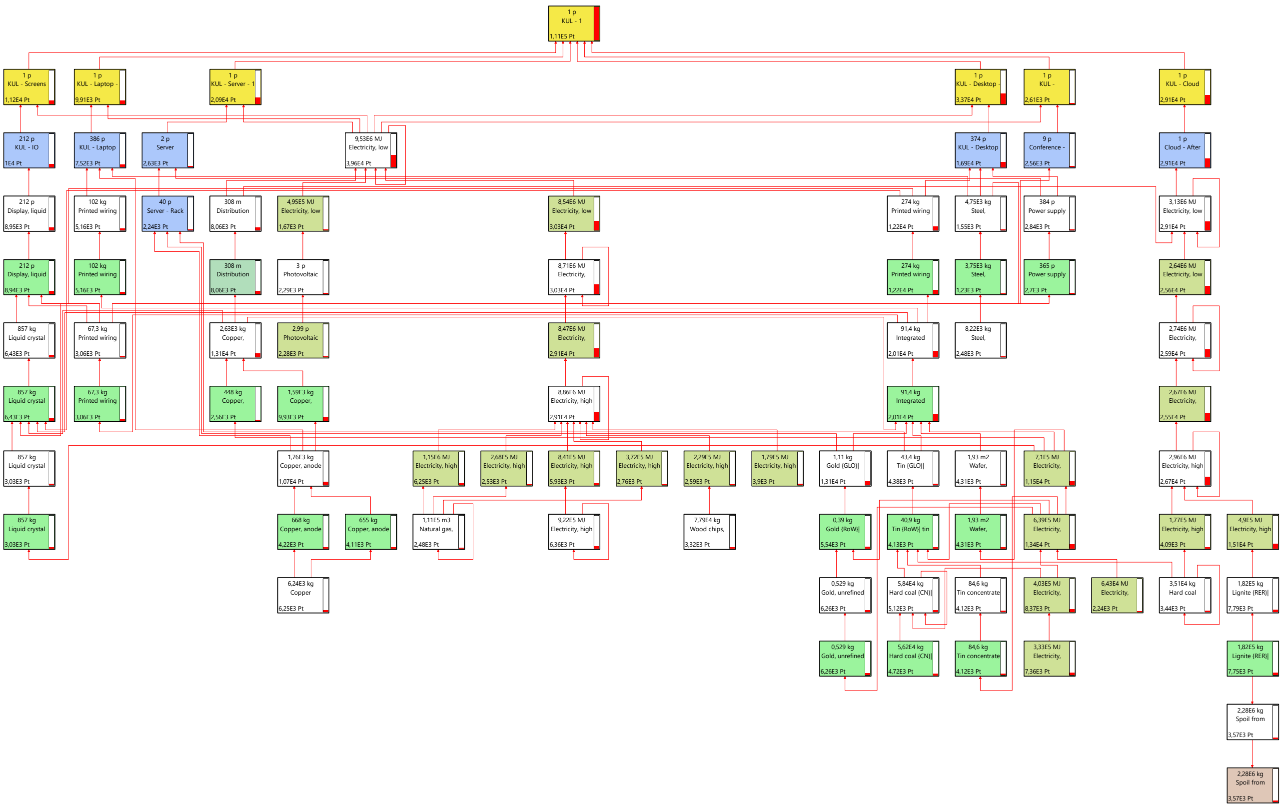
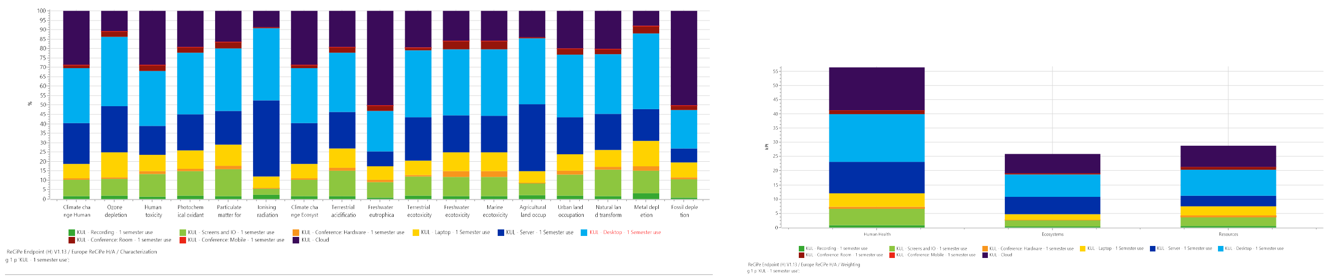


Figure 3.6: Network (2% cut-off) of KU Leuven 1 semester of use



(a) Midpoint

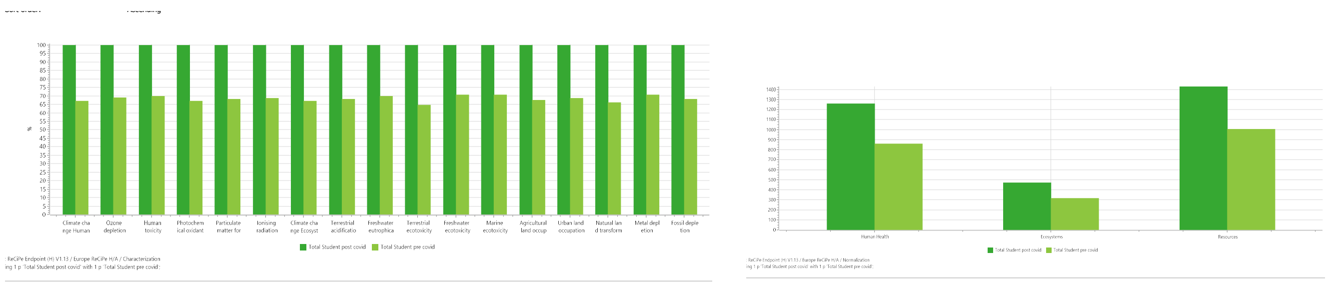
(b) Weighted following ReCipe 2016 Hierarchist

Figure 3.7: Analysis of current situation

In this study, the cloud was running on the typical German energy mix which makes its impact far from negligible. On premises, the desktop remains the largest contributor to environmental impact, even under an ideal 50–50 donation and recycling scenario

3.2 COMPARING BEFORE, DURING & AFTER COVID

3.2.1 Students

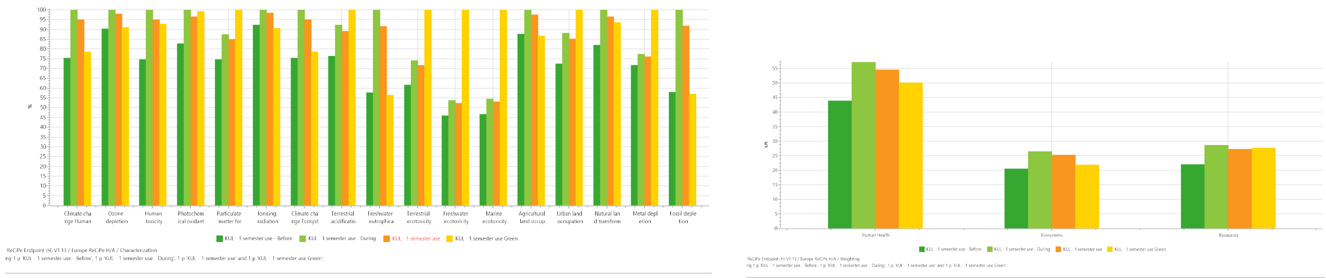


(a) Midpoint (b) Weighted following ReCipe 2016 Hierarchist

Figure 3.8: Comparing the situation before and after COVID, estimation of all students

In this comparative analysis, we considered the shift in study behavior following the COVID-19 pandemic. Approximately 60% of students now choose to watch recorded lectures, whereas pre-COVID, the attendance rate for in-person lectures was significantly higher. We took the entire population of KU Leuven degree-seeking students as the target group. Based on usage assumptions, we estimated that students with only a laptop perform 60% of their study activities digitally, those with both a laptop and a tablet follow a hybrid approach with an even 50–50 time split between the two devices, and the remaining students rely predominantly on paper-based methods.
The comparison between pre- and post-COVID periods was made by estimating the increase in electronic device ownership, using the growth in sales data of corresponding electronics as a proxy [11]. This analysis reveals a clear increase in environmental impact post-COVID. However, it is important to note that we did not account for the potential reduction in transportation-related emissions resulting from increased remote learning.

3.2.2 KU Leuven



(a) Midpoint (b) Weighted following ReCipe 2016 Hierarchist

Figure 3.9: Comparing the situation before, during and after COVID

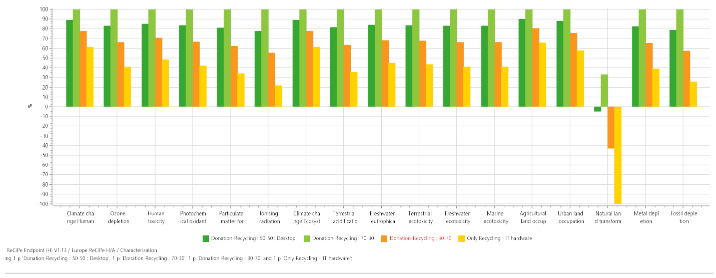
The cloud impact kept rising during COVID and has still yet to come back to normal. Our habit of educational content changed but not our ecological sobriety.

3.2.3 Sensitivity Analysis

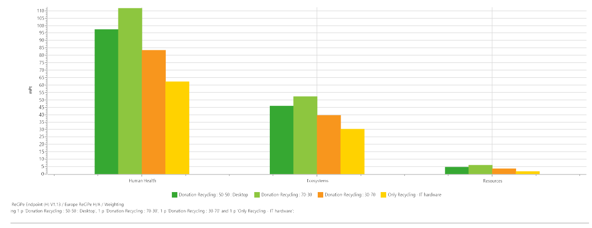
One way to solve this ecological footprint would be to replace the source of electricity by some green one such as wind. In the new scenario based on the actual situation, we can see that producing offshore wind farm will have a greater impact than the current situation.

However, switching to green electricity alone, as Amazon claims [46] is insufficient and an institutional switch should be operated as we will further develop in section 4.3.

3.3 COMPARING POSSIBLE EOL TREATMENTS



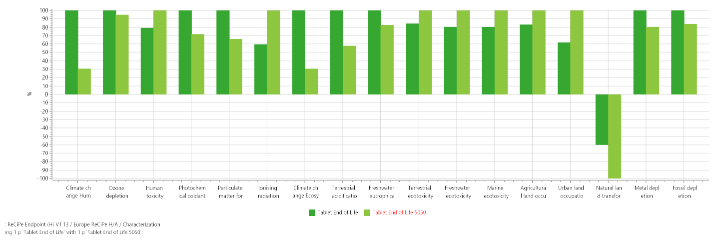
(a) Midpoint



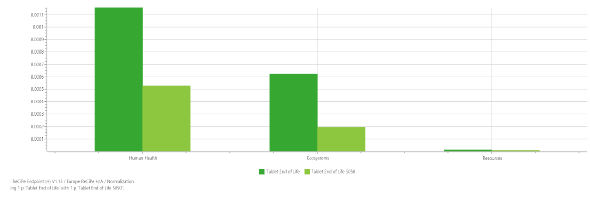
(b) Weighted following ReCipe 2016 Hierarchist

Figure 3.10: Comparing various EOL situation

Contrary to popular belief, donating IT materials through Non Governmental Organization (NGO) to help the one in need in Africa isn't the most sustainable choice. Proper recycling of the material will be more benefical for the environment as we treat locally the goods and do not ship them overseas.



(a) Midpoint



(b) Weighted following ReCipe 2016 Hierarchist

Figure 3.11: Comparing various EOL situation, Tablets

To gain a quick insight into EOL scenarios that include refurbishment, we conducted a comparative analysis between regular disposal and recycling ratios of tablets versus having half to go under refurbishment, taking into account additional transport impacts. The results indicate that refurbishment generally leads to a lower environmental impact.
Based on this finding, we recommend that students, when acquiring electronic devices for academic purposes, consider purchasing refurbished or second-hand equipment that sufficiently meets their needs. This approach significantly reduces environmental burden compared to buying new devices.

3.3.1 Critique

Of course, Simapro is an LCA tool and not a sustainable development tool that also takes into the Sustainable Development Goals (SDG) of the United Nations [67]. So sending overseas may help on the long run which the software doesn't capture.
In our model, we followed what RENEWI stated on [62, 63] but it may not be representative of the actual percentage a desktop or laptop will be recycled. In fact, this number represents the percentage of goods that will be recycled from a certain pool of waste. So one could manipulate the number by putting in the same recycling

pool a thousand of easily recycled goods and a few impossible to recycle which are the most harmful for the environment.
On top of this, our current model may not properly represent the negative impact of recycling and the possible toxic fumes, liquids, ... used in the recycling process.

CHAPTER 4
Possible Improvements

4.1 SUPPORT FOR REFURBISHED ELECTRONICS

Based on the data gathered above, we have identified a major limitation in the recycling efficiency of electronic devices, primarily due to the difficulty of separating compact components. To maximize recycling efficiency, we propose that students consider sending their outdated electronic devices to certified refurbishing vendors at the end of their EOL. This approach allows reusable components to be preserved with only the broken parts being replaced, thereby contributing to environmental sustainability and providing moderate financial returns through vendor buy-back programs.

In addition to responsible disposal, we also recommend that students consider purchasing refurbished tablets and styluses for academic purposes from resellers. These products are typically available at lower prices and carry a significantly reduced environmental footprint. According to a report conducted by ADEME in 2022 [68], purchasing refurbished electronics can reduce the annual environmental impact from 46% to 80% compared to buying new products.

4.2 BALANCING PAPER AND DIGITAL TOOLS IN EDUCATION

Previously, we mentioned that the study by Muhammad Imran [40] reported that the production of one ton of paper for paper-based education requires approximately 5–17 GJ of energy, and generally results in higher CO_2 emissions compared to electronic devices. However, in practical scenarios involving mixed usage, the environmental trade-off largely depends on students' individual usage patterns.

For instance, prior to the COVID-19 pandemic—when paper-based education was predominant—student paper consumption included single-use items such as draft and exercise sheets, moderate-use materials such as printed lecture slides, and long-term resources like handwritten notes. Depending on the study intensity, this consumption could become substantial. In contrast, electronic devices generally have longer lifespans and can fulfill multiple functions—drafting, note-taking, and practicing exercises—based on user preference.

Post-COVID, with the increased adoption of electronic devices in education, we have observed diverse patterns of paper and device usage. Some students prefer drafting on paper and taking notes on a tablet or laptop, while others fully transition to tablets for both. We encourage students to avoid single-use paper disposals by opting to draft and practice on electronic devices whenever feasible. Paper usage should be reserved for content that requires repeated reference and long-term retention.

A specific issue worth addressing is the use of printed materials for open-book exams, which often leads to significant paper waste, as students tend to discard these materials afterward. We propose that such exams be conducted in campus computer labs, where students can access their pre-downloaded notes from the semester. Internet access could be disabled during the exam to maintain academic integrity. According to the findings in [40], exams conducted in this digital format would still be more environmentally friendly in terms of energy use and CO_2 emissions than traditional paper-based exams.

Furthermore, we suggest that students consider sharing or selling printed materials to junior peers instead of discarding them, thereby extending their utility and reducing waste.

4.3 REDUCING CLOUD FOOTPRINT

As presented in section 3.3.1, using green source of electricity is a solution to reduce the environmental impact of the cloud. But, the cloud is volatile and KU Leuven can't control the total supply chain and distribution network. This is why we present here 3 applicable and possible improvements at the scale of the University.

4.3.1 3 possibilities

1. Reducing video footprint

800 MB for an hour of content is already a fairly low number and efforts have been made to limit this footprint (limit to 720p video, lower bitrate, ...) but more can be done. We propose multiple strategies to shrink this number to even lower figure:

- Use AV1 codec instead of H264: this is an Open-Source and more efficient codec reducing the file size by 30 to 50% compared to regular H264 encoded video [69].
- Only record audio and use extremely low Frame per Second (FPS) video: besides for a few lecturers that actively use the blackboard, most of them just use the slides as a support and talk along. So it would make sense to not record through the camera but simply the screen every seconds or less. It could reduce the file size by $\sim 50\%$ depending on various settings [70].

2. More efficient Ultra platform and no PDF streaming

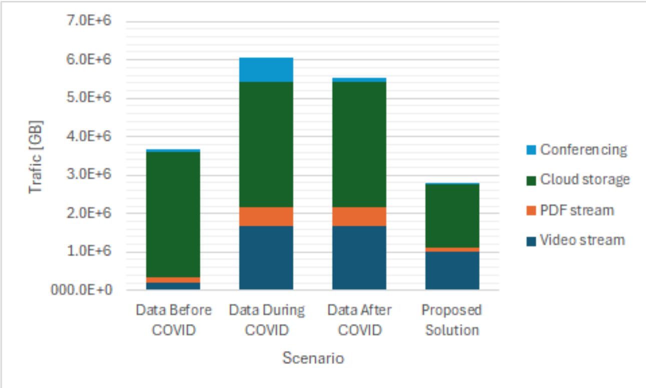
As shown in eq. 2.8, Ultra is not well optimized nor designed for ease of navigation. Its performance are bloated with unnecessary loads that hurt the bandwidth and traffic. Moreover, forcing students to download once the PDF instead of *streaming* it could significantly reduce data transmission and energy consumption. The equations could become:

$$58550 \cdot 12 \cdot 8 \cdot (\mathbf{1}[access] \cdot (2[pages] \cdot \mathbf{5}[MB] + (5 + 2[MB]))) = 95.6[TB] \tag{4.1}$$

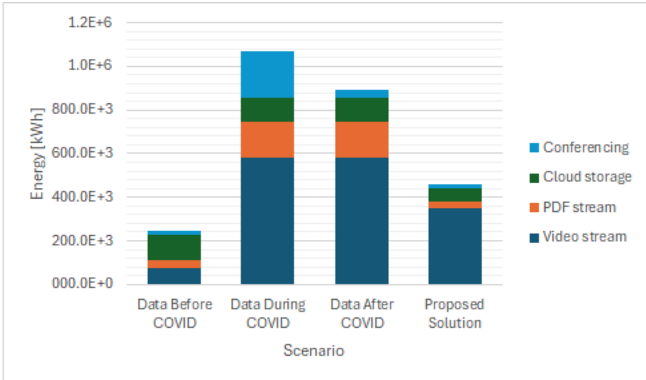
Which is a reduction by a factor 3.7.

3. Limit the cloud storage

A lot of students have some cloud storage but don't actively use it which is by itself consuming a lot of energy. Indeed, even if the 50 GB are not full, there must be somewhere on a server or an edge node 50 GB of free storage for anyone. This pending empty storage is an useless expenditure and could be avoided by further reducing the storage to 25 GB, reducing the Microsoft's cloud impact by 50%.



(a) Traffic in GB



(b) Energy in kWh

Figure 4.1: Reduction in traffic and energy assuming AV1 reduction of 40% and Cloud to 25 GB

4.3.2 Beyond the Ecological standpoint

While cloud is a fantastic technology, easy to scale, efficient resource usage, virtual, ... it can pose some concerns about its social and environmental impact. We are more and more relying on this bit of technology but, lately, voices are raising their concerns about sovereignty in the cloud [71, 72]. Everyday, KU Leuven is uploading confidential, high-value and sensitive data on cloud servers owned by American giant such as Microsoft and Amazon.
Cloud sovereignty is not only a sustainability issue but also a matter of national security. Migrating to cloud that are owned by european companies is possible and will be more sustainable, safer and cheaper on the long run as AWS or Azure are one of the priciest cloud offers available [72, 73, 74].

4.4 IMPROVING LIFE CYCLE OF HARDWARE ON PREMISES

A significant part of KUL's environmental impact is due to the renewing and use of desktops. While it is important to keep hardware up to date to guarantee high quality education tools and for security concerns, there exists some better and smarter ways to achieve this.
Typically, use more modular desktop to re-use some basic components as the case, PSU, disks, ... which are responsible for a small cut of the impact ($\sim 30\%$ across all midpoints).
To stay in line with the philosophy of KU Leuven to virtualize their equipments to ensure better and more efficient use [3]; We could think of using less powerful local machine but which could use server's compute power for more intensive task. This technology already exists and is used by companies around the world using Chrome OS [75]. Of course, this would imply a thorough rebuild of the IT infrastructure but a good place to start is generalizing the use of Linux machine that also have some technology for distributed computing. On top of this, Rocky Linux—which incorporates some distributed computing technology—is already widely used at KU Leuven so pushing for more distributed computing should not be overly difficult [76, 77].

CHAPTER 5
Conclusion

Finally, this project taught us how to properly model and assess the impact of some innocuous practices and understand the scales and all the underlying connections between them. From a structured and thorough search in literature to proper modeling in Simapro. This, all together, allowed us to highlight and take key-measures on the core problematic. An LCA study is a mandatory step for anyone who wants to make a meaningful impact on the world they live in.

Regarding the energy consumption and carbon footprint of Ultra, there exists some open-source to monitor and quantify quickly those metrics [78]. Assessing the footprint of KUL's cloud would be the next logical step for the ICTS team in their quest of green IT.

Regarding personal electronic devices, a more accurate assessment could be achieved by conducting surveys across various campuses. By correlating the ownership data with students' preferred modes of study, more informed recommendations can be made to balance paper-based and various forms of digital-based learning.

5.1 ACKNOWLEDGMENTS

We thank Mr. Brent Hendrickx for his time, help and meaningful suggestions.
Template made by Henri De Plaen.

Glossary

AI Artificial Intelligence. 4

AWS Amazon Web Service. 12, 18, 30

BOM Bill Of Materials. 6, 10–12, 15, 16

CPU Central Processing Unit. 13, 14

ECTS European Credit Transfer and Accumulation System. 5

EOL End Of Life. 19, 20, 22, 26, 28

EPDs Electronic Paper Displays. 5

EU European Union. 10

FPS Frame per Second. 29

GB GigaBytes. 6, 13, 30

ICTS Information and Communication Technologies. 6, 12, 14, 17, 20, 31

IP Intellectual Property. 6

IT Information Technologies. 5, 6, 9, 13, 18, 19, 26, 30, 31

KVM Keyboard, Video (monitor), Mouse. 14

LCA Life Cycle Assessment. 4, 10, 11, 22, 26, 31

LCD Liquid Crystal Display. 16, 19

MB MegaBytes. 12, 13, 29

MOOC Massive Open Online Course. 4, 6

NDA Non Disclosure Agreement. 6

NGO Non Governmental Organization. 26

PDU Power Delivery Unit. 14

PSU Power Supply Unit. 14, 30

SDG Sustainable Development Goals. 26

TDP Thermal Design Power. 14

UPS Uninterruptible Power Supply. 13

WEEE Waste from Electrical and Electronic Equipment. 20

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