Environmental Impact of Media Use in Teaching and Learning at the Department of Informatics

Bachelor Thesis

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Abstract

This bachelor thesis studies the environmental impact caused by the use of lecture notes by Informatics students at the University of Zurich. For this, the life cycle assessment methodology was applied and the product systems were modeled and assessed with Umberto NXT LCA. Three electronic media (desktop computer, laptop computer, tablet computer) and two print media (self-printed lecture notes, printed books of lecture notes) were taken into consideration for the impact assessment. Alternative scenarios were also assessed to identify strategies aiming at an improvement of the environmental performance.

On the basis of the results of this research, it can be concluded that the current use of multiple media to study lecture notes is not environmentally preferred. The results suggest that desktop computer and self-printed lecture notes are the least preferred media and the shift to a purely laptop or tablet computer-based strategy can improve the current environmental performance by up to 80%. Even a combination of printed books, provided by the University, and tablet computer optimizes the current scenario by 42%.

Zusammenfassung

Diese Bachelorarbeit untersucht die Umweltauswirkungen, verursacht durch die Verwendung von Vorlesungsunterlagen durch Informatikstudierende an der Universität Zürich. Dazu wurde die Ökobilanz (Life Cycle Assessment) Methodik angewandt und die Produktsysteme wurden mit Umberto NXT LCA modelliert und ausgewertet. Drei elektronische Medien (Desktop Computer, Laptop Computer, Tablet Computer) und zwei Printmedien (selbstgedruckte Vorlesungsunterlagen, gedruckte Vorlesungsskripts) wurden für die Beurteilung der Umweltauswirkung in Betracht gezogen. Alternative Szenarien wurden ebenfalls ausgewertet, um Strategien zur Verbesserung der Ökobilanz zu identifizeren.

Auf der Grundlage der Ergebnisse dieser Forschung kann der Schluss gezogen werden, dass die aktuelle Verwendung von mehreren Medien, um Vorlesungsunterlagen zu studieren, ökologisch nicht bevorzugt ist. Die Ergebnisse deuten darauf hin, dass Desktop Computer und selbstgedruckte Vorlesungsunterlagen die am wenigsten bevorzugten Medien sind und die Umstellung auf eine rein Laptop oder Tablet Computer-basierte Strategie die aktuelle Umweltbilanz um bis zu 80% verbessern kann. Auch eine Kombination von gedruckten Vorlesungsskripts, die von der Universität zur Verfügung gestellt werden, mit Tablet-Computer optimiert das gegenwärtige Szenario um 42% .

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1. Introduction

1.1 ICT in education

The invasion of ICT into the education system is dramatically affecting the teaching and learning infrastructure worldwide. Class presentations supported by PowerPoint, solving and submitting assignments electronically and publishing video lectures on the internet are some examples illustrating the current use of ICT in education. The emergence of e-learning technologies such as electronic books, podcasts, wikis and blogs has enabled the integration of rich media formats into higher education. While earlier multiple devices were necessary to integrate different sorts of media such as audio, video and web-content, technological advances allow to cut down on the required variety of devices. Students now have the possibility to download digital textbooks, read them on different electronic devices such as laptop computers and e-readers, and make electronic notes during class.

ICT in education is not a new trend. The incorporation of computer-aided learning into the dental and medical education, for instance, has a history of more than 40 years (Gupta, White, & Walmsley, 2004).

Not only are ICT tools being integrated into the face-to-face teaching, efforts are being made – for example in the United States (Kim & Bonk, 2006) - to successfully establish revolutionary education system concepts such as online education and distance learning programmes.

There are four aspects as to how ICT will have an impact on education: what is learned, how it is learned, when and where learning takes place, who is learning and who is teaching (Sharma, 2011, p. 390). The OECD provides a classification of educational courses in tertiary education based on the level of ICT utilization (as cited in Sharma, 2011, p. 383-384). It covers a range from web-supplemented courses where mandatory face-to-face teaching is supplemented by the provision of electronic material and IT-based means of communication such as e-mail over courses where some parts are web-dependent (e.g. group work projects) to fully online courses eliminating location and time constraints.

While the awareness of the benefits of the ICT integration into teaching and learning is growing and implemented in varying degrees, the associated effects on the environment should also be taken into consideration. While ICT improves the efficiency of the teaching and learning infrastructure, it also requires the provision of additional IT infrastructure which results in environmental consequences. These need to be assessed systematically in order to conclude whether the overall environmental performance is improved or deteriorated.

In the next section, some key aspects illustrating the complex relation between ICT and sustainability are explained providing a basic understanding of the subject matter.

1.2 ICT and sustainability

ICT can contribute to a sustainable information society by dematerializing products and services, as Hilty explains: “The long-term availability of ICT services may enable and foster a transition to a less material-intensive economy” (as cited in Hilty, Lohmann & Huang, 2011, p. 16). Dematerialization as a strategy aimed at sustainability is based on the resource decoupling concept (Hilty et al., 2011, p. 15). Resource decoupling is defined by the United Nations Environmental Programme (UNEP) as the resource reduction per unit of economic activity; i.e. for the production of one unit of economic activity, lesser amount of primary resources is required (as cited in Hilty et al., 2011, p. 14). ICT fosters resource decoupling by facilitating the shift from material to immaterial resource use for economic activities (Hilty et al., 2011, p. 15).

However, ICT does not automatically contribute to a dematerialized society. As the following classification by Hilty (2011) shows ICT causes positive as well as negative environmental effects.

Classification of material ICT effects:

- Primary effects are associated with the ICT hardware resulting from production, use and disposal

- Secondary effects are indirect effects of ICT resulting from changes in processes of other products or services (e.g. production, transport) – these effects can result from both an increase or decrease of the material impacts

- Tertiary effects result from medium- or long-term adaptation of behaviour and economic structures

The first category covers the mainly negative effects associated with the life cycle of the hardware (production, distribution, use and disposal) due to resource use and environmental releases (Hilty, 2011; Berkhout & Hertin, 2004).

The second category covers the positive effects associated with the increase in production efficiency and the complete dematerialization of certain products and services. Design software, simulation and modeling tools can support in the evaluation of product design options from an environmental and economic perspective. A better design can reduce the required material and energy resources substantially. Sensors and monitors measuring, modeling and communicating environmental performances contribute to a better understanding of the environmental impacts. This is necessary in order to create motivation to increase the efficiency, productivity and quality in businesses. Electronic devices foster a complete substitution of goods and services which are material-based and information-intensive. Examples illustrating this virtualization are print-based catalogues, newspapers, music, videos and pictures. Secondary effects also include the negative effects resulting from an increase of the use of other products and services. While ICT is for example making global markets and trading possible, it’s also responsible for the associated increase in demand for transport and distribution (Berkhout & Hertin, 2004).

Rebound effects arise when the product or service efficiency increases, but due to an increased demand of the product or service higher material consumption than before is caused on the macro-level. The increased demand eventually results in a re-materialization. This specifically arises due to the lack of demand regulation. Rebound effect is an example of a tertiary effect (Hilty, 2011).

A structural change is caused by the shift from material-intensive products to service-based products resulting in lower resource and energy use. This can be observed from the increase in Internet-based service supply. A green consumerism movement is also expected due to a better information access about environmental sustainability exemplifying a long-term change in behaviour (Berkhout & Hertin, 2004, pp. 915-916).

Primary and secondary effects can be further classified into three types of effects: optimization, induction and substitution. These effects can be quantified using a life cycle assessment approach (Hilty, 2011).

The use of an ICT service can have an optimization effect on any phase within the life cycle of another product (e.g. production, use and disposal). An induction effect occurs when an ICT service influences the consumption of another physical product (decrease or increase). Substitution effect occurs when an ICT service substitutes the use of a physical product (Hilty, 2011).

Substitution effects can be observed in many sectors such as research and development, entertainment, health, travel and production. Another sector where ICT is likely to play a key role in future is the government and public services. It is also establishing new forms of businesses. E-commerce allows buying and selling to be executed over the Internet. This new form of sales has also affected the book publishing industry. Furthermore, new electronic devices such as e-book readers are being developed which are substituting printed books.

In the context of electronic lecture notes used by students, an optimization effect could be the avoidance of extensive paper consumption in the production process for printed lecture material. An induction effect could result from supplementary printouts when using electronic material. A substitution effect arises from the fundamental shift from paper-based to electronic material.

1.3 Motivation and objectives

In developed countries it is unusual that in higher education the lecturer writes notes on a blackboard and students transfer them to their paper notebooks. The notes are often presented in form of electronic files making the course material available online. It is up to the students whether to access the content electronically by using an electronic device or taking a printout. The most evident difference between the two alternatives (print and electronic) occurs during the use. While in the case of reading electronic course material an electronic device is required, no additional resources are needed to read printed material.

In this context, my project specifically studies the environmental impact produced by the use of lecture notes for learning purposes by students at the department of Informatics at the University of Zurich. As the environmental impact depends on many parameters related to the use patterns, it is a further goal to gain insight into the current use patterns of different media for study purposes.

The research questions have been defined thus:

1) What is the total environmental impact produced by the use of print and electronic media for studying lecture notes by students?
2) Is it possible to reduce the total environmental impact and what are the possibilities for optimizing the current environmental performance?

These objectives and research questions would provide a first basis in assessing whether the substitution of printed lecture material by electronic material is supporting the ‘Green by ICT’ concept.

1.4 Definitions

1.4.1 Sustainable development

Oxford dictionaries (n.d.) define sustainable development as “an economic development that is conducted without depletion of natural resources”. However this definition appears to be too narrow compared to the most-cited definition by the World Commission on Environment and Development: “Development that meets the needs of current generations without compromising the ability of future generations to meet their own needs” (as cited in Hilty, 2011, p. 410). Sustainable development is achieved by balancing three interconnected pillars – economy, society and environment. An action aimed at sustainable development must take the potential impact on the society, economy and environment into consideration (Strange & Bayley, 2008, p.24).

1.4.2 Environmental sustainability

John Morelli (2011) defines environmental sustainability as:

> meeting the resource and services needs of current and future generations without compromising the health of the ecosystems that provide them, and more specifically, as a condition of balance, resilience, and interconnectedness that allows human society to satisfy its needs while neither exceeding the capacity of its supporting ecosystems to continue to regenerate the services necessary to meet those needs nor by our actions diminishing biological diversity. (p. 24)

1.4.3 Environmental impact

ISO defines environmental impact as “any change to the environment, whether adverse or beneficial, wholly or partially resulting from an organization’s activities, products or services” (as cited in Whitelaw, 2004, p. 5).

1.4.4 Life cycle assessment

The life cycle assessment (LCA) is a methodology to assess the environmental impacts of a product system (product, process or activity) caused by the energy and material resources and the releases to the environment emitted by a product system. The idea of the methodology is to assess the effects from a life-cycle perspective. The entire life-cycle of a product is modeled beginning from the extraction of raw materials, followed by the manufacturing, distribution and use of the product to its disposal including reuse and recycling of certain materials. The LCA framework consists of four phases as predetermined by the ISO: goal and scope definition, inventory analysis, impact assessment and interpretation. The goal and scope definition sets the framework of the LCA study defining the objectives, the scope and the system boundaries. The result of the inventory analysis is a complete list of energy and material resources serving as inputs for processes of a product system and environmental releases on the output side. Based on the life cycle inventory, the environmental impact is evaluated for different impact categories in the following phase. In a final stage of the LCA study, a critical review of the LCI and LCIA results is conducted and recommendations are given (Curran, 2008, pp. 2168-2174).

1.4.5 Green by ICT

Green by ICT focuses on the optimization of processes through dematerialization accomplished by the integration of ICT. It covers the secondary effects of ICT on sustainability. ICT products can optimize various life cycle phases of other products and services (e.g. product design, production, use and end-of-life treatment). They can also influence the demand of another product: in form of substitution (decrease in demand) or induction (increase in demand). The green by ICT framework is referred as the linked life cycle approach since the life cycle of an ICT product or service is affecting the life cycle of another product or service (Hilty et al., 2011, pp. 17-19).

1.5 Outline

Chapter 2 summarizes the overall methodology applied for the project. Chapter 3 provides a literature review discussing the current state of research in the subject matter ‘print vs. electronic’ from an environmental perspective. The next chapter (chapter 4) is dedicated to the LCA methodology describing the four phases in detail for a solid understanding of the methodology. Chapter 5 involves the modeling of various product life cycles. An empirical study was conducted to gather data regarding the use patterns of the students. The survey design, conduct and data analysis are described in Chapter 6. The calculation of the baseline scenario is presented in Chapter 7. A sensitivity analysis was conducted in Chapter 8 to test the sensitivity of uncertain parameters. Alternative scenarios and their calculations are discussed in Chapter 9. Limitations and the need for future research are summarized in Chapter 10. The final conclusions are presented in Chapter 11.

2 Methodology

The purpose of the project was to assess the environmental impact caused by the use of lecture notes for learning purposes by students who are studying Informatics as a major or minor subject at the department of Informatics, University of Zurich.

The environmental impact was assessed from a life-cycle perspective. For this, the life cycle assessment methodology was followed as described in the ISO standards.

The functional unit was defined as studying lecture notes by one student for one semester. Following media were assumed to be currently used to perform the underlying function: desktop computer, laptop computer, tablet computer, self-printed lecture notes and printed books of lecture notes.

The tool Umberto NXT LCA with the database Ecoinvent 3.01 was used to model the product life cycles of the selected media and to carry out the impact assessment.

As the environmental performance is substantially determined by the use patterns of the different media, it was decided to conduct an electronic survey with the students. The questionnaire was designed, pilot-tested and electronically distributed to the target audience. The collected data was analyzed and used to transform the generic product system models into specific ones.

The environmental impact was assessed with the method Eco-indicator 99 HA w/o LT. This method evaluates the effect on three areas: ecosystem quality, human health, resources. The ecosystem quality considers the impact categories acidification & eutrophication, ecotoxicity, land occupation. The human health is assessed by the impact categories carcinogenics, climate change, ionizing radiation, ozone layer depletion, respiratory effects. Resources comprise fossil fuels and mineral extraction.

The baseline scenario included the use of different media according to the use patterns. It also considered the impact of the data transfer over the Internet and server access.

As the product life-cycle models consist of some uncertain parameters, their sensitivities on the impact results were assessed.

Various alternative scenarios were evaluated and compared with the baseline scenario in order to identify strategies for improvement of the environmental performance.

3 Literature review

The subject matter print versus electronic is a relatively new field in research. Some studies which address the new trend of digitalization have also focused on the environmental impacts of electronic versions of objects such as school textbooks, scholarly journals, newspapers and invoices. The findings of the studies vary mainly due to different system boundaries, data inventories and impact assessment methods.

The following papers listed in Table 3.1 examining the trade-offs between ICT and paper products from an environmental perspective were selected for the literature review to understand the current state of research in the field of print vs. electronic media.

Table 3.1: Selected papers for the literature review

Author	Title of Work
Maria Enroth	Environmental impact of printed and electronic teaching aids, a screening study focusing on fossil carbon dioxide emissions
David L. Gard and Gregory A. Keoleian	Digital versus print: energy performance in the selection and use of scholarly journals
Greg L. Kozak and Gregory A. Keoleian	Printed scholarly books and e-book reading devices: a comparative life cycle assessment of two book options
Åsa Moberg, Martin Johansson, Göran Finnveden and Alex Jonsson	Printed and tablet e-paper newspaper from an environmental perspective – a screening life cycle assessment
Wesley W. Ingwersen, Mary Ann Curran, Michael A. Gonzalez and Troy R. Hawkins	Using screening level environmental life cycle assessment to aid decision making: a case study of a college annual report
Inge Reichart and Roland Hischier	The environmental impact of getting the news. A comparison of on-line, television, and newspaper information delivery
Asa Moberg, Clara Borggren and Goran Finnveden	Books from an environmental perspective – part 2: e-books as an alternative to paper books

The review is structured and discussed according to the following dimensions: functional unit, system boundaries, findings and limitations. Detailed summaries of the individual papers can be found in the Appendix.

3.1 Functional unit

Table 3.2: Defined functional units

Study	Functional Unit	Media
Enroth	use of teaching aid for five years by 5000 students per year	printed textbook desktop computer laptop computer
Gard and Keoleian	one reading of a scientific journal article	printed journal e-journal article on computer
Kozak and Keoleian	reading of 40 scholarly books by a student	printed scholarly book e-book on e-book reader
Moberg et al.	consumption of newspaper during one year by one reader	printed newspaper tablet e-paper newspaper
Ingwersen et al.	reading of 34000 copies of an annual University report by recipients	printed report e-report on desktop computer alternative scenarios include: notebook reader e-reader home printing
Reichart and Hischier	1) reading/watching a single news item by one person 2) reading/watching the entire daily news by one person	printed newspaper e-newspaper on desktop computer TV
Moberg, Borggren, Finnveden	reading of a specific book by one person	paper book e-book on e-book reader

The selected papers comprise LCA studies in different application domains. While Enroth, Gard and Keoleian, Kozak and Keoleian, Ingwersen et al. focused on scholarly books/journals/reports, Moberg et al., and Reichart and Hischier studied novels respectively newspapers. Most of the studies compared two scenarios where either print or electronic medium is used. The focus lies on the environmental consequences of a complete substitution of print media by electronic media. Only the studies by Gard and Keoleian and Ingwersen et al. assessed the environmental consequences when one medium is complemented by the other (i.e. a printout is taken after reading the e-journal/report on a computer). The functional units cover different scopes e.g. Gard and Keoleian, Kozak and Keoleian, Moberg et al., Reichart and Hischier assessed the environmental impact for one person, whereas Enroth and Ingwersen et al. extended the scope to a larger population (5000 respectively 34000 students).

3.2 System boundaries

Table 3.3: Defined system boundaries

Study	Print system	Electronic system
Enroth	- pulp and paper production - transportation of paper - prepress and printing - distribution of the books - use (reading) - waste management (printed product) Excluded: Forestry Editorial work	- formatting of content - use of internet infrastructure for content distribution - production of electronic equipment - distribution of electronic equipment - use (reading) - waste management of electronic equipment Excluded: - Editorial work - use of internet to upload material
Gard and Keoleian	- paper and ink production - printing and assembly - distribution of the journals to the library - journal collection storage - binding - facility infrastructure - personal transportation to library - document delivery from other sources - production, use (incl. paper), disposal of photo copier - disposal of photocopied material Excluded: document creation	- production, use, disposal of desktop computer - file transfer - facility infrastructure - production, use, disposal of server - production and disposal of network equipment - personal transportation to computer work station - production, use (incl. paper) and disposal of laser printer - disposal of printed material Excluded: document creation
Kozak and Keoleian	- ink and paper production - printing, assembly and binding - distribution of the books - use (incl. library facility infrastructure, collection and storage, personal transportation) - disposal Excluded: document creation	- production of the e-reader device, cable and battery - packaging and distribution of the e-reader - use (incl. collection and storage, personal transportation, facility infrastructure, data storage, production and disposal of server, file transfer, production and disposal of network equipment) - disposal of e-reader Excluded: document creation

Moberg et al.	- editorial work (content production) - forestry - pulp and paper production - editorial work -prepress and printing -distribution - use (reading) -waste management of paper	- editorial work (content production) - production of the tablet e-paper device - formatting - uploading on the server - distribution of electronic newspaper via internet - use (reading) - waste management of the electronic device - transportation in different phases
Ingwersen et al.	- design of the report - printing - paper and ink production - distribution of reports (incl. labeling) - use (reading) under light - waste management of report (disposal/recycling)	- design of the report - uploading report on server - use of server for storage - distribution via internet - use (reading)
Reichart and Hischier	- paper production - paper distribution to print office - transportation and distribution to customers - waste management of paper Excluded: - journalism and related transportation activities	- production of TV - production of computer - use of TV - use of computer - operation of infrastructure (data transfer through internet, telephone network, production of TV shows, satellite receiver) - disposal of electronic products Excluded: - journalism and related transportation activities
Moberg, Borggren, Finnveden	- editorial work - forestry - pulp and paper production - transportation of paper to printing office - printing - distribution of books - Internet use for online orders - facility infrastructure - personal transportation - waste treatment of books	- editorial work - additional energy use for editing electronic version - production of e-book reader - distribution of e-book reader - personal transportation - internet use to download an e-book - production and use of desktop computer to buy an e-book - use of server - use (reading) - waste treatment of e-book reader

The studies share similar system boundaries in the print scenario: paper production, paper transport, printing, distribution to customer, use and waste treatment. All studies except for one (Ingwersen et al.) did not consider any environmental impacts during the use phase. Not all studies included facility infrastructure and storage of print products within the system boundaries. This was also dependent on the application domain; infrastructure during the use phase has been taken into consideration for commercial books and scholarly journals which are stored in a shop respectively in a library. The end-of-life management of printed products was treated differently in each study. Kozak and Keoleian, for example, assumed the printed textbooks would not be recycled but remain with the student. Gard and Keoleian did also not include the disposal of scholarly journals as it was assumed the paper journals remained in the library indefinitely. Other studies like Enroth and Ingwersen et al. included fiber recovery, landfill and incineration activities. Nearly all studies assumed that the efforts for the content production were the same irrespective of the medium. Based on this assumption, the content production was excluded from the system boundaries in many cases. In case of electronic systems the main processes included in all studies were: production, transportation, use and disposal of the electronic device, the use of the server and internet infrastructure.

In case of printed journals and commercial books the personal transportation to collect the respective product was included. Similarly, in electronic systems where the e-book readers are to be collected from shops and e-journals are to be read at library, the associated personal transportation was taken into account.

3.3 Findings

Table 3.4: Results of LCA studies

Study	Results
Enroth	The global warming impact of using electronic teaching aid on a laptop computer was approximately 10 times higher than the impact of the use of printed textbook. The global warming impact was approximately 30 times higher when using electronic teaching aid on a desktop computer than the impact caused by use of printed textbook. In case of printed textbooks, pulp and paper production, printing and waste management were the life cycle phases with the highest contributions of fossil carbon dioxide emissions. In case of the use of electronic teaching aid with desktop computer and screen, the use, computer production and screen production contributed the most to the total impact. Transportation caused a small contribution in both cases.

Gard and Keoleian	The findings of the study could not conclusively prove that one system is better than the other in terms of energy consumption. In the traditional system, the paper production, printing, delivery to the library, facility infrastructure and binding were the major contributors if the journal is read only once. When the number of readings per article increased substantially, the major contributor in the digital system shifted from data storage to the use of the desktop computer whereas in the traditional system the main contributors remained the same irrespective of number of readings. The result of the print system was sensitive to number of readings per article, length of article, travel distance and vehicle efficiency. The result of the electronic system was sensitive to number of readings per article, number of students accessing an article, length of article, total active use of desktop computer, travel distance, vehicle efficiency and power grid efficiency. The impact of printing (laser) an electronic article was much lower than that of photocopying a printed article as the activity in both cases also differed in the percentage of double-sided printing. When personal transportation was taken into account, it formed around 3/4 of the total energy consumption in the digital as well as in the traditional system. Use of networking infrastructure was not a significant contributor. For articles that are rarely read, the study suggests, the digital storage was preferred over the printed version. The remote accessibility of an electronic journal was beneficial as the energy consumption caused by the personal transportation could be omitted. In the digital system printing the article instead of reading it on the computer reduced the energy consumption.
Kozak and Keoleian	In terms of global warming, ozone depletion and acidification, the environmental impact of the traditional book system was higher than that of the digital system. Especially, in terms of the global warming impact, the use of printed books caused an impact four times higher than that of the use of e-books on an e-reader. In the print system, the impacts were driven by paper production, electricity consumption for the printing operation and personal transportation. In the electronic system, many of the impacts were driven by the relatively large amount of electricity consumed during the use phase of the e-reader. Server storage created less environmental impact than the physical storage of printed books.

	The life cycle inventory result showed that in terms of resource consumption the traditional book system required more raw materials and water inputs than the electronic system. Similarly, the energy consumption, solid waste production, air and water pollutant emissions were higher in case of printed books. The result of the print system was sensitive to number of users per book. The result of the electronic system was sensitive to number of students accessing the server, total active use of the e-reader, grid efficiency and on-screen readability (and therefore reading time). The length of the book had an equal effect on both systems.
Moberg et al.	In both European and Swedish scenarios, the newspaper consumption using a tablet computer had a lower environmental impact than using printed newspaper for most of the impact categories. In terms of energy use, eutrophication, photochemical ozone creation and aquatic and terrestric ecotoxicity, the environmental impact of the printed version was double of that of the e-version in both scenarios. In the Swedish scenario, Ecotax02 min and Eco-indicator 99 preferred the tablet version whereas Ecotax02 max recommended the printed version although the difference of the weighted result was not significant. In the European scenario, the tablet computer was established as the preferred medium by all three weighting methods. *Printed Newspaper* Paper production was the highest environmental contributor in the print system for all impact categories and weighting methods. The second highest contributors varied between printing, waste management and distribution depending on the weighting method and geographical scenario. *Tablet e-newspaper* For all impact categories, the allocated impact of the tablet computer production had the highest environmental contribution. In terms of human toxicity the waste management created an equal impact as the production phase. Other main contributors varied between editorial work, file transfer and waste management depending on the weighting method and the geographical scenario. The result of the print system was sensitive to number of readers per newspaper copy and number of pages per issue. The result of the electronic system was sensitive to lifetime and daily average use of the tablet computer, energy consumption of internet

	use, size of transmitted data and energy sources. However, due to the limited use of servers the study concluded the high energy use of the Internet was unlikely. Compared to a desktop computer, the tablet computer had a lower energy consumption rate during the use, but also a shorter lifetime and a lower active usage. Printed newspaper had the lowest impact during the use.
Ingwersen et al.	Electronic journals reduced the economic costs and environmental impacts considerably due to avoided printing and distribution activities of physical reports. Total GHG emissions of the print system were double the amount of GHG emissions caused by the electronic system. The paper production and printing are the two main contributors in the print system. Electronic distribution (via internet) causes less environmental impact than physical distribution (via postal service). However, the contribution of the physical distribution to the total impact was not relevant. Due to lack of paper production and printing operation, human and ecosystem toxicity could be noticeably reduced in the electronic system. Reading the electronic report and taking a printout with an inkjet printer caused a higher environmental impact than a physical report printed and distributed by the University. Using a different electronic device did not have a significant effect on the environmental impacts (3-4% of decrease when using a laptop or tablet computer, 10% of increase when using an outdated desktop computer and monitor). The study concluded that if 7.5% of the recipients take a printout of the report, the GHG emissions of the print and electronic systems were equal. With 50% of recipients printing the electronic report, the GHG emissions, energy use and water use increased by 200-300% compared to physical reports distributed by the University.

Reichart and Hischier	*Results for first functional unit (one news item)* For one news item, the printed newspaper cutting produced the least environmental impact followed by online newspaper and TV. For the printed newspaper, the paper production dominated the impact. In case of the online newspaper, the production and use of the computer equipment were the main environmental contributors. The impact resulting from the use of online newspaper was sensitive to reading time whereas the same parameter had less influence in the news consumption through TV. The result of the online reading was also highly sensitive to total active use and lifetime of the computer. *Results for second functional unit (daily news)* The print product system created the highest environmental impact, followed by online newspaper and TV. In case of printed newspapers, the paper production was the largest contributing phase. As long as watching news on TV did not exceed 80 minutes, the activity produced an impact less than a thin printed newspaper (32 pages). If an online newspaper is read for more than 20 minutes, the activity caused the same impact as a thin printed newspaper. If additionally to reading an online newspaper, three pages of news were printed, 10 minutes of online reading was sufficient to cause the same environmental impact as a thin printed newspaper. The result of online reading was more sensitive to the reading time compared to the news consumption through TV and print newspaper. The result of the electronic system was sensitive to source of electricity mix. When substituting Swiss electricity mix with European electricity mix, the environmental impact of the use of electronic media tripled as hydropower takes a high share in the Swiss mix compared to the average European mix.

Moberg, Borggren, Finnveden	No conclusive result was shown as the comparison depended on parameters related to the specific book and user. When an e-book was read on an e-book reader, the impact resulting from the allocated production of the e-reader formed the main environmental contributor for all impact categories. The waste management positively contributed to a great extent due to recycling of materials (e.g. gold and aluminium) and energy recovery. The main electronic components affecting the overall environmental performance were integrated circuits, resistors, capacitors and battery. The use of electricity had a considerable impact on many categories. The preferred system varied based on the considered impact category. In terms of global warming, energy, eutrophication, human toxicity, marine aquatic ecotoxicity, terrestrial ecotoxicity and used resources, the e-book was preferable. The printed book was preferable in terms of acidification, ozone depletion, freshwater aquatic ecotoxicity, photochemical ozone creation. The energy consumption in the print system was higher due to the paper production and use of facility infrastructure. For several impact categories the breakeven point was 30 books i.e. if a greater number of books were read the electronic version was preferred over print medium. However if number of readings per book was doubled, the break-even increased to 60-70 books. The result of the print system was sensitive to number of readings per book, location and technology of pulp and paper mill and delivery type (postal service/self-pick up). The result of the electronic system was sensitive to life time and total active use of the e-reader and use patterns. If the printed book was delivered by postal services instead of self-pick-up, the impact could be considerably reduced.

4 out of 7 studies suggest that the use of electronic media was environmentally preferable than that of print media. 2 studies stated that the preferred medium depended on the choice of impact categories and weight methods. It was generally agreed that the activities contributing considerably to the total impact of the print system were paper production, printing and waste management. As for the electronic system, the production, use and waste management of the electronic device formed the main contributors. The impact of transport activities had varying evaluations.

The results of the print system were sensitive to the following parameters: number of readings per article, length of article, variables related to distribution activities such as vehicle efficiency and travel distance, and percentage of double-sided printing.

In case of the electronic system following sensitivity parameters were established: number of readings per article, number of students accessing the server, length of article, total active use and life time of the electronic device, variables related to distribution activities such as vehicle efficiency and travel distance, power grid efficiency and reading time.

Both studies by Ingwersen et al. and Reichart and Hischier confirmed that the use of electronic media combined with a relatively small amount of printouts was already sufficient to cause an environmental impact in the same amount as an entirely print-based version.

3.4 Limitations

Table 3.5: Limitations in LCA studies

Study	Limitations
Enroth	As a screening LCA was performed; the use of energy and transportation were the two main elements considered in the different phases of the life cycles. Only one impact category was evaluated. Carbon stored in forest products was not considered (biogenic carbon dioxide). Impacts of internet infrastructure and energy allocation between different services were uncertain estimations.
Gard and Keoleian	Network transmission infrastructure (optical/copper cable), satellite-based networks, redundant back-up storage, downloading material to a workstation and central storage file were not considered. Content creation and publishing was considered to be equal for both systems and therefore excluded from the system boundaries. The journal content was restricted to text and standard graphics such as tables, graphs and pictures for a practical comparison. Usage patterns were assumed and no specific survey as part of study was conducted.
Kozak and Keoleian	Technical specification data was not on average basis; a reference model was used.

	Study time (apart from reading) was not considered. Usage patterns and user profile were estimated.
Moberg et al.	The GHG emissions as an indicator for the climate change category were assessed excluding biogenic carbon dioxide uptake or emissions. The journalist's field work was not considered. Data and knowledge gaps regarding emissions of toxicological substances (underestimation of the impact categories focusing on toxicological emissions), waste management of electronic devices, production of e-ink screen, construction and use of internet infrastructure and production of certain supply chemicals for printing were present. No combinations of different product systems were considered in the study. Assumptions were made regarding usage patterns (e.g. lifetime and total active use of the device, number of readers per the printed newspaper). Technical data of tablet computer was based on a specific model. The production of the tablet computer was modeled based on the components. As the study was conducted at a time when tablet computers were not yet established in the market, considered usage patterns could be on conservative side.
Ingwersen et al.	A screening level of LCA was performed. Estimations were based on average US data. The disadvantage of the EIO LCA was the aggregation of specific processes into sectors. Further, the paper production was not divided into different sectors based on source materials and the waste management sector did not differentiate between landfill and recycling. These differentiations could considerably affect the results. For each analyzed electronic product system, a specific model was used as a reference. There was an uncertainty of ink cartridge manufacturer profit margins and ink use. Ensuring an equal effectiveness/benefit of the two options was not part of the study. Usage patterns were estimated.
Reichart and Hischier	Average user behavior was not representative. An average usage pattern for each category (print, online, TV) was calculated

	separately with a sample size of three people. For the first functional unit, advertisements were not included. Newspaper cuttings are presently not sold. Lack of data in the field of electronic products, electricity consumption of the Internet and telephone network was present. The computer production data was based on the TV's printed circuit board assembly, its cabinet and cathode-ray tube. Impact of a shared TV was not taken into account.
Moberg, Borggren, Finnveden	Biotic carbon dioxide was not included in the climate change impact assessment. The production of an e-reader was based on a specific model. It was modeled as a set of the different components. Even though it was assumed that the electronic device was produced in China, the data for the components were Western European or global average data as Chinese data were not available. Data gaps regarding production of e-ink screen, energy consumption for e-reader assembly, waste management of electronic devices and impacts from land use, toxic impacts were present. Potential decrease in physical storage and facility infrastructure of printed books which remained at home was not considered. Not all relevant impact categories were equally covered.

A frequently appeared limitation is the lack of accurate data regarding use patterns to which the results are highly sensitive. Many LCA studies were performed at screening level omitting negligible impacts and activities which cause an equal impact in both alternative systems. All studies have compared scenarios which are entirely print or electronic-based. The use of multiple media in the baseline scenario was not assessed by any study. However, Ingwersen et al. and Moberg et al. have considered a combination of the use of electronic and print media in alternative scenarios. Another common limitation among the studies which considered tablet computers was the lack of data regarding their production efforts and waste management activities. The used data for modeling the tablet computer was often representative for one specific model. Some studies focused on a limited set of impact categories which restricted the assessment of an overall environmental performance.

4 Life cycle assessment

This chapter presents a summary of the Life Cycle Assessment (LCA) methodology as provided by the United States Environmental Protection Agency (pp. 7-60). LCA is a quantitative tool to evaluate the environmental burdens associated with a product throughout its life cycle from the extraction of the raw materials to the disposal of the product. The system under study is called the product system. In this context, product can be referring to either a physical good or a service. Apart from assessing the environmental consequences of an existing product, LCA studies are also carried out to provide assistance in decision making when evaluating different product designs from an environmental perspective. Another application can be to identify processes in production that yield significant potential for optimization with regard to environmental aspects. A fundamental limitation of LCA studies is that it does not take the economic and social dimensions into consideration, but only focuses on the environmental aspect. Furthermore, the assumptions and decisions made during the LCA might be subjective. The accuracy of the results is also dependent on the data availability and quality. Further uncertainty is caused by the lack of spatial and temporal dimensions in the inventory data. Models used in the inventory analysis and impact assessment are limited by the underlying assumptions. The ISO provides some basic principles, however it does not specify the methodology in detail. As the depth of detail and time frame of an LCA study depend on the goal and scope, there is no single method to conduct a LCA study (ISO, 1997).

The LCA procedure is divided into four phases

- Goal and scope
- Inventory analysis
- Impact assessment
- Interpretation

4.1 Goal and scope

4.1.1 Goal

The goal defines

- the purpose of the study
- the intended application of the results
- the intended audience

This LCA step is crucial as the subsequent steps are based on the goal and scope definition. The goal could be related to assessing the resulting environmental performance of an existing product, optimizing a product component and assisting the decision-making in the development of new products, choosing a product with the least effect on human health and the environment. It can be derived by specifying what type of information is needed from the LCA study e.g. the total environmental impact, impact of changes in processes, relative impact of the individual life cycle phases.

4.1.2 Scope

The scope comprehends the description of

- product system(s) under study and system boundaries
- studied functions of the system
- functional unit
- fundamental procedures
- assessment criteria
- data requirements for the study
- allocation procedure
- assumptions
- limitations
- type of critical report, if any
- type and format of report

Product system descriptions and system boundaries

System description determines which processes are considered within the system boundaries. The decision should be consistent with the defined goal of the study. The system description also includes temporal and geographical coverage apart from the system boundaries. A LCA study typically considers the complete life cycle of the product. This comprises the phases:

- Raw material acquisition
  This includes raw material and energy acquisition from the earth and the transportation to the manufacturing site.
- Manufacturing
  The raw materials are the inputs of the manufacturing process. The output of the process is the product under study.

Manufacturing process typically consists of the processing of the raw materials, the production of the final product, the packaging and distribution of the product to the retailer or customer.

- Use

  The use phase comprises the product consumption and storage. This phase may also include reuse and maintenance activities.

- Waste Management

  The waste management phase addresses the disposal and recycling of the used product.

Depending on the goal of the study, it may be justified to exclude certain phases or activities. If two systems are being compared and both consist of an identical step (process or even a life-cycle phase) with the same procedure and quantities of inputs and outputs the respective step may be excluded. However, in this case the environmental impact is not determined in absolute values.

In the goal and scope phase, the initial system boundaries are defined. The boundaries are further refined for each process in the inventory analysis.

When multi-output processes are present, a system expansion is required. It involves the expansion of the system boundaries and the definition of a new function unit when comparing alternative systems. A multi-output process not only produces an output which is relevant for the study, but also a co-product. If multi-output processes are compared with alternative processes which do not produce the same co-products (or co-products at all), the system boundaries are to be expanded. There are two possible approaches: One approach is to include an additional separate process to each alternative system. The added process produces the co-product that is not present in the alternative systems. The other approach is called the avoided burden approach. The environmental impact of the baseline product system which contains the production of a co-product is reduced by the environmental impact associated with an alternative method of the co-product production. The obtained comparison in the avoided burden approach focuses on the main product and disregards the co-products.

Functional unit

The functional unit is a quantification of the studied function provided by the product system. It serves as a reference flow according to which the input and output flows throughout the life cycle of the product system are tailored. The functional unit is also used as the basis when comparing alternative product systems. The functional unit for each alternative system has to be defined in a way so that an equal quantity of product use is compared. A system is qualified as an alternative product system based on functional equivalence i.e. an alternative system must provide a similar functionality as to the one relevant in the baseline system. The functional unit can be defined, for example, in terms of volume, weight and time period.

Fundamental Procedures

The procedure specification includes the choice of level of detail, the application of cut-off criteria (insignificant activities or phases are excluded from the study), the chosen allocation methods and impact categories.

Assessment criteria

The assessment criteria specify how the inventory results are analyzed. Following mid-point impact categories can be selected for the study: climate change, ozone depletion, acidification, eutrophication, photochemical oxidant formation (sommer smog), radiation, human toxicity, ecotoxicity, depletion of abiotic resources, use of biotic resources and land use. The assessment can also be extended to endpoint indicators discussing the impact on three protection areas which are human health, environmental health and resources.

Data quality requirements

Data quality requirements define the characteristics of the required data. They are determined by the purpose of the study and have an impact on the LCA results.

As per ISO 14040, this section should address the temporal, geographical and technological coverage, the precision, sources, completeness and representativeness of the data, the consistency and reproducibility of the methods followed in the study.

A distinction between foreground and background data exists in LCA studies. Foreground data refers to the data describing the primary system. Background data refers to data of auxiliary resources needed as inputs for the primary processes.

The required level of specificity also determines the data requirements. This can be derived from the intended use of the results. It can range from a completely generic study to a completely product-specific study. For each process it should be decided whether the data should be general to represent common industrial practices or focus on company-specific information. Decisions regarding data requirements are often dependent on the data availability, the intended audience and use of the LCA study. The specificity is also linked to the distinction between foreground and background data.

Critical review

Critical review is a technique to verify the LCA study has been performed in accordance to the ISO standards. Critical reviews are optional and depend on the goal of the study.

4.1.3 Ground rules

All assumptions or decisions made during the LCA study need to be documented. If they're omitted, the final results can be misinterpreted. It is common that additional assumptions and limitations follow during the project depending on the availability of the study resources.

Defining quality assurance procedures is necessary to ensure that the LCA conduct is in accordance to the goal and purpose. The decisions depend on the available time, resources and the intended use of the results. In case the results are used for the public, a formal review process is recommended (internal and external reviews by LCA experts or interested parties). If LCA studies are conducted for internal use, an internal reviewer is sufficient. It is advised to attach the documentation by the reviewers in the final report.

In case of comparative studies, equivalent methodological considerations should be applied for all product systems (system boundaries, data quality requirements, allocation procedures etc.). Any differences between the systems need to be reported.

The formal requirements (presentation and content of the final report) can be already specified at this stage. The used methodology, the analyzed systems, the system boundaries, the assumptions should be presented consistently in the final report.

4.2 Life cycle inventory

For the product system under study, a life cycle inventory (LCI) is created to quantify the consumed inputs and released outputs throughout the entire life cycle. The inventory forms the basis for the assessment of the environmental performance of a system. The result of the life cycle inventory phase is a list of quantifications of energy, raw materials and the environmental releases associated with the product system. The data collection is iterative. During this phase new data requirements and limitations can be identified which might influence the data collection procedure in order to meet the goal of the study.

The phase can be divided into 4 steps which are explained below: developing a flow diagram of the studied processes, developing a data collection plan, collecting the data, evaluating and reporting the results.

4.2.1 Developing a flow diagram of the processes

The idea of the flow diagram is to graphically represent the inputs and outputs of the different processes within the life cycle of a product system. Raw material acquisition, manufacturing, use and disposal can be further split into smaller activities for more accurate process specifications. A unit process is the smallest element (activity) in the life cycle inventory for which inputs and outputs are quantified. Each unit process may have electricity, water, transportation and materials on the input side and finished components, products, non-/ hazardous substances and other environmental releases on the output side.

While the goal and scope phase of the LCA defines the initial system boundaries, it is during the inventory phase that the system boundaries are refined as the inputs and outputs for all backend processes are to be specified. The more detailed the system specification is, the more precise the results are. However, there is a trade-off as increased precision requires more time and other resources for the data collection.

Flow diagrams are used to graphically model the baseline and alternative systems. In a comparative study, it is significant to use the same system boundaries and level of detail while modeling. Or else, the results may not be comparable.

It is useful to divide the product system into as a series of subsystems. For each subsystem the inputs and outputs are to be specified. A subsystem can either cover a single activity or a group of subsequent activities depending on the availability of data. The inputs and outputs include energy, materials, solid wastes and environmental releases which are directly associated with the activity, but also resulting from auxiliary activities in the subsystems such as transportation. The sources of the collected data should be always documented as the documentation provides a basis for the data quality assessment.

Some processes may have one or more co-products apart from the main product on the output side. For such processes, an allocation procedure should be defined according to which the inputs and outputs are assigned to the different products.

4.2.2 Develop a LCI data collection plan

The required data accuracy is already defined in the goal and scope definition phase. A LCI data collection plan ensures the used data sources are corresponding to the required data quality.

There are four main elements in the data collection plan: a) defining data quality goals b) identifying data sources and types c) identifying data quality indicators d) developing a data collection worksheet and checklist

Definition of data quality goals ensures to adapt a data collection approach which considers the available time and resources and the required data quality based on the purpose of the study. The number and nature of data quality goals depend on the required level of data accuracy. The data quality goals also serve as criteria to measure the data quality. Since they are closely connected to the purpose of the study, no pre-defined lists of data quality goals are available.

Data quality indicators such as completeness and consistency are used to measure the collected data in terms of quality and to check whether they meet the defined data quality goals. The selection of indicators is project-specific; hence there are no pre-defined lists of indicators.

Determining the data sources and data types for each life cycle phase, process or environmental release ensures the resources are efficiently utilized and the quality goals are met. Examples for data sources include reference books, laboratory test results, journals, industry data reports and publicly available databases. Surveys may also be conducted to capture information from product consumers. Alternatively, market research studies can provide the required data. Data types include measured, modeled, sampled, non-site specific and non-LCI data.

It should also be documented when aggregated data is used covering multiple processes. It is recommends to use current industry data for production processes which reflect latest technologies.

Depending on the goal, scope and defined system boundaries, publicly available life-cycle documents representing industry-average or internal site-specific data may be appropriate. For external life cycle inventory studies it is recommended to complement the average data with data variability sets.

A data collection spreadsheet documents the taken decisions regarding data collection and serves for two purposes a) as a guideline for the data collection and validation e.g. in terms of completeness, consistency and accuracy b) for constructing the database for the inputs and outputs. There are eight decision areas which should be covered in the spreadsheet: purpose of the inventory, system boundaries, geographic scope, types of data, data collection procedures, data quality measures, computational spreadsheet construction and presentation of the results.

As the inventory also consists of certain assumptions, sensitivity analyses are performed to evaluate what-if scenarios and determine the relevance of the parameters for the overall results.

4.2.3 Collect data

Traditional data collection involves research, site-visits and meetings with experts. As an alternative approach, LCA software may be ideal for certain studies depending on the required level of detail. Another method is to use non-site specific inventory data. Several organizations provide basic databases suitable for LCI studies. One possible disadvantage when using inventory data from other databases is the lack of transparency in terms of data quality due to missing documentation.

For multi-output processes, ISO recommends to avoid allocation if possible by either dividing the unit process further into different sub-processes or by expanding the system and including the functions provided by the co-products. However, it is not always possible to avoid allocation. ISO provides various approaches as to how to allocate the inputs and outputs in a multi-output-process. The chosen approach should reflect the physical relationship between the process outputs e.g. based on weight. If no physical relationship between the inputs and outputs exist, the allocation procedure has to be based on other relationships e.g. on the market value of the products.

During the data collection, the system boundaries and data quality goals will be often refined in an iterative way due to data gaps.

4.2.4 Evaluate and document the LCI results

The documentation of the applied methodology, the system boundaries, the baseline and alternative systems and the assumptions made during the inventory phase has to be provided in the LCI documentation.

The final presentation of the LCI results may include the overall result of the product system, relative contribution of life cycle phases to the overall system performance, relative contribution of product components to the overall system performance. The result may also be structured by data categories such as energy consumption and resource use, geographical regionalization and temporal changes.

The LCI findings can be either presented in tabular or graphical form covering the dimensions which are relevant to the purpose and use of the results.

The data accuracy of the inventory will be verified with reference to the goal of the study in the interpretation phase.

4.3 Life cycle impact assessment

The LCI results are evaluated and interpreted in terms of the potential effects on human, ecological health and resource depletion. The life cycle impact assessment (LCIA) establishes a link between the product and its potential environmental impacts. The LCIA relies on simplified models which are suitable for relative comparisons of potential human and environmental impacts. In contrast to the risk assessment, the used models do not assess absolute risk or actual damage.

The phase can be split into 7 steps of which the selection, classification, characterization, evaluation and reporting are mandatory according to ISO.

4.3.1 Selection and definition of impact categories

The impact assessment is carried out by interpreting the LCI results in terms of its potential effect on impact categories. The three main categories are human health, ecological health and resource depletion. For a LCA study, the selection of the impact categories can be deduced from the goal and scope of the project. As the data collection in the LCI phase is determined by the defined impact categories, it is recommended to finalize the selection of categories in the initial goal and scope definition phase.

Commonly used impact categories in LCA studies are: global warming, stratospheric ozone depletion, acidification, eutrophication, photochemical smog, terrestrial toxicity, aquatic toxicity, human health, resource depletion, land use and water use.

4.3.2 Classification

Classification deals with the mapping of the LCI results (input and output flows between the product system and the environment) to the affected impact categories. Each input and output stream is assigned to one or more impact categories. Some flows only affect one impact category; in this case the assignment procedure is clear. For other flows contributing to multiple impact categories the assignment procedure is complex. ISO defines two assignment procedures for LCI results affecting multiple impact categories.

When the effect of a resource consumption or environmental release on multiple categories is independent of each other, it is assigned to the same degree to all the respective impact categories.

When the effects are dependent on each other, the quantified inputs and outputs are spread across the affected impact categories i.e. a share of the inputs and outputs is assigned to each respective impact category.

4.3.3 Characterization

Once the LCI results are assigned to impact categories, characterization is performed. This is based on the fact that the individual resources and emissions assigned to an impact category do not contribute to the category in equal measure. The substances chloroform and methane as an example are both classified to the global warming category. However, one unit of methane has a greater global warming impact than the same unit of chloroform.

The inventory data is translated into comparative impact indicators using characterization factors. A characterization factor is science-based and quantifies the effect of a resource use or emission on a particular impact category. Characterization factors for each impact category are defined separately.

Each impact category typically has one substance which is used as a reference to determine the characterization factors for all other substances. Characterization factors thus describe the effect of a resource use or emission expressed in terms of the effect caused by the reference substance.

For each impact category, the total impact indicator is calculated as following: $Impact\ indicator = \ Inventory\ Data\ x\ Characterization\ factor$

For some impact categories there is an agreement on the acceptable characterization factors, for others they're yet to be established.

4.3.4 Normalization

Normalization is the procedure of normalizing the indicator results to reference values (e.g. baseline result) for comparison purposes. It can be based on the goal and scope of the study. There are different methods for selecting a reference value.

4.3.5 Grouping

Grouping involves the classification of the chosen impact categories to one or more sets. It usually involves sorting (e.g. by characteristics such as emissions) or ranking the indicators (based on their priority). These are the two methods specified by ISO for grouping LCIA data.

4.3.6 Weighting

The impact categories are weighted based on their perceived importance for a study. The weighting process is subjective and should be therefore documented. While the weighting is widely used, it is the least developed LCIA step. It consists of identifying values of stakeholders, defining a weight for each impact and applying the weights on the impact categories to get a weighted total value.

If the results are weighted, it is important to include the un-weighted results in the documentation as well.

4.3.7 Evaluate and document the LCIA results

The accuracy of the results is to be verified. A thorough documentation of the LCIA results, used methodology, analyzed systems, system boundaries, assumptions and limitations is necessary. LCIA has its limitations as many assumptions and simplified models are considered. Depending on the chosen LCIA methods and impact models, the limitations can be reduced.

4.4 Interpretation

The final phase of the LCA study serves as a systematic technique to identify, quantify, check and evaluate the LCI and LCIA results and communicate them to the concerning stakeholders.

ISO (as cited in United States Environmental Protection Agency, 2006) defines two goals which are to be achieved:

> “Analyze results, reach conclusions, explain limitations and provide recommendations based on the findings of the preceding phases of the LCA and to report the results of the life cycle interpretation in a transparent manner“ (p. 54).
>
> “Provide a readily understandable, complete and consistent presentation of the results of an LCA study, in accordance with the goal and scope of the study“ (p. 54).

When using LCA in a comparative study, it is not always easy to conclude which alternative is preferred over the others as the data inventory often consists of non-factual data such as assumptions and estimations implying the uncertainty of the results. Nevertheless, the results do provide a relative assessment of the environmental impacts associated with the product system under study.

There are three steps within the interpretation phase which are explained below.

1) Identification of the significant issues based on the LCI and LCIA
2) Evaluation which consists of completeness, sensitivity, consistency checks
3) Conclusions, recommendations and reporting

4.4.1 Identification of the significant issues based on the LCI and LCIA

Once the results of the first three phases are reviewed in detail and it is ensured that the goal and scope of the study are met, an identification of the elements contributing the most to the LCI and LCIA results for a product system can be accomplished. These elements are called significant issues. The first step also forms the basis for the following step. Due to resource and time constraints, the evaluation step (step 2) is only applied to the data elements contributing the most to the LCI and LCIA results.

The identification of the significant issues can be achieved by applying one of the following recommended approaches:

Contribution analysis: identification of life cycle phases or sets of activities which are significant contributors to the overall impact

Dominance analysis: use of statistical tools and other techniques such as quantitative and qualitative ranking

Anomaly analysis: based on previous experience, unusual deviations from expected results are considered relevant

Significant issues may be in form of inventory parameters (e.g. energy consumption), impact category indicators (e.g. emissions), individual processes or life cycle phases (e.g. transportation).

4.4.2 Evaluation of data completeness, sensitivity, consistency

This step assesses the reliability of the LCA study results

a) Completeness check
   It should be ensured that the inventory data is complete and in accordance to the system boundaries and consistent with the goal and scope. In case of data gaps, these should be documented and their impact on the result should be estimated quantitatively or qualitatively.

b) Sensitivity check
   Sensitivity check is to ensure the reliability of the results. The uncertainty in the significant issues is assessed in terms of its effect on the overall results.

c) Consistency check
   Assumptions, used methods and data should be consistent with the goal and scope of the study. Inconsistencies should be either resolved or at least documented.

It is necessary to ensure the completeness and consistency of the data in order to make conclusions and recommendations.

4.4.3 Conclusions and recommendations

The final step is an interpretation of the LCIA results and the recommendation as to which product produces the least environmental impact and/or one or more areas of concern depending on the goal and scope. Depending on the scope, the presentation of the result can range from of a list of un-normalized, un-weighted impact indicators (an indicator for each impact category) to a single grouped, weighted and normalized score for each product system.

While recommendations provide the needed information for the decision makers, it is equally important to focus on the communication of the uncertainties involved in the results due to lack of accurate data and assumptions.

4.4.4 Reporting the results

After completing the LCA, the LCA study including the results should be documented for communication purposes. The type and format is defined in the goal and scope phase. The report includes the data, methods, assumptions, limitations, results in sufficient detail depending on the intended audience and use.

ISO gives clear guidelines in case a reference document is to be delivered to third-party stakeholders.

A peer review is recommended focusing on and verifying 4 main problematic areas to increase the understanding and consistency of the study: scope/boundaries methodology, data acquisition/compilation, validity of key assumptions and results, and communication of results.

5 Modeling

This chapter includes the system descriptions of following media: desktop computer, laptop computer, tablet computer, self-printed lecture notes, printed books of lecture notes, internet access and server.

The goal of this LCA study is to assess the current environmental performance resulting from studying lecture notes by a student and to identify and evaluate other alternatives. The result of this LCA can be used by the University to understand how the current scenario can be improved by opting for other alternatives with a better environmental performance. The results can also be of use to students to understand how they can decrease the environmental burdens associated with the activity involving the study of lecture notes.

The function is defined as the studying of lecture notes by a student having Informatics as a major or minor subject at the University of Zurich. This function is performed using different product systems in the baseline i.e. desktop computer, laptop computer, tablet computer, self-printed lecture notes and printed books of lecture notes. The individual media are considered functionally equivalent and represent alternative systems.

The functional unit is defined as the study of lecture notes during one semester by an average student enrolled in Informatics at the department of Informatics, University of Zurich. The numerical quantification of the function is derived from the empirical study (Chapter 6).

As for the geographical and technological coverage, the data should be representative for Switzerland and the average level of technology should be reflected. As the LCA study specifically focuses on students from the University of Zurich, data should correspond to the geographical boundaries and also reflect the current user behaviour.

Raw material acquisition, manufacturing including packaging and distribution, use and final disposal have been considered as the initial system boundaries for all product systems. When electronic media is used to study lecture notes or lecture notes are printed by the student, the operation of server and internet access has also been taken into account.

The method Eco-indicator 99 is used for the impact assessment.

The effects on 3 categories are assessed: damage to human health, ecosystem quality and resources.

The impact on each category is assessed by the following sub-categories.

Human health: carcinogenic substances, respiratory effects, climate change, ionising radiation and ozone layer depletion.

Ecosystem quality: ecotoxic substances, acidification, eutrophication and land use.

Resources: depletion of minerals and fossil fuels.

5.1 Life cycle of desktop computer

5.1.1 Generic

The life cycle considers production, transport, use and disposal. The desktop computer was modeled along with its essential peripherals optical mouse, keyboard and LCD monitor. The individual devices are modeled with the Ecoinvent datasets.

Production

The desktop computer (without screen), the optical mouse and the keyboard were modeled with the original datasets provided by Ecoinvent 3.01. As there was no corresponding dataset to model a 23-inch LCD monitor, the same was modeled with the Ecoinvent dataset for a 17-inch monitor based on the following approach.

The original dataset of the LCD display assumes a screen size of 17-inch and a weight of 5.1 kg (Hischier, Classen, Lehmann and Scharnhorst, 2007, “Electronic Devices”, p. 105). The average screen size of the respondents’ desktop computers is 23-inch. It was assumed the display aspect ratio is 16:9 and the depth of the monitor remains the same independent of the monitor size. It was therefore decided that the weight of the LCD monitor was proportional to the area of the display. The number of units of a 17-inch display to represent a 23-inch display was thus calculated based on the weight.

Calculation for modeling a 23-inch LCD display:

$(16x)^2 + (9x)^2 = 17^2 \quad x^2 = 0.86$

Area of 17” display: $144x^2 = 123.49\ in^2$

$(16z)^2 + (9z)^2 = 23^2 \quad z^2 = 1.57$

Area of 23” display: $144z^2 = 226.04\ in^2$

Weight of 23” display = Weight of 17” display x $\frac{\text{Area of 23" display}}{\text{Area of 17" display}}$

Weight of 23" display = $\frac{5.1 \ x \ 226.04}{123.49}$ = 9.34 kg

Weight of 23" display = 1.83 x Weight of 17" display

1.83 units of the 17-inch display were used to model a 23-inch display. Based on the above calculations, the 23-inch display has a weight of 9.34 kg. The original dataset for the 17-inch display assuming a weight of 5.1 kg might be a conservative value. In order to have a rough estimate regarding the weight of 17-inch and 23-inch monitors, some monitor models were selected and the findings are summarized in Table 5.1 below. The required information was taken from the respective technical specifications.

Table 5.1: Monitor models

Model	Screen size	Weight
Dell E178WFP 17-inch Widescreen Flat Panel LCD Monitor	17 inch	2.7 kg
HP Compaq LA1751g	17 inch	8.4 kg (unclear whether packaging material also included)
LG L1742SE	17 inch	3 kg
LG T1710B	17 inch	3.9 kg
Samsung 17inch LCD Monitor (743BPLUS)	17 inch	4.7 kg (including packaging)
HP EliteDisplay E231 23-inch LED Backlit Monitor (ENERGY STAR)	23 inch	6.1 kg
Dell UltraSharp 23 Monitor - U2312HM	23 inch	2.96 kg (panel only)
LG IPS236V-PN	23 inch	4 kg
Samsung 23 inch Business LCD Monitor B2330	23 inch	4.9 kg
Philips V-Line 23 236V3LSB/75	23 inch	3.19 kg

The examples illustrate there is a large variance in the weights and it is possible that 5.1 respectively 9.34 kg is a reasonable worst-case approximation.

Packaging

The weight of the packaging material was not clearly documented for the desktop computer and the peripherals except for the LCD display.

The original dataset of the LCD display considers 1.5 kg of packaging material for a 5.1 kg display (Hischier et al., 2007, "Electronic Devices", p. 105). To estimate the quantity of the packaging material required for other peripherals and the desktop computer, it was assumed the quantity is proportional to the weight of the respective device.

Table 5.2: Packaging material for desktop computer and peripherals

Device	Weight of device	Quantity of packaging material
LCD display	9.34 kg	2.74 kg
Keyboard	1.18 kg	0.35 kg
Desktop computer, without screen	11.3 kg	3.32 kg
Optical mouse	0.12 kg	0.04 kg

As the quantity of the packaging material for the keyboard and optical mouse are negligible compared to that of the display and desktop computer, it was omitted in the production and disposal phase.

Based on Table 5.2, the weight of packaged desktop computer and peripherals is 28.37 kg in total. This value was considered for modeling the transportation activity.

Transportation

The transportation specification was determined by two parameters: distance and weight. It was assumed the production of the desktop computer and the peripherals take place in China. The transportation from China to a European customer was modeled as 15000 km of distance by transoceanic freight ship and 500 km by freight lorry. The estimation of the distances is based on a LCA study conducted by Moberg et al. (2010). Ecoinvent datasets were used to model the two means of transport.

Disposal

The disposal of the desktop computer and LCD display was modeled according to the global market for a used desktop computer and used LCD display. For the peripherals optical mouse and keyboard, the end-of-life treatment was modeled in a less specific method using the dataset “treatment of used IT accessory” due to lack of specific data. All disposal datasets originate from Ecoinvent 3.01. The datasets of the desktop computer, keyboard and optical mouse used in the production phase already take the waste treatment activities into consideration. As the dataset for the LCD display used in the modeling of the display production does not include the waste treatment, the disposal of the LCD display was modeled separately according to the global market of a used LCD display.

All production and disposal datasets are valid for the global market and for the time period 1998-2013.

The production and disposal datasets of the desktop computers and peripherals in Ecoinvent 3.01 are based on environmental product declarations (power adapter), literature (keyboard and display) and measurements conducted at the EMPA (desktop computer and optical mouse) (Hischier et al., 2007, “Electronic Devices”, pp. 21, 104, 121, 127, 142). The datasets for all electronic devices are valid globally, corresponding to the global nature of the supply chain in the IT industry.

The data for the electronic devices derive from the time period 2002-2003. The documentation states that it is still representing the currently used devices, maybe not entirely corresponding to the latest technology. However this data for 2002-2003 is definitely on conservative side considering the current market for such devices show decreased weights for such items (Hischier et al., 2007, “Electronic Devices”, pp. 17-18).

The production datasets cover the extraction and processing of the raw materials, the production and transportation to the production site of individual components such as printed wiring boards and hard disk drive, energy and water consumptions during manufacturing and assembly, the infrastructure and the packaging (Hischier et al., 2007, “Electronic Devices”, pp. 20, 104, 120, 125-126, 140).

The Ecoinvent dataset of the keyboard assumes a keyboard with a weight of 1.18 kg (Hischier et al., 2007, “Electronic Devices”, p. 120). This however may not completely represent current keyboards used by students as recent models have a lighter weight. Some keyboard models were selected and the findings are presented in Table 5.3. The required information was taken from the respective technical specifications. Similar to the case of monitors, the weight of keyboards has a wide range.

Table 5.3: Keyboard models

Model	Weight
BTC 6311U Ultra Slim Keyboard	0.58 kg
DSI Modular Mac Mechanical Keyboard	1.13 kg
Microsoft® Wedge™ Mobile Keyboard	0.24 kg
Das Keyboard Model S Professional	1.36 kg
HP USB Standard Keyboard (DT528A)	1.4 kg

The Ecoinvent dataset for optical mouse assumes a weight of 0.12 kg (Hischier et al., 2007, “Electronic Devices”, p. 125). This corresponds to current specifications of mouse in market.

5.1.2 Specific

The data for the use phase is derived from the survey (see Chapter 6). Table 5.4 comprises the parameters which were considered in the model and the associated values collected from the survey.

It was assumed the device was not used for 4 weeks in a year. Further, the data for daily average consumption in the three use modes (active, standby/sleep, off) applied to 6 of 7 days in a week.

Electricity consumption during use phase was modeled with the Swiss market for low voltage electricity.

Table 5.4: User-specific data for desktop computer

Parameter	Value
Desktop computer owners, non-owners	54% owners 46% non-owners
Daily number of hours in active mode	4.84 hours
Daily number of hours in standby/sleep mode	2.11 hours
Daily number of hours in off mode	17.05 hours
Lifetime	5.52 years
Energy consumption of desktop computer and monitor for one hour of active use	0.33 kWh
Screen size	23 inch
Total reading time on desktop computer per student per semester	58.56 hours

The energy consumption rates for the sleep and off mode were taken from Ecoinvent 3.01.

The total average reading time of the desktop computer owners is already weighted according to the ratio owners/non-owners and has a value of 58.56 hours (see Table 5.4).

Figure 5.1: Life cycle of desktop computer modeled in Umberto NXT LCA

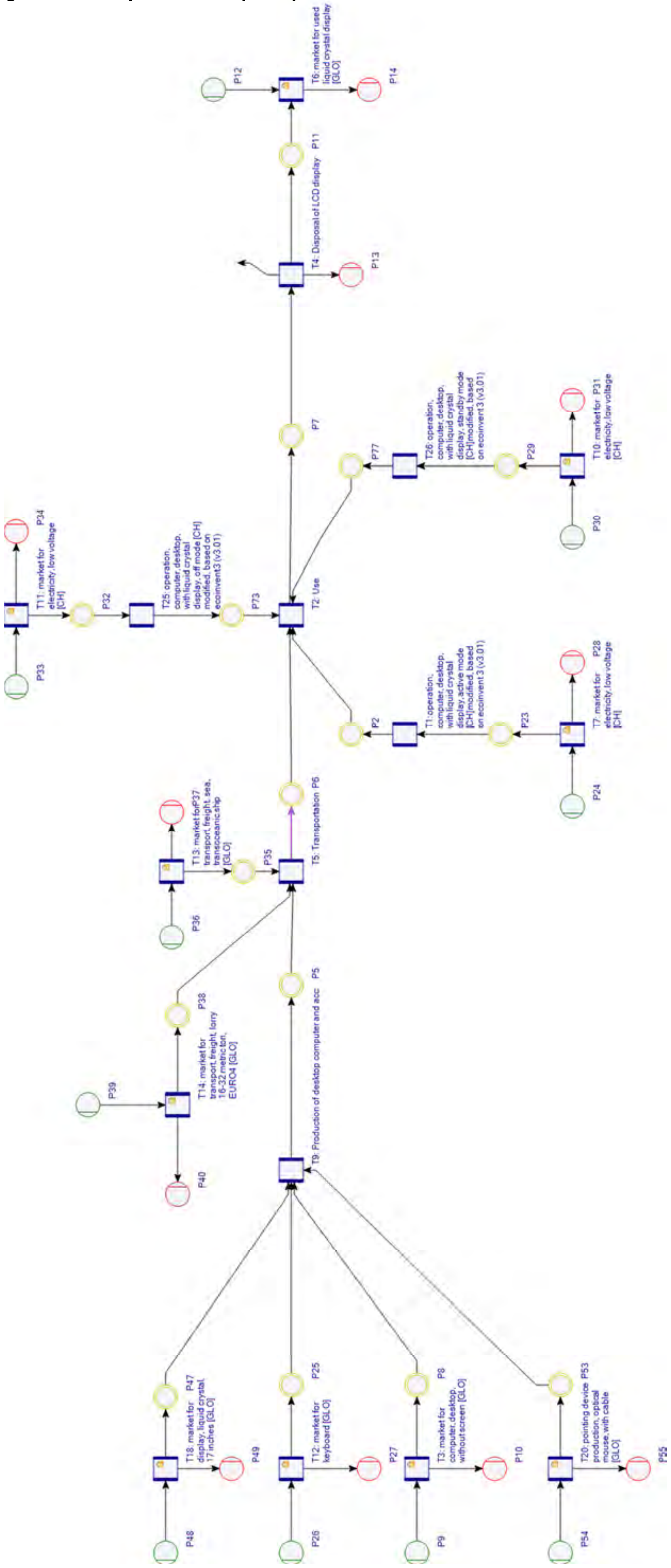


Figure 5.2: Production and transportation processes of desktop computer modeled in Umberto NXT LCA

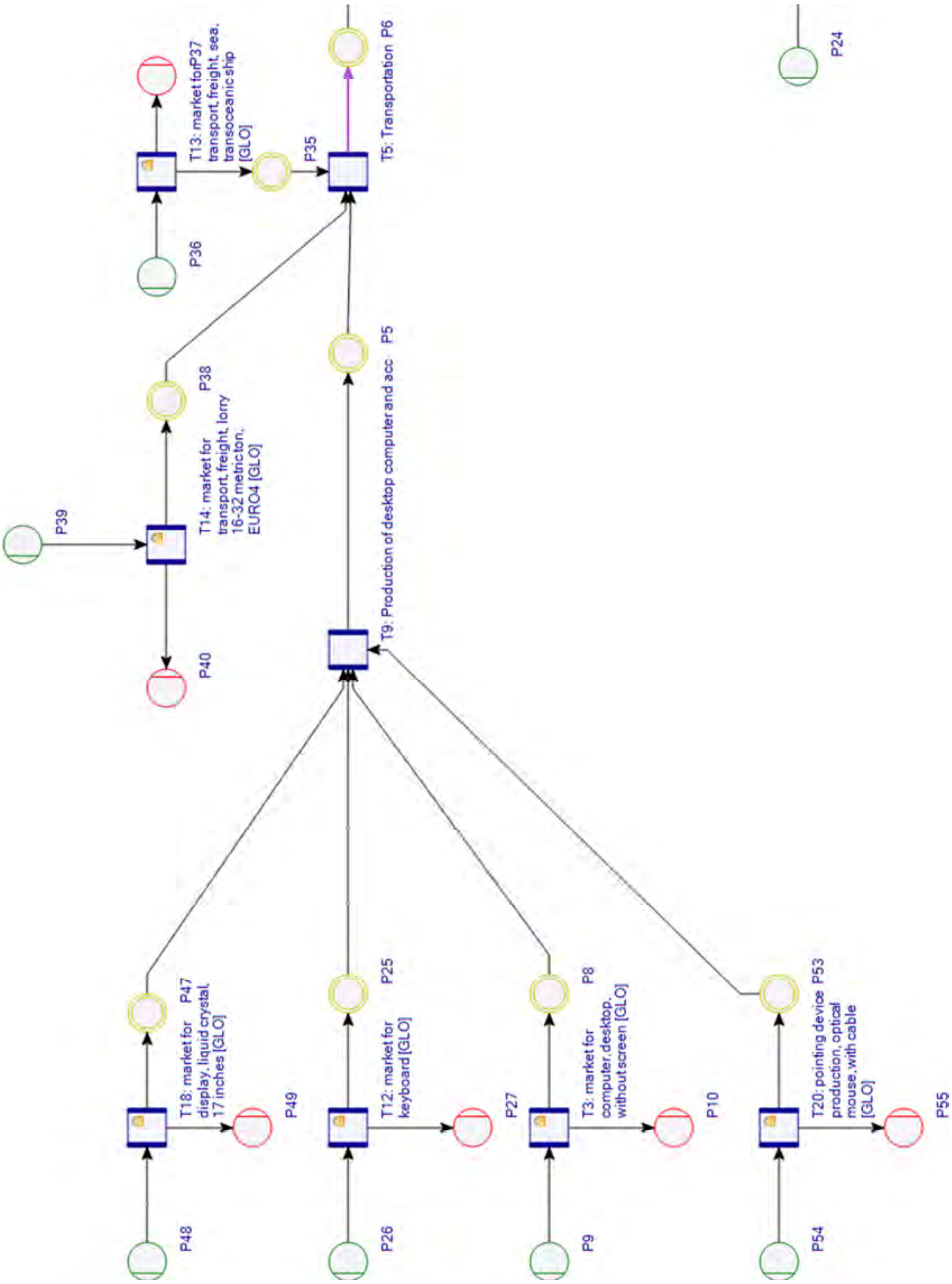
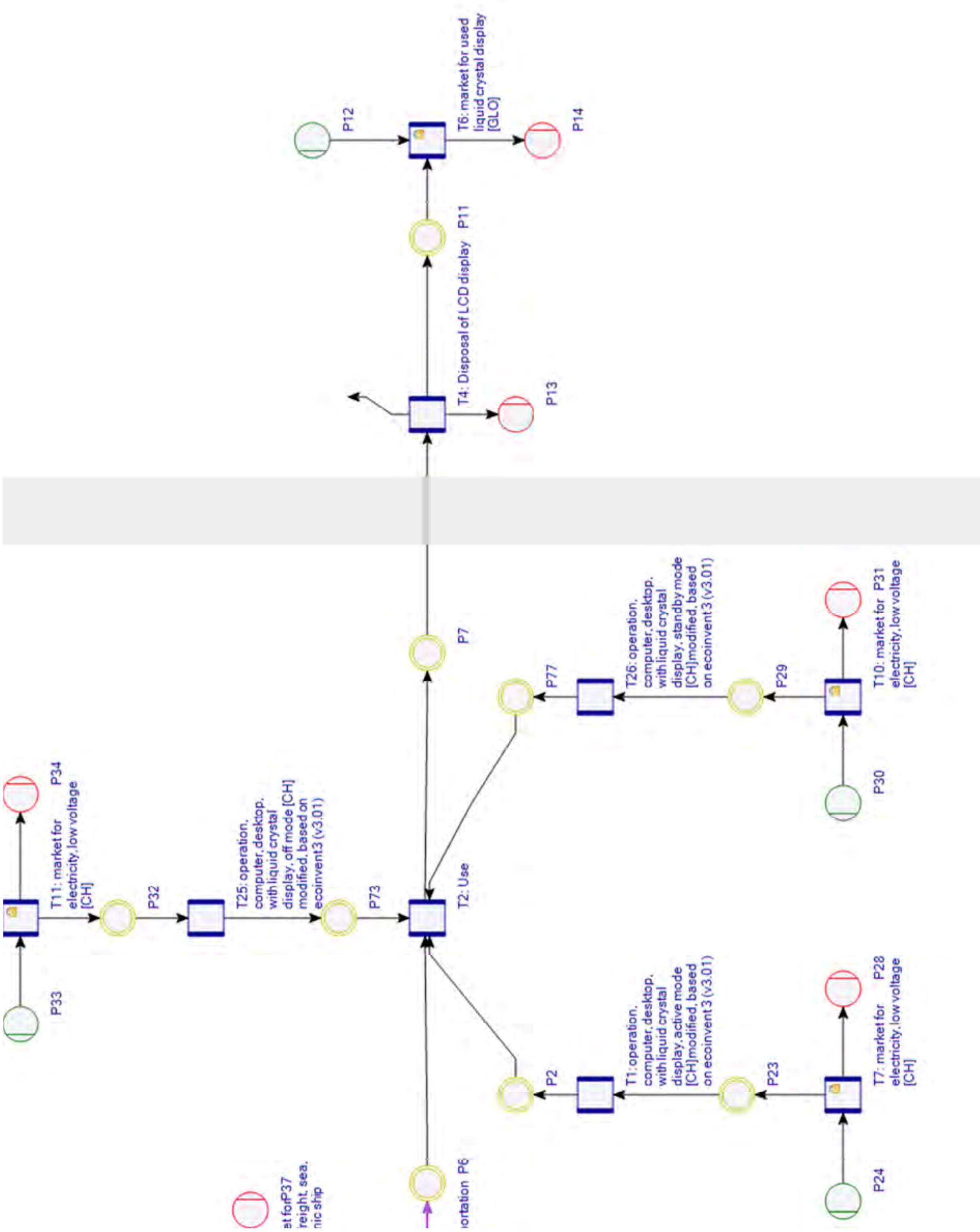


Figure 5.3: Use and disposal processes of desktop computer modeled in Umberto NXT LCA



5.2 Life cycle of laptop computer

5.2.1 Generic

The life cycle considers production, transport, use and disposal. The laptop computer was modeled with the Ecoinvent datasets.

Production

The Ecoinvent dataset for laptop computer assumes a display of 12.1 inches (Hischier et al., 2007, “Electronic Devices”, p. 134). The weight of the 12.1-inch LCD display is 0.33 kg (Hischier et al., 2007, “Electronic Devices”, p. 132). As the laptop computer display of the students has an average screen size of 16 inches, the original display dataset was adjusted by increasing the quantity of the dataset “LCD display, unmounted”. It was assumed the display aspect ratio of the laptop computer was 16:9. The additional quantity of display was determined as following.

Calculation for modeling a 16-inch LCD display:

$(16x)^2 + (9x)^2 = 12.1^2 \quad x^2 = 0.43$

Area of 12.1” display: $144x^2 = 62.56$ in^2

$16z^2 + 9z^2 = 16^2 \quad z^2 = 0.76$

Area of 16” display: $144z^2 = 109.39$ in^2

Weight of 16” display = Weight of 12.1” display x $\frac{\text{Area of 16" display}}{\text{Area of 12.1" display}}$

Weight of 16” display = $\frac{0.328\ x\ 109.39}{62.56}$ = 0.57 kg

Therefore, an additional input of 0.25 kg display was included in the production process. Assembly efforts at production site for the additional display were not considered.

Packaging

The Ecoinvent documentation states that the laptop computer requires 0.98 kg of packaging material (Hischier et al., 2007, “Electronic Devices”, p. 132).

The total weight of the packaged laptop computer is 4.37 kg, including the additional display accounting for the 16-inch display. This value was considered for the specification of the transportation activity.

Transportation

The transportation specification was determined by two parameters: distance and weight. Similar to the case of the desktop computer, it was assumed the production of the laptop computer takes place in China. The transportation from China to a European customer was modeled as 15000 km of distance by transoceanic freight ship and 500 km by freight lorry. The estimation of the distances is based on a LCA study conducted by Moberg et al. (2010). Ecoinvent datasets were used to model the two means of transport.

Disposal

The disposal of the laptop computer was modeled according to the global market of a used laptop computer. The dataset used for the production of the laptop computer already takes the waste treatment activities into consideration. The disposal of the additional LCD display was not considered as the electronic devices are disposed as a unit and the disposal of individual components can't be modeled with the Ecoinvent database.

The Ecoinvent dataset for the production of the laptop computer is derived from literature (Hischier et al., 2007, "Electronic Devices", p. 134).

The data for the electronic devices derive from the time period 2002-2003. The Ecoinvent documentation states that it is still representing the currently used devices, maybe not entirely corresponding to the latest technology. However this data for 2002-2003 is definitely on conservative side considering the current market for such devices show decreased weights for such items (Hischier et al., 2007, "Electronic Devices", p. 17-18).

The production dataset covers the extraction and processing of the raw materials, the production and transportation to production site of individual components such as printed wiring boards and hard disk drive, energy and water consumptions during manufacturing and assembly, the infrastructure and the packaging (Hischier et al., 2007, "Electronic Devices", p. 133).

The production and disposal datasets are valid for the global market and for the time period 2001-2013.

5.2.2 Specific

The data for the use phase is derived from the survey (see Chapter 6). Table 5.5 comprises the parameters which were considered in the model and the associated values collected from the survey.

It was assumed the device was not used for 4 weeks in a year. Further, the data for daily average consumption in the three use modes (active, standby, off) applied to 6 of 7 days in a week.

Electricity consumption during use phase was modeled with the Swiss market for low voltage electricity.

Table 5.5: User-specific data for laptop computer

Parameter	Value
Laptop computer owners, non-owners	100% owners
Daily number of hours in active mode	7.62 hours
Daily number of hours in standby/sleep mode	6.22 hours
Daily number of hours in off mode	10.16 hours
Lifetime	4 years
Energy consumption of laptop computer for one hour of active use	0.02 kWh
Screen size (laptop display or additional monitor)	16 inches
Total reading time on laptop computer per student per semester	264.98 hours

The energy consumption rates for the sleep and off mode were taken from Ecoinvent 3.01.

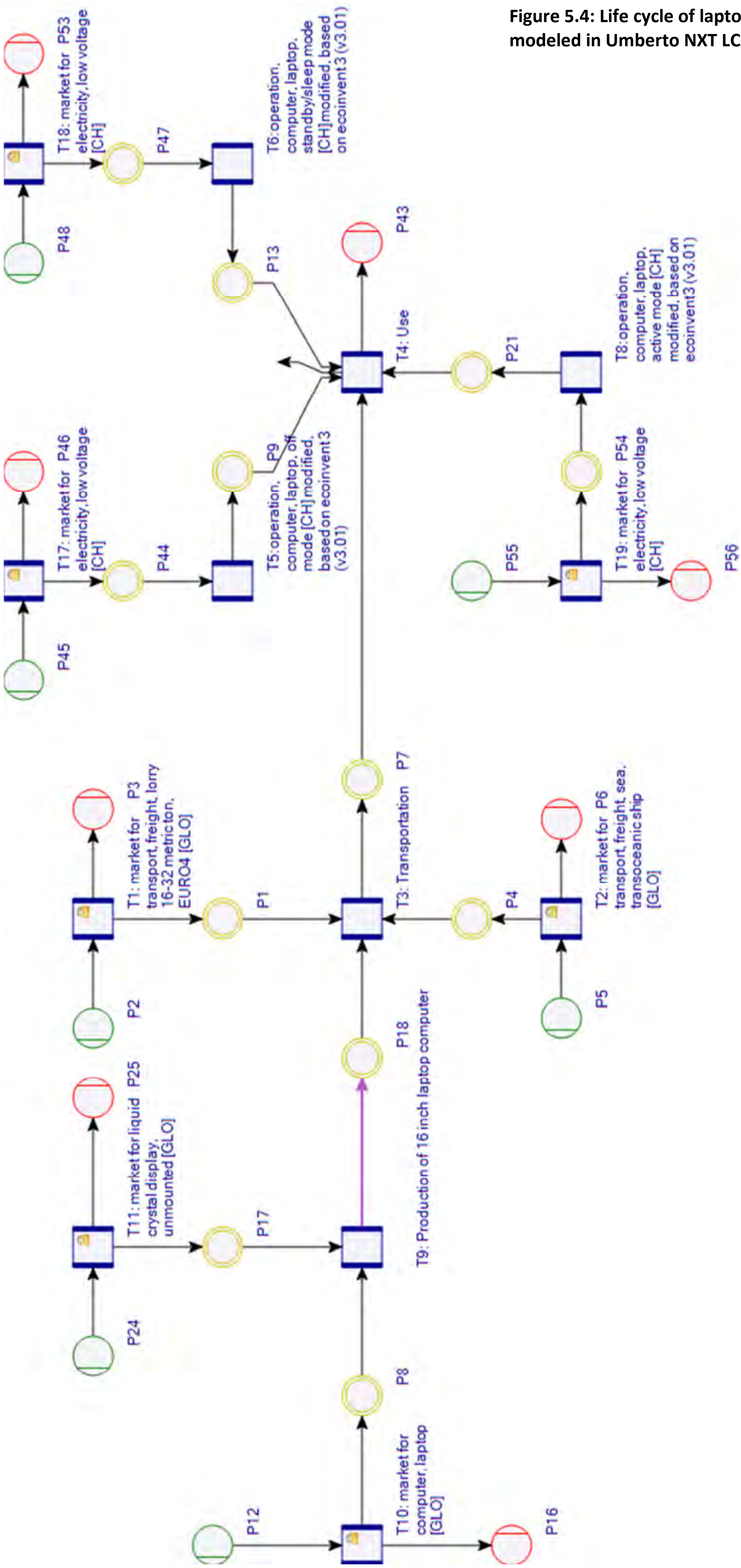


Figure 5.4: Life cycle of laptop computer modeled in Umberto NXT LCA

5.3 Life cycle of tablet computer

5.3.1 Generic

As Ecoinvent 3.01 does not provide datasets for the tablet computer yet, the life cycle of the same was modeled from scratch. The life cycle is split into the processes: production, packaging, transportation, unpacking, use and disposal. The Apple product iPad 2 WiFi + 3G was used as a reference model.

Production

The composition of materials for the production was taken from the environmental report provided by Apple (2012, p. 2). The weight of the iPad is 613g. The linking of material composition to the corresponding datasets from Ecoinvent 3.01 is shown in the table below.

Table 5.6: Material composition of iPad 2

Material	Ecoinvent dataset	Quantity
Aluminium	Aluminium, wrought alloy	140 g
Battery	Battery, Li-on, rechargeable, prismatic	131 g
Glass	Part of display	115 g
Circuit boards	Printed wiring board, surface-mounted, unspecified, Pb-free	40 g
Other metals	Silver, gold, palladium, copper	26 g
Plastics	Polystyrene, high-impact	19 g
Display	Liquid crystal display, unmounted	142 g
Total		**613 g**

It was assumed the 115 grams of glass in the specification refers to the glass used in the LCD display. The dataset “liquid crystal display, unmounted” from Ecoinvent 3.01 was used in the model with a quantity of 257 grams (115 grams of glass, 142 grams of display). Since the iPad display is LED lit, LED lights were also included as an input material for the production. 36 LED lights are used for the backlighting of the iPad 2 (Seifert, 2012). The Ecoinvent documentation of the dataset for light emitting diodes specifies a weight of 0.35 grams for one 5 mm LED (Hischier et al., 2007, “Electronic Components”, p. 83). No details about the dimensions of the LEDs used in iPads could be elicited. It was assumed 5 mm LED’s are used in iPads. Based on this assumption, 12.6 grams of LED’s were considered in the tablet computer model. Circuit boards were modeled using the dataset “printed wiring board, surface-mounted, unspecified”. The environmental report of iPad 2 (Apple, 2012) specifies that the material composition is lead-free (Pb-free); the corresponding Pb-free dataset was used for the circuit board.

Following data was taken from a report on e-waste and recycling (Electronics TakeBack Coalition, 2013, p. 8) and used to specify the composition mix of 'other metals' mentioned in the technical specification of the iPad.

According to the report one ton of mobile phones contain:

Table 5.7: Material composition of mobile phone

Metal	Quantity	Share
Silver	3.5 kg	2.7%
Gold	0.34 kg	0.24%
Palladium	0.14 kg	0.096%
Copper	130 kg	97%

The composition mix of 'other metals' was modeled with the four metals in the same proportion as calculated in Table 5.7.

Table 5.8: Composition of other metals

Metal	Quantity
Copper	0.97 x 26 grams
Gold	0.0024 x 26 grams
Palladium	0.00096 x 26 grams
Silver	0.027 x 26 grams

High-impact polystyrene was chosen as the type of plastic used in the tablet computer, as it is the leading plastic type used in consumer electronics (Plastics, n.d.).

For the power adapter of the iPad, the dataset "power adapter for laptop" was taken, adjusting the quantity (number of units) based on the weight of the power adapter of the iPad. The Ecoinvent dataset for the power adapter of a laptop computer assumes a weight of 513 grams whereas the weight of the iPad 2 power adapter is 85 grams (Hischier et al., "Electronic Devices", 2007, p. 141; Apple, n.d.). As a result, the power adapter for the tablet computer was modeled as 0.16 units of the dataset for the power adapter of the laptop computer.

No information could be collected regarding the production factory. The voltaic cell factory dataset was taken as used in the modeling of the laptop computer production. The share of the factory assigned to one unit of tablet computer was estimated as following.

Based on the Ecoinvent documentation, 1.3 million units of laptop computers per year are produced in a factory which has a lifetime of 25 years (Hischier et al., 2007, "Electronic Devices", pp. 134-135). The laptop computer has an average weight of 3.15 kg (Hischier et al., 2007, “Electronic Devices”, p. 135). The tablet computer is modeled with a weight of 0.6 kg. Based on the ratio 3.15/0.6, it was presumed 5.25 times more tablet computer units than laptop computer units could be produced per year in the same factory. The allocation of the factory was calculated based on the number of units that could be produced within the factory. The factory share for the production of one tablet computer was modeled with 5.79E-09 units of voltaic cell factory.

Assembly efforts were estimated based on the assembly efforts for the laptop computer production. 1.66 kWh of electricity (medium voltage) is accounted for the production of a laptop computer in Ecoinvent 3.01. It was assumed the assembly efforts are proportional to the weight of the product. The calculated factor above was considered and 1/5.25 of 1.66 kWh represented the assembly efforts for the tablet computer production. The same approach was applied to the outputs of the laptop computer production “tap water, at user”, “water [air/unspecified]”, “water [water/unspecified]” and “waste water, unpolluted”. The electricity consumption was modeled with the respective Ecoinvent dataset for the Chinese market as it was assumed the tablet computer production takes places in China.

Packaging

For the packaging, following components as shown in Table 5.9 were included based on the Apple report (2012, p. 2).

Table 5.9: Packaging material for iPad 2

Material	Ecoinvent dataset	Quantity
Paper (corrugated, molded fiber)	Corrugated board box	440 g
High impact polystyrene	Polystyrene, high-impact	68 g
Other plastics	Polystyrene, general purpose	9 g

Transportation

As for the transportation, the Apple report (2012) indicates the iPads are transported by airline (p. 2). No further details were found and following assumptions were made: The production takes place in Chengdu, China. The route from Chengdu, China to Frankfurt, Germany was traveled by airline. The air distance was approximated with 7812 km (Prokerala. Travel & Tourism, n.d.). Then, the goods are transported by freight lorry for 500 km as estimation for the average transportation distance in Europe. This value was taken from the LCA study by Moberg et al. (2010). Global Ecoinvent datasets were used to model the two means of transport.

Unpacking

The disposal of the packaging material was modeled with the datasets “waste treatment of paper board, sorting plant” and “treatment of waste polystyrene, municipal incineration”. Both datasets are specific to the Swiss region.

Disposal

As the laptop computer and tablet computer have similar components, the disposal phase was modeled using the “market for used laptop computer” dataset from Ecoinvent with a quantity of 0.7 kg (weight of iPad 2 and power adapter). The weight of the power adapter was taken into account as the dataset for the used laptop computer also includes the waste treatment of the power adapter.

5.3.2 Specific

For the use phase, data is derived from the survey (see Chapter 6). Table 5.10 comprises the parameters which were considered in the model and the associated values collected from the survey.

It was assumed the device was not used for 4 weeks in a year. Further, the data for daily average consumption in the three use modes (active, standby/sleep, off) applied to 6 of 7 days in a week.

Electricity consumption during use phase was modeled with the Swiss market for low voltage electricity.

Table 5.10: User-specific data for tablet computer

Parameter	Value
Tablet computer owners, non-owners	62.3% owners, 37.7% non-owners
Daily number of hours in active mode	4.23 hours
Daily number of hours in standby/sleep mode	15.65 hours
Daily number of hours in off mode	4.12 hours
Lifetime	3.25 years
Energy consumption of tablet computer for one hour of active use	0.002 kWh
Screen size	9.74 inches
Total reading time on tablet computer per student per semester	50.25 hours

The average screen size of the tablet computer the students own is 9.74 inches which corresponds to the dimensions of the reference model (9.7 inches).

The energy consumption rate for the sleep mode was taken from the iPad 2 specification (Apple, 2012, p. 1).

The total average reading time of the tablet computer owners is already weighted according to the ratio owners/non-owners and has a value of 50.25 hours as stated in Table 5.10.

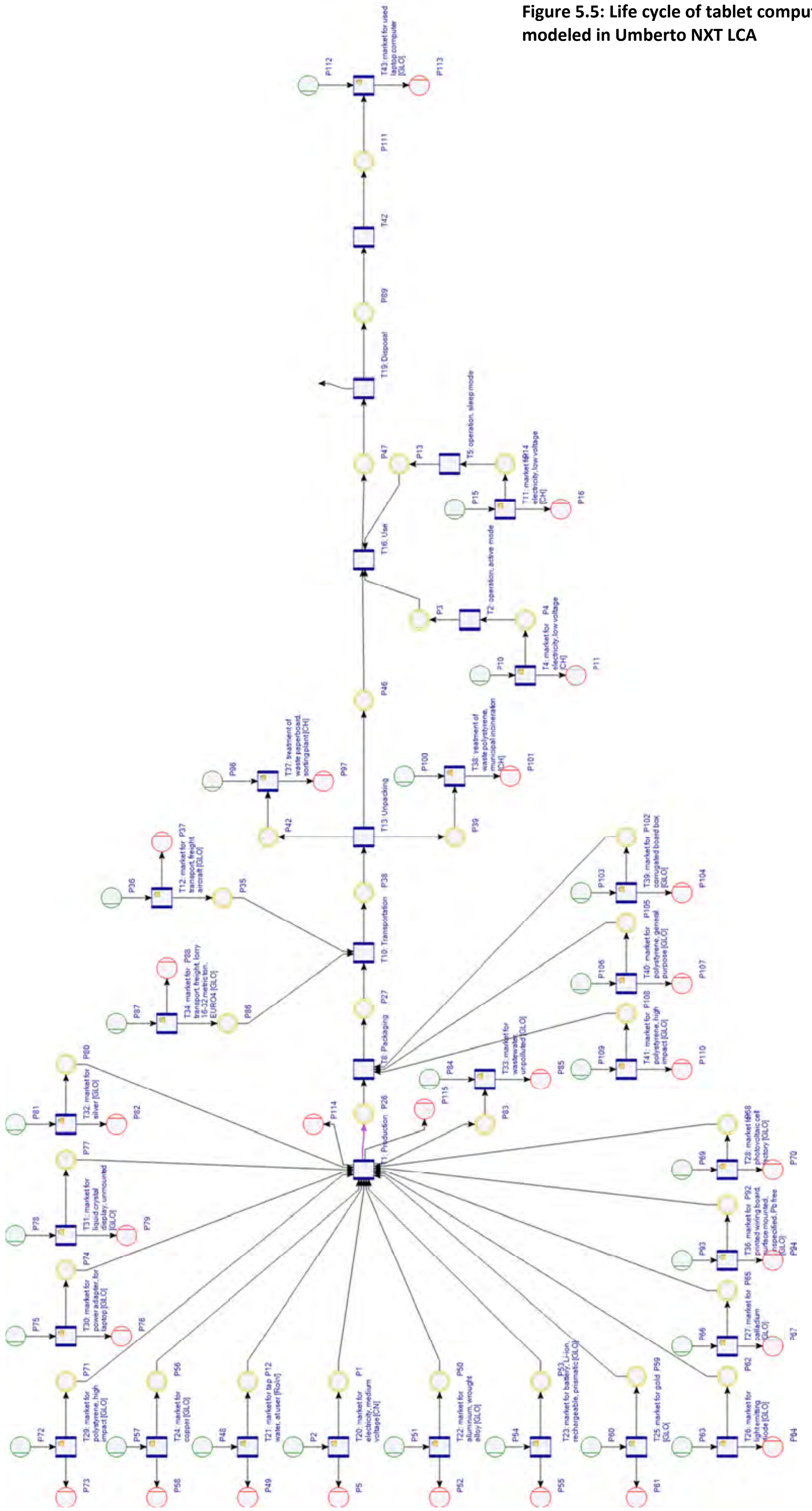


Figure 5.5: Life cycle of tablet computer modeled in Umberto NXT LCA

Figure 5.6: Production process of tablet computer modeled in Umberto NXT LCA

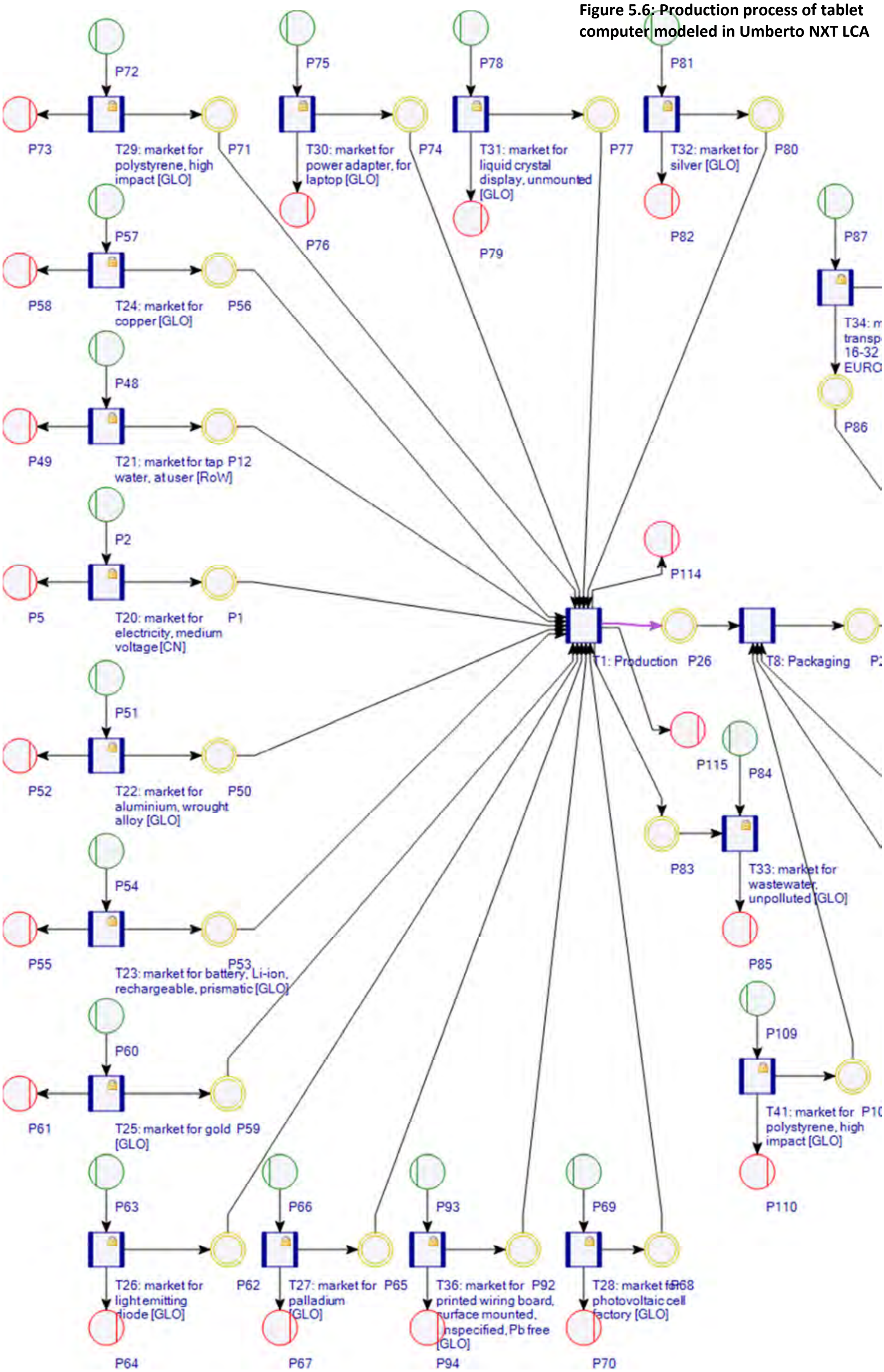
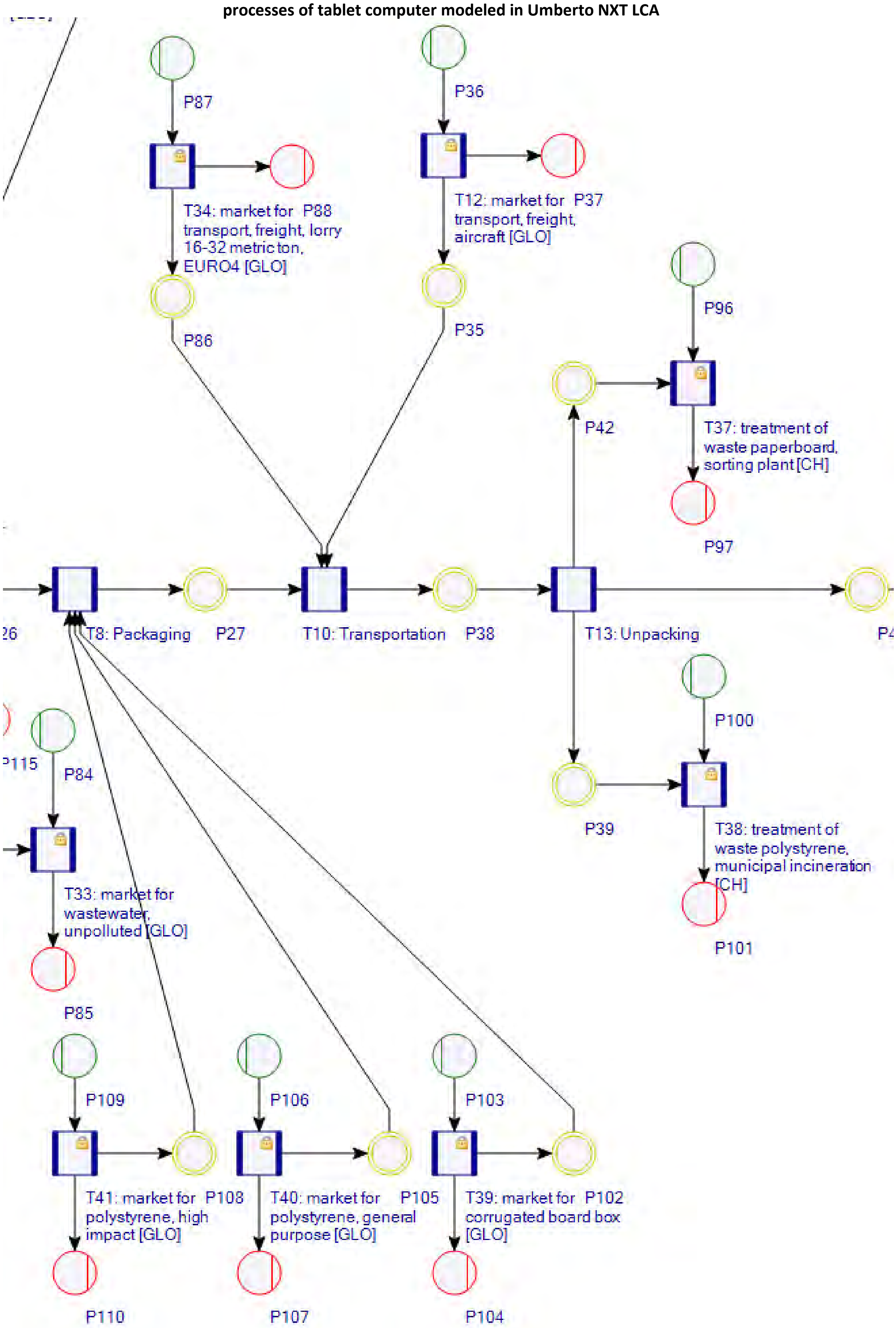


Figure 5.7: Packaging, transportation and unpacking processes of tablet computer modeled in Umberto NXT LCA



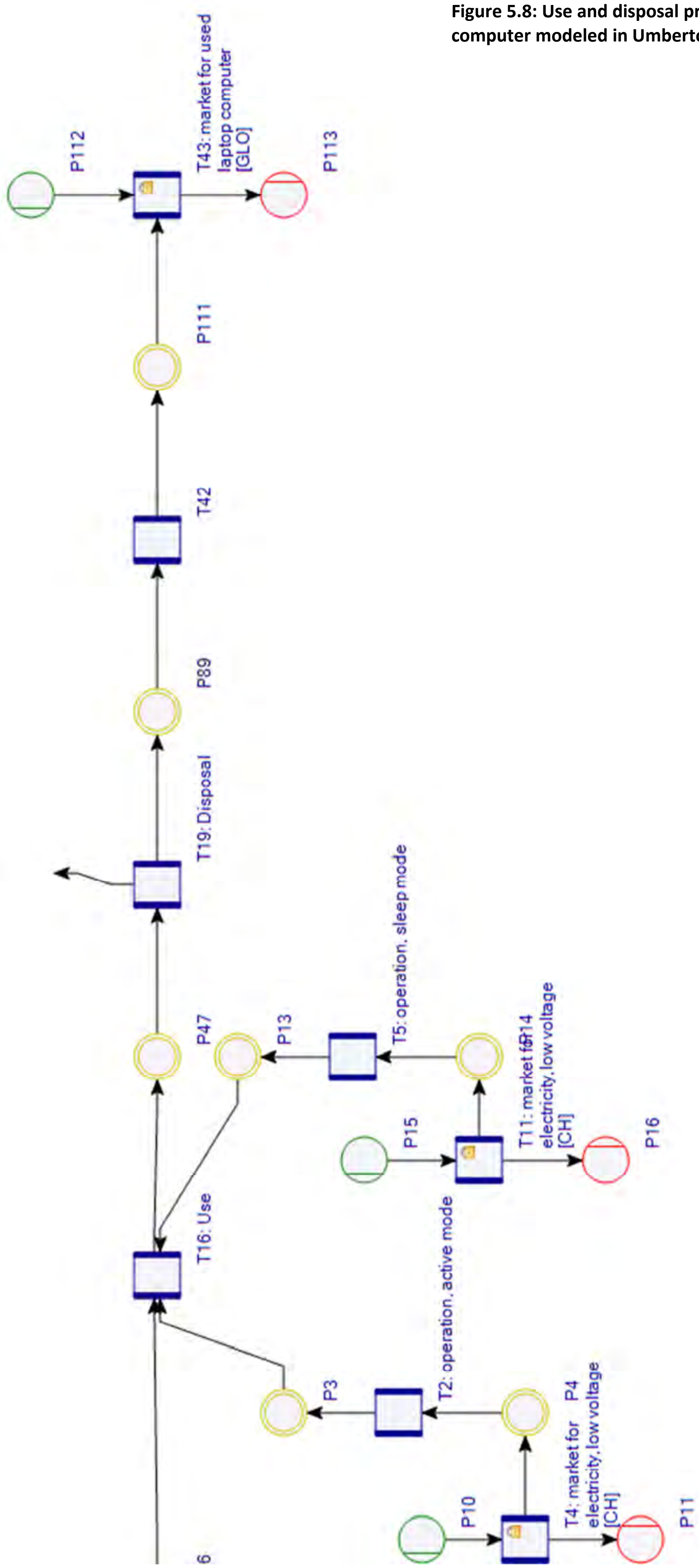


Figure 5.8: Use and disposal processes of tablet computer modeled in Umberto NXT LCA

5.4 Life cycle of self-printed lecture notes

5.4.1 Generic

The life cycle of the self-printed lecture notes considers the paper production, paper transportation, printing, use and disposal.

Production

Typical office paper used for printing is wood-free and uncoated. The dataset for wood-free, uncoated paper was used to model the paper production. The dataset applies to the European market i.e. it represents the wood-free uncoated paper which is consumed in average Europe. The dataset includes the transport from the production site to a central distribution site within average Europe.

Transport

It was assumed paper was transported by freight train from the distribution site to a European customer. Site-specific data were chosen to model the transportation. To estimate the distance of travel, the distribution center in average Europe was assumed to be in Frechen, Germany (a specific distribution center of paper distribution company Antalis). 600 km was taken into account for the distance between the distribution center and a student in Zurich (Google Maps, 2014; Antalis, 2013).

Printing

As there were no datasets available to model the inkjet printing, the printing activity was modeled entirely with the use of laser printers (colour). The required input and output resources for the printing activity were taken from the Ecoinvent documentation. The printing activity considers the laser printer, paper, toner and electricity on the input side; printed paper, used toner and a particular chemical substance emitted during the printing process on the output side.

The printing dataset assumes a power rating of 300W for the printer and a printing rate of 4 pages per minute. This was consistent with specifications of some printers in the Swiss market. The toner dataset in Ecoinvent was allocated to the printing activity based on its powder content. As per the Ecoinvent documentation, 5% coverage of printed paper consumes 0.02 grams of powder (Hischier et al., 2007, “Use”, pp. 96-97).

Concerning the allocation of the printer, it was assumed a student owning a printer prints 200 pages per month and uses the printer for 4 years. It was further assumed that the office paper used for printing has a weight of 80 g/m^2.

On the output side of the printing activity, the Ecoinvent documentation states 2.4E-07 kg of the substance Benzene is emitted for 200 single-sided pages. As no clear information is provided in the Ecoinvent documentation regarding toner cartridges, the weight of an empty toner cartridge was estimated 1.605 kg based on product-specific information (Ink and Toner Plus, n.d.). The used toner cartridge was allocated to the printing activity based on the use of the toner and modeled with the dataset for waste treatment of a used toner.

For the electricity consumption, the Swiss market for low voltage electricity was used. The printer and toner were modeled with global market datasets. The dataset for laser printer considers the production and disposal.

Use

No resources or emissions were considered during the use phase.

5.4.2 Specific

Printing

The amount of paper used to print lecture notes in relation to the functional unit is 16 pages per week. It was assumed lecture notes are printed over 20 weeks (15 weeks during semester and additional 5 weeks).

From the survey responses (Chapter 6) it was established that double-sided printing applied to 58.3% of the printed material. This was also taken into consideration and the quantifications of the energy consumption, printer and toner allocation on the input side were adjusted accordingly. Similarly, the used toner and the substance Benzene were quantified taking the double-sided printing into account.

The baseline system therefore considers 320 printed papers with 58.3% of double-sided printing.

The printing coverage of an average printed page with lecture notes is largely determined by the content. Based on the fact that the average student prints 4 lecture slides per page, 5% of printing coverage per printed page was assumed.

Disposal

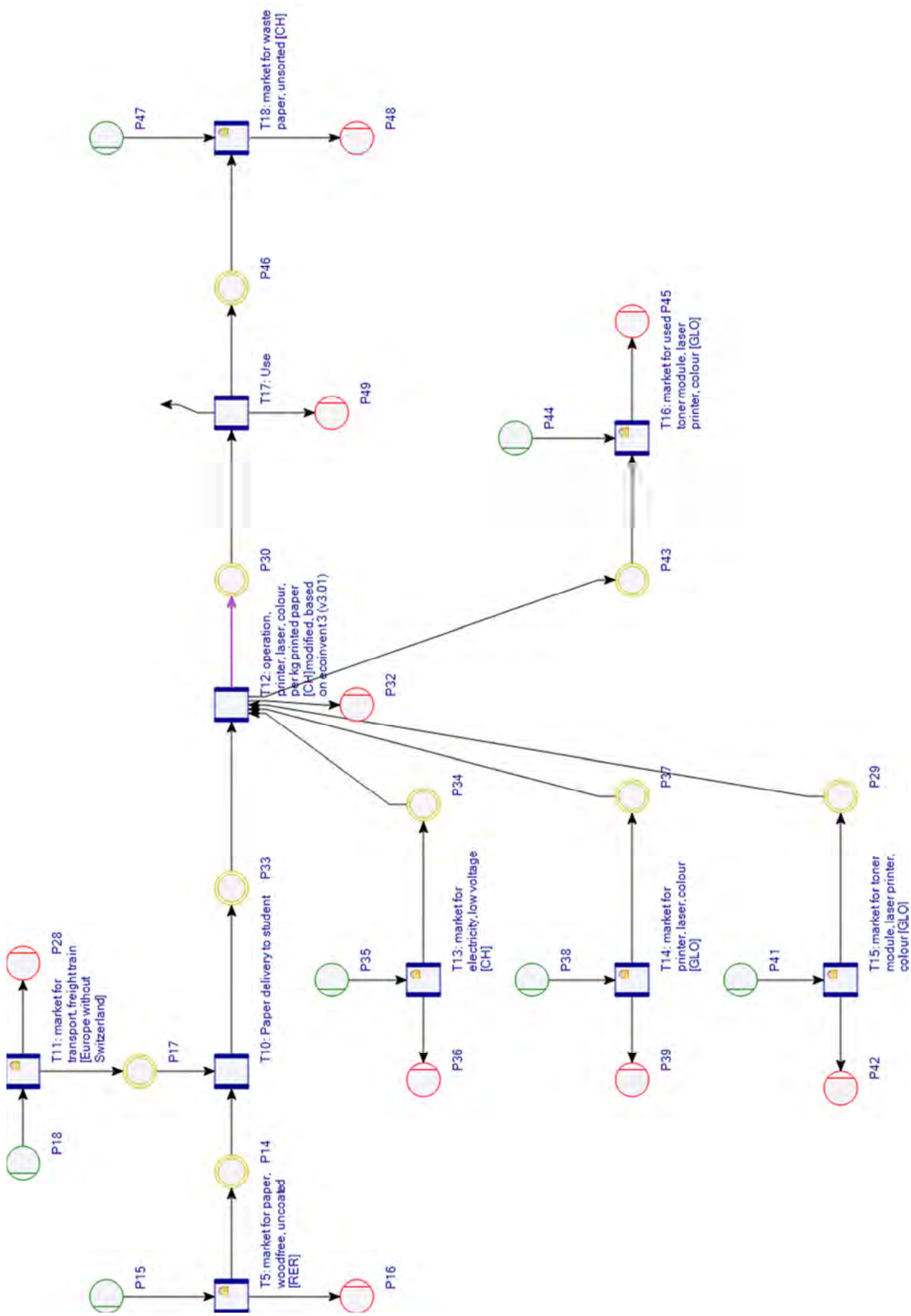
The waste management of paper was modeled according to the Swiss market for unsorted waste paper. The students specified whether the self-printed lecture notes were disposed, given to others or remained undisposed after use. No recycling of the self-printed lecture notes was taken into consideration as the lecture notes vary yearly and it was therefore assumed that even if a student borrows lecture notes of past semesters he will still print the current version. As for the waste treatment of lent lecture notes, it was assumed 50% of the material is disposed and 50% remains undisposed. 44% of the self-printed material is therefore disposed in total.

Table 5.11 shows the parameters which were considered in the model and the associated values collected from the survey (Chapter 6).

Table 5.11: User-specific data for self-printed lecture notes

Parameter	Value
Average percentage of double-sided printing	58.3%
After use	42% disposed 54% remains with student 4% given to others
Average number of printed pages	16 pages per week
Average number of lecture slides per page	4

Figure 5.9: Life cycle of self-printed lecture notes modeled in Umberto NXT LCA



5.5 Life cycle of printed book of lecture notes

5.5.1 Generic

The life cycle of the printed book of lecture notes considers the paper production, paper transportation, printing, assembly, delivery, use and disposal.

Production

Based on available printed books, it was assumed the paper used for printed books of lecture notes was wood-free coated paper. The respective dataset was used to model the paper production. The dataset applies to the European market i.e. it represents the wood-free coated paper which is consumed in average Europe. The dataset includes the transport from the production site to a central distribution site within average Europe.

Transport

It was assumed paper was transported by freight train from the distribution site to a European customer. Site-specific data were chosen to model the transportation. To estimate the distance of travel, the distribution center in average Europe was assumed to be in Frechen, Germany (a specific distribution center of paper distribution company Antalis) and the print office was assumed to be located in Dübendorf (Akeret Druck AG). 600 km was taken into account for the distance between the distribution center and the print office (Google Maps, 2014; Antalis, 2013).

Printing

The printing activity was modeled using laser printers (colour). The required input and output resources for the printing activity were taken from the Ecoinvent documentation. The printing activity considers the laser printer, paper, toner and electricity on the input side; printed paper, used toner and a particular substance emitted during the printing process on the output side.

The printing dataset assumes a power rating of 300W for the printer and a printing rate of 4 pages per minute. The dataset represents a typical home printer and printers used in small offices. This may not be representing printer equipment in print offices. The toner dataset was allocated to the printing activity based on its powder content. As per the documentation, 5% coverage of printed paper consumes 0.02 grams of powder (Hischier et al., 2007, “Use”, pp. 96-97; “Device”, p. 148).

Concerning the allocation of the printer, it was assumed the printer in print offices processes orders in the size of 800 pages per day for 365 days a year and has a lifetime of 4 years. It was further assumed that the paper used for printed books of lecture notes has a weight of 110 g/m^2. This was approximated based on the number of pages and the weight of an existing printed book of lecture notes. The individual pages are printed on both sides. This was also taken into consideration and the quantifications of the energy consumption, the printer and toner allocation were adjusted accordingly.

On the output side of the printing activity, the Ecoinvent documentation states 2.4E-07 kg of the substance Benzene is emitted for 200 single-sided pages. As no clear information is provided in the Ecoinvent documentation regarding toner cartridges, the weight of an empty toner cartridge was estimated 1.605 kg based on product-specific information (Ink and Toner Plus, n.d.). The used toner cartridge was allocated to the printing activity based on the use of the toner and modeled with the dataset for waste treatment of a used toner. Both the inputs and outputs of the printing activity were quantified taking the double-sided printing into consideration.

For the electricity consumption, the Swiss market for low voltage electricity was used. The printer and toner were modeled with global market datasets. The dataset for laser printer considers the production and disposal.

Assembly

The assembly of the printed book included the binding of the printed pages into a book format. Due to lack of data an adhesive of 30 grams was assumed for the binding of a printed book of lecture notes. The dataset for polyurethane (rigid foam) provided in Ecoinvent was used to model the adhesive. It was further assumed the assembly takes place at the print office.

Delivery

The printed books are transported from the print office to the University with a light commercial freight vehicle. The distance between the print office and the University was estimated 7.6kms (Google Maps, 2014).

Use

No resources or emissions were considered during the use phase.

5.5.2 Specific

The average number of pages in a printed book of lecture notes was estimated based on the 11 most visited courses of the students who participated in the survey. The number of slides and the number of A4-size text pages were calculated separately for each course as shown in Table 5.12. An A4-size text page is defined as a page in portray layout including text and images which is printed in original size (i.e. one page per side).

Table 5.12: Amount of lecture notes for 11 most visited courses

Course	Slides	A4-size text pages
Software Engineering	1100	247
Wirtschaftsinformatik	779	96
Distributed Systems	597	20
Informatik I	858	76
Formal Methods for Computer Science II	1209	264
BWL III	736	77
Advanced Programming in C++	478	14
Microeconomics	372	102
System Software	525	75
Formal Methods for Computer Science I	325	138
Informatik im Unternehmen	504	146

An average printed book consists of 680 slides and 114 A4-size text pages. Based on an existing printed book of lecture notes, it was assumed that two lecture slides are printed on one page; one A4-size text page is printed on one page. A printed book therefore consists of 227 double-sided printed pages. The average printed book of lecture notes has a weight of 1.6 kg (printed pages including adhesive).

For each student the following quotient was calculated:

$$Number\ of\ printed\ books\ of\ lecture\ notes/Number\ of\ courses$$

An average student possesses 0.06 printed books per course. With an average of 5 courses per semester, a student owns 0.32 printed books per semester. This was the number of printed books considered for the baseline system.

5% of printing coverage per printed page was further assumed. As the particular parameter is possibly underestimated, it was tested in the sensitivity analysis (Chapter 8).

Disposal

The waste management of paper was modeled according to the Swiss market for unsorted waste paper and waste polyurethane foam (collection for final disposal). The students specified whether the printed books are disposed, given to others or remained undisposed after use. No recycling of the printed books was taken into consideration as the lecture notes vary yearly and it was therefore assumed that even if a student borrows printed books of past semesters he will still buy the current version. As for the waste treatment of lent printed books, it was assumed 50% of the books are disposed and 50% remain undisposed. 21% of the printed books per student are therefore disposed in total.

Table 5.13 shows the parameters which were considered in the model and the associated values collected from the survey (Chapter 6).

Table 5.13: User-specific data for printed books of lecture notes

Parameter	Value
After use	15% disposed 73% remains with student 12% given to others
Average number of printed books of lecture notes per student and semester	0.32 printed books of lecture notes
Average number of slides and A4-size text pages per course	680 lecture slides, 114 A4-size text pages

Figure 5.10: Life cycle of printed book modeled in Umberto NXT LCA

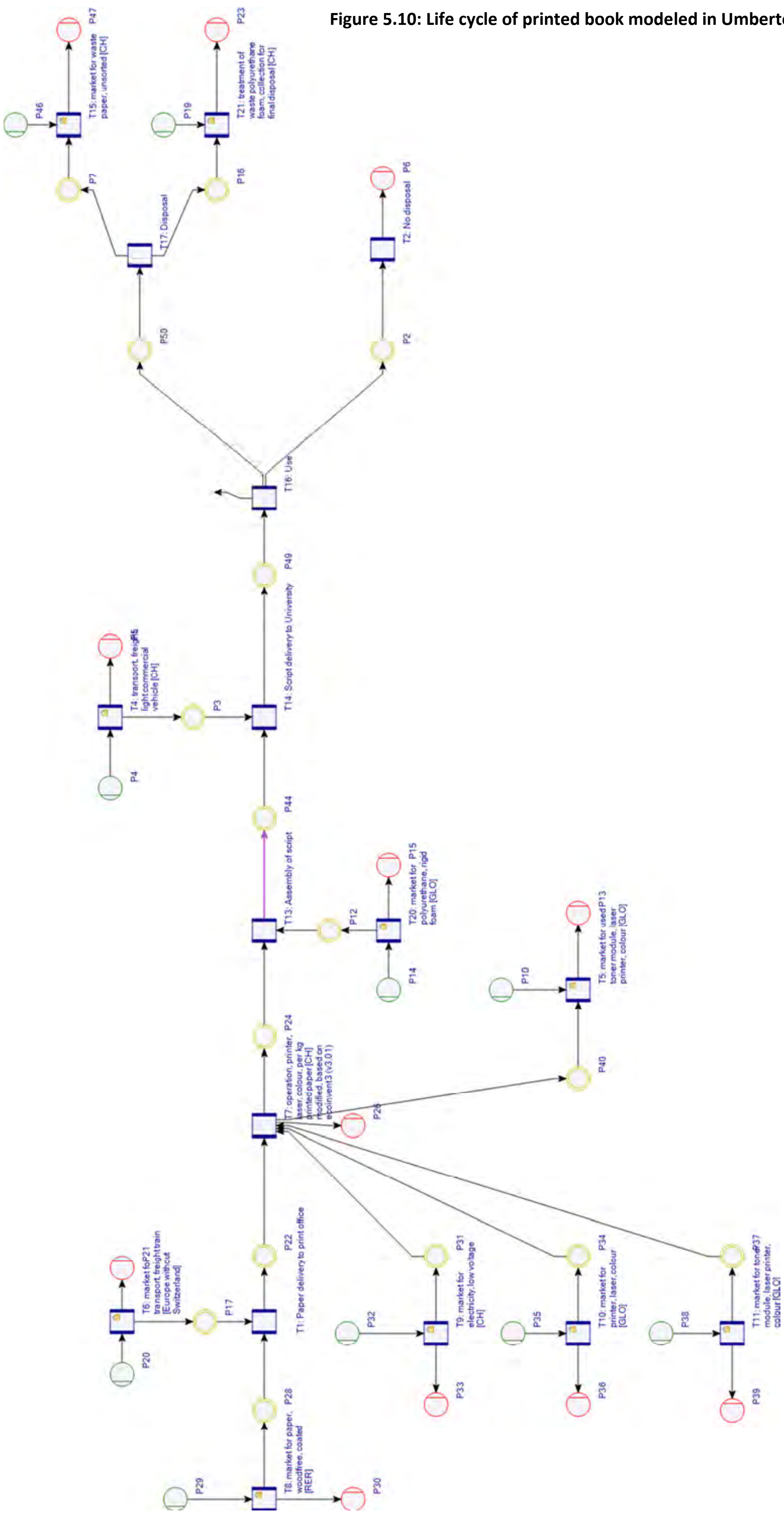


Figure 5.11: Paper production and delivery processes of printed book modeled in Umberto NXT LCA

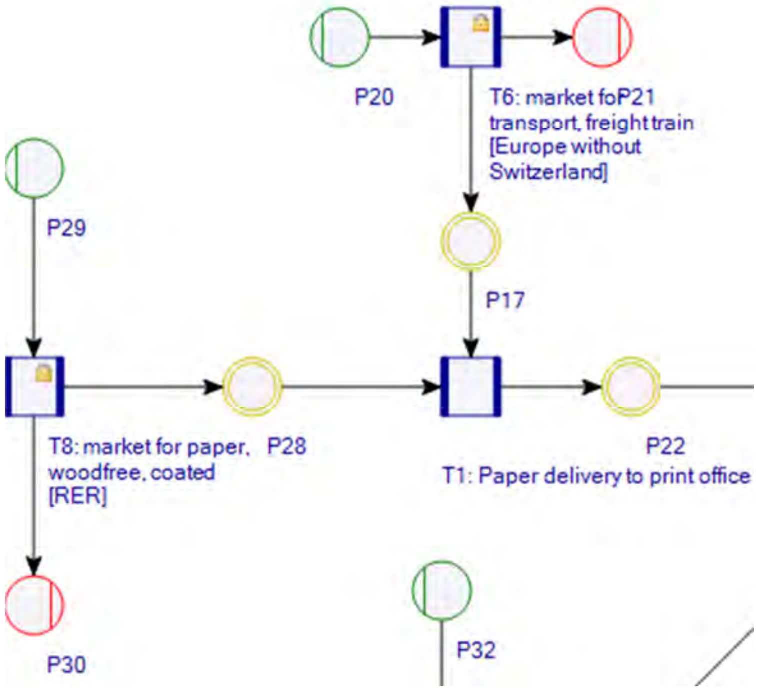
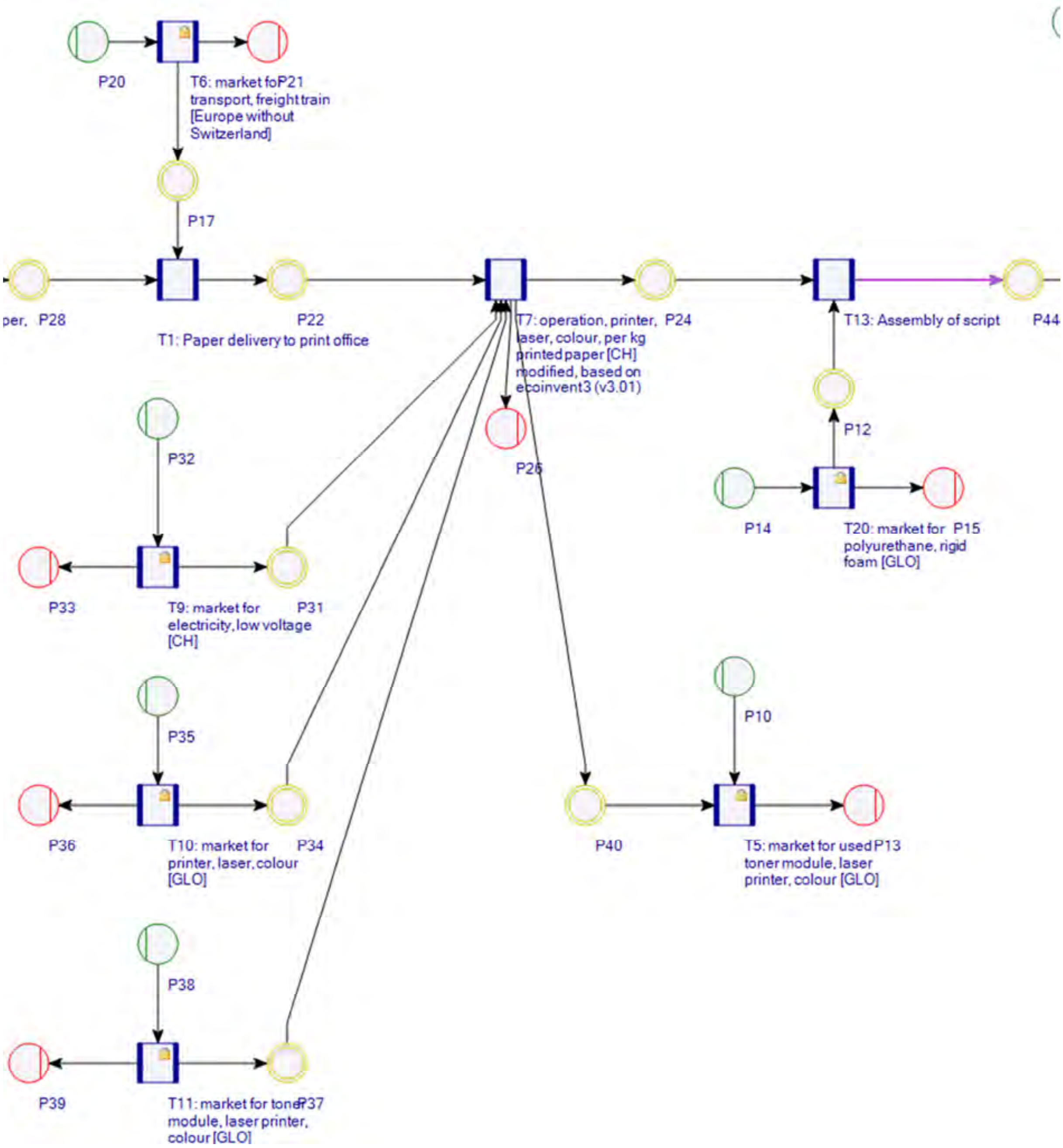


Figure 5.12: Printing and book assembly processes of printed book modeled in Umberto NXT LCA



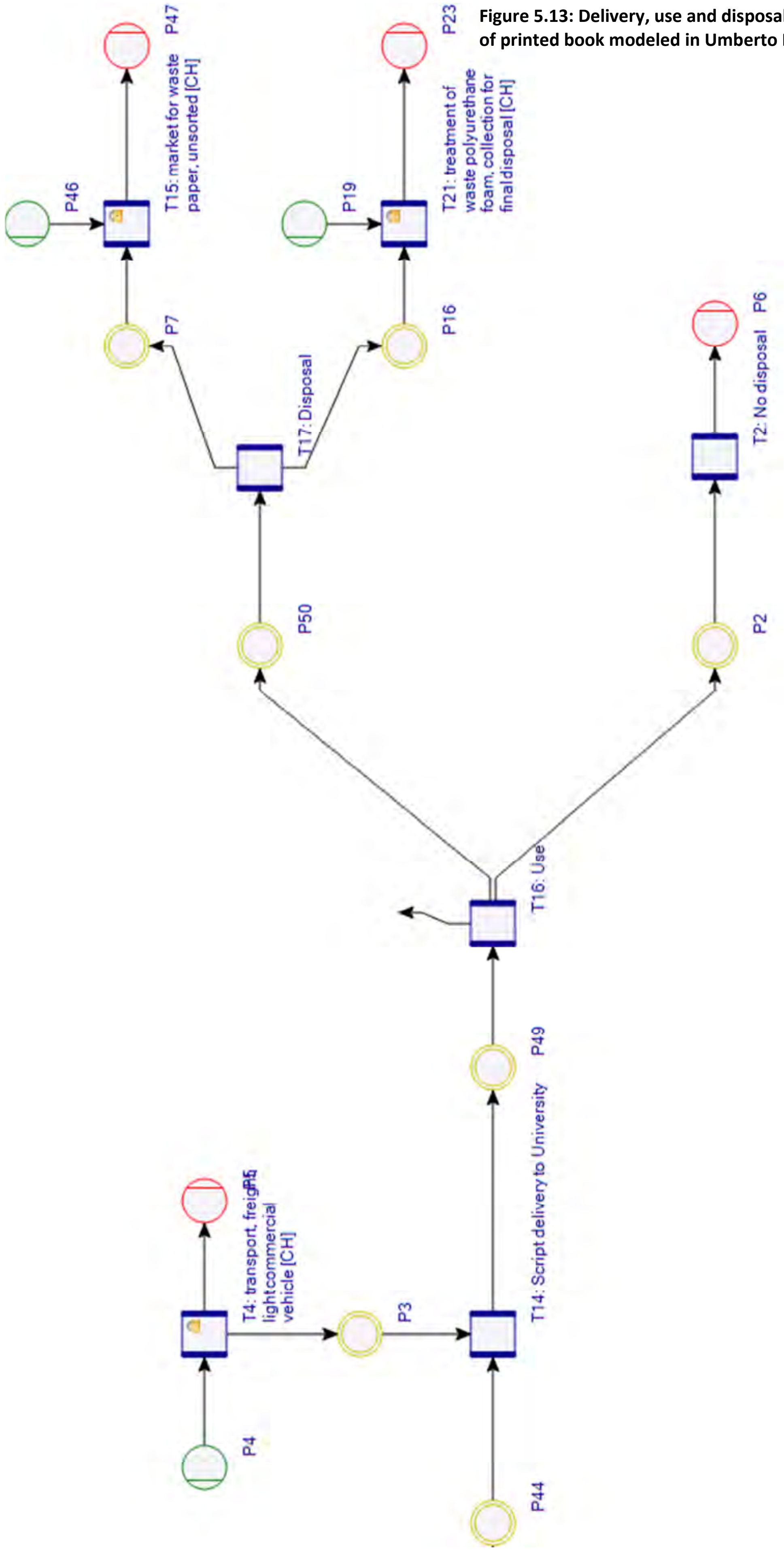


Figure 5.13: Delivery, use and disposal processes of printed book modeled in Umberto NXT LCA

5.6 Internet access

The baseline scenario also takes the energy consumption caused by the internet access into account.

When a student accesses the lecture notes over the Internet, the material is transmitted from the University server where the data is stored. For this study, the following networks are considered for the data transfer: wired LAN, private wireless LAN, public wireless LAN, mobile network.

To quantify the energy consumption for accessing the Internet, the following table is taken from the report "Grüne Software" (Hilty et al., 2013, p. 12). The unit is kWh/GB.

Table 5.14: Energy consumption of internet access in kWh/GB

Access network	2010	2015 (Projection)
Mobile network, optimistic	0.729	0.162
Mobile network, pessimistic	1.367	0.302
WLAN (private), optimistic	0.159	0.037
WLAN (private), pessimistic	0.372	0.220
WLAN (public), optimistic	0.001	-
WLAN (public), pessimistic	0.030	-

As Table 5.14 shows, the energy consumption is higher when the internet is accessed over a mobile network than over WLAN. Furthermore, there is a relevant difference between a private and public WLAN. When the internet is accessed over public WLAN, it results into lower energy consumption than when accessing it over private WLAN. This is due to the fact that the public hotspot is used by a wider group of users. This leads to a lower allocation of the energy consumption for an individual person in case of public WLAN access (Hilty et al., 2013, p. 12).

The 2015 projection for the mobile network is based on the presumption of a better use of the network capacity which results in to an optimization of the mobile network. For the private WLAN, the network utilization is expected to remain constant; the decrease in energy consumption per data unit is a result of the technical advances. For the public hotspot, no projections were established (Hilty et al., 2013, p. 12).

As a noteworthy optimization can be observed between 2010 and 2015, a linear interpolation for the year 2013 was calculated to estimate the current energy consumption rates. As for the public WLAN, 2010 figures were used as estimates for 2013.

Table 5.15: Estimated energy consumption of internet access for 2013

Mobile network, optimistic	Mobile network, pessimistic	Private WLAN, optimistic	Private WLAN, pessimistic	Public WLAN, optimistic	Public WLAN, pessimistic
0.389	0.728	0.086	0.281	0.001	0.030

The total average data volume (of lecture notes) per semester and student is 185 MB (37 MB per course x 5 courses). This was estimated based on the 11 most visited courses among the survey respondents. The collected data can be found in the Appendix.

Network usage patterns with regard to the access of lecture notes were also collected from the survey (Chapter 6). An average student accesses the lecture notes in following proportions:

Table 5.16: Network usage for accessing lecture notes

Network	Share of total data volume	Data volume
LAN	15%	27.75 MB
WLAN, private	42%	77.7 MB
WLAN, public	35%	64.75 MB
Mobile network	4%	7.4 MB

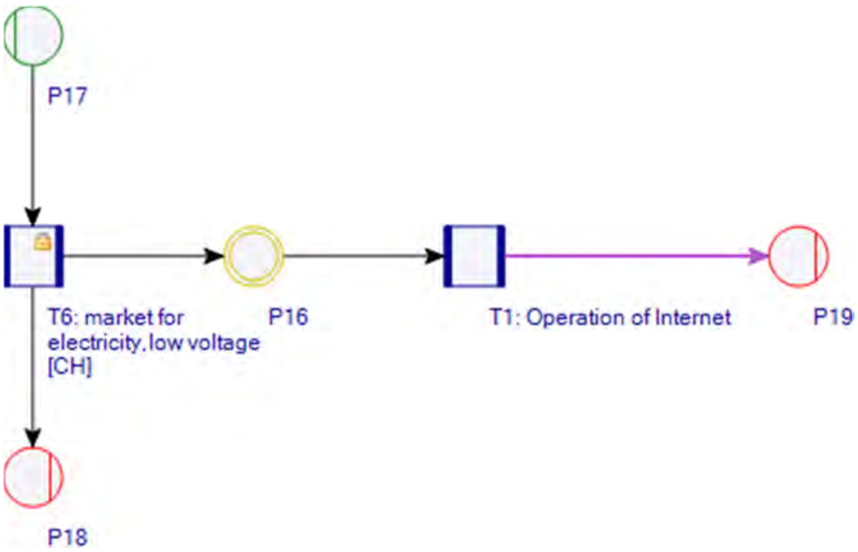
The remaining 4% of the total data volume is transferred over physical data storage devices such as USB stick and CD. Based on the Table 5.15 and 5.16, the energy consumption from the internet access was estimated as shown in Table 5.17.

Table 5.17: Energy consumption of accessing lecture notes

Network	Energy consumption
LAN (pessimistic)	= 0.281 x 0.0271 = 0.0076 kWh
WLAN, private (pessimistic)	= 0.281 x 0.0759 = 0.0213 kWh
WLAN, public (pessimistic)	= 0.03 x 0.0632 = 0.0019 kWh
Mobile network (pessimistic)	= 0.728 x 0.0072 = 0.0052 kWh
Total	**0.0361 kWh**

The energy consumption was modeled with the Ecoinvent dataset for the Swiss market.

Figure 5.14: Internet access modeled in Umberto NXT LCA



5.7 Server

The lecture material is stored on the University server. The use of the server has been considered in the LCA study. The production and disposal of the server were not taken into account. Based on the share of the lecture material on the server it would result in a negligible allocation of the impact caused by the production and disposal of the server. Only the use phase was modeled in which the direct electricity consumption for the server operation including cooling was taken into account. Other infrastructure such as maintenance efforts and room facility were not considered.

It was assumed the lecture notes were available on the server for 20 weeks i.e. during the semester (15 weeks) and additional 5 weeks. The server was assumed to be operational 24 hours a day, 365 days in a year.

The allocated energy consumption for the server operation was based on the amount of the used storage space for lecture notes and the number of enrolled students.

5.7.1 Calculation of file size per course

The file size of the lecture notes was estimated as follows:

In the survey questionnaire there was a section where the students had to specify which courses they had taken this semester. The different courses were tabulated and sorted according to the number of respondents who were enrolled in the particular course. The 11 most visited courses by the students are shown in Table 5.18. For each of these courses, the total file size of lecture notes was collected from the University websites. Lecture notes include lecture slides, A4-size text pages, supplementary documents etc. The collected data can be found in the Appendix.

Table 5.18: Total file size of lecture notes for 11 most visited courses

Course name	Total file size
Software Engineering	74332 KB
Wirtschaftsinformatik	36491 KB
Distributed Systems	34877 KB
Informatik I	27594 KB
Formal Methods for Computer Science 2	114820 KB
BWL III	26839 KB
Advanced Programming in C++	4167 KB
Mikroökonomik	4737 KB
Systems Software	29405 KB
Formale Grundlagen der Informatik I	11864 KB
Informatik für Ökonomen I	38412 KB

Data regarding total file size for every course visited by each survey respondent could not be collected. The average file size for a course was calculated as the average of the above 11 courses which is nearing 37 MB. This was used as an estimation for the total file size of lecture notes which is accessed by a student for one course.

It was assumed that the course material of a particular course was accessed over the Internet exactly once by each student who is enrolled in the respective course. The energy consumption of the server was allocated to the functional unit by dividing the energy consumption for the storage of the lecture notes by the number of students enrolled into the course.

5.7.2 Number of students per course

A striking difference between the number of students attending an informatics course and an economics course was observed. There was also a difference in the number of students between first year courses (assessment courses) and second/third year courses (non-first year bachelor courses). Based on these two differences, the average number of first year economics courses, first year informatics courses, second/third year economics courses, second/third year informatics courses attended by a student was calculated. For these calculations only students with the profile Wirtschaftsinformatik as a major were taken into account. Other profiles were excluded due to data gaps. The calculation is based on the survey data.

For each semester category the average number of courses for the four course types was calculated based on the survey data and weighted according to the distribution of the respondents in terms of the number of semesters studied.

Table 5.19: Distribution of courses according to course type and semester

Weight	Semester	First year informatics	First year economics	Second/third year informatics	Second/third year economics
0.24	1	2	4	0	0
0.29	3	0.13	1	2.86	1.2
0.03	4	0.5	0.5	5.5	0
0.25	5	0.08	0.42	5.58	0.83
0.13	7	0	0	2	0.6
0.04	9	0	0	0.5	0
0.01	11	0	0	0	1

Table 5.20: Average course type distribution

First year informatics	First year economics	Second/third year informatics	Second/third year economics	Total
0.55	1.36	2.7	0.65	5.25

As the average number of courses per student based on the survey has been established as 5, distribution coming to a total of 5.25 in Table 5.20 was adjusted with a factor of 0.95. Difference arises out of number of respondents which varied for each survey question.

Table 5.21: Adjusted average course type distribution

Course type	Number of courses
First year informatics	0.52
First year economics	1.29
Second/third year informatics	2.57
Second/third year economics	0.62

The 11 most represented courses were categorized into the four course types and the number of students for these courses was collected from the University sites (e.g. number of students who enrolled into the respective OLAT course, exam seating plans). For two courses the number of students was approximated based on the available information.

Table 5.22: Number of students per course

Course name	Course type	Number of enrolled students
Formale Grundlagen der Informatik I	First year informatics	161
Informatik I	First year informatics	196
Informatik für Ökonomen I	First year economics	926
Mikroökonomik	First year economics	936
Systems Software	Second/third year informatics	55
Wirtschaftsinformatik	Second/third year informatics	57
Advanced Programming in C++	Second/third year informatics	57
Formal Methods for Computer Science 2	Second/third year informatics	59
Distributed Systems	Second/third year informatics	79
Software Engineering	Second/third year informatics	81
BWL III	Second/third year economics	666

To estimate the average number of students for each course type, the lowest value (as a worst case approximate) for each case was chosen from Table 5.22.

Table 5.23: Average number of students per course type

Course type	Average number of students
First year informatics	161
First year economics	926
Second/third year informatics	55
Second/third year economics	666

5.7.3 Allocation of server operation

The total file size share on the server allocated to an average student was calculated as following:

= (0.52/161 + 1.29/926 + 2.57/55 + 0.62/666) x 37 MB = 1.93 MB

The environmental storage costs for 1.93 MB were therefore allocated to the functional unit.

The power ratings of typical servers were observed from the data of manufacturers as presented in Table 5.24.

Table 5.24: Power rating of servers

Server model	Storage	Power rating
HP ProLiant ML370 Generation 5 (G5)	8 TB	800 W
Dell PowerEdge RT10	12 TB	2x570 W
IBM System X3690X5	16 TB	2x675 W

Based on the above information in Table 5.24, 68.5 W is the average power rating for 1 TB. Additionally, power rating of the same amount was considered for server cooling purposes. The average power rating for 1 TB of server including cooling considered for this study is 137 W.

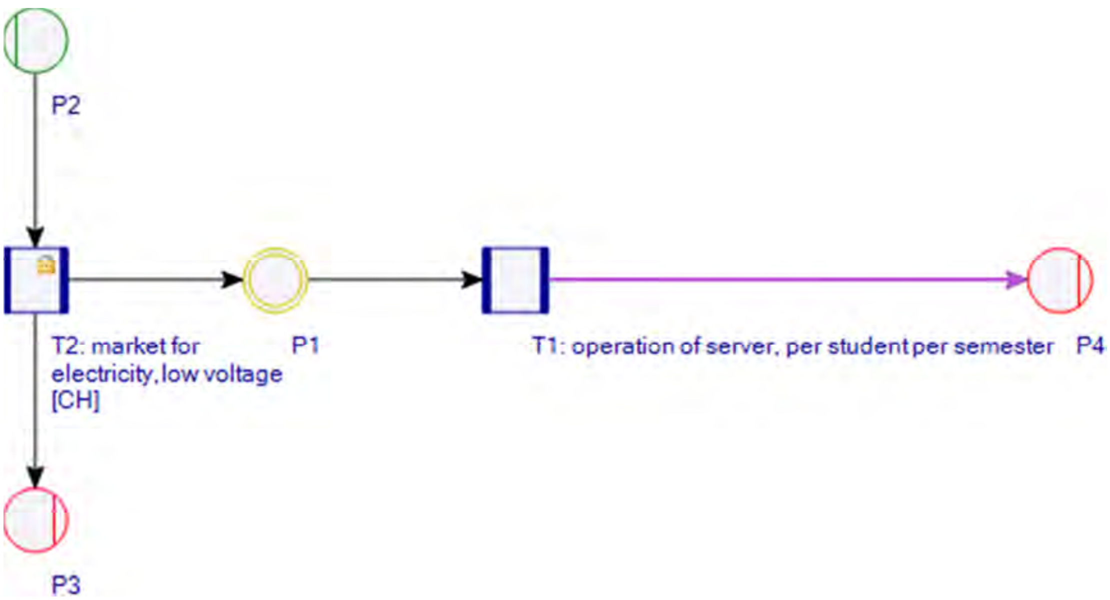
The power consumption of the server for 1.93 MB over a period of 20 weeks is:

$$1.93\text{MB}/1\text{TB} \times 137\ \text{W} \times 24\text{h} \times 7 \times 20 = 0.000849\ \text{kWh}$$

This is the energy consumption allocated to an average student accessing lectures notes during one semester.

The energy consumption was modeled with the Ecoinvent dataset for the Swiss market.

Figure 5.15: Server operation modeled in Umberto NXT LCA



6 Empirical study

6.1 Survey planning and design

As the result of the environmental performance is substantially determined by the usage patterns of the devices and as the patterns will be also different from country to country and student to student, I decided to conduct a survey to collect more specific information about the characteristics of Informatics students at the University of Zurich. Even though conducting face-to-face interviews by means of a catalogue of questions could clarify uncertainties and increase the data quality, it requires more time and other resources. This is why a self-administered questionnaire was designed.

6.1.1 Survey research objectives

The objective of the survey was to elicit the usage patterns of the Informatics students in regard to the following media: desktop computer, laptop computer, tablet computer, smartphone and printed paper. The goal of the project was to determine the environmental impact associated with the lecture notes being read by the students using different media. For this, data regarding general usage patterns as well as specific to studying lecture notes was required. The collected data was used to calculate the defined scenarios.

6.1.2 Definition of target audience

The target audience comprises bachelor students studying Informatics as a major or minor subject at the University of Zurich.

6.1.3 Sample

The intention was to send out the survey electronically to the entire target population. The sample was a non-probability sample as the survey recipients themselves decided whether they wanted to take part in the survey or not. The findings only provide information about those who responded and it may not be representative enough to make conclusions about the defined population.

6.1.4 Design of questionnaire

It was decided to implement the questionnaire using the survey tool SurveyMonkey. The questions to be asked were mainly about the use behaviour and personal characteristics such as age, gender and number of studied semesters. The order of the questions was determined based on the priority and logical structure of the questions. As the survey tool also stored data of incomplete questionnaires, it was considered to be useful to prioritize the questions in a way that partly filled in questionnaires could still provide useful information. The questions were mostly of closed-ended type as open-ended questions are difficult to transform into quantitative data. Some questions were hybrid so that the respondent could also answer in an open-ended way. This was particularly applied in cases where the set of options seemed to be incomplete. For many closed-ended questions an ordinal response scale (Likert-scale) was chosen in order to determine the frequency of behavior. The overarching questions based on which the survey questions derived are:

- Which media are used how frequently by a student to study lecture notes?
- How much time does a student spend on studying lecture notes for one semester on average?
- What are the general usage patterns of the electronic devices used by a student?
- How much power is consumed during the use phase of the electronic devices?

It was ensured that the survey was anonymous i.e. no personal data was collected which could be used to track the respondent. The tool also ensured that only one survey could be submitted from one IP address. The questionnaire is attached in the Appendix.

6.1.5 Pilot test of questionnaire

Once the survey design was finalized, pilot tests were conducted as a pretest for validation purposes. Participants for the mock-up questionnaire were potential respondents and were chosen from the defined survey population. The objective of the pilot test was to ensure the instructions were clear, the wordings of the survey were understandable and to check whether the respondents noticed any logical gaps. Questions were refined to eliminate ambiguity based on the received feedback. For some questions the response choices had to be adapted. The time the respondents took to complete the survey was also measured. As it was difficult for the students to take out time for a thorough face-to-face test, the questionnaire was sent out electronically. The filled in questionnaires were sent back with valuable feedbacks. Some interviews were conducted in person. Face-to-face interviews provided feedback concerning the clarity of the questions and the logical structure. Few additional questions were included during the pilot-testing phase which couldn’t be tested with all pilot test participants. The duration to complete the survey covered a range from 10 minutes to 25 minutes. In general, it was considered as a relatively time-consuming survey. However, it was difficult to reduce the scope as data regarding use patterns was substantial for the LCA study.

6.2 Conduct of survey

The survey was carried out electronically and published on SurveyMonkey. The distribution to the target population was done by the University using the appropriate mailing list. The survey was open for two weeks from 22nd November until 8th December. By the time the survey was published, the module booking period was closed and since it was nearing end of term, it could be expected the students have developed a study routine which could provide more accurate assessments regarding their usage patterns.

In addition, a reminder was sent to the students using the mailing list of icu.uzh.ch. A total of 95 respondents participated in the survey. However, not all of them completed the survey till the end.

6.3 Survey data analysis

This section presents the results of the survey. It is divided into the following topics:

- Respondents characteristics
- Use of different media for study of lecture notes
- General use patterns of electronic media
- Power rating of electronic media
- Data access patterns
- Use of podcasts

6.3.1 Respondents characteristics

Figure 6.1: Distribution of respondents

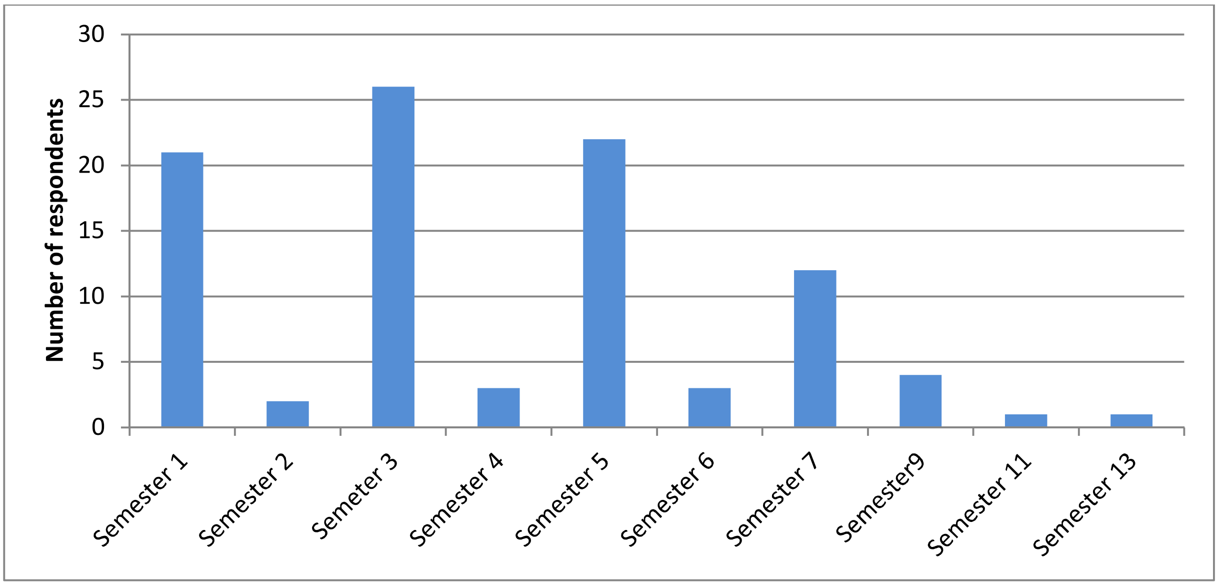
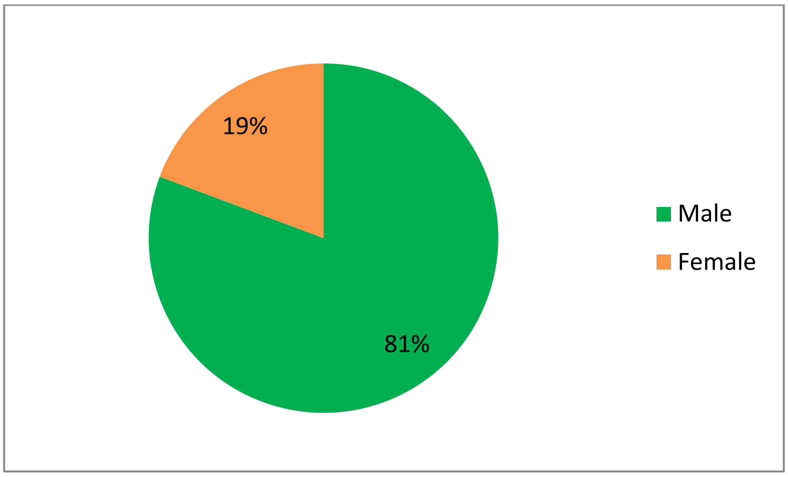


Figure 6.1 shows the distribution of the students according to the number of semesters studied at the University. As the survey was conducted in the autumn semester, it was expected the students mainly belong to the categories semester 1, semester 3 and semester 5. The graph indicates a well distributed sample across the different academic years.

Students attending semester 2, 4 and 6 could be explained as the ones who had skipped semesters during their studies and therefor did not count the unattended semester(s).

Figure 6.2: Gender of respondents



The gender distribution of the respondents is shown in Figure 6.2. The average age of the respondents is 24.5 years.

Figure 6.3: Study profile (major and minor in Informatics)

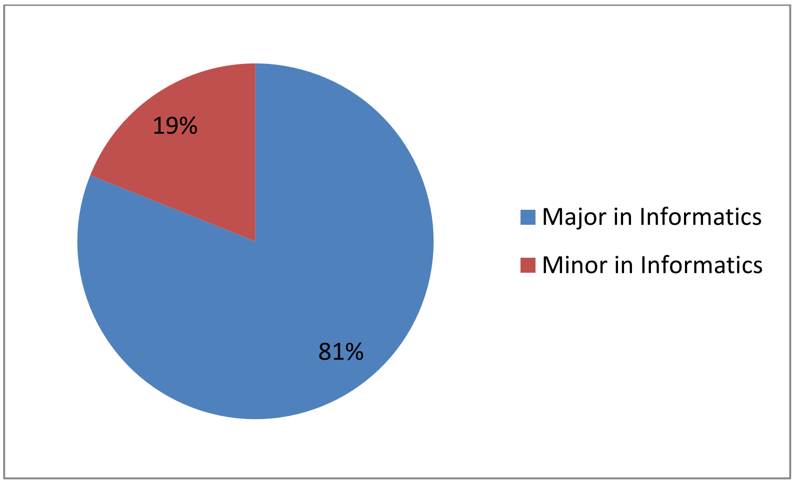


Figure 6.3 shows a distribution of the respondents who are either majoring in Informatics or have Informatics as a minor subject.

Figure 6.4: Study profile (business informatics, software systems, applied informatics)

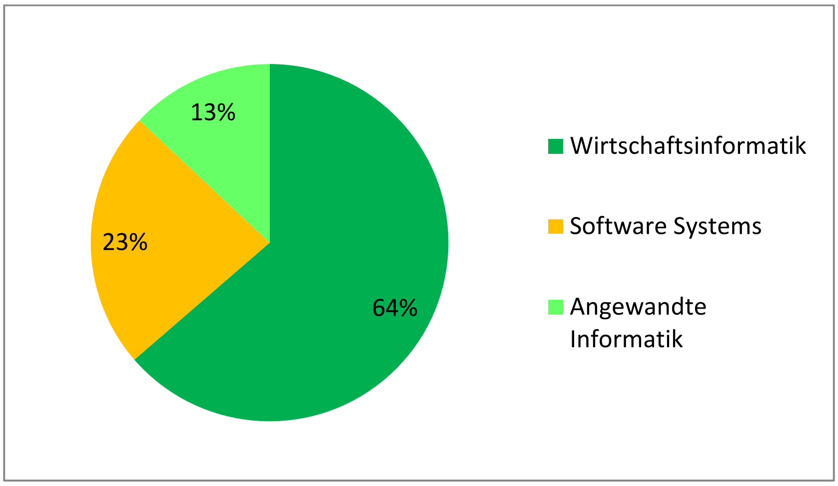


Figure 6.4 shows the classification of the students majoring in Informatics. The study profile of the respondents very accurately represents the study profile of the population (62% business informatics, 38% other informatics profile as given in the University statistics (Universität Zürich, 2013)).

The average number of lectures attended by the student is 5. The median has a value of 6. The difference is due to some outliers such as 0 and 11. Some students who answered with 0 explained that they're only attending labs and seminars this semester. Other course types such as labs and seminars were excluded from the study as they have irregular schedules and the amount of lecture notes for such courses is limited.

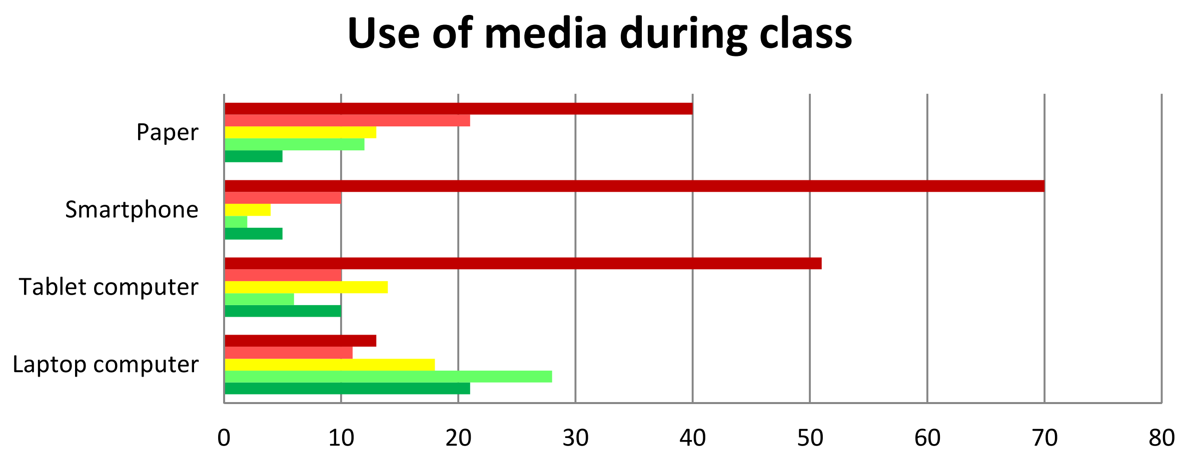
The average number of credits booked by a student is 24. The median value is 30 which corresponds to the recommended workload per semester.

6.3.2 Use of different media for study of lecture notes

To get an overall impression of the usage patterns of media which are used for studying lecture notes, the following questions were included in the survey:

1) How often do you use a laptop computer/tablet computer/smartphone/material in printed form to follow lecture material during class
2) How often do you use a desktop computer/laptop computer/tablet computer/smartphone/material in printed form to study lecture material outside class

Figure 6.5: Use of media during class



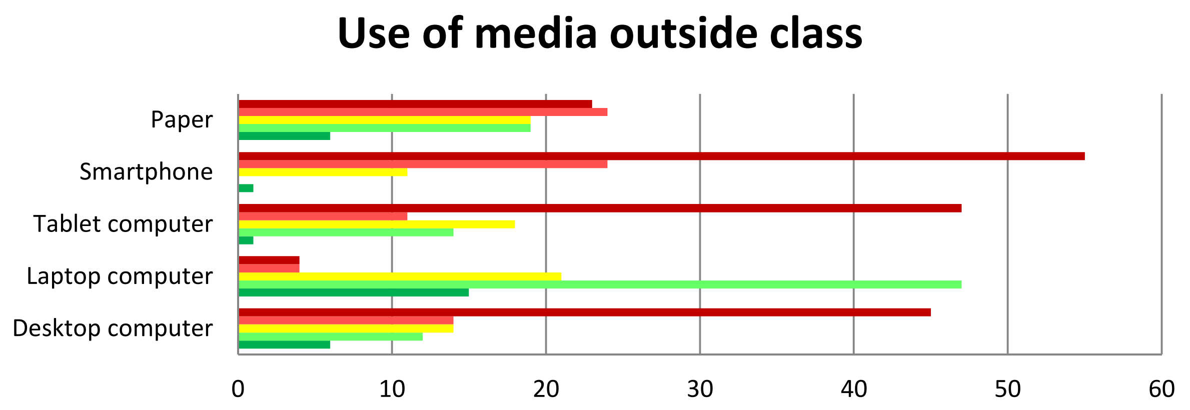
	Laptop computer	Tablet computer	Smartphone	Paper
never	13	51	70	40
seldom	11	10	10	21
sometimes	18	14	4	13
usually	28	6	2	12
always	21	10	5	5

Values 1-5 were assigned to the response categories to calculate the average response value for each medium.

Medium	Average response value
Laptop computer	3.36
Tablet computer	2.05
Smartphone	1.48
Paper	2.13

The analysis of the responses shows that the laptop computer (54%) is the most used medium for reading purposes during class, followed by paper and tablet computer (18%). Smartphone is used very rarely. Only 5.5% use it most frequently. This would also be reflecting the inconvenience associated with reading lecture notes on a smartphone for a longer period. Printed material in form of commercial printed books or self-printed lecture notes are never used in class by 44% of the respondents. 56% of the students never use the tablet computer as a device for reading lecture notes during class. This could be partly attributed to the non-availability of the device among the students and the recentness of its market penetration.

Figure 6.6: Use of media outside class



	Desktop computer	Laptop computer	Tablet computer	Smartphone	Paper
never	45	4	47	55	23
seldom	14	4	11	24	24
sometimes	14	21	18	11	19
usually	12	47	14	0	19
always	6	15	1	1	6

Values 1-5 were assigned to the response categories to calculate the average response value for each medium.

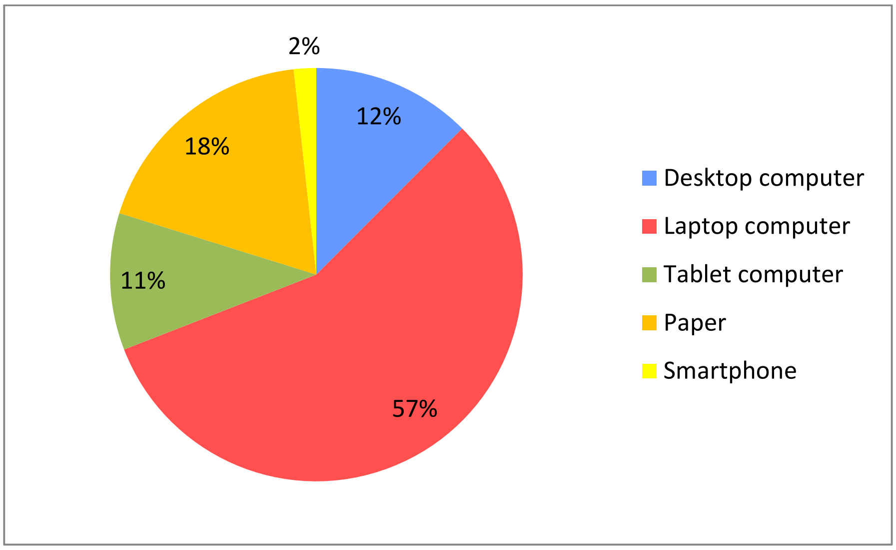
Medium	Average response value
Desktop computer	2.12
Laptop computer	3.71
Tablet computer	2.02
Smartphone	1.55
Paper	2.57

The above tabulation shows that laptop computer is the predominantly used medium outside class (68%), followed by paper (27%) and desktop computer (20%). Smartphone is used sometimes by 12% of the respondents.

Comparing the use of media during and outside class, it can be observed that use of all media has increased except for the tablet computer. Tablet computer is used more in class possibly due to its high convenience from a portability perspective. The highest increase in absolute terms can be observed for the paper-based material. This observation might hint that students decide after attending the class by hindsight which lecture notes are considered relevant enough to print.

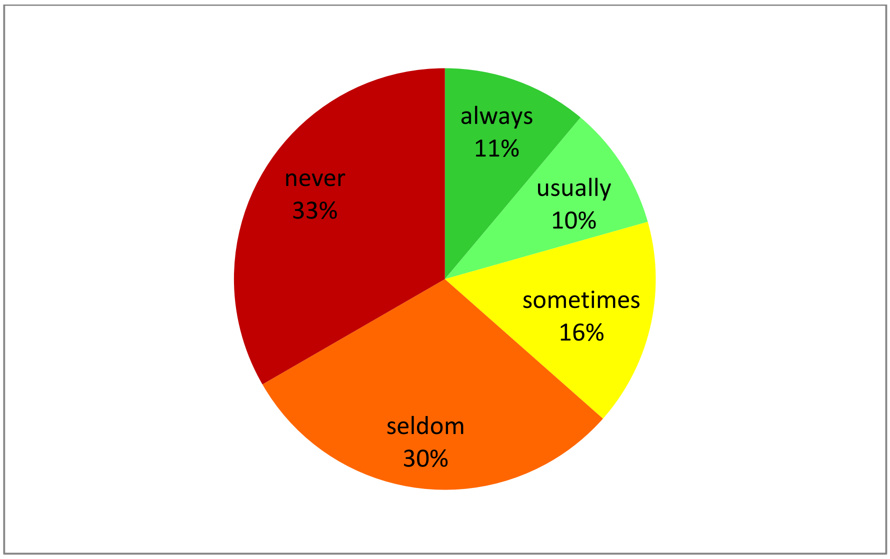
The average time a student spends per week and course for studying lecture notes is 5.8 hours. The following chart shows how the time is spent on the different media.

Figure 6.7: Time spent studying lecture notes on different media



It can be observed that laptop computer is the main electronic device which is used for studying lecture notes. Use of smartphone is irrelevant. 75% of the time spent for lecture notes involves the media laptop computer and print-based material. Another interesting finding is that 80% of the total study time is executed on electronic media.

Figure 6.8: Frequency of printing



More than 60% of the students responded to ‘seldom’ or ‘never’ when asked about their frequency of printing lecture notes. An interesting observation is that approximately every 10^{th} student of the sample prints all lecture notes. On average, 58% of the lecture notes printed by students are printed on both sides. Students who print frequently always use the double-sided printing option. Students who rarely or never print use the double-sided setting for 59% of the total amount of printed material.

Possible explanations of the cautious paper consumption could be either environmentally-conscious behaviour or a purely cost-based decision. 19% of the students never set up their printer for double-sided printing when using it for printing lecture notes. These students have in common that they print lecture notes occasionally or seldom.

As for the number of slides printed per page, the mean and median value is 4. An average of 24 pages per week is printed among the students who print. An average student therefore prints 16 pages per week. Among the students who print frequently, the average number of pages printed per week is 35.

Laser printer is used by 52% of the respondents. 86% of the students who always print lecture notes are owners of a laser printer.

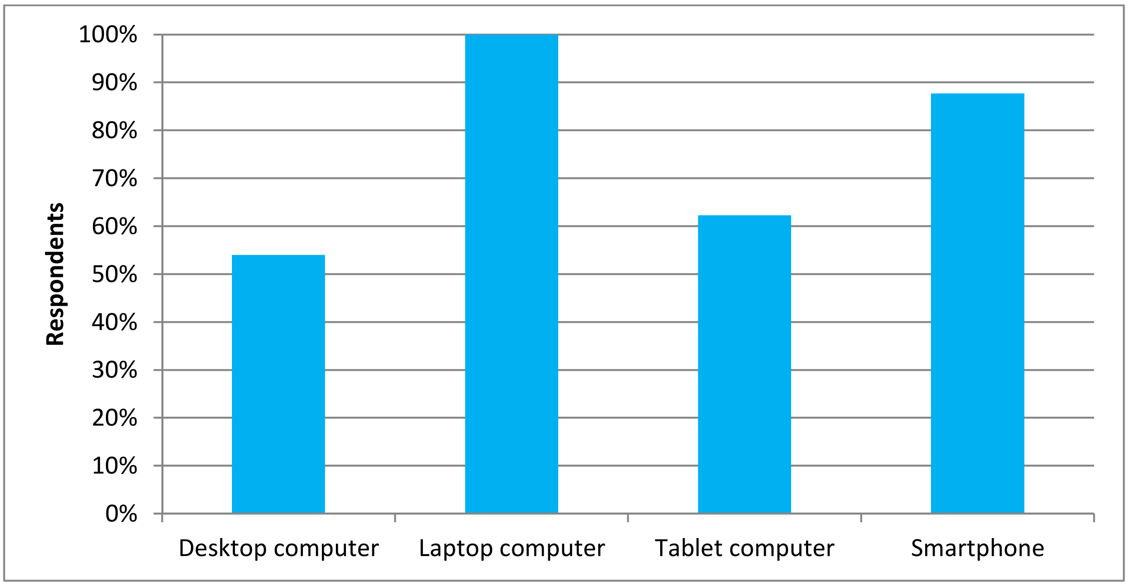
After the use of the self-printed lecture notes, 54% is kept, 42% is disposed and 4% is given to fellow students. As for the printed books of lecture notes, 73% is kept, 15% is disposed and 12% is given to others. Purchased academic material is therefore less often disposed compared to self-printed ones.

6.3.3 General use patterns of electronic media

The chart in Figure 6.9 shows the ownership of the different devices. All the respondents own a laptop computer. Almost 90% of the students have a smartphone. Only every second student possesses a desktop computer. This finding corresponds to the trend that among young adults laptop computers and other mobile devices have overtaken desktop computers. (Lenhart, Purcell, Smith, & Zickuhr, 2010, p. 11)

The ownership rate for the tablet computer is slightly higher than that of the desktop computer.

Figure 6.9: Ownership of electronic devices



The Venn diagram below classifies each student into a set depending on the devices that he owns. Around 60% of the students who own a tablet computer also have a desktop computer, a smartphone and a laptop computer. More than 98% of the respondents own more than one device. The most appeared combination is the one with laptop computer and smartphone (89%).

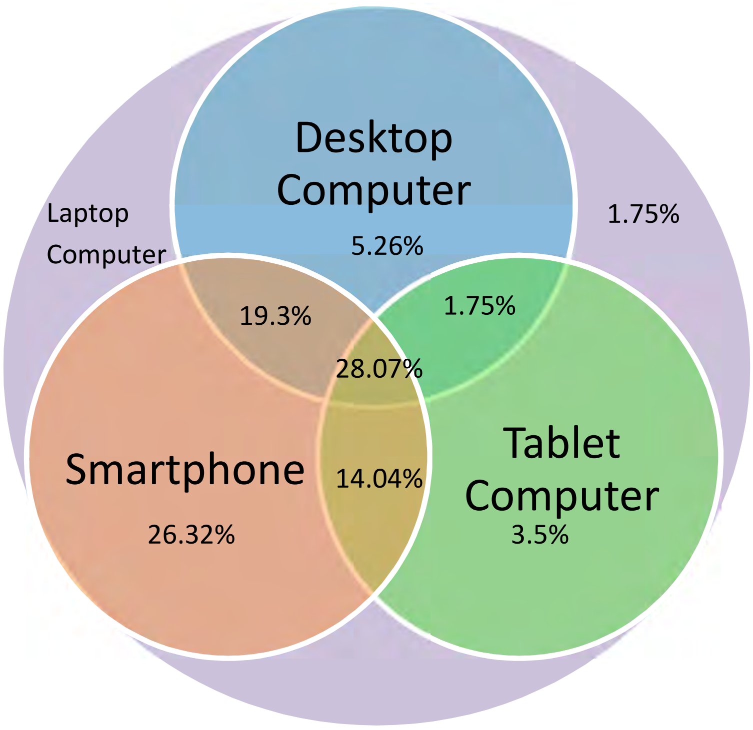
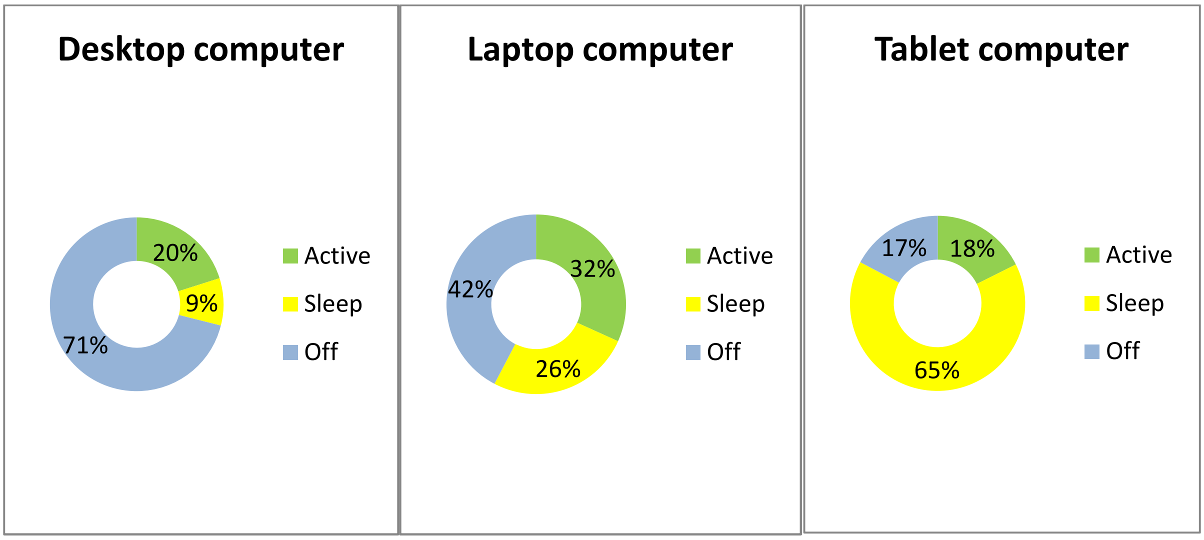


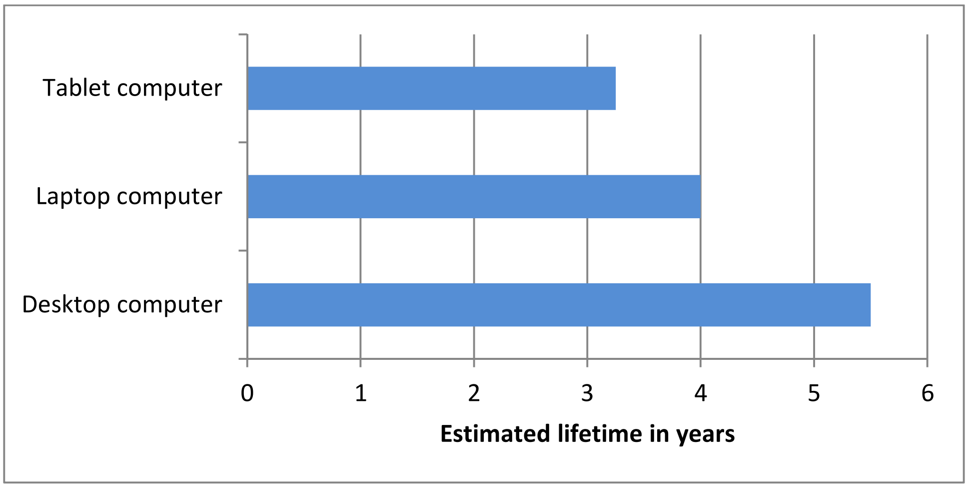
Figure 6.10: Use patterns of desktop, laptop and tablet computer



The above charts in Figure 6.10 show in which modes the respective device is operated during 24 hours of a day. It was already mentioned that only half of the respondents own a desktop computer. The analysis of the use patterns indicate that students who own desktop computers do not use it very frequently on daily basis – around 5 hours per day. The laptop computer is used more frequently; more than 7 hours a day. Assuming an average workload of 8 hours a day, the result shows that the laptop computer is the primary device for the daily computational tasks. The use pattern of the tablet computer might imply that it is not yet able to serve as a substitution of the laptop computer for the daily computer-based activities. When the tablet computer is not in active use, it is more often in sleep mode than in off mode. On the other hand, the laptop computer is more frequently in off mode than in sleep mode when not operated.

The smartphone is rarely in off-mode; an average of 48 minutes per day. It is operated in active mode for 8.6 hours. However, many respondents have taken the non-off-time as active time instead of separating active and standby time. The use pattern for the smartphone is therefore imprecise.

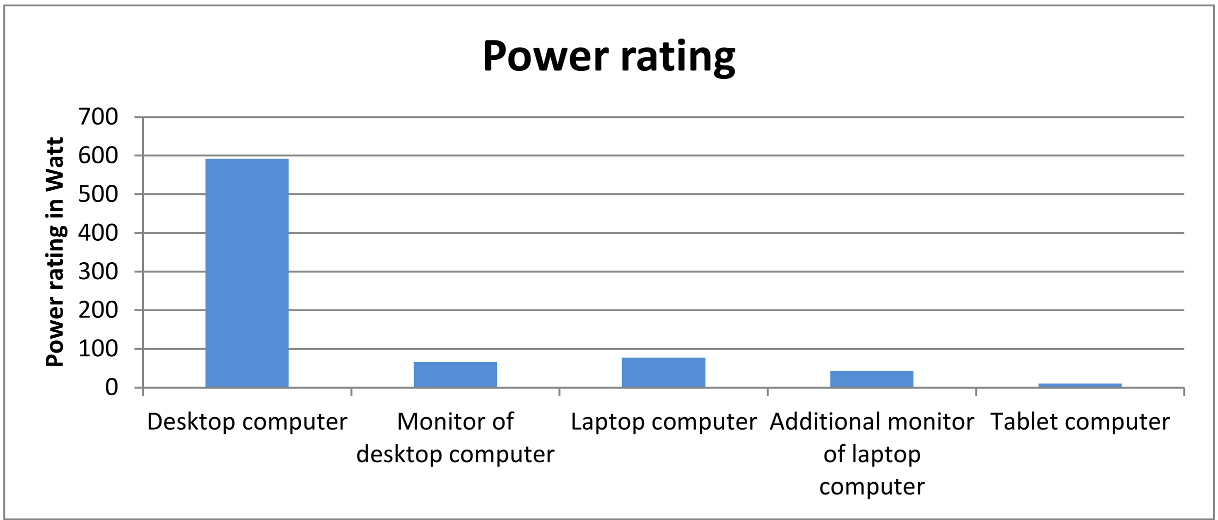
Figure 6.11: User-estimated lifetime of electronic devices



As for the lifetime of the devices, the desktop computer has a higher user estimated lifetime than the mobile devices. This shows that the desktop computer which is used less compared to other two remains for a longer period undisposed possibly due to the lack of need for a replacement. The tablet computer is a relatively new product on the market. Because of the constant technological developments the students seem to be willing to buy up-to-date products and replace the tablet computer more often compared to the laptop and desktop computer resulting into a shorter lifecycle of the tablet computer. The smartphone has a user-estimated lifetime of 2.5 years.

6.3.4 Power rating of electronic media

Figure 6.12: Power rating of electronic devices



The average power ratings of the devices have a range from 10 Watts to 590 Watts. This clearly indicates that the power requirement decreases as new mobile devices are developed. The average battery runtime of a laptop computer is 6 hours with a charge time of 2.5 hours. The tablet computer has an average battery runtime of 12 hours and a charge time of 3.5 hours.

Even though the input power rating was asked for the power supply units of the laptop and tablet computer, most of the respondents entered data for the power on the output side as this is more prominently indicated on the power supply unit. As the input power consumption of the charger is required to estimate the energy consumption when using the laptop and tablet computers, the power efficiency level of different laptop and tablet computer manufacturers was assessed.

Most of the HP, Apple, Dell, Lenovo and Acer power supplies for laptop computers are Energy Star certified indicating a power efficiency level of at least 86%.

As for the tablet computer, the power efficiency level was assessed for three tablet manufacturers: Apple, Samsung and Google. All of them have a power efficiency of at least 86% i.e. the power supplies are Energy Star certified.

As for the energy consumption of the active use of an electronic device, the rating indicated on the engraved plate of a device denotes the maximum power that the device can handle. It is the sum of the maximum power ratings of the individual components such as CPU, motherboard, RAM, video card, hard drive, optical drive, case fan etc. For each component there are several parameters which determine its actual power consumption when in use.

An average computer consumes between 36 W and 250 W in active mode (Bray, 2006, p. 8). This shows that there is a vast variation in the magnitude of the energy consumption.

For this project it was of interest to determine the energy consumption while reading the lecture notes on the electronic device. However, as explained above, this does not correspond to the maximum value on the rating plate. The CPU may also not be operating at full capacity.

An online energy consumption calculator (eXtreme Power Supply Calculator Lite, 2013) for the desktop computer was used to approximate the value range covering different configurations. The average power consumption corresponded approximately to ½ of the average power rating collected from the survey. For the desktop computer (without monitor), the energy consumption during active use was therefore estimated as ½ of the average power rating (296 Watt).

Similarly, the energy consumption of the monitor varies from model to model. The average CRT monitor has a power consumption ranging between 66 W and 135 W in active mode (Bray, 2006, p. 10). It was assumed the students own a LCD monitor. Studies focusing on the LCD monitor evaluated an energy consumption varying between 15 W and 35 W (Bray, 2006, p. 11). The energy consumption also depends on the brightness setting. A particular Dell monitor model can consume up to 163 W in active mode at the highest brightness (Ertl, n.d.). The average power rating of the monitor elicited from the survey is 66 W which seems reasonable based on the literature. Similar to the desktop computer (without monitor), ½ of the power rating of the monitor was taken into consideration for the energy consumption during the active use.

To estimate the energy consumption per hour of active use on a desktop computer, the following formula was applied:

$$\frac{1}{2}\ x\ (power\ rating\ of\ desktop\ computer + monitor)$$

For the laptop and tablet computer, the energy consumption for one hour of active use was estimated using a similar approach:

$$\frac{1}{2}\ x\ \frac{power\ rating\ of\ power\ supply\ unit}{power\ efficiency}\ x\ \frac{charging\ time}{battery\ life}$$

The energy consumption in the sleep and off mode for the desktop and laptop computer were taken from Ecoinvent 3.01. They correspond to the values found in the literature (Bray, 2006, pp. 8-9, 18). It is assumed that the desktop computer is always plugged into a mains socket. This is the reason why the desktop computer consumes energy even during the off mode. The calculated energy consumption rates for the desktop, laptop and tablet computer are shown in Table 6.1, 6.2. and 6.3.

Table 6.1: Energy consumption of desktop computer

Mode	Energy consumption for one hour of use
Active	0.33 kWh
Sleep	0.03 kWh (Ecoinvent 3.01)
Off	0.0035 kWh (Ecoinvent 3.01)

Table 6.2: Energy consumption of laptop computer

Mode	Energy consumption for one hour of use
Active	0.02 kWh
Sleep	0.004 kWh (Ecoinvent 3.01)
Off	0.0015 kWh (Ecoinvent 3.01)

For the tablet computer, the energy consumption during the sleep mode is based on the iPad 2 specifications (Apple, 2012, p. 1). For both active and sleep mode, the energy consumption was adjusted with the power efficiency factor of 0.8 (Apple, 2012, p. 1).

Table 6.3: Energy consumption of tablet computer

Mode	Energy consumption for one hour of use
Active	0.00185 kWh
Sleep	0.0005625 kWh
Off	0 kWh

The average screen size of the monitor of the desktop computer, laptop computer and tablet computer are shown in Table 6.4.

Table 6.4: Screen size of electronic devices

Device	Screen size in inches
Monitor of desktop computer	23''
Laptop computer (either the screen of the laptop computer or the connected separate monitor)	16''
Tablet computer	9.7"

6.3.5 Data access patterns

A student accesses the lecture notes using different networks. The following table shows the shares of different networks accessed based on the total data volume of lecture notes which a student accesses during one semester.

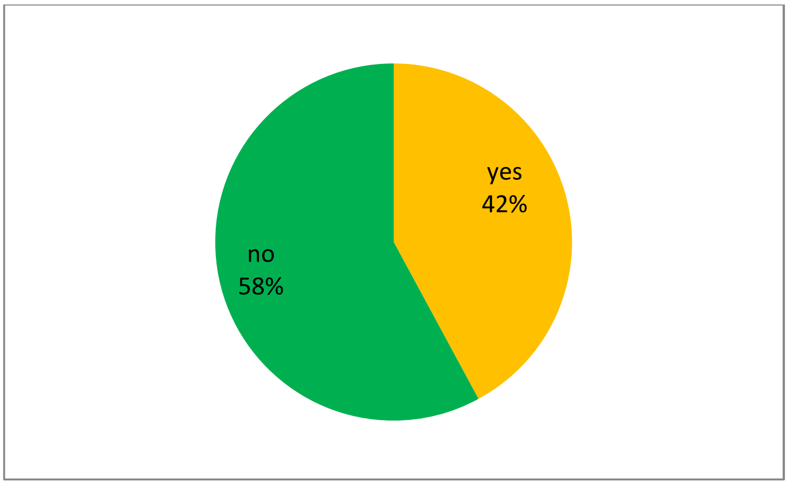
Table 6.5: Network usage by students

Network	Share of total data accessed
LAN	15%
WLAN, private	42%
WLAN, public	35%
Mobile network	4%

4% of the total data is transferred over physical data storage devices such as USB stick and CD.

6.3.6 Use of podcasts

Figure 6.13: Use of podcasts



As Figure 6.13 shows 42% of the students follow at least one course online through podcasts in place of physical attendance. These students watch podcasts 5.25 hours a week on average. Assuming a class has a duration of 2 hours, the result shows that around 2-3 courses are watched online. As podcasts are not available for all the courses yet, this is a good indication that subject to availability of podcasts the likelihood of students using podcasts is high.

7 Calculation of baseline scenario

The environmental impact was assessed with Eco-indicator 99 HA w/o LT (Eco-indicator 99 from a hierarchist perspective without considering long-term emissions).

Eco-indicator 99 focuses on 3 areas of damage: human health, ecosystem quality and resources. The damage to human health is measured by the number and duration of diseases and the number of years lost due to premature death from environmental causes. This area considers the impact categories climate change, ozone layer depletion, carcinogenic effects, respiratory effects and ionizing radiation. The damage to ecosystem quality assesses the effect on species diversity. The impact categories used for this area are ecotoxicity, acidification, eutrophication and land-use. The category resources is expressed as the surplus energy needed for future extractions of minerals and fossil fuels (Ministry of Housing, Spatial Planning and the Environment, 2000, p. 7).

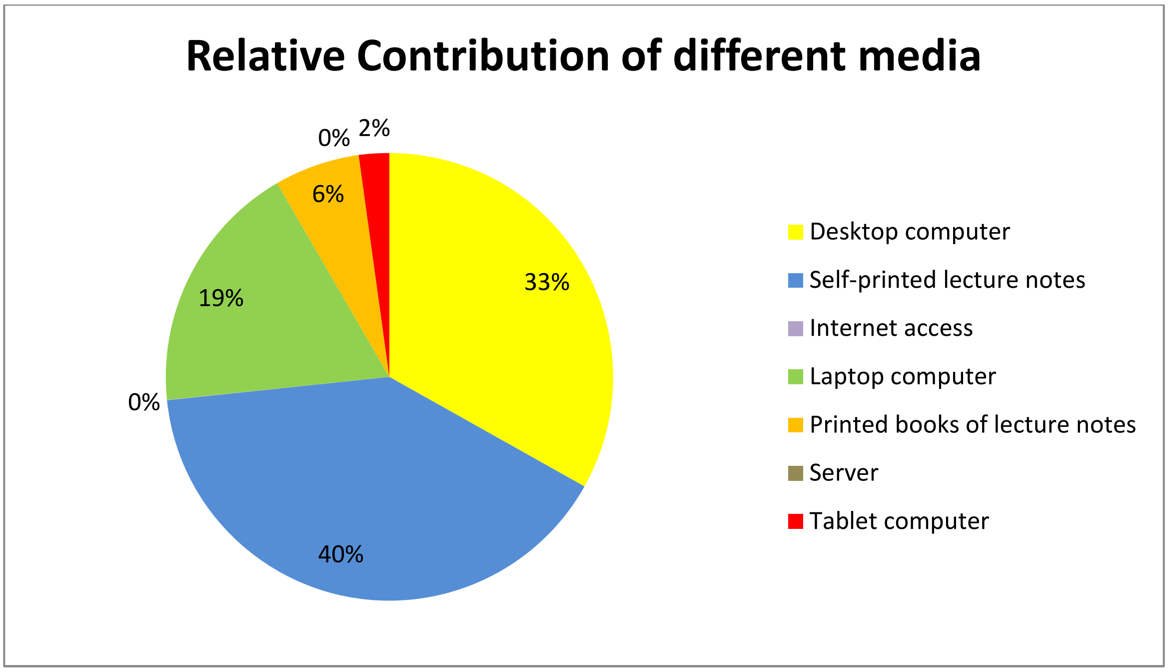
Eco-indicator 99 measures the environmental impact in terms of Eco-indicator points (Ministry of Housing, Spatial Planning and the Environment, 2000, p. 9).

The baseline system considers the use of desktop computer, laptop computer, tablet computer, self-printed lecture notes, printed books of lecture notes, internet access and operation of server. The functional unit is defined as one average student studying lecture notes using different media for one semester. The environmental impact of the baseline system is shown in Table 7.1.

Table 7.1: Environmental impact of baseline system in Eco-indicator 99 HA w/o LT

Area of Damage	Impact category	Eco-indicator points
Ecosystem quality	Land occupation	0.29 points
	Ecotoxicity	0.15 points
	Acidification and eutrophication	0.05 points
Human health	Respiratory effects	0.68 points
	Climate change	0.15 points
	Carcinogenics	0.13 points
	Ionizing radiation	0.003 points
	Ozone layer depletion	0.0001 points
Resources	Fossil fuels	0.63 points
	Mineral extraction	0.12 points
Total		**2.21 points**

Figure 7.1: Relative contributions of the different media



As shown in Figure 7.1 the environmental impact of the current scenario is mainly caused by the use of self-printed lecture notes, desktop computer and laptop computer. The use of printed books of lecture notes causes a relatively minor impact of 6%. The use of tablet computer, internet access and operation of server are insignificant contributors to the overall environmental performance of 2.21 Eco-indicator points.

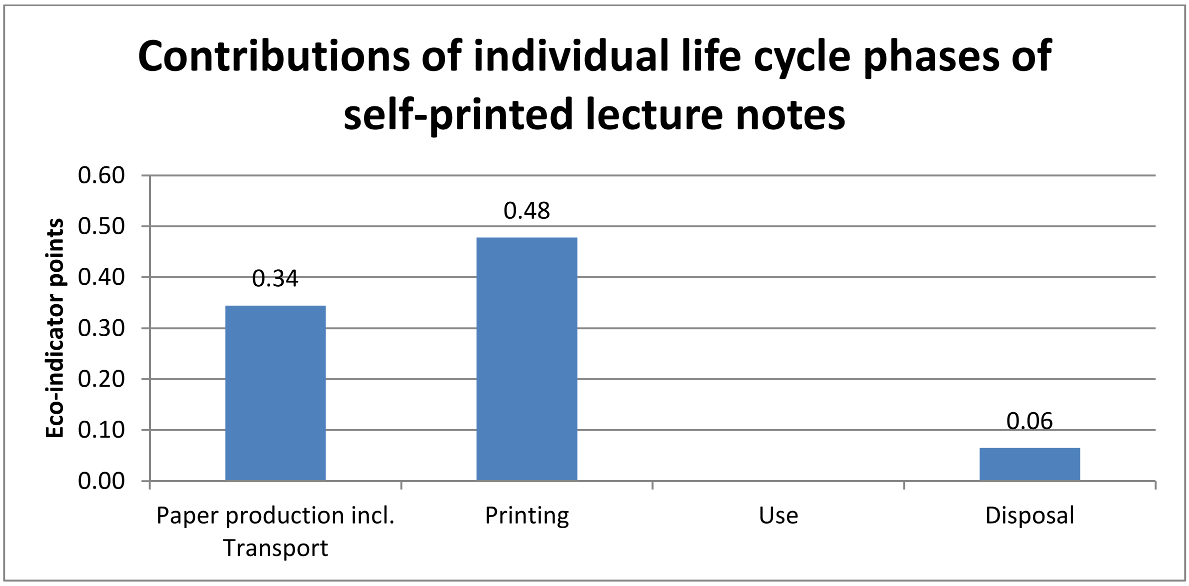
The impact category land occupation is the highest contributor (0.29 Eco-indicator points) to the ecosystem quality category. Respiratory effects are the highest contributors (0.68 Eco-indicator points) to the human health category. Fossil fuels (0.63 Eco-indicator points) contribute the most to the resources category. These three impact categories cover 70% of the total impact.

72% of the land use impact is caused by the self-printed lecture notes. Respiratory effects in the baseline scenario are mainly caused by the use of desktop computer and self-printed lecture notes, approximately 35% each. Similarly, the use of desktop computer and self-printed lecture notes are the main contributors to the use of the fossil fuels. This shows that the self-printed lecture notes in the baseline scenario strongly affect all three environmental areas.

7.1 Self-printed lecture notes

Self-printed lecture notes are the media with the highest contribution (40%) to the total environmental performance of the baseline scenario with 0.89 Eco-indicator points. Self-printed lecture notes refer to the lecture notes that an average student prints over one semester.

Figure 7.2: Contribution of self-printed lecture notes



As Figure 7.2 illustrates paper production (incl. transport) and printing are the most relevant processes. The element creating the substantial contribution within the printing activity is the use of the printer. Compared to a printer in print offices, a home printer has an overall low utilization rate. This results in a relatively high allocation of the impact caused by the printer production and disposal to the defined functional unit. High paper consumption is also responsible for the impact. An important parameter influencing the paper consumption is the percentage of double-sided printing. As observed from the survey, this feature is not always used by the students. During the use phase, no environmental impact is considered. 0.06 Eco-indicator points is attributed to the waste treatment of the disposed self-printed lecture notes.

7.2 Desktop computer and peripherals

The total impact of the desktop computer's use in relation to the defined functional unit is 0.73 Eco-indicator points. The impact assessment also considers the use of the peripherals LCD monitor, keyboard and optical mouse. The contributions of the different life cycle phases are shown in Figure 7.3. Transportation refers to the transportation of the desktop computer and its peripherals to the end-costumer. The phase combining production and disposal is the highest contributor to the total impact, followed by the use phase. The production and disposal bar also includes the packaging and the disposal of the packaging material. The impact resulting from the transportation of the devices to the end-costumer is unimportant. The high allocation of the production and disposal is due to the fact that the desktop computer in general is not used frequently – an average of 4.84 hours of active use in a day as the survey results indicate. Further, the total environmental impact associated with its entire life cycle is large.

Figure 7.3: Contribution of desktop computer

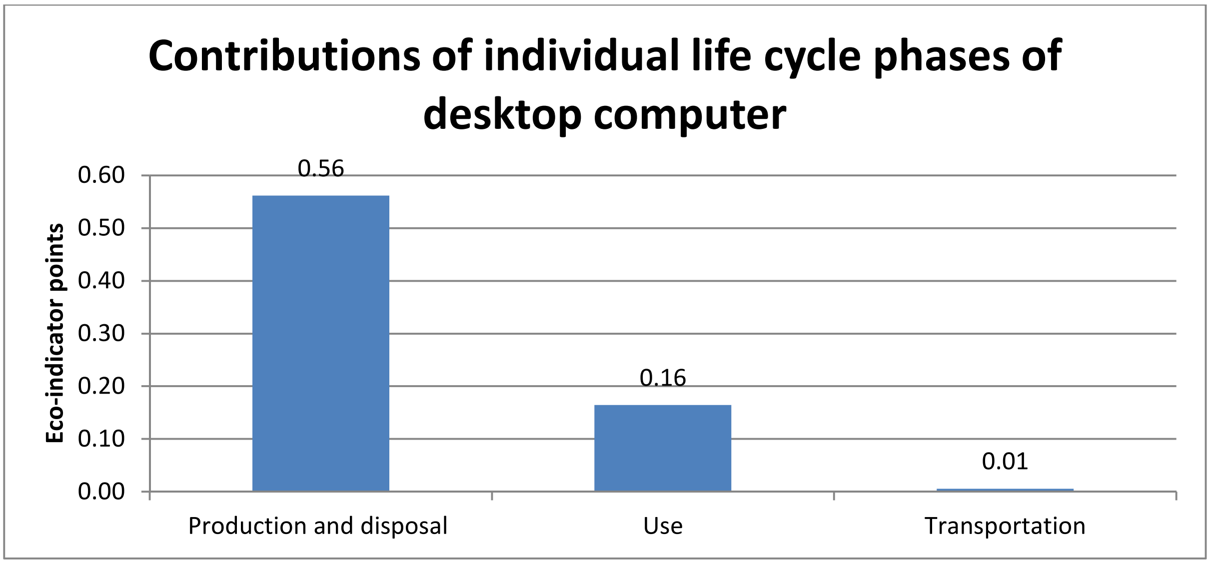
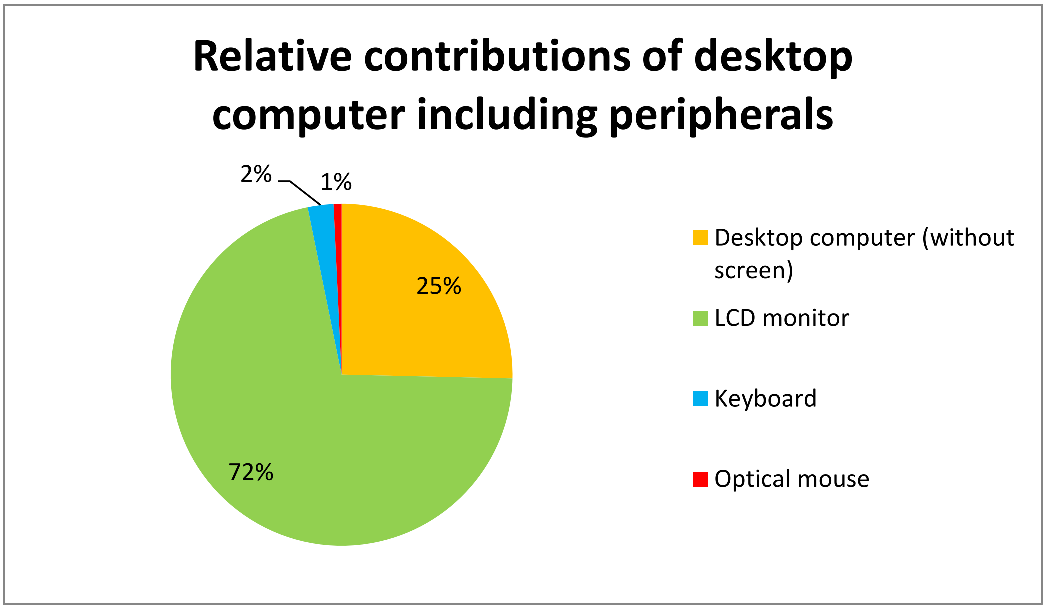


Figure 7.4: Relative contributions of desktop computer including peripherals

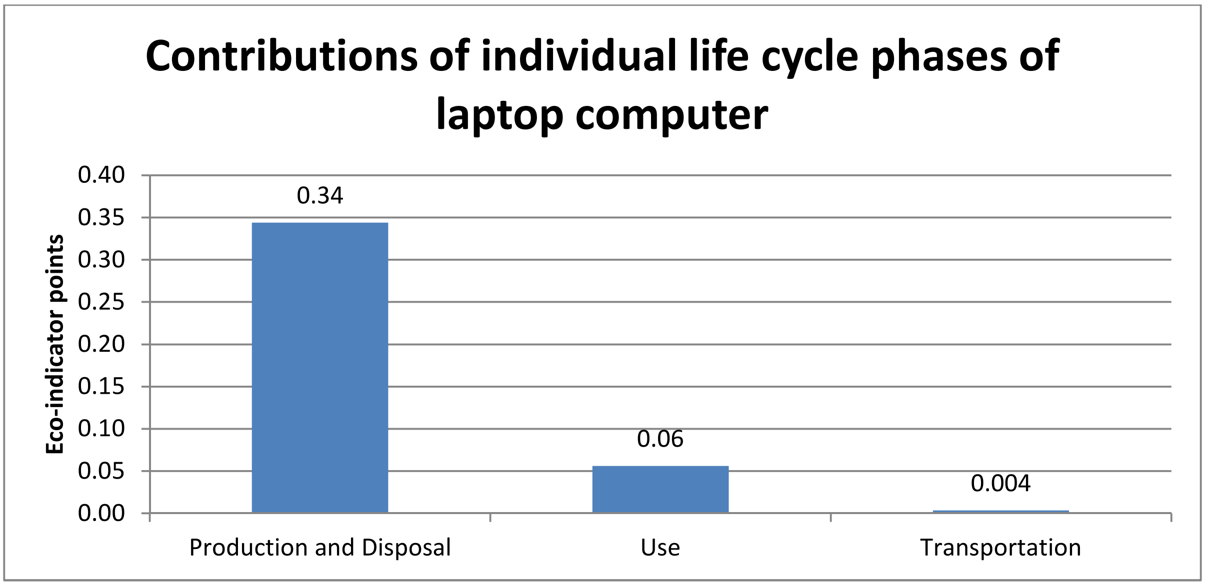


Of all desktop computer peripherals, the LCD monitor causes the highest environmental impact within the production and disposal phase as shown in Figure 7.4. It causes an impact roughly three times of the one resulting from the desktop computer (without screen).

7.3 Laptop computer

The total environmental impact of the laptop computer's life cycle in relation to the functional unit contributes to 0.40 Eco-indicator points.

Figure 7.5: Contribution of laptop computer

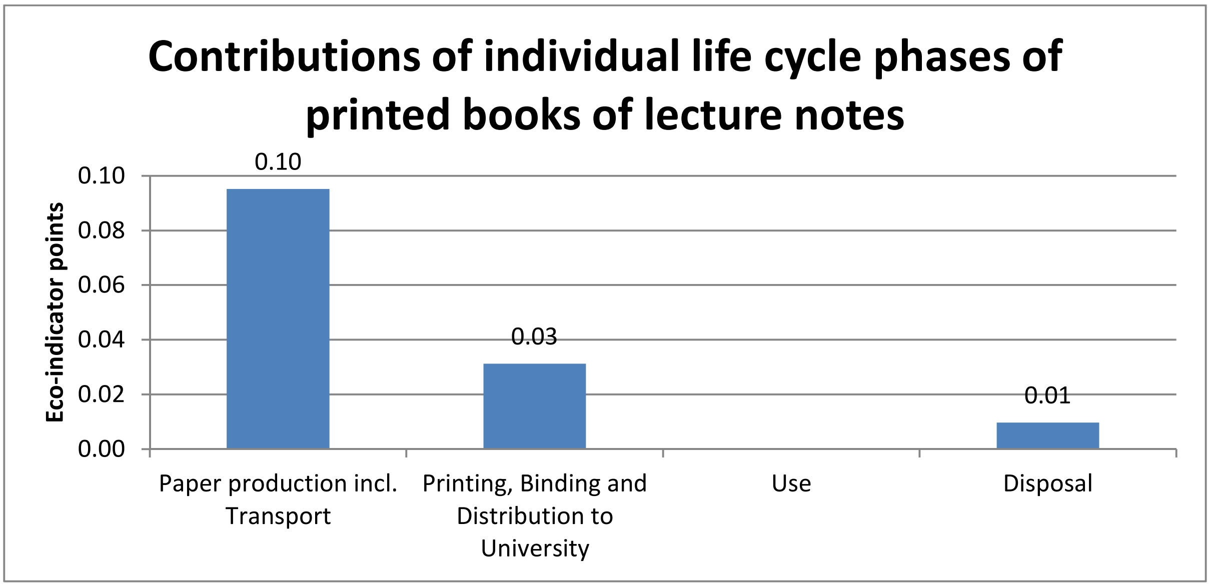


Similar to the results of the desktop computer, the allocated production and disposal of the laptop computer contributes the most to the total environmental performance of the laptop computer, followed by the use phase. The transportation of the laptop computer to the end-customer causes an irrelevant impact of 0.004 Eco-indicator points. The production and disposal bar also includes the packaging and disposal of the packaging material.

The effect of the laptop computer use to the overall environmental performance is important as the laptop computer is owned by every student and it is the medium on which the highest amount of time is spent for the activity involving the study of lecture notes. However, the environmental impact resulting from the laptop computer use is still less than the contribution from the use of the desktop computer. This is because the laptop computer in general is used extensively – an average of 7.62 hours a day. A high usage rate of the device results in a lower allocation of the production and disposal impact to one hour of use. Another reason is the production of a laptop computer requires lesser amount of resources and energy compared to the production of a desktop computer.

7.4 Printed books of lecture notes

Figure 7.6: Contribution of printed books of lecture notes

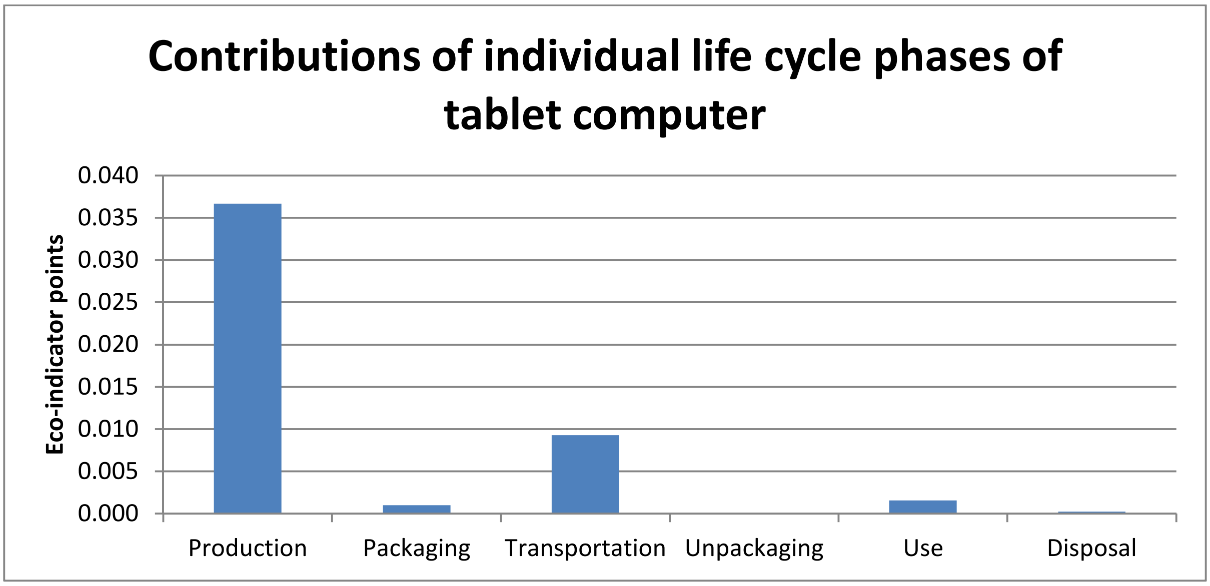


The printed book of lecture notes refers to the purchasable textbook containing the lecture notes. It contributes to 6% of the total environmental performance (0.14 Eco-indicator points). Paper production has the highest impact within the printed books contribution, followed by the production of the script (printing, binding, distribution). The printing activity causes noticeably lower environmental burdens than the paper production, in comparison to the case of self-printed lecture notes, as the utilization rate of the printer in print offices is much higher and therefore the allocated impact of the print office printer is lower than that of the home printer. As in the case of self-printed lecture notes, no environmental impact was caused during the use phase of the printed books.

7.5 Tablet computer

As each activity of the tablet computer's life cycle was modeled separately, the individual contributions are shown in Figure 7.7.

Figure 7.7: Contribution of tablet computer (all phases)



The life cycle of the tablet computer allocated to the functional unit contributes to 0.05 Eco-indicator points. The result is relatively low compared to the other electronic devices out of two reasons: 1) the tablet computer is the least used device for studying lecture notes. 2) The materials and energy used for the device production are considerably less in amount compared to the quantities required for a laptop or desktop computer. The production and transportation are the most significant phases within the life cycle of the tablet computer. The use phase has a low contribution to the overall lifecycle of the tablet computer due to the low energy consumption.

Figure 7.8: Contribution of tablet computer

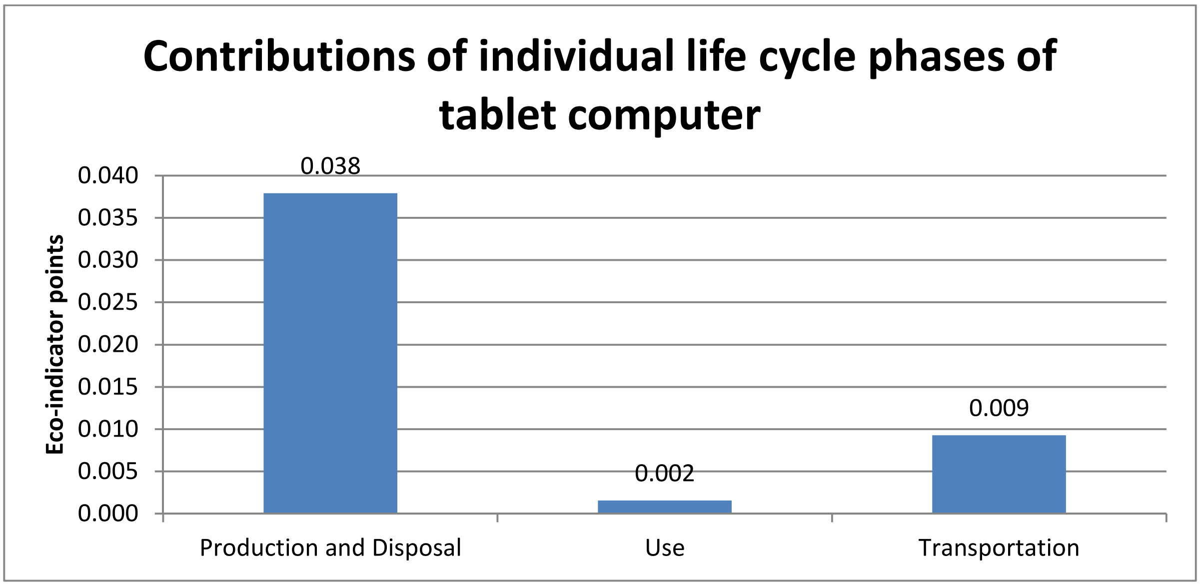


Figure 7.8 summarizes the phases shown in Figure 7.7 to three phases.

7.6 Internet access

The internet access causes an environmental impact of 2.86E-04 Eco-indicator points. This amounts to less than 1% of the total environmental impact of the baseline system.

7.7 Server

Providing the content on the server causes an insignificant environmental impact of 6.72E-06 Eco-indicator points. The impact is only measured in terms of the energy consumption of the server operation and neglects the allocated impact share of other life cycle phases of the server.

8 Sensitivity analysis

As the modeling of the baseline and alternative scenarios includes data which are based on estimations and assumptions the sensitivity of some uncertain parameter values was tested. Table 8.1 shows the parameters, the chosen sensitivity factors and the implication on the baseline result.

Table 8.1: Sensitivity analysis

Parameter	Sensitivity factor	Impact with sensitivity factor in Eco-indicator points	Change of baseline impact
Reading time	0.5 2	1.62 3.39	**-27%** **+53%**
Lifetime of desktop computer	2	1.92	-13%
Total daily usage of desktop computer	1.2	2.11	-5%
Lifetime of laptop computer	0.75	2.32	+5%
Total daily usage of laptop computer	1.2	2.15	-3%
Energy consumption for one hour use in active mode of desktop computer	0.5	2.13	-4%
Energy consumption for one hour use in active mode of laptop computer	0.5	2.18	-1%
Amount of self-printed papers of lecture notes	0.5	1.76	**-20%**
Amount of printed books	0.5	2.14	-3%
Print coverage in printed books	2	2.23	+1%

On the whole, the total reading time and the amount of self-printed lecture notes are highly sensitive to the total baseline result. The baseline assumes a total reading time of 5.8 hours per week and course. It is to be noted that the doubling and halving of the reading time only affects the impact resulting from the use of the electronic devices; the impact caused by the use of printed material, server and internet access remain unchanged.

As the energy consumption of the desktop and laptop computers while studying lecture notes may be overestimated, the respective parameters were varied in the sensitivity analysis. The change in impact of the baseline result however indicates that these effects are not relevant.

It was also of interest to see how an increase in the lifetime and total daily usage of the desktop computer affects the baseline scenario as the use of this particular device is a large contributor to the baseline impact.

The average lifetime of a laptop computer considered in the study is four years. This may be not reflecting the current use behaviour as a rapidly declining trend of the lifetime of mobile devices can be observed. However, a decrease of the lifetime by 25% does not have a relevant effect on the baseline compared to the impact of the increased/decreased reading time and amount of self-printed lecture notes.

Print coverage defines the quantity of ink used for a printed page. As this parameter is difficult to estimate for printed books of lecture notes, 5% of print coverage was considered in the baseline scenario. As shown in Table 8.1 the doubling of the print coverage to 10% affects the baseline impact in a negligible extent.

9 Alternative scenario analysis

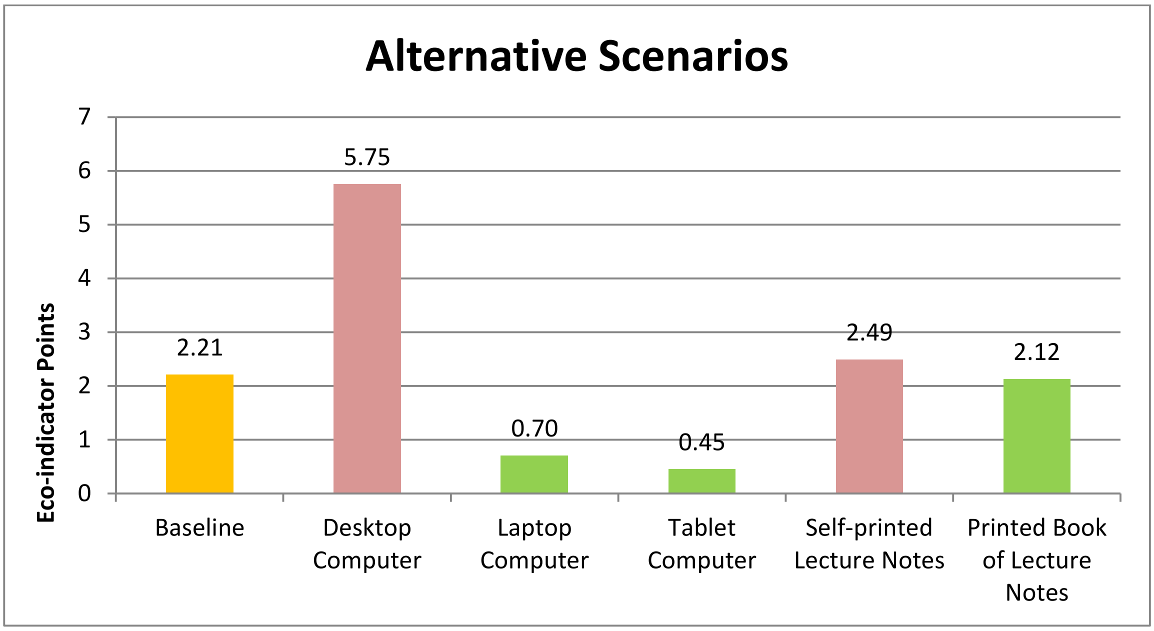
The goal of this chapter is to identify the impact of changes from the baseline system leading to either an increase or a decrease in the environmental performance. These changes are modeled as scenarios. Based on these scenarios, it is helpful to identify potential strategies for an environmental improvement. The first five scenarios focus in each case on exactly one medium i.e. the lecture notes are studied either on desktop computer, laptop computer, tablet computer or printed material. In the case of printed material, two scenarios were differentiated: a) the scenario where the student prints the lecture notes b) the scenario where the university provides the lecture notes in form of printed books. Further scenarios assess combinations of multiple media.

The total time spent studying lecture notes across different media by a student during one semester is 460 hours on average. For each of the following five scenarios, it was assumed 460 hours is spent entirely on the respective medium. The same system boundaries as defined in the baseline scenario (Chapter 5) were selected for the alternative scenarios.

For all three electronic-based scenarios (desktop computer only, laptop computer only, tablet computer only) the use of the respective device, internet access to download the lecture notes and operation of server has been taken into account. In case of the self-printed scenario, the use of a laptop computer to download the lecture notes, internet access, operation of the server and the subsequent printing operation were considered. In case of the printed book scenario, the life-cycle of the printed books from the baseline was taken into account.

9.1 Single media

Figure 9.1: Alternative single-media scenarios



9.1.1 Desktop computer scenario

As defined the desktop computer scenario models the case where the lecture notes are studied by the student using only the desktop computer. In this case, the environmental impact of 5.75 Eco-indicator points is 2.5 times higher than the baseline.

As the relative contributions of individual impact categories and processes are the same as in the baseline system, these won't be discussed further.

The result can be explained by two reasons: The environmental impact associated with the total life cycle of the desktop computer is in general very high due to high energy and resource consumption during the production. Due to the relatively low usage rate of the device, 6% of the life cycle is allocated to the functional unit i.e. studying lecture notes for one semester solely on a desktop computer.

Following example gives us an idea of the magnitude of Eco-indicator points: driving a private car for 500 km of distance causes an environmental impact of 5 Eco-indicator points (de Vos-Effting & van Gijlswijk, p. 12).

Therefore the usage of desktop computer as the only medium for studying lecture notes by a student causes an environmental burden of a magnitude equivalent to the one resulting from e.g. traveling Zurich to Cologne by car.

9.1.2 Laptop computer scenario

When a student studies the lecture notes entirely on the laptop computer, the environmental impact is 0.70 Eco-indicator points. This scenario serves as an improvement of the baseline by 68%. As the laptop computer is the medium on which the highest amount of time is spent studying lecture notes in the baseline scenario, the relative increase in the impact of the laptop computer use between the baseline scenario (0.4 Eco-indicator points) and this scenario is low compared to other scenarios.

The impact of the laptop computer scenario is more than eight times lower than the impact resulting from the desktop computer scenario. In terms of use patterns, the laptop computer is used almost twice as often as the desktop computer.

The differences in the usage patterns and LCIA results of the first two alternative scenarios suggest that it is preferable to execute the reading activity on an electronic medium which has a high usage rate. This will ensure that the relative impact of all life cycle phases (specifically of the production) allocated to the functional unit is reduced. This has also been confirmed by other studies (Chapter 3).

9.1.3 Tablet computer scenario

The tablet computer scenario contributes to 0.45 Eco-indicator points. There is a clear preference of the tablet computer among the alternative scenarios with electronic devices (desktop, laptop and tablet computer) from an environmental perspective. Even though tablet computers are less actively used compared to laptop computers, the overall consumption of resources and energy respectively the total volume of emissions during the life cycle of the tablet computer is substantially low compared to the other electronic devices.

Thus, it can be concluded that a low usage rate can be offset by the overall low production efforts for an electronic device.

The tablet computer scenario also has the lowest environmental contribution among all the studied scenarios. It reduces the environmental impact of the baseline scenario by 80%. Currently not every student owns a tablet computer yet. However, it can be expected that the ownership rate increases in the future and considering the popularity of mobile devices, it is anticipated that the impact resulting from studying lecture notes decreases.

9.1.4 Printed book of lecture notes scenario

This scenario assesses the environmental impact in case the university provides the lecture notes to the students in form of printed books. Currently, only few courses offer lecture notes in book format in student shops. However, the University might think of taking over the responsibility of the printing for all courses and reduce the environmental burdens. This scenario contributes to 2.12 Eco-indicator points. Shifting from multi-media to a paper-based strategy would improve the current situation by 4%.

This shows that printed paper does not necessarily increase the environmental impact.

Compared to the scenarios with electronic devices, only the desktop computer scenario contributes to a higher environmental impact than the printed book scenario. However, it must be taken into consideration that once the lecture notes are available in electronic format, the students will be typically accessing them through different (print and electronic) media. It is unlikely that a student will be strictly accessing them on one medium. This use behaviour has been confirmed with the conducted survey and as the LCIA result of the baseline indicates there is still scope of improvement.

9.1.5 Self-printed lecture notes scenario

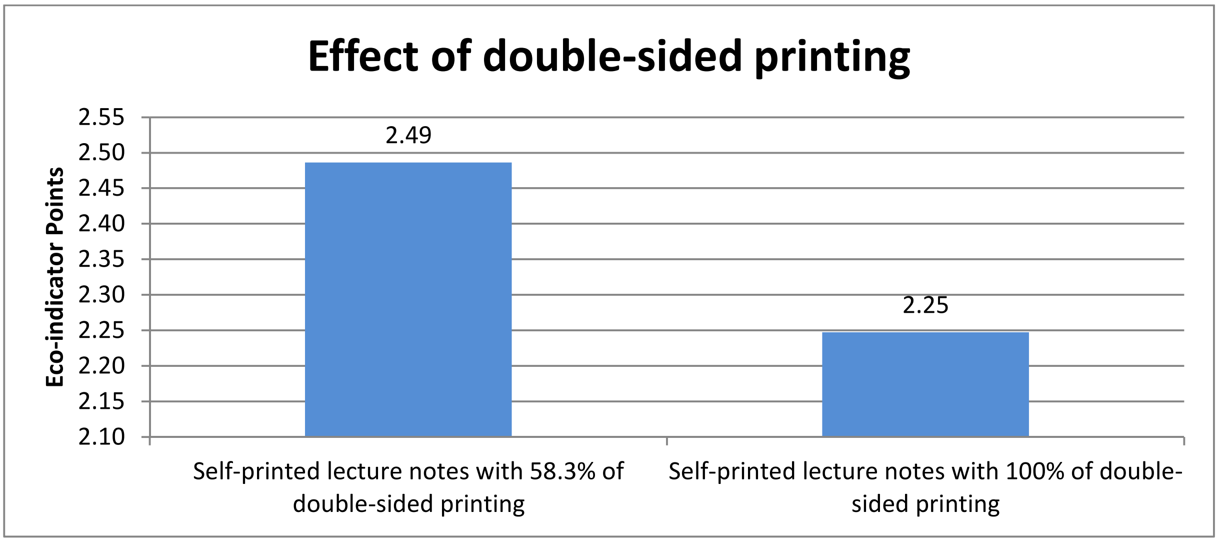
If the student prints all lecture notes with a laser printer at home, it causes an environmental impact of 2.49 Eco-indicator points. It is therefore not advisable for a student to print all lecture notes as the baseline system contributes to a lower impact by 13%.

In case of print-based scenarios the alternative where the University places an order with the print office is preferred over the self-printed lecture notes scenario, as the environmental burden in the first case is 15% lower than in the second.

The main contribution to the impact of print-based scenarios derives from the paper consumption. The self-printed scenario considers double-sided printing for 58.3% of the material as taken from the survey analysis. In the printed book scenario 100% of double-sided printing is taken into account. Further, there is a higher utilization of the laser printer in a print office than at home. This also contributes to a different allocation of the impact resulting from the printer life cycle to the two print-based scenarios.

If the student always prints on both sides of a page i.e. 100% of double-sided printing, the paper consumption can be reduced and the environmental impact is 2.25 Eco-indicator points i.e. a reduction of 10% can be achieved by optimizing the printing activity (see Figure 9.2).

Figure 9.2: Effect of double-sided printing



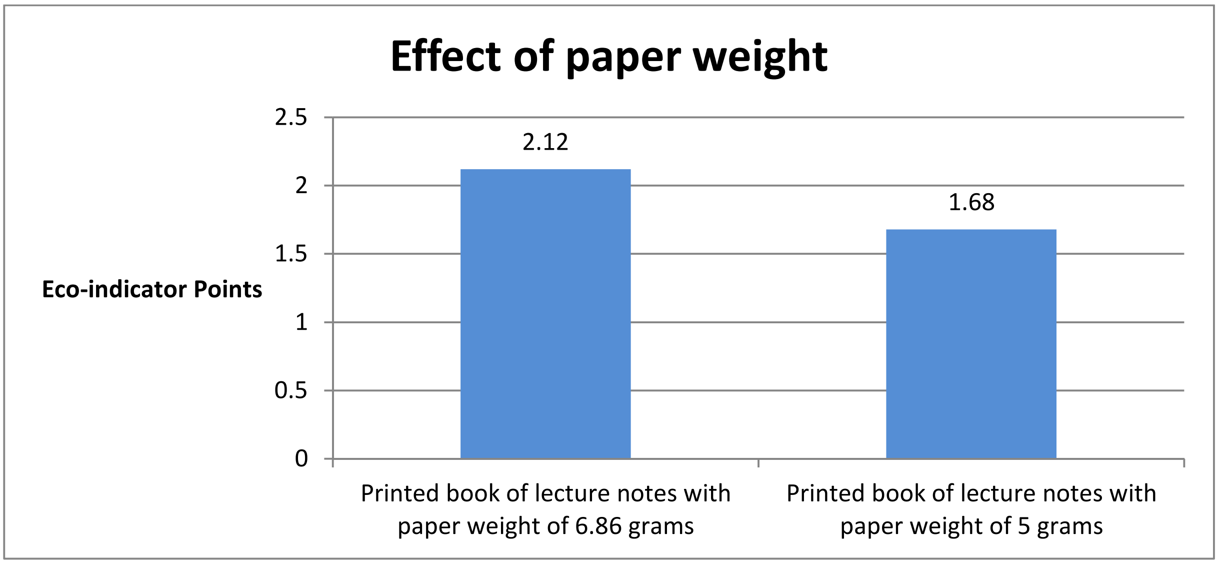
9.1.6 Printed book of lecture notes scenario 2

As the above results show when the printing activity is taken over by the University instead of the student (considering 100% of double-sided printing in both cases), there is an improved efficiency of around 6%. The improvement can be further increased by changing the weight of paper. It was assumed the student uses standard office paper which has a weight of 5 grams/paper. In case of the printed book, a thicker paper type was considered i.e. 6.86 grams/paper.

A second printed book scenario was constructed considering a paper weight of 5 grams/paper which allows a better comparison between the student and University print-based scenarios.

When the print office uses 80 g/m^2 paper the environmental impact is 1.68 Eco-indicator points (see Figure 9.3). This indicates that selecting paper with a lighter weight has a considerable effect on the magnitude of impact. Switching from 6.86 grams to 5 grams per paper reduces the environmental impact by 21% in the printed book scenario. Compared to the baseline scenario the environmental performance can be improved by 24% with this scenario.

Figure 9.3: Effect of paper weight



From the four studied paper-based alternatives, the scenario where the University provides printed books of lecture notes using the standard 80 g/m^2 paper causes the least environmental impact.

9.2 Multiple media

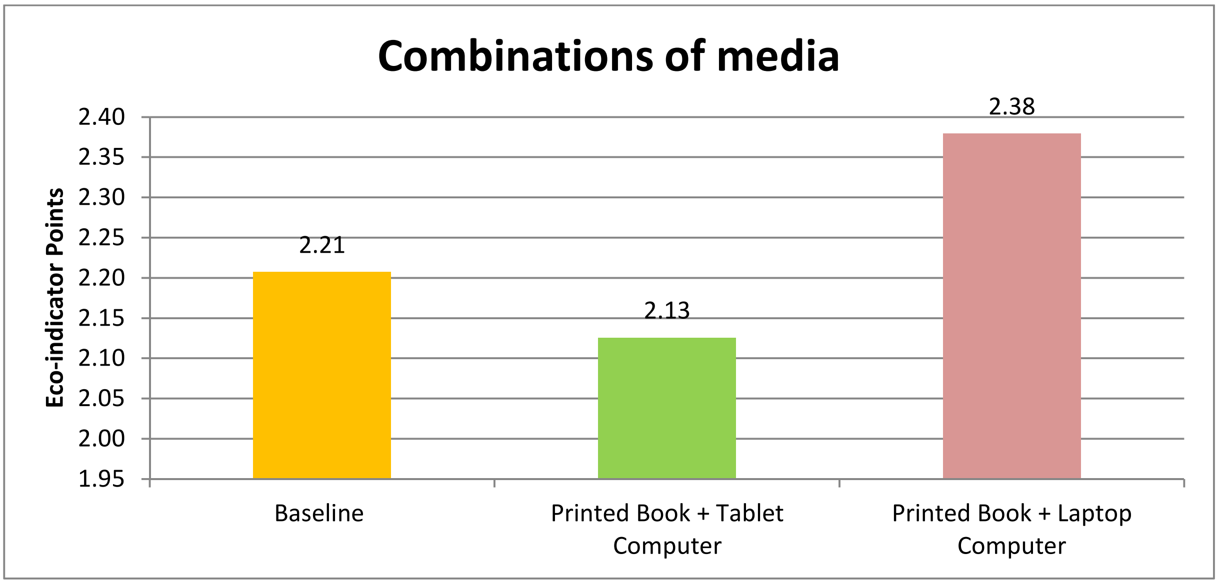
This section analyzes combinations of different media.

In the first part, four combinations are assessed which can be classified as worst-case scenarios. They represent the situation when lecture notes are owned in print version (either in form of printed books or self-printed) yet all lecture notes are accessed and studied electronically.

Figure 9.4 shows the printed books combined with laptop respectively tablet computers. It models the scenarios where the student studies the lecture notes entirely on either device and additionally owns printed books of lecture notes for each course but does not use them.

In Figure 9.4 the printed book refers to the printed book of lecture notes with 80 g/m^2 paper.

Figure 9.4: Combinations of electronic media and printed books



The results indicate that when printing is taken over by the print office, lecture notes can be read on a tablet computer despite owning printed books and the combined impact would be still less than that of the baseline scenario. If the lecture notes are read entirely on the laptop computer and additionally printed books are bought, this would contribute to an impact greater than the baseline. It is therefore recommended to buy print books only if they're used and the time spent on the electronic device (if at all) is reduced.

However, it must be noted in both alternative scenarios (printed book + tablet computer, printed book + laptop computer) the reading time considered in the use phase of the respective electronic device is the total time a student spends studying lecture notes. Thus, assuming that some parts are read on printed paper, the alternative scenario with the laptop computer and printed books can possibly still be a considerable improvement compared to the baseline.

Figure 9.5: Combinations of electronic media and self-printed lecture notes

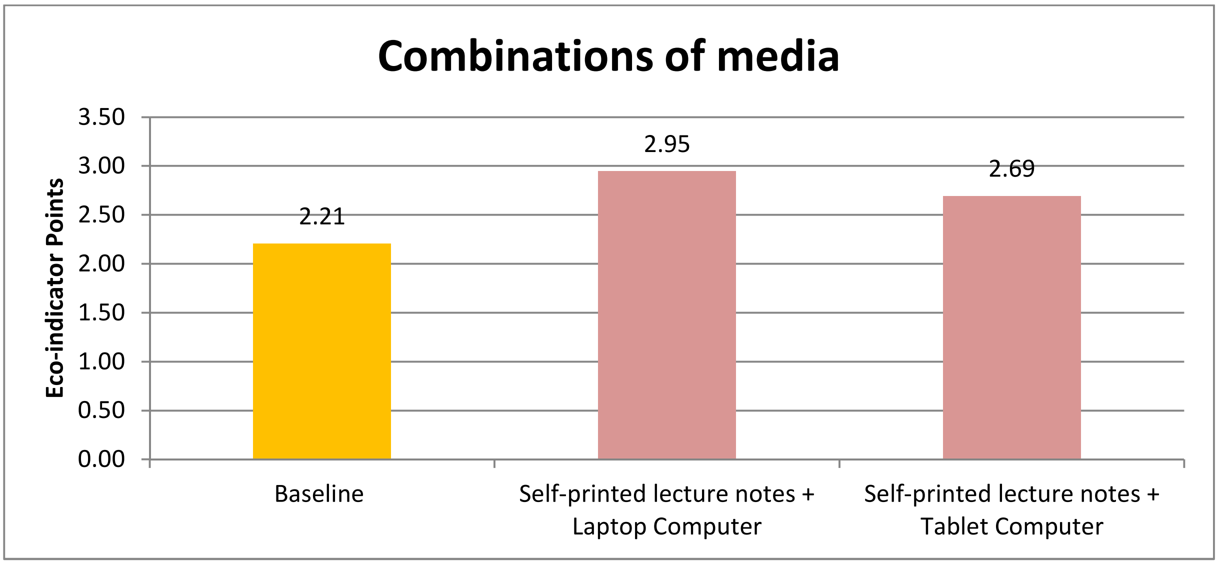


Figure 9.5 assesses the environmental impact when all lecture notes are printed by the student (100% of double-sided printing considered) additionally to studying them entirely on a laptop or tablet computer. Similar to Figure 9.4 the scenarios model a worst-case situation where despite printing all lecture notes the student consumes them electronically.

Both scenarios lead to a great increase of the environmental impact compared to the baseline scenario. Similar to the scenarios above in Figure 9.4, the scenarios in Figure 9.5 consider the total studying time for lecture notes is executed on the respective electronic device. However, if the total reading time is split into electronic and print media, the environmental impact can possibly be less than in the baseline system.

The above four scenarios assess the impact when the lecture notes are consumed entirely electronically despite owning them in printed form. In case of printed books, the outcome is not as crucial (deviation of -4% respectively +7%) as it is in the case of self-printed lecture notes (deviation of +33% respectively +22%).

Figure 9.6: Combination of laptop and tablet computer

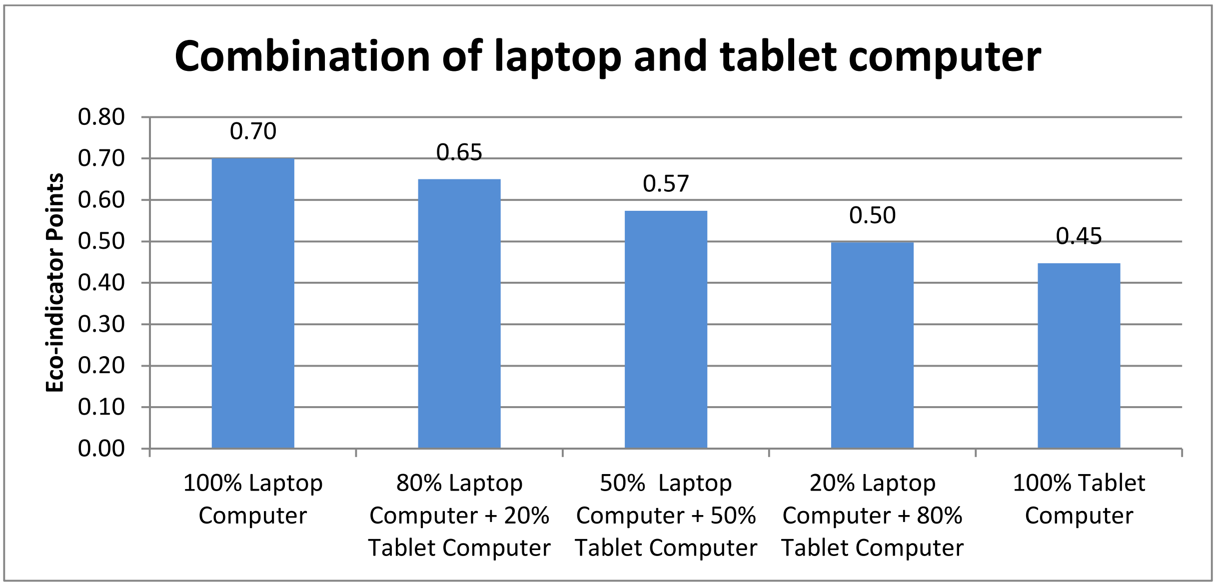


Figure 9.6 shows different combinations in the use of laptop and tablet computer for studying lecture notes on electronic medium. The environmental impact ranges between 0.45 and 0.7 Eco-indicator points. The graph shows that a substitution of the laptop computer by the tablet computer is environmentally preferred. It also displays that the environmental impact is proportional to the reading time i.e. if the reading time on the laptop computer is halved, the impact resulting from the use of laptop computer will also reduce by 50%.

Figure 9.7: Combination of electronic media and self-printed lecture notes (50% each)

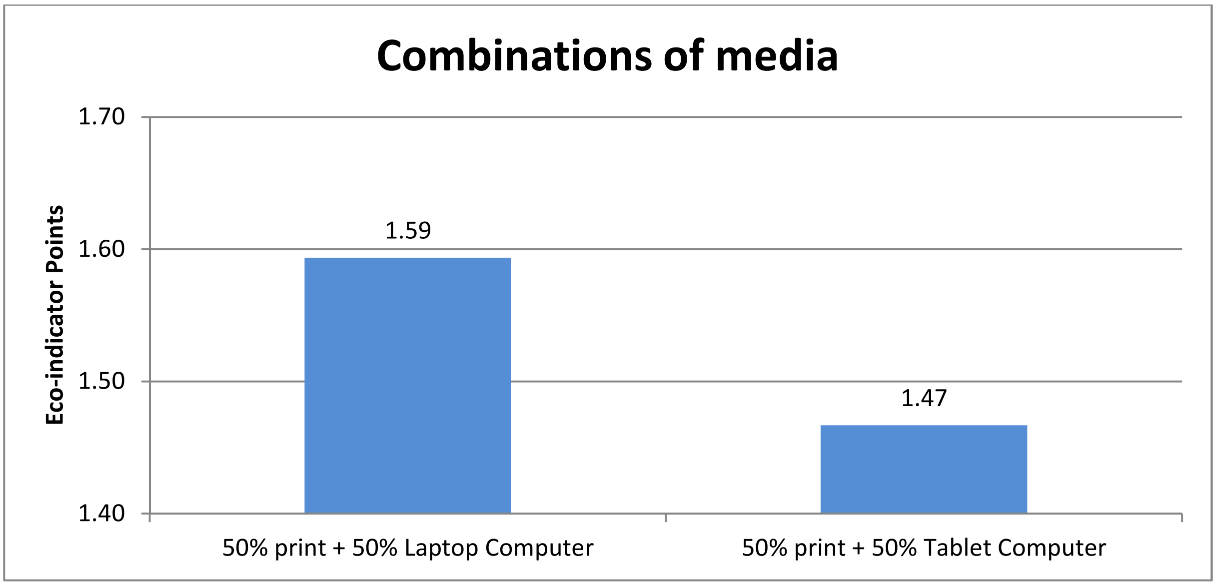


Figure 9.7 shows the impact when 50% of the lecture notes are read on printed paper and 50% of the total reading time is spent on the laptop computer respectively tablet computer. Printed material here refers to the lecture notes that are self-printed (58.3% of the material is printed on both sides). The difference between the two scenarios is not substantial (8%) as the impact is majorly caused by the self-printed material which is equal for both cases.

However, compared to the baseline and the printed books scenario both alternatives cause a much lower impact. If the student consciously uses the double-sided printing functionality for all lecture notes, the environmental impact will reduce to 1.47 Eco-indicator points in case of the combination with laptop computer and 1.35 Eco-indicator points with tablet computer.

Figure 9.8: Combination of electronic media and printed books (50% each)

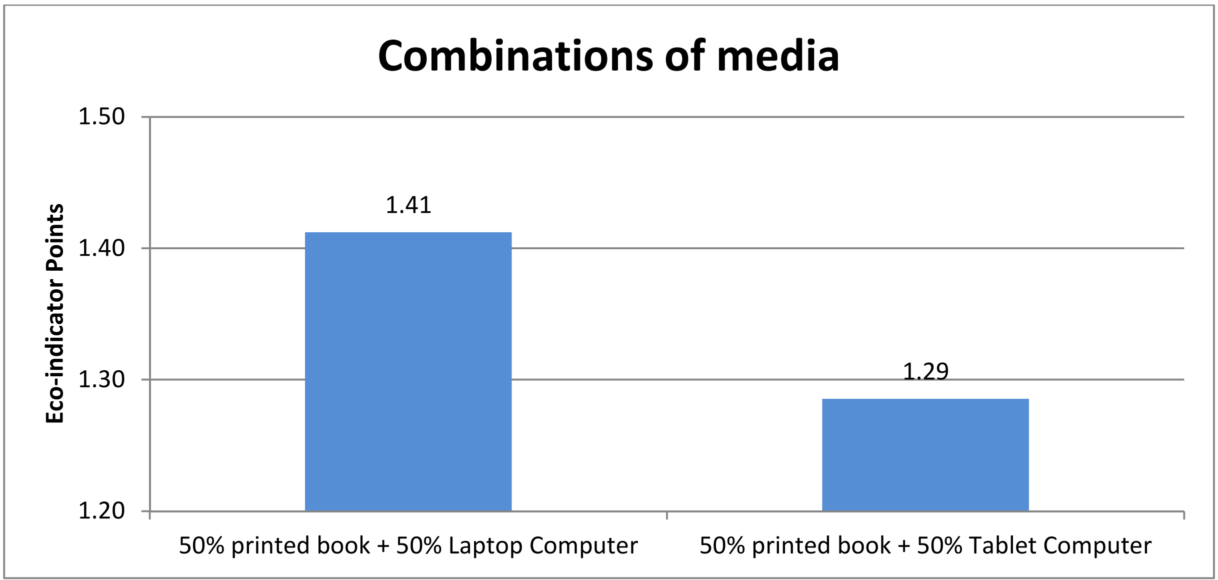


Figure 9.8 displays the result for scenarios where 50% of the lecture notes are consumed through printed books (6.86 grams/paper) and 50% of the total reading time is spent on the laptop computer respectively tablet computer.

As the first five alternative scenarios suggest, if 50% of the lecture notes are read on print media and the remaining on an electronic device, the tablet computer and printed book form the combination with the least environmental impact with an improvement by 42% of the baseline performance.

If in future the university decides to use standard 80 g/m^2 paper, the environmental impact can be further reduced: printed books in combination with laptop computer cause an impact of 1.19 Eco-indicator points and in combination with tablet computer 1.06 Eco-indicator points.

A fundamental difference between electronic and print media is that there is no impact caused during the use phase in case of paper. For each electronic media a threshold value was calculated (see Table 9.1). That is the maximum number of hours that could be spent on the respective device studying lecture notes which causes an environmental impact equal to that of the printed book scenario (6.86 g/paper). If a student strictly uses only one electronic device for the lecture notes, buying printed books is the environmentally preferred solution if the respective threshold value is exceeded.

Table 9.1: Threshold values for electronic devices

Electronic device	Threshold value
Desktop computer	170 hours
Laptop computer	1395 hours
Tablet computer	2187 hours

10 Limitations and need for further research

So far no LCA studies have assessed combinations of different media in the baseline. More such studies are needed in order to compare the results and obtain new findings.

10.1 Limitations in the scope

Only the direct energy consumption for the operation of the server was considered in this study, other phases and associated components such as facility infrastructure were excluded.

Maintenance services were disregarded during the use phase of all electronic devices.

Smartphone as a medium was ignored in the study. Its relative use for studying lecture notes was below 2%. Based on the determined usage patterns it could be established that 0.13% of the entire life cycle of a smartphone was to be allocated to the baseline. Assuming that the smartphone has a similar material composition as the tablet computer and a lighter weight than the tablet computer, it is likely that the use of smartphone does not have a relevant contribution to the baseline.

Data for the binding process of printed books was missing; only the adhesive substance was considered neglecting the assembly efforts such as the use of binding equipment.

10.2 Limitations in the data sets

The used material composition of the tablet computer is representative for a specific model. It is difficult to estimate the variation from the average values. Data regarding production efforts and waste treatment of the tablet computer in terms of energy and water could not be gathered and rough estimations were made based on the available data for the laptop computer.

Due to data lack inkjet printers were excluded from the study. This neglect may have resulted in the underestimation of the environmental impact of the baseline scenario.

The production of home printers and printers in print offices was modeled in the same way.

10.3 Limitations in the survey data

It was assumed there is no difference in the reading time on different media i.e. to read a unit of lecture notes, the same amount of time is spent irrespective of the medium.

No accurate data regarding energy consumption when using the respective electronic medium to study lecture notes could be collected as there are many user-specific interdependent parameters. The calculation was estimated based on the power ratings of the electronic devices.

Data regarding reading time was estimated by the students and may not be 100% accurate.

10.4 Limitations in the assumptions

In case of printed material (self-printed lecture notes and printed books of lecture notes) the number of readings per document was assumed 1 as the material varies annually and it was assumed students who borrow lecture notes from previous years will still own the current version of lecture notes.

11 Conclusions

The aim of the bachelor thesis has been to analyze what impact studying lecture notes using various media has on the environment. The life cycle assessment methodology (Chapter 4) was applied in a simplified way. The underlying functional unit was defined as studying lecture notes during one semester using different media by a BSc Informatics student at the University of Zurich.

The motivation for this project was to understand how the wide range in media to access lecture notes affects the environment. Lecture notes are usually provided in electronic format. This allows the student to consume the material electronically as well as in printed form. Some courses also offer lecture notes in form of a printed book.

LCA studies in the field of print vs. electronic have mostly concentrated on one specific electronic system. In contrast, this study takes the diversity of the electronic products into consideration that are used for study purposes i.e. desktop computer, laptop computer and tablet computer. As for the print-based systems, the self-printed lecture notes (lecture material printed by the student) as well as the printed books of lecture notes available in student shops were included in the study. A total of five product systems were considered in the baseline and alternative scenarios.

The life cycles of these systems were modeled with Umberto NXT LCA (Chapter 5). As the usage patterns regarding the considered media in general and specific to the functional unit determines the magnitude of the impact more accurately, an electronic survey with BSc Informatics students was conducted to elicit the required information. The survey results were then evaluated (Chapter 6) and the collected data provided values for the respective parameters in the life cycle models. The impact of the baseline system was assessed using the commonly applied method Eco-indicator 99. The total environmental impact of the baseline system associated with the defined functional unit is 2.21 Eco-indicator points (Chapter 7).

The three main systems contributing the most to this impact are self-printed lecture notes (40%), desktop computer (33%) and laptop computer (19%) sorted by the relative contribution to the total impact. It has to be noted that the order does not necessarily correspond to that based on relative use of the respective system to perform the function associated with the functional unit.

The survey results indicate that the highest amount of time studying lecture notes is spent on the laptop computer (57%) followed print-based material (18%) - self-printed lecture notes and print books - and desktop computer (12%).

The fact that the use of the desktop computer causes the second highest contribution to the overall environmental performance despite being only the third most used medium underscores the fact that the impact of the desktop computer life cycle per use unit is higher than that of the laptop computer.

The LCA study helped to identify the phases with the highest contribution within the impact of each different system life cycle in the baseline.

In case of the use of all three electronic devices, the impact resulting from the production efforts allocated to the functional unit contributes the most – ranging between 75 and 85%. The use phase contributes to 22% in case of desktop computer, 14% in case of laptop computer and 3% in case of tablet computer, in terms of the respective product system impact. The impact of the use phase depends on two factors: the time spent on the respective device for studying lecture notes and the energy consumption for one use unit.

As for the transportation of the electronic devices to the end-costumer, the efforts are insignificant contributors to the impact resulting from the use of desktop computer and laptop computer (<1%). In case of the use of the tablet computer by the average student, the environmental burden associated with the transportation is relatively high (19%). This can be explained by the fact that the production efforts and energy consumption during the use of a tablet computer are substantially lower than that of a laptop computer. Therefore, there is an increase in the relative contribution of the transportation activities.

There was a noteworthy difference between the self-printed lecture notes and printed books of lecture notes in terms of the relative contributions of the life cycle phases. In the case of self-printed lecture notes, the printing activity (54%) dominated the impact resulting from the use of self-printed lecture notes whereas the paper production (70%) contributed the most to the impact resulting from the printed books system. The difference arises from the amount of paper considered in both systems in the baseline scenario. Both systems differed in characteristics such as type of paper, degree of double-sided printing and printer utilization. The total contribution of both print-based systems to the baseline differed noticeably mainly due to the limited availability of printed books of lecture notes.

Providing the course content on the server allocated to a student has a negligible contribution to the overall impact. Even though University-specific data could not be collected, the effect of the generic data indicates that it is not sensitive to the total environmental performance.

The impact of the internet access to download the electronic lecture notes was measured in terms of energy consumption and contributes in a negligible extent to the total environmental impact.

A second goal of the project was to analyze the outcomes of different scenarios and to identify strategies for potential improvement of the baseline performance (Chapter 9).

As the baseline scenario comprehends the use of 5 different systems, it was of interest to analyze the impact if the activity of studying lecture notes is executed using solely one system i.e. if the lecture notes are studied only using desktop computer, laptop computer, tablet computer, self-printed lecture notes or printed books of lecture notes.

The results of the single-media strategies show that the tablet computer would produce the least environmental impact (baseline impact reduced by 80%) and the desktop computer the highest (increase of 160%). If the University would substitute all the electronic lecture material with printed books the impact could be reduced by 4-24% depending on the type of paper. If the student only uses self-printed lecture notes, the resulting impact is higher than the baseline. However, if the student always prints double-sided, the impact has a magnitude equal to that of the baseline. Except for the desktop computer, all other single-media alternatives have been proven to be a strategy towards potential improvement.

In order to reduce the environmental impact the students can be suggested to use preferably the tablet computer or laptop computer to study lecture notes and avoid all other media. However, since it is not possible to force a student to perform the activity exclusively on one medium and forbid printed material, the printed books solution could be enforced by the University and discontinue with the provision of electronic content. This would at least ensure a definite reduction of 4-24%. Traditionally, books are printed with circulations which have not been taken into consideration. The additional impact might lower or even offset the improvement. Alternatively, the University could place a print-on-demand order as the number of students enrolled in a course and therefore the required number of book copies is known.

As the sensitivity analysis (Chapter 8) has shown the total baseline impact is highly sensitive to the total reading time and to the amount of self-printed lecture notes. Extending the lifetime or the active use of the desktop computer can further reduce the total impact. Varying the same parameters for the laptop computer had a less noticeable effect. If the student increases the percentage of double-sided printing from currently 58.3% to 100%, the impact resulting from the self-printed system can be reduced by 10%.

Some multi-media strategies were also analyzed. The assessment of multiple-media combinations indicated as expected that it is not advisable to spend the total studying time on electronic media despite printing all lecture notes respectively buying all printed books.

If a student only uses laptop or tablet computer or a combination of both and does not own any printed material, the baseline impact can be reduced by 68-80%.

For students who might still prefer to combine printed and electronic medium, it is recommended to consume 50% of the lecture notes through printed media (either self-printed or printed books) and 50% using either a laptop or tablet computer. This strategy ensures a reduction of at least 28-42%. As expected, printed books and tablet computer is environmentally the most preferred combination (reduction of 42%).

Based on the baseline and alternative scenarios, it can be said that the diversity of the media use is environmentally not preferable and has to be changed. As the students are provided with electronic course material they can additionally take printouts and the environmental impact is unnecessarily increased. It is therefore recommended to either not provide printed textbooks and disable the printing functionality for the electronic lecture notes – i.e. the lecture notes are strictly studied on electronic media. The underlying assumption is that the desktop computer is not the used medium. The second alternative is to implement the complete substitution with the printed book strategy. This substitution strategy is only successful if the lecture slides are no more electronically accessible. This would ensure a reduction up to 24%.

It can be expected that future mobile devices are even more eco-friendly and the environmental impact resulting from the study of lecture notes will naturally decrease. However, the self-printing option should be restricted as it has the largest effect on the total baseline impact. With the availability of podcasts and the likelihood of its increase it would be interesting for future research to assess scenarios where the physical attendance of classes is substituted by the consumption of podcasts.

The analysis of alternative scenarios provides recommendations for individual students who are environmentally conscious as well as for the University to gain insight into the environmental consequences and to identify scope for improvement. This study only focuses on the environmental performance and does not consider the social and economic aspects. To implement a sustainable strategy, all three aspects should be taken into consideration.

12 References

Akeret Druck AG. (n.d.). Retrieved February 11, 2014, from Akeret AG: http://www.akeret-ag.ch/

Antalis. (2013). *Our Locations*. Retrieved February 10, 2014, from Antalis: http://www.antalis.com/business/en/sites/antalis.com/home/about-us/our-locations.html

Apple. (2012). *iPad 2.* Apple. Retrieved January 20, 2014, from http://images.apple.com/environment/reports/docs/iPad2_Product_Environmental_Report_2012.pdf

Berkhout, F., & Hertin, J. (2004, October). De-materialising and re-materialising: digital technologies and the environment. *Futures, 36*(8), 903-920.

Bray, M. (2006). *Review of Computer Energy Consumption and Potential Savings.* White Paper.

Curran, M. (2008). Life-Cycle Assessment. In *Human Ecology: Life-Cycle Assessment* (pp. 2168-2174). Cincinnati: Elsevier B.V.

de Vos-Effting, S., & van Gijlswijk, R. (n.d.). *A life cycle based Eco design consideration for the Rainbow Warrior III.* Retrieved from HISWA Symposium: http://www.hiswasymposium.com/assets/files/pdf/2009/Hiswa%20Symposium%202008%20Vos%20Effting%20and%20Van%20Gijlswijk.pdf

Electronics TakeBack Coalition. (2013, September 25). *Facts and Figures on E-Waste and Recycling.* Retrieved January 1, 2014, from Electronics TakeBack Coalition: http://www.electronicstakeback.com/wp-content/uploads/Facts_and_Figures_on_EWaste_and_Recycling.pdf

Enroth, M. (2009). Environmental impact of printed and electronic teaching aids, a screening study focused on fossil carbon dioxide emissions. *Advances in Printing and Media Technology*, *36*, pp. 1-9.

Ertl, A. (n.d.). *How much electricity does a Computer consume?* Retrieved January 1, 2014, from Technische Universität Wien: http://www.complang.tuwien.ac.at/anton/computer-power-consumption.html

eXtreme Power Supply Calculator Lite. (2013, December 25). Retrieved January 1, 2014, from eXtreme Outer Vision: http://www.extreme.outervision.com/psucalculatorlite.jsp

Gard, D. L., & Keoleian, G. A. (2003). Digital versus Print. Energy Performance in the Selection and Use of Scholarly Journals. *Journal of Industrial Ecology, 6*(2), 115-132.

Google Maps. (2014). Distance between Dübendorf and Zurich. Retrieved February 11, 2014

Google Maps. (2014). Distance between Frechen and Dübendorf. Retrieved February 11, 2014

Google Maps. (2014). Distance between Frechen and Zurich. Retrieved February 1, 2014

Gupta, B., White, D., & Walmsley, A. (2004, Apr.). The attitudes of undergraduate students and staff to the use of electronic learning. *British Dental Journal, 196*(8), 487-492.

Hilty, L. M. (2011). Information and Communication Technologies for a More Sustainable World. In D. M. Haftor, & A. Mirijamdotter (Eds.), *Information and Communication Technologies, Society and Human Beings: Theory and Framework* (pp. 410-418). IGI Global.

Hilty, L., Lohmann, W., & Huang, E. M. (2011). Sustainability and ICT - An overview of the field. *Notizie di Politeia, 27*(104), 13-28.

Hilty, L., Lohmann, W., Behrendt, S., Evers-Wölk, M., Fichter, K., & Hintemann, R. (2013). *Grüne Software.* Unpublished manuscript. Retrieved January 1, 2014

Hischier, R., Classen, M., Lehmann, M., & Sharnhorst, W. (2007). *Part I-V. Life cycle Inventories of Electric and Electronic Equipment: Production, Use and Disposal.* Dübendorf: Empa/Technology & Society Lab, Swiss Centre for Life Cycle Inventories.

Ingwersen, W. W., Curran, M. A., Gonzalez, M. A., & Hawkins, T. R. (2012). Using screening level environmental life cycle assessment to aid decision making. A case study of a college annual report. *International Journal of Sustainability, 13*(1), 6-18.

Ink & Toner Plus. (n.d.). *HP LaserJet Q7551X Black Print Cartridge Genuine HP Toner*. Retrieved January 1, 2014, from Ink & Toner Plus.

ISO. (1997). *14040: Environmental Management - Life Cycle Assessment - Principles and Framework.* Geneva: International Organization for Standardization.

ISO. (2004). *14001: Environmental Management System.* Geneva: International Standards Organization.

Kim, K.-J., & Bonk, C. J. (2006). The Future of Online Teaching and Learning in Higher Education: The Survey Says... *EDUCAUSE QUARTERLY*(4), pp. 22-30.

Kozak, G. L., & Keoleian, G. A. (2003). Printed Scholarly Books and E-book Reading Devices:A Comparative Life Cycle Assessment of Two Book Options. *IEEE*, 291-296.

Lenhart, A., Purcell, K., Smith, A., & Zickuhr, K. (2010). *Social Media & Mobile Internet Use Among Teens and Young Adults.* Pew Research Center, Washington, D.C.

Ministry of Housing, Spatial Planning and the Environment. (2000, October). *Eco-indicator 99 - Manual for Designers. A damage oriented method for Life Cycle Assessment.* Retrieved January 1, 2014, from Pre Sustainability: http://www.pre-sustainability.com/download/manuals/EI99_Manual.pdf

Moberg, A., Borggren, C., & Finnveden, G. (2011). Books from an environmental perspective - Part 2: e-books as an alternative to paper books. *International Journal Life Cycle Assessment, 16*, 238-246.

Moberg, A., Johannson, M., Finnveden, G., & Jonsson, A. (2010). Printed and tablet e-paper newspaper from an environmental perspective - A screening life cycle assessment. *Environmental Impact Assessment Review*, 177-191.

Morelli, J. (2011). Environmental Sustainability: A Definition for Environmental Professionals. *Journal of Environmental Sustainability, 1*, 19-27.

Oxford Dictionaries. (n.d.). Sustainable Development. Retrieved February 7, 2014, from http://www.oxforddictionaries.com

Plastics. (n.d.). *Ten Facts to Know about Plastics from Electronics.* Retrieved January 11, 2014, from American Chemistry Council: http://plastics.americanchemistry.com/Ten-Facts-About-Plastics-from-Electronics

Prokerala. Travel & Tourism. (n.d.). *Distance From Shuangliu Airport To Frankfurt International Airport*. Retrieved January 15, 2014, from Prokerala. Travel & Tourism: http://www.prokerala.com/travel/airports/distance/from-ctu/to-fra/

Reichart, I., & Hischier, R. (2003). The Environmental Impact of Getting the News. *Journal of Industrial Ecology, 6*(3-4), 185-200.

Seifert, D. (2012, March 8). *New iPad said to pack twice as many backlight LEDs as iPad 2*. Retrieved January 1, 2014, from MobileBurn: http://www.mobileburn.com/18869/news/new-ipad-said-to-pack-twice-as-many-backlight-leds-as-ipad-2

Sharma, K. (2011). The Role of ICT in Higher Education for the 21st Century : ICT as A Change Agent for Education. *VSRD International Journal of Computer Science & Information Technology, 1*(6), 382-391.

Strange, T., & Bayley, A. (2008). *Sustainable Development: Linking economy, society, environment.* Paris: OECD Publications.

United States Environmental Protection Agency. (2006, May). *Life Cycle Assessment: Principles and Practice.* Retrieved Jan 1, 2014, from United States Environmental Protection Agency.

Universität Zürich. (2013, December 3). *Studierendenstatistik für Herbstsemester 2013*. Retrieved February 1, 2014, from Universität Zürich: http://www.fi.uzh.ch/br/mis/stud/semester/hs13.html

Whitelaw, K. (2004). *ISO 14001 Environmental Systems Handbook.* Oxford: Elsevier.

13 Appendix

13.1 Appendix A – Literature review

Books from an environmental perspective – Part 2: e-books as an alternative to paper books

Subject of study

The aim of the study was to analyze the environmental impacts of an e-book read on an e-book reader, to identify the challenges determining the extent of the impact and to compare the e-book product system with a paper book product system.

Impact categories

Energy, global warming potential, abiotic depletion, acidification potential, eutrophication potential, ozone depletion potential, human toxicity potential, freshwater aquatic ecotoxicity potential, marine aquatic ecotoxicity potential, terrestrial ecotoxicity potential, photochemical ozone creation potential

Functional unit

One specific book bought and read by one person

Method used

A screening LCA was made for both product systems.

For the impact assessment, CML assessment methods were used.

Data basis

Data from Ecoinvent 2.0 was used and some site/company specific data as approximations whenever the average data was not available.

The Swedish average electricity mix was used for processes taking place in Sweden.

Data concerning waste management was based on Ecoinvent 2.0.

The electronic device was modeled as a set of components which were identified from a technical description of a specific e-reader device. The average data on production of the components were taken from the Ecoinvent 2.0 database.

Studied system and boundaries

Average e-book was defined as an electronic version of a 360 page hardcover novel. The editorial work was considered to be equal for both the electronic and printed book systems. Additional energy use for editing the electronic version was considered.

The total energy and heat use in the offices for the editorial work were allocated to the functional unit according to the specific book's share of total purchases.

The studied system includes the editorial work of the e-book (including use of servers and data storage), the production of the e-book reader, the distribution of the e-book reader to Swedish retailers, downloading and reading of e-books and the waste management of the e-book reader.

The e-book reader could be either bought at a traditional bookshop or over the internet. Collecting the device from a bookstore or a pick-up point was attributed with a personal transportation of 2km by a passenger car.

The distribution of the e-book reader was modeled as transportation from China to Central Europe by boat for 15,000 km, then by lorry for an average of 500km to possible retailers in Sweden.

Since the e-book could be bought online, the production and use of desktop computer and internet access were considered in the study. 8 min and 2.2 MB were estimated as the time spent on the website including downloading and the amount of data transfer (accessing website + downloading).

Internet use was modeled as use of modem (9W) and the hubs, routers, switches of the internet infrastructure. Production of cables and carbon dioxide emissions related to construction work and dismantling, operation and production of the desktop computer were also included.

Regarding waste management, 48 weight% of the reader was recycled, 29 weight% incinerated and 23 weight% went to landfill.

The paper book system is described in another paper. The book was printed on average European wood-free paper and sold in a traditional bookshop.

Key assumptions

Editorial work is the same for a printed book and an e-book

The e-book reader was produced in China

The e-book was produced and read in Sweden

The e-book is read by only one person

The e-book, a PDF file of 1.5 MB, was downloaded with an average desktop computer

Reading the e-book requires one charging of the battery – 2.5Wh, the battery needed charging every 2-3 weeks.

During the life cycle of the e-book reader, 48 books of 360 pages were read.

75% of e-book readers were treated as electronic waste. However, the impact of the remaining devices was not considered.

Findings

Environmental impacts of an e-book read on an e-book reader

From a life cycle perspective, the production of the e-book reader forms the main environmental contributor for all impact categories. The waste management also contributed to some extent through recycling of materials and energy recovery.

The main electronic components affecting the overall environmental performance were integrated circuits, resistors, capacitors and battery.

Impact category	**Main cause**
Terrestrial ecotoxicity	Use of gold
Acidification	Palladium
Photochemical ozone creation	Palladium
fresh water aquatic toxicity	Disposal of waste from palladium refining and from wafer production
marine aquatic toxicity	Disposal of waste from palladium refining and from wafer production
Eutrophication	Wafer production
Human toxicity	Aluminium and Copper production

Further, recycling of gold and aluminium reduced the total impact and the use of electricity had a considerable impact on many categories.

E-book vs. paper book

E-book is preferable for following impact categories	**Printed book is preferable for following impact categories**
global warming	acidification
energy	ozone depletion
eutrophication	freshwater aquatic ecotoxicity
human toxicity	photochemical ozone creation
marine aquatic ecotoxicity	
terrestrial ecotoxicity	
resources used	

The total energy consumption was higher for the paper book due to the energy contained in the biomass from the forest and the energy consumption at the bookshop.

For several impact categories (climate change, abiotic depletion, eutrophication, human toxicity, marine aquatic ecotoxicity, terrestrial ecotoxicity), the breakeven point was 30 books (valid for this study). That means if a greater number of books are read the electronic version is preferred over paper medium. However if the books are read twice, the break-even shifts to 60-70 books. This is because the use phase creates no impact in the print system as opposed to the electronic system.

The break-even point for the cumulative energy was 20.

For other impact categories, the breakeven point lies above 30 such as acidification with a break-even point of 200. This indicates a very high amount of acidification in the electronic system.

Part 1 paper indicated that paper books bought via the internet and delivered by postal services had a lower impact as opposed to a self-pick up with personal transportation. Location and technology of pulp and paper mill also influence the environmental performance.

No conclusive result was shown as the comparison depends on parameters related to a specific book and to a specific user. Parameters such as life time of an e-reader device, total active use of the e-reader and usage habits are equally crucial.

Limitations

Biotic carbon dioxide was not included in the climate change impact assessment.

E-book reader with an e-ink screen was the only electronic device studied.

For assessing the impact of the production of an e-reader, a specific device/model was used as the basis.

Even though it was assumed that the electronic device was produced in China, the data concerning the components were western European or global average data as Chinese data were not available.

Production of e-ink screen was not considered due to lack of data.

The production of the e-device was modeled as a set of the different components. Energy consumption for assembling the device was therefore not included.

Information on waste management of electronic devices is uncertain.

Potential decrease in physical storage and facility infrastructure of printed books which remained at home was not considered.

Not all relevant impact categories were equally well covered.

The toxic impact category is uncertain due to data gaps and impacts from land use not considered.

Digital versus Print – Energy Performance in the Selection and Use of Scholarly Journals

Subject of study

The study assesses the digital library in comparison with the printed library specifically for journal collections

Impact categories

The paper studies the impact category energy consumption.

Functional unit

One reading of one scientific journal article

An article consists of 12 pages which is equivalent to 0.97 hours of reading time.

The electronic journal is viewed online and has the same content as the printed one, having a file size of 1,524 kB.

System boundaries

Digital library system

Life cycles of computer, file transfer, facility infrastructure, server, network equipment, laser printer were considered.

Traditional library System

Life cycles of paper and ink production, printing, physical delivery of the journals to the library, journal collection storage, facility infrastructure, binding, copiers were considered.

Method used

The LCA method was applied and evaluated on the basis of five scenarios with parameters i.e. number of readings per article, printing in the digital system, copying in the traditional system, personal transport.

Data basis

Parameters affecting the energy consumption such as electricity production and grid efficiency are for the North American region.

Ecoinvent 1.2 database

Key assumptions

Digital system

For the online reading only desktop computers were used. Further, it was assumed the server's location is at a university in California, receiving requests from clients located in Michigan.

The study assumes the papers used for printing electronic journals are not recycled or incinerated, the resulting impact is calculated as the foregone landfill impact.

Traditional system

The use period of print journals was assumed 10 years. However, the journals wouldn't be physically disposed and would remain the library.

Findings

The range of the total energy consumption caused by the digital system was 4.10-216 MJ, for the traditional system 0.55-525 MJ per functional unit. The findings of the study could not conclusively prove that one system is better than the other in terms of energy consumption.

As the number of readings per article increases, the allocated energy consumption for the data storage decreases per functional unit.

In the traditional system, the paper production, printing, delivery to the library, facility infrastructure and binding are the major contributors if the journal is read only once. Similarly, for the digital system the server is the major source for a single reading per article.

For four scenarios the number of readings per article was set to 1000 which led to a decrease of the respective energy allocations.

In those scenarios, the major contributor shifts from data server to online reading in the digital system.

For the traditional system the library building infrastructure and the paper production formed a major contributor and that remained same irrespective of number of readings.

The increase of energy consumption due to copying in case of traditional system and laser printing in case of digital system was significant and unequal as copying was considered single-sided, laser printing double-sided which resulted in a greater paper production in the traditional system.

In scenarios where personal transportation was included, this formed 73% of the total energy consumption in the digital system and 82% in the traditional system.

The study shows that the results are highly sensitive to the following parameters

- Number of readings per article had the greatest impact on the results for both systems
- The length of the article had an influence on several processes
- Total active use of the computer determines the extent of energy allocation
- Travel distance and vehicle efficiency are significant
- Digital systems results are sensitive to power grid efficiency

Even though no conclusive statement which system is energy efficient could be made, the study makes the following general conclusions.

- Energy consumption for one functional unit is heavily dependent on the number of readings of an article. For articles that are rarely read, the study suggests, the digital storage consumes less energy than the printed version
- Networking infrastructure is not a significant contributor (<0.2% of the total digital system's energy consumption)
- Personal transportation results in a high energy consumption

  The remote accessibility of an electronic journal is beneficial as the energy consumption caused by the transport will be omitted

  In a digital system printing the article instead of reading it on the computer reduces the energy consumption.

Limitations

Network transmission infrastructure (optical/copper cable), satellite-based networks, redundant back-up storage, downloading material to a workstation, central storage file were not considered.

As document creation and publishing was considered to be equal for both systems, it was excluded from the system boundaries. The information presented in the journals is restricted to text and standard graphics such as tables, graphs and pictures for a sensible comparison.

Usage patterns were assumed and no specific survey as part of study was conducted.

Environmental impact of printed and electronic teaching aids, a screening study focusing on fossil carbon dioxide emissions

Subject of study

The study compares the environmental impact of printed and electronic teaching aids (textbook) in a compulsory school system in Sweden.

Impact categories

The paper studies the impact category global warming and focuses on the emissions of fossil carbon dioxide. It is the only climate gas considered for the analysis.

Functional unit

Use of teaching aid for 2,000,000 hours (5 years x 5000 students x 2 hours/week s x 40 weeks/year)

A student uses the teaching aid 2 hours per week for 40 weeks in a year.

Studied system and boundaries

Printed textbook system

The life cycle includes the pulp and paper production, transportation of paper by truck, prepress, printing, distribution of the books by truck, use during studies and waste management.

Web-based system

The life cycle includes formatting the teaching aid, use of internet infrastructure, production of computer equipment for each student, distribution of computer equipment, use of electronic equipment during studies and waste management of electronic devices.

Forestry and editorial work were not considered in this study. Editorial work was assumed to be the same for both the systems.

Use of internet infrastructure for uploading the material is not considered.

Method used

A screening LCA

Two scenarios were studied for each product system: for the printed product two different energy levels were used for the printing process. For the electronic product two different electronic devices were used: laptops consuming low energy and desktops with LCD screens consuming high energy.

Data basis

For the pulp and paper production the data was specific to Sweden.

Key assumptions

The students live in six different cities in Norway.

The printed product has a weight of 0.8 kg/book.

17% of paper waste at the production was considered.

Life time of the computer equipment was assumed 5 years with total usage of 10900 hours.

Printed System

Transportation of paper to the printing company by truck

No emissions from the use of printed products

Waste management of paper: 80% fiber recovery and 20% incineration

All types of energy consumption were included such as electricity and heat.

Based on a study, the use of ink for offset printing was considered 5.8 kg/tonne printed product. Based on another study, 1180 kg of fossil CO_2 emissions/ tonne printing ink were considered.

It was assumed the printing company is located in Norway and the books were transported by truck to six different cities within Norway at 400 kms of distance.

Digital system

Formatting editorial work was estimated 50 hours, representing the extra time needed compared to the load of the editorial work for a printed version.

The activity formatting was performed using a desktop computer and a screen.

Based on a study, following values were considered for the use phase: 78 W for the desktop, 31 W for the LCD screen and 32 W for the laptop.

The size of the electronic material was estimated 1500 MB.

The energy consumption caused by the use of the internet infrastructure was dependent on the size of the downloaded files and based on the value 3 Wh/MB from a study.

The use of access technologies such as modem and DSLAM are considered. 9W for modem and 5W for DSLAM.

For the laptop production it was assumed 81 kg CO_2 equivalents of emission, for the desktop production 138 CO_2 equivalents of emission, for the LCD screen production 55 kg CO_2 equivalents of emission (based on a study)

For the waste management 95% material and energy recovery and 5% landfill were assumed based on a study. Impact estimates were 1 kg CO_2 equivalents for a desktop/laptop and 4 kg of CO_2 equivalents for a LCD screen.

Ten different schools download the teaching material from the internet only once a year.

Findings

The impact on global warming of an electronic teaching aid is approximately 10 times higher than the impact of a printed textbook when laptops are used. As desktop computer and screen consume higher amount of energy compared to laptops, the impact is approximately 30 times higher for the electronic teaching aid using a computer compared to the printed system.

In the traditional system pulp and paper production (50%), printing (35%) and waste management (9%) were the phases of the life cycle with the highest fossil carbon dioxide emissions.

In the digital system considering a high energy scenario with desktops and laptops the use (44%), computer production (38%) and screen production (15%) were the phases with the highest emissions.

Transport didn’t contribute significantly to the emissions.

Limitations

As a screening LCA was performed, the use of energy and transportation were the two main elements assessed in the different phases of the life cycles.

A limitation of the study is the range of impact categories studied- only one impact category was evaluated.

The biogenic carbon dioxide is defined as zero – carbon stored in forest products has not been considered.

There exist some uncertainties regarding impacts of internet infrastructure and energy allocation between different services.

The environmental impact of getting the news

Subject of Study

This study compares the environmental impact of three different ways of daily news consumption: a) reading printed newspaper b) reading online newspaper c) watching news on TV

Weighting methods

Method of environmental scarcity (applicable to Switzerland for 1997) and the Eco-Indicator 99

Functional unit

As differences between the three media exist in terms of presentation and content of news, two functional units were defined.

The first functional unit ensures similar content was compared

1) Reading or watching a single news item

The second functional unit compares the activity of being informed about daily news

2) Reading or watching the daily news entirely, including advertisements/banners

Studied system and boundaries

The entire life cycles of the computer, TV and printed newspapers were assessed including transportation.
The distribution of the printed newspapers to central locations via van and from there to points of sale and households via van, car, moped and foot is considered. Paper recycling was also taken into account. 35% of the newspaper disposal was used for incineration purposes. The disposal of electronic devices was also considered.

Paper production has different manufacturers – paper with a high share of virgin fibers is imported from Scandinavian countries, paper with a high percentage of recycled fiber is produced in Germany or Switzerland. Printing process is located near Lucerne and Zurich.

Upstream processes such as heat generation from fossil fuel and biomass were also considered.

The power supply was modeled on national level depending on the location of power consumption (either Scandinavian or German/Swiss electricity mix).

Operation of infrastructure such as data transfer via Internet, telephone network, production of TV shows and satellite receiver were also covered. Manufacture and disposal of the same infrastructure were however not included.

Journalism and related transportation processes were not considered.

Method used

LCA

5 Swiss-German media products were chosen as a basis for the estimations.

Print edition of NZZ, Print edition of Blick, online edition of NZZ, online edition of Blick, main news and weather forecast at 7:30 p.m. on Swiss-German TV channel SF1.

Four specific news items were chosen to calculate approximate average time duration and size of content for each media format. In order to achieve a sensible comparison, for the first functional unit the news item was limited to national or international news of high importance and the weather forecast.

For the printed newspaper, only the corresponding newspaper cutting was considered.

180 sec watching TV, 90 sec of opening and reading an online newspaper, 250 cm^2 of printed newspaper were used as reference flows.

For the second functional unit, the average time duration for reading/watching daily news was quantified on similar basis. The reference unit for the printed and electronic newspaper was calculated as the average of the print versions of Blick and NZZ, respectively the online versions of both.

25 min watching TV, 10 min reading an online newspaper, 43% of Blick & NZZ were the reference flows for the second functional unit.

A sensitivity analysis was conducted for the use phase where European electricity mix was used instead of Swiss.

Data basis

For the production of the TV the German or European electricity mix was used.

During the use phase the electricity consumption is based on the Swiss electricity mix.

For the paper production process, data was based on paper manufacturers and printing plants information.

Energy consumption of the TV, computer, telephone network and Internet were partly based on other papers.

Data for manufacturing processes of all three media (TV, Computer, Newsprint paper) had different sources. TV production data is based on inventory data from Gensch and Quack.

Key assumptions

The average number of readers per print edition was assumed 2.3. The news on TV is watched by one person.

The user was defined as an adult consumer in Switzerland using a computer, TV and newspaper in an average way.

Life time of a TV is assumed 8 years, that of a computer 4 years and printed newspaper of 1 day.

Total active use of TV is assumed 253 min/day, that of a computer 120 min/day.

The power consumption of a TV in standby mode is 5W, in active mode 94W.

The power consumption of a computer in active mode is 145W.

Due to data lack it was assumed the computers are either actively used or disconnected.

Findings

Results for first functional unit – one news item

The printed newspaper cutting produces the least impact on the environment. The online newspaper product system and the TV product system create a greater environmental impact than the printed version. For the online newspaper, the use phase creates a significant environmental impact and it varies depending on the reading speed and time to open the website. The time variation is relatively limited in the TV product system as the news program has fixed schedules. According to the study, even taking the time parameter into consideration, the potential environmental impact of the online system will be greater than that of the TV system. This result was confirmed by both assessment methods.

For the printed newspaper, the paper production dominates the impact.

For the online newspaper, the production of the computer equipment and the use are mainly responsible for the impact. The total active use and the lifetime of the computer can significantly influence the results. Within the use phase of the online system, the operation telephone network consumes 59% of the power consumption and data transfer via router 23%. The computer has a less crucial effect of 18%.

Results for the second functional unit – daily news

Both the assessment methods led to similar results. When the product system consists of the entire newspaper, the printed product system creates the highest environmental impact, the paper production phase being the largest contributor (78%) of all life cycle stages. A sensitivity analysis was made to see how the results vary with the parameter reading time. The analysis showed that reading online created a higher increase of impact than watching on TV. For the printed newspaper, the reading time is irrelevant as no environmental impacts are associated with the use phase.

When watching news on TV lasts for less than 80 minutes, the TV produces an impact less than a printed thin newspaper (32 pages). 20 minutes of Internet surfing creates the same impact as a thin printed newspaper. If additionally three pages of online news are printed, 10 minutes online reading is sufficient to create the same environmental impact as a thin newspaper.

When using the European electricity mix instead of the Swiss, the environmental impact of electronic media is tripled as hydropower takes a high share in the Swiss mix compared to the average European mix.

Limitations

Average user behavior was not representative. An average usage pattern for each category (print, online, TV) was defined separately.

For the first functional unit, advertisements were not included.

Newspaper cuttings are presently not sold.

Lack of data in the field of electronic products, electricity consumption of the Internet and the telephone network

Due to lack of data, the computer production data is based on TV’s printed circuit board assembly, its cabinet and its cathode-ray tube.

Impact of a shared TV is not evaluated.

Using screening level environmental life cycle assessment to aid decision making. A case study of a college annual report

Subject of Study

The aim of the study is to compare the environmental impacts of a printed university annual report with an electronic version of the same. The annual report of the University of Cincinnati College of Engineering and Applied Sciences was used as a reference.

Functional Unit

Reading of 34,000 copies of the annual report by the recipients

Studied system and boundaries

Printed report system

The life cycle begins with the design phase of the report, followed by the printing phase. The required processes in the background i.e. paper and ink production are also included. After sorting and labeling the reports, the reports are distributed by the US Postal Service. Subsequently, the report is read under light in the use phase. At the end of the life cycle, the report is disposed – either recycled or landfill.

Electronic report system

The life cycle begins with the report design. The electronic file is then uploaded onto the web server. The distribution phase consists of the Internet connection and the downloading of the report on to the student's computer. During the use phase, the report is read on the computer. The disposal of the e-report is not required.

Environmental Impacts

Greenhouse gas emissions, energy use by source type, total water consumption, human health and ecosystem-related impacts

Method used

Screening LCA

An economic input output approach was used to create the life cycle inventory. In this approach, cost data which is sector-specific is used instead of material data.

The US Economic Input Output LCA 2002 Purchaser Price model was used.

For each life cycle phase, costs for the services were quantified.

The life cycle phases were then attributed to the corresponding IO sectors.

Thereafter the environmental impacts were evaluated.

Alternative scenarios of the electronic system were modeled with different electronic devices (notebook computer, e-reader (iPad), older model desktop) and varying percentages (5, 10, 25, 50, 100%) of readers printing the report.

Data basis

Average US data was used for the assessment.

Costs related to design, printing and distribution were provided by the UC CEAS. Costs related to reading and disposal were estimated.

Key Assumptions

Design of the report requires same time and costs for both systems

Printed report weighs 133 g

The report is directly labeled and delivered by the US Postal Service

9 KWh/GB was the estimation for the storage and data transfer based on Taylor and Koomey (2008)

Reading time of 15 minutes was spent in both systems

For both systems, the use phase requires two 60 W bulbs

The screen of the computer is a LCD screen

Energy required for the production and disposal of a computer is not considered

Regarding disposal, the household collection and transport to the waste management center costs is 0.05$/kg

No individual printing of the electronic report is considered in the base scenario

Findings

The electronic system reduces the economic costs and environmental impacts significantly. The financial benefit is mainly due to the avoided printing and postal distribution activities. Costs caused by the readers did not differ significantly in both systems.

Total GHG emissions of the printed system are double the amount of GHG emissions caused by the electronic system. The two main contributors are paper production and printing.

The distribution phase caused less environmental impact in the electronic system than in the printed system.

However, reading the electronic report caused more GHG emissions than a printed one.

In terms of water and energy use, the consumption is less for the electronic system.

Similarly, the human toxicity and ecosystem toxicity impacts could be reduced by over 70% in the electronic system due to the lack of paper production and printing.

Main contributors to the energy costs are the paper production and electricity sectors. The electricity sector in the design and production phases contributes the most to the GHGs and water use categories. Metal mining sector is mainly responsible for the two toxicity categories.

The paper production and printing phases are considered to be the highest environmental contributors which can be avoided with an electronic system. Reading the electronic report and taking a printout with an inkjet printer causes a higher environmental impact than the one printed and distributed by the university. The design phase is another significant contributor. The physical distribution of the printed reports did not affect the performance greatly.

Alternative scenario results

Using a different electronic device does not have a significant impact on the environmental impacts. Use of notebook computer or an iPad reduced the energy consumption by 3 and 4%, while an obsolete desktop and monitor use increased the energy consumption by 10%. Regarding the option of printing an electronic report, the study concludes that if 7.5% of the recipients take a printout of the report, the GHG emissions of the printed and electronic systems become equal. With 50% of recipients printing the report, the categories GHG emissions, energy use and water use create an impact which is 3 to 4 times higher than that of a printed report.

Limitations

Screening level of LCA was performed

Average US data was used for estimations

The disadvantage of the EIO LCA is the aggregation of specific processes into sectors

Alternative scenarios were limited

Another disadvantage of the EIO LCA is that paper production is not divided into different sectors based on source materials and the waste management sector does not differentiate between landfill and recycling. These differentiations could considerably affect the environmental performance.

One specific model representing each analyzed electronic device was used.

There is an uncertainty of ink cartridge manufacturer profit margins and ink use

Ensuring an equal effectiveness/benefit of the two options was not part of the study.

Reader behaviours were estimated.

Printed and tablet e-paper newspaper from an environmental perspective – A screening life cycle assessment

Subject of Study

The aim of the study is to assess and compare the potential environmental impacts of printed newspaper and tablet e-paper newspaper.

Impact categories

Resources used, acidification, climate change, eutrophication, photochemical oxidant formation, ozone depletion and toxicity

Functional Unit

The consumption of newspaper during one year by one unique reader

Studied system and boundaries

Printed newspaper system

In the LCA following activities were modeled: forestry, pulp and paper production, editorial work, prepress, printing, distribution and waste management. The production of supply material was also considered.

E-tablet newspaper system

In the LCA following activities were modeled: production of the tablet e-paper device, editorial work, distribution of electronic newspaper via internet, use phase and waste management of the electronic device. Transportation in the different phases was also considered.

Regarding distribution, the electronic newspaper is sent from a server to the individual readers.

Content production of the newspaper was represented in the LCA in terms of energy use (only electricity and heat were assessed for the editorial work).

Method used

A screening LCA was performed on both the systems.

The LCA models were applied to a European scenario and a Swedish scenario. The scenarios differed in the electricity mix, waste management and distribution.

Two weighting methods were applied to the results: Exotax 02 and Ecoindicator 99 (with hierarchist perspective)

The energy consumption for the content production was allocated equally between all readers (independent whether they access the printed or electronic version).

Data basis

Ecoinvent 1.2 was the main data source.

Prepress and printing data were company-specific and based on previous studies.

Some data was specific to a Swedish newspaper company.

Data regarding Internet infrastructure and energy use for data transfer refer to the findings of Taylor and Koomey (2008).

Key Assumptions

Total number of unique readers per day was estimated 86 000. (Considering three types of readers: printed, internet and tablet based)

Printed newspaper

An average newspaper consists of 40 pages in tabloid format.

32 000 copies are printed per day.

On average a newspaper is read by 2.4 readers.

The paper is European average of 45 g/m2 mechanical pulp and DIP containing newsprint.

For the distribution it is assumed 0.0043 l fuel/newspaper was required in the European scenario and 0.015 l fuel/newspaper in the Swedish scenario; the transport per newspaper in the European scenario is less than in the Swedish.

The waste management of newspaper in the European scenario is modeled as 60% material recycling, 30% landfill and 10% incineration.

In the Swedish scenario the waste management is divided into 80% of material recycling and 20% of incineration.

Tablet e-paper newspaper

The electronic equipment is assumed to be produced in China and transported to Europe by ship and truck.

An estimation of the internet infrastructure is included, which consists of the operation of the modem (9 W) and energy use for the core network.

The modem is not turned off when not in use and the allocation of the energy use of the modem covers downloading and a share of the stand by energy.

The average internet user uses the internet for 80 min per day according to a Swedish study.

The average household is assumed 2 persons in Sweden.

20 s/day of internet usage for the newspaper is assumed.

This study assumes an energy use of 3Wh/Mb for servers and data storage.

The e-newspaper is sent twice a day to the reader – 5 MB/day

30 mins of daily reading time of the newspaper is assumed. Other 30 mins of time is spent daily on the tablet.

The lifetime of the tablet is one year.

Regarding disposal, 70% of the material is assumed to be recycled and 30% is incinerated.

Electronic device has a power of 0.75 W

Uploading speed is estimated 3 MB/s

Power consumption for reading is assumed 0.001 W

Downloading speed is assumed 0.25 MB/s

Findings

The result shows there is a potential for tablets to decrease the impact of newspapers.

For the European scenario, it could be concluded that for all impact categories which were taken into consideration, the printed newspaper had a higher potential environmental impact than the electronic system.

For the Swedish scenario, the result was similar – except for the impact of the marine aquatic ecotoxicity, the environmental impact was higher for the printed newspaper.

For total energy use, eutrophication, photochemical ozone creation and for aquatic and terrestric ecotoxicity, the environmental impact of the printed version was double of that of the e-version in both scenarios.

For all the three weighting methods the tablet version was the preferred medium in the European scenario.

In the Swedish scenario, Ecotax02 min and Eco-indicator 99 also preferred the tablet version whereas the Ecotax02 max recommended the printed version although the difference between the print and electronic weighting result is not significant.

Printed Newspaper

For both scenarios the paper production had the highest environmental impact for most of the impact categories.

In the European scenario, 45% of the global warming impact is caused by the paper production. The printing activity was the second highest contributing activity for global warming. In the Swedish scenario, 40% of the global warming impact is caused by the paper production and 30% by the distribution.

The printing causes a lower impact in Sweden than in Europe (in average) indicating a higher printing efficiency in Sweden than the European average.

All three weighting methods identified the paper production phase as the highest contributor. The second highest contributors vary between printing, waste management, distribution depending on the method and the scenario.

Tablet e-newspaper

For all impact categories, the production of the electronic device had the highest environmental impact (in both scenarios). For the category human toxicity the waste management phase created an equal impact as the production phase.

Apart from the production, the impact caused by editorial work and downloading was also significant for many impact categories.

Weighting the results with Ecoindicator 99 and Exotax 02 max, the result shows the tablet e-paper production had the highest impact, followed by editorial work and downloading. For Exotax 02 min editorial work, device production, waste management and downloading were the main contributors. However, incineration had the highest impact in the Swedish scenario, whereas in the European scenario editorial work, production and incineration had an equal impact.

Life time and internet energy use sensitivity analysis

A sensitivity analysis was performed with an increased lifetime of 2 years and the high energy use of internet (16Wh/MB). Doubling the lifetime had a positive impact on the environmental performance; the same effect could be achieved by doubling the daily average use of the device. With an internet use of higher energy consumption, the total impact of the electronic system increased significantly and the size of the newspaper file became a crucial indicator. However, due to the limited use of servers the study concludes the high energy use of the Internet is unlikely.

Different weighting methods focus on different impact categories, resulting in different conclusions regarding the major contributing activities. As the importance of toxicological emissions varies from method to method and knowledge gaps regarding the same exist, the weighting results are uncertain.

The most significant phase of the life cycle for both product systems was the production of the paper and the production of the e-device. For the printed system, number of readers per copy and number of pages per issue were the main factors, similarly the lifetime and multiuse of the e-device for the electronic system. Compared to a web-based newspaper read on a computer, the tablet version has the advantage of low energy consumption during the use phase. On the other hand, the benefits of a computer are a longer lifetime and a multipurpose device. Printed newspaper has the lowest impact during the use phase.

Electricity sources can influence the results as the results for the two scenarios were demonstrated. The Swedish electricity mix in general creates a lower impact than the European average.

Limitations

The greenhouse gas emissions as an indicator for the climate change impact category were assessed excluding biogenic carbon dioxide uptake or emissions.

The journalist’s field work was not considered.

Data and knowledge gaps regarding emissions of toxicological substances (underestimation of the impact categories focusing on toxicological emissions)

The main data lacking for the electronic system was concerning waste management of electronic devices, production of e-ink screen, construction and use of internet infrastructure. Estimations had to be made.

For the printed system, data regarding the production of certain supply chemicals were lacking.

No combinations of different product systems were considered in the study.

The study also concludes that many assumptions regarding usage patterns were made, which have a major impact on the results – such as lifetime and total use of the device and number of readers for the printed newspaper.

Technical data regarding the electronic device was based on the iRex iLiad tablet device.

The tablet is a new product; usage patterns of the device may not be representative once the product is well established in the market.

The production of the electronic device was modeled based on the components.

Printed Scholarly Books and E-book Reading Devices: A comparative Life Cycle Assessment of Two Book Options

Subject of study

The aim of the study was to analyze the life cycle environmental aspects of e-publishing of scholarly books and e-readers and to apply the life cycle models to various scholarly e-book applications and compare the LCA results with conventional printed books.

Impact categories

Global warming, Ozone depletion, Acidification

Functional Unit

Digital system's functional unit

Downloading and reading 40 scholarly e-books on a REB 1100 e-reader

Printed system's functional unit

Reading 40 printed scholarly books

Studied system and boundaries

Traditional Book System

The analyzed system includes the ink and the paper production, followed by the book printing operations (printing, assembling and binding). The book product is then shipped to a wholesaler's warehouse and then to a retail bookstore or library. The use phase includes the library facility infrastructure, collection and storage, personal transportation of the student and the book retrieval and reading by the student. At the end of the life cycle, the book is disposed.

Digital Book System

The analyzed system includes the processing of the raw materials, the production of the e-reader device, the cable and the battery. The final product is then shipped to a wholesaler's warehouse and from there to a retail book store or library. The distribution phase also considers the production and disposal of the packaging. The use phase consists of the following activities: collection and storage, personal transportation, facility infrastructure, data storage, server production and disposal, file transfer, production and disposal of network equipment and the actual e-reader use (reading books). The end of life management phase consists of the disposal of the e-reader.

Method used

LCA models were developed for both systems. The life cycle was split into five phases: material production, manufacturing, product distribution, use and end-of-life management

Data basis

The REB 1100 e-book reader was chosen as the e-reader model for the study

Key assumptions

The document creation and publishing is excluded from the system boundaries as it is considered to be the same for both systems.

The e-book contains the same content as the printed one in form of digital text. No other rich media is included in the e-book for a sensible comparison.

The life time of the e-reader was assumed 5 years.

The screen type of the e-reader was a LCD screen.

The user is a typical college student in the United States owning an e-book reading device

He is enrolled into a 4 year B.A. program. The student has 5 classes per semester. Over the four years, the student is enrolled into total 40 classes.

It is assumed the student must buy one scholarly book per class – a total of 40 textbooks for the program

The student will buy 5 books per visit to the bookstore – 8 trips to the bookstore will be made

The lifetime of a printed book is assumed 4 years

The student keeps the books with himself instead of disposing them.

The average size of a printed book is assumed 500 pages with a standard 7” x 10” size. The corresponding e-book has a file size of 1,372 kB. (53.6 MB for 40 books)

Each book is only read once.

In each class there are 30 students which access the books from a server in the digital system.

Findings

For all the selected impact categories, the environmental impact of the traditional book system was higher than that of the digital system. Especially, for the category global warming, the impact of the printed system was almost four times higher than the impact of the digital system.

For the printed system, the impacts were driven by paper production, electricity for printing operation and personal transportation. For the electronic book system, many of the impacts were driven by the relatively large amount of electricity consumed during the use phase. Server storage created less environmental impact than the physical storage of printed books.

The Life Cycle Inventory result showed that in terms of resource consumption the traditional book system required more raw materials and water inputs. Similarly, the energy consumption and solid waste production were higher. It also produced more air and water pollutant emissions.

The findings of the sensitivity analysis were

- The results for the printed book system is dependent on the number of users per book
- The length of the book has an equal effect on both systems
- When fixed-cost allocations are small, the personal transportation has a significant impact
- Even if personal transportation is not considered, the digital system is preferred over the conventional
- The number of students accessing the server has a significant influence on the environmental impact of the electronic system
- In terms of energy consumption, as long 2 persons in total are accessing the server, the e-reader system is eco-friendlier than the printed system
- The total active use of the e-reader determines the share of the allocation of several processes
- Grid efficiency has an important influence on the digital system's outcome

Limitations

Technical specification data was not on average basis but a reference model was used.

Study time was not considered.

Usage patterns and user profile were estimated but a survey was not conducted to gather the information.

13.2 Appendix B – Process specifications of baseline scenario (inputs/outputs)

Server

Input / Output | Generic Materials | Parameters | Allocations

Material	Place	Material T	Coefficient	Unit	Function
electricity, low voltage	P1	Good	8.49E-04	kWh	0.000849

Material	Place	Material Type	Coefficient	Unit	Function
Operation of server	**P4**	**Reference**	**1.00**	**unit**	

Internet Access

Input / Output | Generic Materials | Parameters | Allocations

Material	Place	Material T	Coefficient	Unit	Function
electricity, low voltage	P16	Good	16.40	kWh	

Material	Place	Material Type	Coefficient	Unit	Function
Operation of Internet	**P19**	**Reference**	**1.00**	**unit**	

Printed books of lecture notes (referred as "Script")

T8: market for paper, woodfree, coated [RER]

T1: Paper delivery to print office

Input / Output | Generic Materials | Parameters | Allocations

Material	Place	Material T	Coefficient	Unit	Function
paper, woodfree, coated	P28	Good	1.00	kg	
transport, freight train	P17	Good	0.60	metric	

Material	Place	Material Type	Coefficient	Unit	Function
paper, woodfree, coated	P22	Good	1.00	kg	

T6: market for transport, freight train [Europe without Switzerland]

T7: operation, printer, laser, colour

Input / Output | Generic Materials | Parameters | Allocations

Material	Place	Material T	Coefficient	Unit	Function
electricity, low voltage	P31	Good	0.50	kWh	2*5/6*300/1000
paper, woodfree, coated	P22	Good	1.37	kg	200*6.86/1000
printer, laser, colour	P34	Good	3.42E-04	unit	2*200/(800*365*4)
toner module, laser printer, colour	P37	Good	0.03	unit	2*200/13000

Material	Place	Material Type	Coefficient	Unit	Function
printed paper	P24	Good	1.38	kg	200*6.9/1000
Benzene [air/unspecified]	P26	Bad	4.80E-07	kg	2*2.4E-07
used toner module, laser pri	P40	Bad	0.05	kg	1.605*2*200/13000

T9: market for electricity, low voltage [CH]

T10: market for printer, laser, colour [GLO]

T11: market for toner module, laser printer, colour [GLO]

T5: market for used toner module, laser printer, colour [GLO]

T13: Assembly of script

Input / Output | Generic Materials | Parameters | Allocations

Material	Place	Material T	Coefficient	Unit	Function
polyurethane, rigid foam	P12	Good	0.03	kg	
printed paper	P24	Good	1.57	kg	6.9*227/1000

Material	Place	Material Type	Coefficient	Unit	Function
Script of lecture slides	P44	Good	1.00	unit	

T20: market for polyurethane, rigid foam [GLO]

T14: Script delivery to University

Input / Output | Generic Materials | Parameters | Allocations

Material	Place	Material T	Coefficient	Unit	Function
Script of lecture slides	P44	Good	1.00	unit	
transport, freight, light commercial vehicl	P3	Good	0.01	metric	1.5963*7.6/1000

Material	Place	Material Type	Coefficient	Unit	Function
Script of lecture slides	P49	Good	1.00	unit	

T4: transport, freight, light commercial vehicle [CH]

T16: Use

Input / Output | Generic Materials | Parameters | Allocations

Material	Place	Material T	Coefficient	Unit	Function
Script of lecture slides	P49	Good	1.00	unit	

Material	Place	Material Type	Coefficient	Unit	Function
Script of lecture slides	RF(3)	Virtual Ref	1.00	unit	
Used Script	P2	Bad	1.26	kg	0.79*1.5963
Used Script	P50	Bad	0.34	kg	0.21*1.5963

T2: No disposal

Input / Output | Generic Materials | Parameters | Allocations

Material	Place	Material T	Coefficient	Unit	Function
Used Script	P2	Bad	1.00	kg	

Material	Place	Material Type	Coefficient	Unit	Function
Used Script	P6	Bad	1.00	kg	

T17: Disposal

Input / Output | Generic Materials | Parameters | Allocations

Material	Place	Material T	Coefficient	Unit	Function
Used Script	P50	Bad	1.00	kg	

Material	Place	Material Type	Coefficient	Unit	Function
waste paper, unsorted	P7	Bad	0.98	kg	1.5663/1.5963
waste polyurethane foam	P16	Bad	0.02	kg	0.03/1.5963

T15: market for waste paper, unsorted [CH]

T21: treatment of waste polyurethane foam, collection for final disposal [CH]

Self-printed Lecture Notes (referred as "printed paper")

T5: market for paper, woodfree, uncoated [RER]

T10: paper delivery to student

Input / Output | Generic Materials | Parameters | Allocations

Material	Place	Material T	Coefficient	Unit	Function
paper, woodfree, uncoated	P14	Good	1.00	kg	
transport, freight train	P17	Good	0.60	metric	

Material	Place	Material Type	Coefficient	Unit	Function
paper, woodfree, uncoated	P33	Good	1.00	kg	

T11: market for transport, freight train [Europe without Switzerland]

T12: operation, printer, laser, colour

Input / Output | Generic Materials | Parameters | Allocations

Material	Place	Material T	Coefficient	Unit	Function
electricity, low voltage	P34	Good	0.40	kWh	1.583*5/6*300/1000
paper, woodfree, uncoated	P33	Good	1.00	kg	200*5/1000
printer, laser, colour	P37	Good	0.03	unit	1.583*200/9600
toner module, laser printer, colour	P29	Good	0.02	unit	200/13000*1.583

Material	Place	Material Type	Coefficient	Unit	Function
printed paper	P30	Good	1.01	kg	200*5.03166/1000
Benzene [air/unspecified]	P32	Bad	3.80E-07	kg	1.583*2.4E-07
used toner module, laser pri	P43	Bad	0.04	kg	1.605*200/13000*1.583

T13: market for electricity, low voltage [CH]

T14: market for printer, laser, colour [GLO]

T15: market for toner module, laser printer, colour [GLO]

T16: market for used toner module, laser printer, colour [GLO]

T17: Use

Input / Output | Generic Materials | Parameters | Allocations

Material	Place	Material T	Coefficient	Unit	Function
printed paper	P30	Good	1.00	kg	

Material	Place	Material Type	Coefficient	Unit	Function
printed paper	**RF(2)**	**Virtual Ref**	**1.00**	**kg**	
waste paper, unsorted	P46	Bad	0.44	kg	
waste paper, unsorted	P49	Bad	0.56	kg	

T18: market for waste paper, unsorted [CH]

Desktop Computer

T9: Production of desktop computer and acc.

Input / Output | Generic Materials | Parameters | Allocations

Material	Place	Material T	Coefficient	Unit	Function
computer, desktop, without screen	P8	Good	1.00	unit	
display, liquid crystal, 17 inches	P47	Good	1.83	unit	
keyboard	P25	Good	1.00	unit	
pointing device, optical mouse, with cabl	P53	Good	1.00	unit	

Material	Place	Material Type	Coefficient	Unit	Function
desktop computer and acc.	P5	Good	1.00	unit	

T18: market for display, liquid crystal, 17 inches [GLO]

T12: market for keyboard [GLO]

T3: market for computer, desktop, without screen [GLO]

T20: pointing device production, optical mouse, with cable [GLO]

T5: Transportation

Input / Output | Generic Materials | Parameters | Allocations

Material	Place	Material T	Coefficient	Unit	Function
desktop computer and acc.	P5	Good	1.00	unit	
transport, freight, lorry 16-32 metric ton,	P38	Good	14.19	metric	500*28.37/1000
transport, freight, sea, transoceanic ship	P35	Good	425.55	metric	15000*28.37/1000

Material	Place	Material Type	Coefficient	Unit	Function
desktop computer and acc.	P6	Good	1.00	unit	

T14: market for transport, freight, lorry 16-32 metric ton, EURO4 [GLO]

T13: market for transport, freight, sea, transoceanic ship [GLO]

T2: Use

Input / Output | Generic Materials | Parameters | Allocations

Material	Place	Material T	Coefficient	Unit	Function
desktop computer and acc.	P6	Good	1.00	unit	
operation, computer, desktop, with liquid	P2	Good	7'694.44	hour	5.52*(52-4)*6*4.84
operation, computer, desktop, with liquid	P73	Good	27'105.41	hour	5.52*(52-4)*6*17.05
operation, computer, desktop, with liquid	P77	Good	3'354.39	hour	5.52*(52-4)*6*2.11

Material	Place	Material Type	Coefficient	Unit	Function
desktop computer and acc.	P7	Good	1.00	unit	

T25: operation, computer, desktop, with liquid crystal display, off mode [CH], modified

Input / Output | Generic Materials | Parameters | Allocations

Material	Place	Material T	Coefficient	Unit	Function
electricity, low voltage	P32	Good	3.50E-03	kWh	

Material	Place	Material Type	Coefficient	Unit	Function
operation, computer, deskto	P73	Good	1.00	hour	

T11: market for electricity, low voltage [CH]

T1: operation, computer, desktop, with liquid crystal display, active mode [CH], modified

Input / Output | Generic Materials | Parameters | Allocations

Material	Place	Material T	Coefficient	Unit	Function
electricity, low voltage	P23	Good	0.33	kWh	(592+66)*0.5/1000

Material	Place	Material Type	Coefficient	Unit	Function
operation, computer, deskto	P2	Good	1.00	hour	

T7: market for electricity, low voltage [CH]

T26: operation, computer, desktop, with liquid crystal display, standby mode [CH], modified

Input / Output | Generic Materials | Parameters | Allocations

Material	Place	Material T	Coefficient	Unit	Function
electricity, low voltage	P29	Good	0.03	kWh	

Material	Place	Material Type	Coefficient	Unit	Function
operation, computer, deskto	P77	Good	1.00	hour	

T10: market for electricity low voltage

T4: Disposal of LCD Display

Input / Output | Generic Materials | Parameters | Allocations

Material	Place	Material T	Coefficient	Unit	Function
desktop computer and acc.	P7	Good	1.00	unit	

Material	Place	Material Type	Coefficient	Unit	Function
desktop computer and acc.	**RF**	**Virtual Ref**	**1.00**	**unit**	
desktop computer and acc.	P13	Bad	1.00	unit	
used liquid crystal display	P11	Bad	9.32	kg	9.32

T6: market for used liquid crystal display [GLO]

Laptop Computer

T9: Production of 16 inch laptop computer

Input / Output | Generic Materials | Parameters | Allocations

Material	Place	Material T	Coefficient	Unit	Function
computer, laptop	P8	Good	1.00	unit	
liquid crystal display, unmounted	P17	Good	0.25	kg	

Material	Place	Material Type	Coefficient	Unit	Function
16 inch laptop computer	P18	Good	1.00	unit	

T10: market for computer, laptop [GLO]

T11: market for liquid crystal display, unmounted [GLO]

T3: Transportation

Input / Output | Generic Materials | Parameters | Allocations

Material	Place	Material T	Coefficient	Unit	Function
16 inch laptop computer	P18	Good	1.00	unit	
transport, freight, lorry 16-32 metric ton,	P1	Good	2.19	metric	500*4.373/1000
transport, freight, sea, transoceanic ship	P4	Good	65.60	metric	15000*4.373/1000

Material	Place	Material Type	Coefficient	Unit	Function
16 inch laptop computer	P7	Good	1.00	unit	

T2: market for transport, freight, sea, transoceanic ship [GLO]

T1: market for transport, freight, lorry 16-32 metric ton, EURO4 [GLO]

T4: Use

Input / Output | Generic Materials | Parameters | Allocations

Material	Place	Material T	Coefficient	Unit	Function
16 inch laptop computer	P7	Good	1.00	unit	
operation, computer, laptop, active mode	P21	Good	8'778.24	hour	(52-4)*4*6*7.62
operation, computer, laptop, off mode	P9	Good	11'704.32	hour	(52-4)*4*6*10.16
operation, computer, laptop, standby/sle	P13	Good	7'165.44	hour	(52-4)*4*6*6.22

Material	Place	Material Type	Coefficient	Unit	Function
16 inch laptop computer	RF	Virtual Ref	1.00	unit	
16 inch laptop computer	P43	Bad	1.00	unit	

T8: operation, computer, laptop, active mode [CH] modified

Input / Output | Generic Materials | Parameters | Allocations

Material	Place	Material T	Coefficient	Unit	Function
electricity, low voltage	P54	Good	0.02	kWh	42.78/2/1000

Material	Place	Material Type	Coefficient	Unit	Function
operation, computer, laptop,	P21	Good	1.00	hour	

T19 : market for electricity, low voltage [CH]

T6: operation, computer, laptop, standby/sleep mode [CH] modified

Input / Output | Generic Materials | Parameters | Allocations

Material	Place	Material T	Coefficient	Unit	Function
electricity, low voltage	P47	Good	4.00E-03	kWh	

Material	Place	Material Type	Coefficient	Unit	Function
operation, computer, laptop,	P13	Good	1.00	hour	

T18: market for electricity, low voltage [CH]

T5: operation, computer, laptop, off mode [CH] modified

Input / Output | Generic Materials | Parameters | Allocations

Material	Place	Material T	Coefficient	Unit	Function
electricity, low voltage	P44	Good	1.50E-03	kWh	

Material	Place	Material Type	Coefficient	Unit	Function
operation, computer, laptop,	P9	Good	1.00	hour	

T17: market for electricity, low voltage [CH]

Tablet Computer

T1: Production

Material	Place	Material T	Coefficient	Unit	Function
aluminium, wrought alloy	P50	Good	0.14	kg	
battery, Li-ion, rechargeable, prismatic	P53	Good	0.13	kg	
copper	P56	Good	0.03	kg	0.97*26/1000
electricity, medium voltage	P1	Good	0.32	kWh	1.66/5.25
gold	P59	Good	6.24E-05	kg	0.0024*26/1000
light emitting diode	P62	Good	0.01	kg	
liquid crystal display, unmounted	P77	Good	0.24	kg	0.257-0.0126
palladium	P65	Good	2.50E-05	kg	0.00096*26/1000
photovoltaic cell factory	P68	Good	5.79E-09	unit	1/(25*7900000/6)/5.25
polystyrene, high impact	P71	Good	0.02	kg	
power adapter, for laptop	P74	Good	0.16	unit	
printed wiring board, surface mounted, u	P92	Good	0.04	kg	
silver	P80	Good	7.02E-04	kg	0.027*26/1000
tap water, at user	P12	Good	307.62	kg	1615/5.25

Material	Place	Material Type	Coefficient	Unit	Function
iPad	P26	Good	1.00	unit	
wastewater, unpolluted	P83	Bad	0.31	m3	1.62/5.25
Water [air/unspecified]	P114	Bad	0.02	m3	0.1/5.25
Water [water/unspecified]	P115	Bad	0.29	m3	1.52/5.25

T32: market for silver [GLO]

T31: market for liquid crystal display, unmounted [GLO]

T30: market for power adapter, for laptop [GLO]

T29: market for polystyrene, high impact [GLO]

T24: market for copper [GLO]

T21: market for tab water, at user [RoW]

T20: market for electricity, medium voltage [CN]

T22: market for aluminium, wrought alloy [GLO]

T23: market for battery, Li-ion rechargeable, prismatic [GLO]

T25: market for gold [GLO]

T26: market for lightemitting diode [GLO]

T27: market for palladium [GLO]

T36: market for printed wiring board, surface mounted, unspecified, Pb free [GLO]

T28: market for photovoltaic cell factory [GLO]

T33: market for wastewater, unpolluted [GLO]

T8: Packaging

Input / Output | Generic Materials | Parameters | Allocations

Material	Place	Material T	Coefficient	Unit	Function
corrugated board box	P102	Good	0.44	kg	
iPad	P26	Good	1.00	unit	
polystyrene, general purpose	P105	Good	9.00E-03	kg	
polystyrene, high impact	P108	Good	0.07	kg	

Material	Place	Material Type	Coefficient	Unit	Function
packaged iPad	P27	Good	1.00	unit	

T41: market for polystyrene, high impact [GLO]

T40: market for polystyrene, general purpose [GLO]

T39: market for corrugated board box [GLO]

T10: Transportation

Input / Output | Generic Materials | Parameters | Allocations

Material	Place	Material T	Coefficient	Unit	Function
packaged iPad	P27	Good	1.00	unit	
transport, freight, aircraft	P35	Good	9.49	metric	7812*1.215/1000
transport, freight, lorry 16-32 metric ton,	P86	Good	0.61	metric	500*1.215/1000

	Material	Place	Material Type	Coefficient	Unit	Function
▶	packaged iPad	P38	▲ Good	1.00	unit	

T34: market for transport, freight, lorry 16-32 metric ton, EURO4 [GLO]

T12: market for transport, freight, aircraft [GLO]

T13: Unpacking

Input / Output | Generic Materials | Parameters | Allocations

	Material	Place	Material T	Coefficient	Unit	Function
▶	packaged iPad	P38	▲ Good	1.00	unit	

	Material	Place	Material Type	Coefficient	Unit	Function
▶	iPad	P46	▲ Good	1.00	unit	
	waste paperboard	P42	▲ Bad	0.44	kg	
	waste polystyrene	P39	▲ Bad	0.08	kg	0.068+0.009

T37: treatment of waste paperboard, sorting plant [CH]

T38: treatment of waste polystyrene, municipal incineration [CH]

T16: Use

Input / Output | Generic Materials | Parameters | Allocations

Material	Place	Material T	Coefficient	Unit	Function
iPad	P46	Good	1.00	unit	
operation, iPad, active mode	P3	Good	3'959.28	hour	3.25*(52-4)*6*4.23
operation, iPad, sleep mode	P13	Good	14'648.40	hour	3.25*(52-4)*6*15.65

Material	Place	Material Type	Coefficient	Unit	Function
iPad	P47	Good	1.00	unit	

T2: operation, active mode

Input / Output | Generic Materials | Parameters | Allocations

Material	Place	Material T	Coefficient	Unit	Function
electricity, low voltage	P4	Good	1.85E-03	kWh	3.7/2/1000

Material	Place	Material Type	Coefficient	Unit	Function
operation, iPad, active mod	P3	Good	1.00	hour	

T4: market for electricity, low voltage [CH]

T5: operation, sleep mode

Input / Output | Generic Materials | Parameters | Allocations

Material	Place	Material T	Coefficient	Unit	Function
electricity, low voltage	P14	Good	5.63E-04	kWh	0.45/0.8/1000

Material	Place	Material Type	Coefficient	Unit	Function
operation, iPad, sleep mode	P13	Good	1.00	hour	

T11: market for electricity, low voltage [CH]

T19: Disposal

Input / Output | Generic Materials | Parameters | Allocations

Material	Place	Material T	Coefficient	Unit	Function
iPad	P47	Good	1.00	unit	

Material	Place	Material Type	Coefficient	Unit	Function
iPad	RF	Virtual Ref	1.00	unit	
iPad	P89	Bad	1.00	unit	

T42: Conversion

Input / Output | Generic Materials | Parameters | Allocations

Material	Place	Material T	Coefficient	Unit	Function
iPad	P89	Bad	1.00	unit	

Material	Place	Material Type	Coefficient	Unit	Function
used laptop computer	P111	▲ Bad	0.70	kg	0.613+0.085

T43: market for used laptop computer [GLO]

13.3 Appendix C – Data regarding booked courses from survey responses

Course name	Number of survey respondents
Software Engineering	24
Wirtschaftsinformatik	21
Distributed Systems	17
Informatik I	15
Formal Methods for Computer Science II (L+E)	15
BWL III	13
Fortgeschrittene Programmierung in C++	13
Mikrokönomik	12
System Software	12
FGDI 1	11
Info Oek	11
BWL 1	11
IT Projektmanagement	10
Financial Accounting	10
Mathematik I	9
UNIX-Betriebssysteme und -Werkzeuge	6
XML Technologies	5
Introduction to Game Theory	5
Einführung in die Computerlinguistik 1	5
HCI	5
Requirements Engineering I	4
Praktikum Datenbanksysteme	4
Principles in HRM	4
Finance	3
Multimedia Systems (L+E)	3
The neurobiology of consciousness	2
Programmiertechniken in der Computerlinguistik 3	2
Structure Plasticity Repair of Nervous System	2
Progr. Techniken CL 1	2
Empirische Wirtschaftsforschung	2
Corporate Finance 1	2
Informatik Vertiefung	2
Computer Simulationen	1
Neuromorphic Engineering	1
Development of Nervous System	1
Operations Management	1
Vertiefung Schweizer Politik	1
design thinking	1
Geist und Sprache	1
Fundamentals of Image Processing and Computer Vision	1

Rohstoffe der Erde	1
Sustainable HCI (MSC)	1
VT Pol Oek	1
Einführung in die Ethik für Wirtschaftswissenschaftler/innen	1
Governance	1
Lithosphäre	1
Seminar Graphics & Multimedia	1
Business and Society	1
Erd- und Klimageschichte	1
International Management (BOEC0330)	1
Neuroinformatik	1
Database Management and Performance Tuning	1
Compilerdesign	1
Spezialisierung Schweizer Politik	1
CL AV Sprachtechnologie als Beitrag zur Barrierefreiheit	1
Testkonstruktion und Testtheorie	1
Physische Geographie V	1
Vertiefung Policy Analyse	1
CL AV Sprachtechnologie für grosse Datenmengen: Von Informationsextraktion bis Web Mining	1
Fundamentals of Image Processing and Computer Vision	1
Vertiefung Geographische Informationswissenschaften	1
Designing Effective Organization	1
Andwendung der Methoden	1
Methoden der Fernerkundung	1
Wahlmodul Direkte Demokratie	1
Antropologiegeschichte	1
Computergestütztes Experimentieren I	1

13.4 Appendix D – Data regarding file size of individual courses

Formal Methods for Computer Science I

File size in KB	#slides	# A4 text-size pages
213		15
189		12
398		23
693		53
307		11
2307	30	
438		13
578	30	
1321	43	
323	30	
1836	41	
786	32	
804	39	
894	28	
246	23	
198	24	
73	5	
260		11
11864	**325**	**138**

Informatik im Unternehmen

Total file size in KB	Total #slides	Total #A4 text pages
38412	**504**	**146**

Informatik I

File size in KB	#slides	#A4 text-size pages
961	66	
416	19	
1753	59	
985	45	
835	26	
1069	42	
731	48	
380	18	
775	21	
1149	49	
130		5
163		6
126		8
167		6
148		5
175		9
103		2
45		4
82		8
279		8
201		7
127		8
8023	35	
668	77	
2482	128	
793	102	
2972	59	
199	47	
1657	17	
27594	**858**	**76**

Mikroökonomik

File size in KB	# slides	# A4 text-size pages
584	49	
1155	114	
590	77	
659	99	
208	26	
48		4
91		7
86		6
63		5
91		5
117		7
117		7
103		7
71		7
88		5
72		8
72		8
103	7	
26		2
42		3
39		3
40		2
32		1
45		3
30		2
35		2
32		2
30		2
37		2
31		2
4737	**372**	**102**

Software Engineering

File size in KB	# slides	# A4 text-size pages
156		3
1245	65	
503	13	
45981	122	
586		55
1861	41	
1177	21	
629	14	
4514	104	
1129	73	
373	13	
598	65	
677	39	
272	49	
527	31	
956	53	
667	50	
509	40	
626	38	
257	36	
649	35	
136	13	
191	21	
304	32	
139	18	
120	10	
384	7	
1509	41	
2383		3
175		4
401		7
180		4
221		5
1254	56	
387		6
189		5
185		4
340		1
63		2
118		12

268		7
275		18
127		13
259		13
170		24
428		23
14		4
162		20
16		4
21		5
21		5
74332	**1100**	**247**

Distributed Systems

File size in KB	# slides	# A4 text-size pages
3828	63	
1977	97	
2109	51	
436	23	
2945	43	
1050	29	
2686	66	
4678	89	
14888	136	
41		3
239		17
34877	**597**	**20**

Advanced Programming in C++

File size in KB	# slides	# A4 text-size pages
10		3
432	53	
499	58	
395	47	
477	58	
397	50	
240	25	
450	43	
380	46	
354	42	
483	56	
29		6
21		5
4167	**478**	**14**

Formal Methods for Computer Science II

File size in KB	# slides	# A4 text-size pages
16		2
83		5
105		6
497		28
615		28
83		2
120		6
118		2
235		5
289		5
321		14
4463	115	
35064	282	
4021	33	
6061		28
249		24
5539		28
1740		14
6762		24
1494		20
2083	49	
2686	88	
4529	126	
3382	91	
12441	185	
4048	59	
4976	65	
4633	57	
6627	59	
108		2
284		3
142		4
479		6
479		6
48		2
114820	**1209**	**264**

Systems Software

File size in KB	# slides	# A4 text-size pages
592	27	
591	31	
1239	29	
691	25	
382	20	
973	39	
580	68	
329	31	
1572	61	
1189	47	
94		2
1353	27	
117		2
666	13	
131		3
904	16	
535		3
1205	22	
373	7	
104		2
765	14	
91		2
494	48	
14435		61
29405	**525**	**75**

BWL III

File size in KB	# slides	# A4 text-size pages
476	44	
914	42	
658	44	
709	42	
459	30	
13	1	
593	44	
537	42	
668	47	
248	30	
171		5
136		4
139		3
153		4
11	1	
139		12
1470		1
291		2
1382	26	
433		6
253		2
964	29	
427		9
250		2
819	24	
415		8
250		3
652	22	
535		9
221		2
426	13	
260		4
218	15	
137	9	
107	11	
30	3	
147	11	
255	18	
108		1
3077	55	
2138	40	

2165	36	
1657	29	
1728	28	
26839	**736**	**77**

Wirtschaftsinformatik

File size in KB	# slides	# A4 text-size pages
849		5
4712		46
3587		28
204		1
121		1
149		2
167		3
400		2
266		2
43		1
53		1
44		1
47		1
265		2
253	17	
700	36	
1375	51	
886	30	
1989	74	
1432	68	
1142	70	
3316	86	
3317	53	
2430	51	
1525	42	
3511	64	
2424	103	
299	11	
473	9	
349	9	
163	5	
36491	**779**	**96**

13.5 Appendix E – Survey questionnaire

***1. In welchem Semester studierst du?**

Semester

***2. Studierst du Informatik im Hauptfach oder Nebenfach?**

- Hauptfach
- Nebenfach

***3. Gib die Studienrichtung an**

- Wirtschatsinformatik
- Softwaresysteme
- Angewandte Informatik
- Sonstiges (bitte angeben)

***4. Wie viele Vorlesungen hast du dieses Semester gebucht (andere Typen von Lehrveranstaltungen wie Seminare und Praktika sind ausgeschlossen)?**

Anzahl Vorlesungen

***5. Wie vielen Credits entspricht das in der Summe? (nur Vorlesungen)**

Anzahl Credits

***6. Wie oft liest du die Vorlesungsunterlagen während der Vorlesung auf**

	immer	meistens	manchmal	selten	nie
einem Laptop mit	◯	◯	◯	◯	◯
einem Tablet mit	◯	◯	◯	◯	◯
einem Smartphone mit	◯	◯	◯	◯	◯
gedrucktem Papier mit	◯	◯	◯	◯	◯

***7. Wie oft liest du die Vorlesungsunterlagen ausserhalb der Vorlesung (zu beliebigen Zwecken z.B. als Grundlage für das Lösen von Assignments, zur Prüfungsvorbereitung, zur Vorbereitung auf die Vorlesung) auf**

	immer	meistens	manchmal	selten	nie
einem Desktop Computer	◯	◯	◯	◯	◯
einem Laptop	◯	◯	◯	◯	◯
einem Tablet	◯	◯	◯	◯	◯
einem Smartphone	◯	◯	◯	◯	◯
gedrucktem Papier	◯	◯	◯	◯	◯

Wie viele Stunden pro Woche benützt du die einzelnen Medien zum Studieren der Vorlesungsunterlagen (inkl. während der Vorlesung)?

Bitte trage für jede im laufenden Semester gebuchte Vorlesung den Vorlesungstitel, die entsprechende Anzahl Credits und die verbrachte Zeit pro Woche für die einzelnen Medien ein. Die verbrachte Zeit bezieht sich ausschliesslich auf die Vorlesungsunterlagen

Fülle für die gebuchten Vorlesungen jeweils alle Zeilen aus. Für Geräte, die du nicht verwendest, trage bei den Zeitangaben eine 0 ein.

Es ist möglich, die Angaben für bis zu 12 Vorlesungen zu machen.

*8. Vorlesung 1

Vorlesungstitel

Credits

Verbrachte Zeit (in Stunden) pro Woche auf dem Desktop Computer

Verbrachte Zeit (in Stunden) pro Woche auf dem Laptop

Verbrachte Zeit (in Stunden) pro Woche auf dem Tablet

Verbrachte Zeit (in Stunden) pro Woche auf Papier (gedrucktes Material)

Verbrachte Zeit (in Stunden) pro Woche auf dem Smartphone

Besitzt du dazu ein Vorlesungsskript vom Studentenladen?

9. Vorlesung 2

Vorlesungstitel

Credits

Verbrachte Zeit (in Stunden) pro Woche auf dem Desktop Computer

Verbrachte Zeit (in Stunden) pro Woche auf dem Laptop

Verbrachte Zeit (in Stunden) pro Woche auf dem Tablet

Verbrachte Zeit (in Stunden) pro Woche auf Papier (gedrucktes Material)

Verbrachte Zeit (in Stunden) pro Woche auf dem Smartphone

Besitzt du dazu ein Vorlesungsskript vom Studentenladen?

10. Vorlesung 3

Vorlesungstitel

Credits

Verbrachte Zeit (in Stunden) pro Woche auf dem Desktop Computer

Verbrachte Zeit (in Stunden) pro Woche auf dem Laptop

Verbrachte Zeit (in Stunden) pro Woche auf dem Tablet

Verbrachte Zeit (in Stunden) pro Woche auf Papier (gedrucktes Material)

Verbrachte Zeit (in Stunden) pro Woche auf dem Smartphone

Besitzt du dazu ein Vorlesungsskript vom Studentenladen?

11. Vorlesung 4

Vorlesungstitel	
Credits	
Verbrachte Zeit (in Stunden) pro Woche auf dem Desktop Computer	
Verbrachte Zeit (in Stunden) pro Woche auf dem Laptop	
Verbrachte Zeit (in Stunden) pro Woche auf dem Tablet	
Verbrachte Zeit (in Stunden) pro Woche auf Papier (gedrucktes Material)	
Verbrachte Zeit (in Stunden) pro Woche auf dem Smartphone	
Besitzt du dazu ein Vorlesungsskript vom Studentenladen?	

12. Vorlesung 5

Vorlesungstitel	
Credits	
Verbrachte Zeit (in Stunden) pro Woche auf dem Desktop Computer	
Verbrachte Zeit (in Stunden) pro Woche auf dem Laptop	
Verbrachte Zeit (in Stunden) pro Woche auf dem Tablet	
Verbrachte Zeit (in Stunden) pro Woche auf Papier (gedrucktes Material)	
Verbrachte Zeit (in Stunden) pro Woche auf dem Smartphone	
Besitzt du dazu ein Vorlesungsskript vom Studentenladen?	

13. Vorlesung 6

Vorlesungstitel	
Credits	
Verbrachte Zeit (in Stunden) pro Woche auf dem Desktop Computer	
Verbrachte Zeit (in Stunden) pro Woche auf dem Laptop	
Verbrachte Zeit (in Stunden) pro Woche auf dem Tablet	
Verbrachte Zeit (in Stunden) pro Woche auf Papier (gedrucktes Material)	
Verbrachte Zeit (in Stunden) pro Woche auf dem Smartphone	
Besitzt du dazu ein Vorlesungsskript vom Studentenladen?	

14. Vorlesung 7

Vorlesungstitel	
Credits	
Verbrachte Zeit (in Stunden) pro Woche auf dem Desktop Computer	
Verbrachte Zeit (in Stunden) pro Woche auf dem Laptop	
Verbrachte Zeit (in Stunden) pro Woche auf dem Tablet	
Verbrachte Zeit (in Stunden) pro Woche auf Papier (gedrucktes Material)	
Verbrachte Zeit (in Stunden) pro Woche auf dem Smartphone	
Besitzt du dazu ein Vorlesungsskript vom Studentenladen?	

15. Vorlesung 8

Vorlesungstitel	
Credits	
Verbrachte Zeit (in Stunden) pro Woche auf dem Desktop Computer	
Verbrachte Zeit (in Stunden) pro Woche auf dem Laptop	
Verbrachte Zeit (in Stunden) pro Woche auf dem Tablet	
Verbrachte Zeit (in Stunden) pro Woche auf Papier (gedrucktes Material)	
Verbrachte Zeit (in Stunden) pro Woche auf dem Smartphone	
Besitzt du dazu ein Vorlesungsskript vom Studentenladen?	

16. Vorlesung 9

Vorlesungstitel	
Credits	
Verbrachte Zeit (in Stunden) pro Woche auf dem Desktop Computer	
Verbrachte Zeit (in Stunden) pro Woche auf dem Laptop	
Verbrachte Zeit (in Stunden) pro Woche auf dem Tablet	
Verbrachte Zeit (in Stunden) pro Woche auf Papier (gedrucktes Material)	
Verbrachte Zeit (in Stunden) pro Woche auf dem Smartphone	
Besitzt du dazu ein Vorlesungsskript vom Studentenladen?	

17. Vorlesung 10

Vorlesungstitel	
Credits	
Verbrachte Zeit (in Stunden) pro Woche auf dem Desktop Computer	
Verbrachte Zeit (in Stunden) pro Woche auf dem Laptop	
Verbrachte Zeit (in Stunden) pro Woche auf dem Tablet	
Verbrachte Zeit (in Stunden) pro Woche auf Papier (gedrucktes Material)	
Verbrachte Zeit (in Stunden) pro Woche auf dem Smartphone	
Besitzt du dazu ein Vorlesungsskript vom Studentenladen?	

18. Vorlesung 11

Vorlesungstitel	
Credits	
Verbrachte Zeit (in Stunden) pro Woche auf dem Desktop Computer	
Verbrachte Zeit (in Stunden) pro Woche auf dem Laptop	
Verbrachte Zeit (in Stunden) pro Woche auf dem Tablet	
Verbrachte Zeit (in Stunden) pro Woche auf Papier (gedrucktes Material)	
Verbrachte Zeit (in Stunden) pro Woche auf dem Smartphone	
Besitzt du dazu ein Vorlesungsskript vom Studentenladen?	

19. Vorlesung 12

Vorlesungstitel

Credits

Verbrachte Zeit (in Stunden) pro Woche auf dem Desktop Computer

Verbrachte Zeit (in Stunden) pro Woche auf dem Laptop

Verbrachte Zeit (in Stunden) pro Woche auf dem Tablet

Verbrachte Zeit (in Stunden) pro Woche auf Papier (gedrucktes Material)

Verbrachte Zeit (in Stunden) pro Woche auf dem Smartphone

Besitzt du dazu ein Vorlesungsskript vom Studentenladen?

*20. Wie oft druckst du Vorlesungsunterlagen aus?

◯ immer ◯ meistens ◯ manchmal ◯ selten ◯ nie

*21. Verwendest du dabei Papiergrösse A4?

◯ Ja

◯ Nein, sondern:

*22. Wie viel Prozent der selbst ausgedruckten Vorlesungsunterlagen sind beidseitig bedruckt?

Prozent

*23. Wie viele Vorlesungsfolien oder Skriptseiten pro gedruckte Seite druckst du durchschnittlich aus?

◯ 1

◯ 2

◯ 4

◯ 6

◯ 9

◯ 16

◯ Sonstiges (bitte angeben)

*24. Wie viel Blatt Papier pro Woche Vorlesungszeit verwendest du ungefähr, um Vorlesungsunterlagen auszudrucken (insgesamt für alle Vorlesungen)?

Anzahl

*25. Welchen Druckertyp verwendest du überwiegend, um Vorlesungsunterlagen auszudrucken?

◯ Tintenstrahldrucker

◯ Laserdrucker

26. Falls du beide Druckertypen verwendest (Tintenstrahl und Laser), wie viel Prozent der ausgedruckten Vorlesungsunterlagen werden auf einem Laserdrucker gedruckt?

Prozent

*27. Was passiert mit den ausgedruckten Vorlesungsunterlagen nach Semesterende (in Prozent)?

	in Prozent
entsorge ich als Altpapier	
behalte ich	
gebe ich weiter an Mitstudenten	

Sonstiges (bitte angeben)

Falls du keine gekauften Vorlesungsunterlagen besitzt, trage bei der folgenden Frage überall 0% ein.

*28. Was passiert mit den gekauften Vorlesungsunterlagen/Skripts nach Semesterende (in Prozent)?

	in Prozent
entsorge ich als Altpapier	
behalte ich	
gebe ich weiter an Mitstudenten	

Sonstiges (bitte angeben)

*29. Hast du einen Desktop Computer?

- Ja
- Nein

Bitte fülle die folgende Tabelle aus.

Die Anzahl Stunden pro Tag im aktiven, Standby- & Off-Modus muss in der Summe 24 sein.

*30. Desktop Computer

Anzahl Stunden pro Tag im aktiven Modus	
Anzahl Stunden pro Tag im Standby-Modus	
Anzahl Stunden pro Tag im Off-Modus	
Geschätzte Lebensdauer in Anzahl Jahren (vom Einkauf bis zur Ausserbetriebnahme)	
Leistung des Desktop Computers(siehe Leistungsschild) - bitte gib auch die Einheit ein (Watt oder VA oder A)	
Leistung des Monitors(siehe Leistungsschild) - bitte gib auch die Einheit ein (Watt oder VA oder A)	
Bildschirmdiagonale des Monitors in Zoll	

*31. Hast du einen Laptop?

- ja
- nein

Bitte fülle die folgende Tabelle aus.

Die Anzahl Stunden pro Tag im aktiven, Standby- & Off-Modus muss in der Summe 24 sein.

*32. Laptop

Anzahl Stunden pro Tag im aktiven Modus	
Anzahl Stunden pro Tag im Standby-Modus	
Anzahl Stunden pro Tag im Off-Modus	
Geschätzte Lebensdauer in Anzahl Monaten (vom Einkauf bis zur Ausserbetriebnahme)	
Leistung des Netzteils, das zum Aufladen verwendet wird (siehe Leistungsschild) - bitte gib auch die Einheit ein (Watt oder VA oder A)	
Akkulaufzeit in Anzahl Stunden	
Dauer zum Aufladen des Akkus in Anzahl Stunden	
Leistung eines separaten Monitors, falls verwendet (siehe Leistungsschild) - bitte gib auch die Einheit ein (Watt oder VA oder A)	
Bildschirmdiagonale des meistens verwendeten Displays oder Monitors in Zoll	

*33. Hast du ein Tablet?

- ◯ ja
- ◯ nein

Bitte fülle die folgende Tabelle aus.

Die Anzahl Stunden pro Tag im aktiven, Standby- & Off-Modus muss in der Summe 24 sein.

*34. Tablet

Anzahl Stunden pro Tag im aktiven Modus	
Anzahl Stunden pro Tag im Standby-Modus	
Anzahl Stunden pro Tag im Off-Modus	
Geschätzte Lebensdauer in Anzahl Monaten (vom Einkauf bis zur Ausserbetriebnahme)	
Input-Leistung des Netzteils, das zum Aufladen verwendet wird (siehe Leistungsschild) - bitte gib auch die Einheit ein (Watt oder VA oder A)	
Akkulaufzeit in Anzahl Stunden	
Dauer zum Aufladen des Akkus in Anzahl Stunden	
Bildschirmdiagonale des Displays in Zoll	

*35. Hast du ein Smartphone?

- ◯ ja
- ◯ nein

Bitte fülle die folgende Tabelle aus.

Die Anzahl Stunden pro Tag im aktiven, Standby- & Off-Modus muss in der Summe 24 sein.

*36. Smartphone

Anzahl Stunden pro Tag im aktiven Modus	
Anzahl Stunden pro Tag im Standby-Modus	
Anzahl Stunden pro Tag im Off-Modus	
Geschätzte Lebensdauer in Anzahl Monaten (vom Einkauf bis zur Ausserbetriebnahme)	
Input-Leistung des Netzteils, das zum Aufladen verwendet wird (siehe Leistungsschild) - bitte gib auch die Einheit ein (Watt oder VA oder A)	
Akkulaufzeit in Anzahl Stunden	
Dauer zum Aufladen des Akkus in Anzahl Stunden	
Bildschirmdiagonale des Displays in Zoll	

*37. Wie oft greifst du auf die gleichen Vorlesungsmaterialien über ein elektronisches Gerät zu, die du bereits ausgedruckt hast?

- ◯ immer
- ◯ meistens
- ◯ manchmal
- ◯ selten
- ◯ nie

Sonstiges (bitte angeben)

*38. Vorlesungunterlagen gelangen auf meine elektronischen Medien (geschätzt in % des Datenvolumens):

	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
über physische Datenträger (z.B. USB-Stick, CD/DVD)	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
über Internet, LAN-Zugang	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
über Internet, privaten WLAN-Zugang	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
über Internet, öffentlichen WLAN-Zugang (inkl. Uni)	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
über Internet, Zugang via Mobilfunknetz	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

Sonstiges (bitte angeben)

*39. Gibt es Vorlesungen im laufenden Semester, in denen du nicht präsent bist, sondern die du überwiegend online verfolgst? (Podcast/MOOC)

- ◯ ja
- ◯ nein

*40. Wie viele Stunden pro Vorlesungswoche verbringst du hierfür (Podcast/MOOC) insgesamt vor einem elektronischen Medium?

Anzahl Stunden pro Vorlesungswoche	

***41. Geschlecht**

◯ männlich

◯ weiblich

***42. Wie alt bist du?**

Anzahl Jahre

Vielen Dank für deine Zeit und die Teilnahme! :)

43. Bemerkungen:

13.6 Appendix F – Umberto exports of baseline scenario

Results of desktop computer. Reference flow: $\frac{58.56\ hrs}{4.84\ x\ (52-4)\ x\ 6\ x\ 5.52\ hrs}$

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, acidification & eutrophication w/ o LT:

Colo	Product	Quantity	Unit
	desktop computer and acc	0.02	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, ecotoxicity w/ o LT:

Colo	Product	Quantity	Unit
	desktop computer and acc	0.07	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, land occupation w/ o LT:

Colo	Product	Quantity	Unit
	desktop computer and acc	0.03	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, total w/ o LT:

Colo	Product	Quantity	Unit
	desktop computer and acc	0.11	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, carcinogenics w/ o LT:

Colo	Product	Quantity	Unit
	desktop computer and acc	0.05	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, climate change w/ o LT:

Colo	Product	Quantity	Unit
	desktop computer and acc	0.05	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, ionising radiation w/ o LT:

Colo	Product	Quantity	Unit
	desktop computer and acc	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, ozone layer depletion w/ o LT:

Colo	Product	Quantity	Unit
	desktop computer and acc	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, respiratory effects w/ o LT:

Colo	Product	Quantity	Unit
	desktop computer and acc	0.24	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, total w/ o LT:

Colo	Product	Quantity	Unit
	desktop computer and acc	0.34	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, fossil fuels w/ o LT:				
	Colo	Product	Quantity	Unit
		desktop computer and acc	0.22	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, mineral extraction w/ o LT:				
	Colo	Product	Quantity	Unit
		desktop computer and acc	0.06	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, total w/ o LT:				
	Colo	Product	Quantity	Unit
		desktop computer and acc	0.28	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - total w/ o LT, total w/ o LT:				
	Colo	Product	Quantity	Unit
		desktop computer and acc	0.73	points

Raw data of desktop computer

Row Labels	Summe von Quantity
T6: market for used liquid crystal display [GLO]	0.000266323
T14: market for transport, freight, lorry 16-32 metric ton, EURO4 [GLO]	0.001550723
T20: pointing device production, optical mouse, with cable [GLO]	0.0041457
T13: market for transport, freight, sea, transoceanic ship [GLO]	0.004340413
T11: market for electricity, low voltage [CH]	0.00571438
T10: market for electricity, low voltage [CH]	0.006061504
T12: market for keyboard [GLO]	0.013810565
T3: market for computer, desktop, without screen [GLO]	0.142283514
T7: market for electricity, low voltage [CH]	0.152481768
T18: market for display, liquid crystal, 17 inches [GLO]	0.401119559
Grand Total	**0.731774448**

Results of laptop computer. Reference flow: $\frac{264.98\ hrs}{4\ x\ (52-4)\ x\ 6\ x\ 7.62\ hrs}$

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, acidification & eutrophication w/ o LT: 0.01 poir				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.01	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, ecotoxicity w/ o LT: 0.03 points				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.03	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, land occupation w/ o LT: 9.90E-03 points				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.01	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, total w/ o LT: 0.05 points				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.05	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, carcinogenics w/ o LT: 0.03 points				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.03	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, climate change w/ o LT: 0.04 points				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.04	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, ionising radiation w/ o LT: 7.16E-04 points				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, ozone layer depletion w/ o LT: 2.02E-05 points				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, respiratory effects w/ o LT: 0.14 points				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.14	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, total w/ o LT: 0.21 points				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.21	points

LCIA Method: eco-indicator 99, (H,A) w/o LT - resources w/o LT, fossil fuels w/o LT: 0.11 points				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.11	points
LCIA Method: eco-indicator 99, (H,A) w/o LT - resources w/o LT, mineral extraction w/o LT: 0.03 points				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.03	points
LCIA Method: eco-indicator 99, (H,A) w/o LT - resources w/o LT, total w/o LT: 0.14 points				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.14	points
LCIA Method: eco-indicator 99, (H,A) w/o LT - total w/o LT, total w/o LT: 0.40 points				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.40	points

Raw data of laptop computer

Row Labels	Summe von Quantity
T1: market for transport, freight, lorry 16-32 metric ton, EURO4 [GLO]	0.00094806
T2: market for transport, freight, sea, transoceanic ship [GLO]	0.002653583
T17: market for electricity, low voltage [CH]	0.004194344
T18: market for electricity, low voltage [CH]	0.006847459
T11: market for liquid crystal display, unmounted [GLO]	0.031857361
T19: market for electricity, low voltage [CH]	0.044858508
T10: market for computer, laptop [GLO]	0.311922031
Grand Total	**0.403281346**

Results of tablet computer. Reference flow: $\frac{50.25\ hrs}{3.25\ x\ (52-4)\ x\ 6\ x\ 4.23\ hrs}$

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, acidification & eutrophication w/ o LT: 1.40E-03				
	Colo	Product	Quantity	Unit
		iPad [A137 (T19 -> RF)] (0.(	0.00	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, ecotoxicity w/ o LT: 3.46E-03 points				
	Colo	Product	Quantity	Unit
		iPad [A137 (T19 -> RF)] (0.(	0.00	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, land occupation w/ o LT: 8.90E-04 points				
	Colo	Product	Quantity	Unit
		iPad [A137 (T19 -> RF)] (0.(	0.00	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, total w/ o LT: 5.75E-03 points				
	Colo	Product	Quantity	Unit
		iPad [A137 (T19 -> RF)] (0.(	0.01	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, carcinogenics w/ o LT: 3.58E-03 points				
	Colo	Product	Quantity	Unit
		iPad [A137 (T19 -> RF)] (0.(	0.00	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, climate change w/ o LT: 3.35E-03 points				
	Colo	Product	Quantity	Unit
		iPad [A137 (T19 -> RF)] (0.(	0.00	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, ionising radiation w/ o LT: 3.18E-05 points				
	Colo	Product	Quantity	Unit
		iPad [A137 (T19 -> RF)] (0.(	0.00	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, ozone layer depletion w/ o LT: 1.26E-06 points				
	Colo	Product	Quantity	Unit
		iPad [A137 (T19 -> RF)] (0.(	0.00	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, respiratory effects w/ o LT: 0.02 points				
	Colo	Product	Quantity	Unit
		iPad [A137 (T19 -> RF)] (0.(	0.02	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, total w/ o LT: 0.02 points				
	Colo	Product	Quantity	Unit
		iPad [A137 (T19 -> RF)] (0.(	0.02	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, fossil fuels w/ o LT: 0.02 points

Colo	Product	Quantity	Unit
	iPad [A137 (T19 -> RF)] (0.	0.02	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, mineral extraction w/ o LT: 2.94E-03 points

Colo	Product	Quantity	Unit
	iPad [A137 (T19 -> RF)] (0.	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, total w/ o LT: 0.02 points

Colo	Product	Quantity	Unit
	iPad [A137 (T19 -> RF)] (0.	0.02	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - total w/ o LT, total w/ o LT: 0.05 points

Colo	Product	Quantity	Unit
	iPad [A137 (T19 -> RF)] (0.	0.05	points

Raw data of tablet computer

Row Labels	Summe von Quantity
T28: market for photovoltaic cell factory [GLO]	8.72335E-06
T37: treatment of waste paperboard, sorting plant [CH]	1.76171E-05
T38: treatment of waste polystyrene, municipal incineration [CH]	2.02975E-05
T40: market for polystyrene, general purpose [GLO]	3.72942E-05
T29: market for polystyrene, high impact [GLO]	7.93862E-05
T33: market for wastewater, unpolluted [GLO]	9.20954E-05
T21: market for tap water, at user [RoW]	0.000102888
T34: market for transport, freight, lorry 16-32 metric ton, EURO4 [GLO]	0.000110751
T20: market for electricity, medium voltage [CN]	0.000182281
T43: market for used laptop computer [GLO]	0.000239807
T41: market for polystyrene, high impact [GLO]	0.000284119
T27: market for palladium [GLO]	0.000451405
T32: market for silver [GLO]	0.000572801
T39: market for corrugated board box [GLO]	0.000662232
T4: market for electricity, low voltage [CH]	0.000735747
T11: market for electricity, low voltage [CH]	0.000827663
T24: market for copper [GLO]	0.001533354
T30: market for power adapter, for laptop [GLO]	0.001592549
T25: market for gold [GLO]	0.00169925
T22: market for aluminium, wrought alloy [GLO]	0.001711565
T23: market for battery, Li-ion, rechargeable, prismatic [GLO]	0.001745789
T26: market for light emitting diode [GLO]	0.003219956
T12: market for transport, freight, aircraft [GLO]	0.009183969
T36: market for printed wiring board, surface mounted, unspecified, Pb free [GLO]	0.010367892
T31: market for liquid crystal display, unmounted [GLO]	0.013307305
Grand Total	**0.048786736**

Results of self-printed lecture notes. Reference flow: 1.61 kg

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, acidification & eutrophication w/ o LT: 0.01 poir				
	Colo	Product	Quantity	Unit
		printed paper [A67 (T17 ->	0.01	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, ecotoxicity w/ o LT: 0.04 points				
	Colo	Product	Quantity	Unit
		printed paper [A67 (T17 ->	0.04	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, land occupation w/ o LT: 0.21 points				
	Colo	Product	Quantity	Unit
		printed paper [A67 (T17 ->	0.21	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, total w/ o LT: 0.27 points				
	Colo	Product	Quantity	Unit
		printed paper [A67 (T17 ->	0.27	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, carcinogenics w/ o LT: 0.04 points				
	Colo	Product	Quantity	Unit
		printed paper [A67 (T17 ->	0.04	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, climate change w/ o LT: 0.05 points				
	Colo	Product	Quantity	Unit
		printed paper [A67 (T17 ->	0.05	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, ionising radiation w/ o LT: 2.88E-04 points				
	Colo	Product	Quantity	Unit
		printed paper [A67 (T17 ->	0.00	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, ozone layer depletion w/ o LT: 1.44E-05 points				
	Colo	Product	Quantity	Unit
		printed paper [A67 (T17 ->	0.00	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, respiratory effects w/ o LT: 0.25 points				
	Colo	Product	Quantity	Unit
		printed paper [A67 (T17 ->	0.25	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, total w/ o LT: 0.34 points				
	Colo	Product	Quantity	Unit
		printed paper [A67 (T17 ->	0.34	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, fossil fuels w/ o LT: 0.25 points

Colo	Product	Quantity	Unit
	printed paper [A67 (T17 ->	0.25	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, mineral extraction w/ o LT: 0.03 points

Colo	Product	Quantity	Unit
	printed paper [A67 (T17 ->	0.03	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, total w/ o LT: 0.28 points

Colo	Product	Quantity	Unit
	printed paper [A67 (T17 ->	0.28	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - total w/ o LT, total w/ o LT: 0.89 points

Colo	Product	Quantity	Unit
	printed paper [A67 (T17 ->	0.89	points

Raw Data of self-printed lecture notes

Row Labels	Summe von Quantity
T12: operation, printer, laser, colour, per kg printed paper [CH] modified, based on ecoinvent 3 (v3.01)	4.69915E-08
T11: market for transport, freight train [Europe without Switzerland]	0.00363742
T13: market for electricity, low voltage [CH]	0.005011428
T16: market for used toner module, laser printer, colour [GLO]	0.050501496
T18: market for waste paper, unsorted [CH]	0.06471737
T15: market for toner module, laser printer, colour [GLO]	0.090742321
T14: market for printer, laser, colour [GLO]	0.33150635
T5: market for paper, woodfree, uncoated [RER]	0.340737088
Grand Total	**0.886853521**

Results of printed book of lecture notes. Reference flow: 0.32065 units

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, acidification & eutrophication w/ o LT: 2.34E-03

Colo	Product	Quantity	Unit
	Script of lecture slides [A16	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, ecotoxicity w/ o LT: 2.27E-03 points

Colo	Product	Quantity	Unit
	Script of lecture slides [A16	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, land occupation w/ o LT: 0.04 points

Colo	Product	Quantity	Unit
	Script of lecture slides [A16	0.04	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, total w/ o LT: 0.05 points

Colo	Product	Quantity	Unit
	Script of lecture slides [A16	0.05	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, carcinogenics w/ o LT: 2.96E-03 points

Colo	Product	Quantity	Unit
	Script of lecture slides [A16	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, climate change w/ o LT: 6.89E-03 points

Colo	Product	Quantity	Unit
	Script of lecture slides [A16	0.01	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, ionising radiation w/ o LT: 4.91E-05 points

Colo	Product	Quantity	Unit
	Script of lecture slides [A16	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, ozone layer depletion w/ o LT: 2.40E-06 points

Colo	Product	Quantity	Unit
	Script of lecture slides [A16	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, respiratory effects w/ o LT: 0.04 points

Colo	Product	Quantity	Unit
	Script of lecture slides [A16	0.04	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, total w/ o LT: 0.05 points

Colo	Product	Quantity	Unit
	Script of lecture slides [A16	0.05	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, fossil fuels w/ o LT: 0.04 points				
	Colo	Product	Quantity	Unit
		Script of lecture slides [A16	0.04	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, mineral extraction w/ o LT: 8.57E-04 points				
	Colo	Product	Quantity	Unit
		Script of lecture slides [A16	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, total w/ o LT: 0.04 points				
	Colo	Product	Quantity	Unit
		Script of lecture slides [A16	0.04	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - total w/ o LT, total w/ o LT: 0.14 points				
	Colo	Product	Quantity	Unit
		Script of lecture slides [A16	0.14	points

Raw data of printed book of lecture notes

Row Labels	Summe von Quantity
T7: operation, printer, laser, colour, per kg printed paper [CH] modified, based on ecoinvent 3 (v3.01)	1.35044E-08
T21: treatment of waste polyurethane foam, collection for final disposal [CH]	5.12243E-05
T4: transport, freight, light commercial vehicle [CH]	0.000447049
T10: market for printer, laser, colour [GLO]	0.000783027
T6: market for transport, freight train [Europe without Switzerland]	0.001135155
T9: market for electricity, low voltage [CH]	0.001440184
T20: market for polyurethane, rigid foam [GLO]	0.003711626
T15: market for waste paper, unsorted [CH]	0.009655426
T11: market for toner module, laser printer, colour [GLO]	0.010384968
T5: market for used toner module, laser printer, colour [GLO]	0.014513119
T8: market for paper, woodfree, coated [RER]	0.094072115
Grand Total	**0.136193906**

Results of Internet access. Reference flow: 0.0361 kWh

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, acidification & eutrophication w/ o LT: 4.55E-06

Colo	Product	Quantity	Unit
	Operation of Internet [A24 (	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, ecotoxicity w/ o LT: 2.11E-05 points

Colo	Product	Quantity	Unit
	Operation of Internet [A24 (	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, land occupation w/ o LT: 1.40E-05 points

Colo	Product	Quantity	Unit
	Operation of Internet [A24 (	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, total w/ o LT: 3.97E-05 points

Colo	Product	Quantity	Unit
	Operation of Internet [A24 (	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, carcinogenics w/ o LT: 1.23E-05 points

Colo	Product	Quantity	Unit
	Operation of Internet [A24 (	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, climate change w/ o LT: 2.75E-05 points

Colo	Product	Quantity	Unit
	Operation of Internet [A24 (	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, ionising radiation w/ o LT: 3.06E-06 points

Colo	Product	Quantity	Unit
	Operation of Internet [A24 (	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, ozone layer depletion w/ o LT: 6.60E-08 points

Colo	Product	Quantity	Unit
	Operation of Internet [A24 (	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, respiratory effects w/ o LT: 6.26E-05 points

Colo	Product	Quantity	Unit
	Operation of Internet [A24 (	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, total w/ o LT: 1.06E-04 points

Colo	Product	Quantity	Unit
	Operation of Internet [A24 (	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, fossil fuels w/ o LT: 1.29E-04 points				
	Colo	Product	Quantity	Unit
		Operation of Internet [A24 (	0.00	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, mineral extraction w/ o LT: 1.17E-05 points				
	Colo	Product	Quantity	Unit
		Operation of Internet [A24 (	0.00	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, total w/ o LT: 1.40E-04 points				
	Colo	Product	Quantity	Unit
		Operation of Internet [A24 (	0.00	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - total w/ o LT, total w/ o LT: 2.86E-04 points				
	Colo	Product	Quantity	Unit
		Operation of Internet [A24 (	0.00	points

Raw data of Internet access

Row Labels	Summe von Quantity
T6: market for electricity, low voltage [CH]	0.000285558
Grand Total	**0.000285558**

Results of server. Reference flow: 0.000849 kWh

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, acidification & eutrophication w/ o LT: 1.07E-07				
	Colo	Product	Quantity	Unit
		Operation of server [A5 (T1	0.00	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, ecotoxicity w/ o LT: 4.97E-07 points				
	Colo	Product	Quantity	Unit
		Operation of server [A5 (T1	0.00	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, land occupation w/ o LT: 3.30E-07 points				
	Colo	Product	Quantity	Unit
		Operation of server [A5 (T1	0.00	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, total w/ o LT: 9.33E-07 points				
	Colo	Product	Quantity	Unit
		Operation of server [A5 (T1	0.00	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, carcinogenics w/ o LT: 2.90E-07 points				
	Colo	Product	Quantity	Unit
		Operation of server [A5 (T1	0.00	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, climate change w/ o LT: 6.47E-07 points				
	Colo	Product	Quantity	Unit
		Operation of server [A5 (T1	0.00	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, ionising radiation w/ o LT: 7.21E-08 points				
	Colo	Product	Quantity	Unit
		Operation of server [A5 (T1	0.00	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, ozone layer depletion w/ o LT: 1.55E-09 points				
	Colo	Product	Quantity	Unit
		Operation of server [A5 (T1	0.00	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, respiratory effects w/ o LT: 1.47E-06 points				
	Colo	Product	Quantity	Unit
		Operation of server [A5 (T1	0.00	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, total w/ o LT: 2.48E-06 points				
	Colo	Product	Quantity	Unit
		Operation of server [A5 (T1	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, fossil fuels w/ o LT: 3.03E-06 points				
	Colo	Product	Quantity	Unit
		Operation of server [A5 (T1	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, mineral extraction w/ o LT: 2.76E-07 points				
	Colo	Product	Quantity	Unit
		Operation of server [A5 (T1	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, total w/ o LT: 3.30E-06 points				
	Colo	Product	Quantity	Unit
		Operation of server [A5 (T1	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - total w/ o LT, total w/ o LT: 6.72E-06 points				
	Colo	Product	Quantity	Unit
		Operation of server [A5 (T1	0.00	points

Raw data of server

Row Labels	Summe von Quantity
T2: market for electricity, low voltage [CH]	6.71937E-06
Grand Total	**6.71937E-06**

13.7 Appendix G – Umberto exports of sensitivity analysis

Total daily usage desktop computer (1.2)

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, acidification & eutrophication w/ o LT: 0.01 poir				
	Colo	Product	Quantity	Unit
		desktop computer and acc	0.01	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, ecotoxicity w/ o LT: 0.06 points				
	Colo	Product	Quantity	Unit
		desktop computer and acc	0.06	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, land occupation w/ o LT: 0.02 points				
	Colo	Product	Quantity	Unit
		desktop computer and acc	0.02	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, total w/ o LT: 0.10 points				
	Colo	Product	Quantity	Unit
		desktop computer and acc	0.10	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, carcinogenics w/ o LT: 0.05 points				
	Colo	Product	Quantity	Unit
		desktop computer and acc	0.05	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, climate change w/ o LT: 0.04 points				
	Colo	Product	Quantity	Unit
		desktop computer and acc	0.04	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, ionising radiation w/ o LT: 1.83E-03 points				
	Colo	Product	Quantity	Unit
		desktop computer and acc	0.00	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, ozone layer depletion w/ o LT: 4.41E-05 points				
	Colo	Product	Quantity	Unit
		desktop computer and acc	0.00	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, respiratory effects w/ o LT: 0.20 points				
	Colo	Product	Quantity	Unit
		desktop computer and acc	0.20	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, total w/ o LT: 0.29 points				
	Colo	Product	Quantity	Unit
		desktop computer and acc	0.29	points

LCIA Method: eco-indicator 99, (H,A) w/o LT - resources w/o LT, fossil fuels w/o LT: 0.19 points				
	Colo	Product	Quantity	Unit
		desktop computer and acc	0.19	points
LCIA Method: eco-indicator 99, (H,A) w/o LT - resources w/o LT, mineral extraction w/o LT: 0.05 points				
	Colo	Product	Quantity	Unit
		desktop computer and acc	0.05	points
LCIA Method: eco-indicator 99, (H,A) w/o LT - resources w/o LT, total w/o LT: 0.24 points				
	Colo	Product	Quantity	Unit
		desktop computer and acc	0.24	points
LCIA Method: eco-indicator 99, (H,A) w/o LT - total w/o LT, total w/o LT: 0.63 points				
	Colo	Product	Quantity	Unit
		desktop computer and acc	0.63	points

Desktop Computer	0.63
Laptop Computer	0.40
Tablet Computer	0.05
Self-printed LN	0.89
Printed Book of LN	0.14
Internet Access	0.00
Server	6.72E-06
Total	**2.11**

Total daily usage laptop computer (1.2)

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, acidification & eutrophication w/ o LT: 8.74E-03

Colo	Product	Quantity	Unit
	16 inch laptop computer [A	0.01	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, ecotoxicity w/ o LT: 0.03 points

Colo	Product	Quantity	Unit
	16 inch laptop computer [A	0.03	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, land occupation w/ o LT: 8.59E-03 points

Colo	Product	Quantity	Unit
	16 inch laptop computer [A	0.01	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, total w/ o LT: 0.05 points

Colo	Product	Quantity	Unit
	16 inch laptop computer [A	0.05	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, carcinogenics w/ o LT: 0.02 points

Colo	Product	Quantity	Unit
	16 inch laptop computer [A	0.02	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, climate change w/ o LT: 0.03 points

Colo	Product	Quantity	Unit
	16 inch laptop computer [A	0.03	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, ionising radiation w/ o LT: 6.71E-04 points

Colo	Product	Quantity	Unit
	16 inch laptop computer [A	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, ozone layer depletion w/ o LT: 1.85E-05 points

Colo	Product	Quantity	Unit
	16 inch laptop computer [A	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, respiratory effects w/ o LT: 0.12 points

Colo	Product	Quantity	Unit
	16 inch laptop computer [A	0.12	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, total w/ o LT: 0.18 points

Colo	Product	Quantity	Unit
	16 inch laptop computer [A	0.18	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, fossil fuels w/ o LT: 0.10 points				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.10	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, mineral extraction w/ o LT: 0.02 points				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.02	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, total w/ o LT: 0.12 points				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.12	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - total w/ o LT, total w/ o LT: 0.34 points				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.34	points

Desktop Computer	0.73
Laptop Computer	0.34
Tablet Computer	0.05
Self-printed LN	0.89
Printed Book of LN	0.14
Internet Access	0.00
Server	6.72E-06
Total	**2.15**

Energy consumption for one hour active use of desktop computer (0.5)

LCIA Method: eco-indicator 99, (H,A) w/o LT - ecosystem quality w/o LT, acidification & eutrophication w/o LT: 0.02 poir

Colo	Product	Quantity	Unit
	desktop computer and acc	0.02	points

LCIA Method: eco-indicator 99, (H,A) w/o LT - ecosystem quality w/o LT, ecotoxicity w/o LT: 0.06 points

Colo	Product	Quantity	Unit
	desktop computer and acc	0.06	points

LCIA Method: eco-indicator 99, (H,A) w/o LT - ecosystem quality w/o LT, land occupation w/o LT: 0.02 points

Colo	Product	Quantity	Unit
	desktop computer and acc	0.02	points

LCIA Method: eco-indicator 99, (H,A) w/o LT - ecosystem quality w/o LT, total w/o LT: 0.10 points

Colo	Product	Quantity	Unit
	desktop computer and acc	0.10	points

LCIA Method: eco-indicator 99, (H,A) w/o LT - human health w/o LT, carcinogenics w/o LT: 0.05 points

Colo	Product	Quantity	Unit
	desktop computer and acc	0.05	points

LCIA Method: eco-indicator 99, (H,A) w/o LT - human health w/o LT, climate change w/o LT: 0.04 points

Colo	Product	Quantity	Unit
	desktop computer and acc	0.04	points

LCIA Method: eco-indicator 99, (H,A) w/o LT - human health w/o LT, ionising radiation w/o LT: 1.06E-03 points

Colo	Product	Quantity	Unit
	desktop computer and acc	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/o LT - human health w/o LT, ozone layer depletion w/o LT: 2.83E-05 points

Colo	Product	Quantity	Unit
	desktop computer and acc	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/o LT - human health w/o LT, respiratory effects w/o LT: 0.22 points

Colo	Product	Quantity	Unit
	desktop computer and acc	0.22	points

LCIA Method: eco-indicator 99, (H,A) w/o LT - human health w/o LT, total w/o LT: 0.31 points

Colo	Product	Quantity	Unit
	desktop computer and acc	0.31	points

LCIA Method: eco-indicator 99, (H,A) w/o LT - resources w/o LT, fossil fuels w/o LT: 0.18 points				
	Colo	Product	Quantity	Unit
		desktop computer and acc	0.18	points
LCIA Method: eco-indicator 99, (H,A) w/o LT - resources w/o LT, mineral extraction w/o LT: 0.06 points				
	Colo	Product	Quantity	Unit
		desktop computer and acc	0.06	points
LCIA Method: eco-indicator 99, (H,A) w/o LT - resources w/o LT, total w/o LT: 0.24 points				
	Colo	Product	Quantity	Unit
		desktop computer and acc	0.24	points
LCIA Method: eco-indicator 99, (H,A) w/o LT - total w/o LT, total w/o LT: 0.66 points				
	Colo	Product	Quantity	Unit
		desktop computer and acc	0.66	points

Desktop Computer	0.66
Laptop Computer	0.40
Tablet Computer	0.05
Self-printed LN	0.89
Printed Book of LN	0.14
Internet Access	0.00
Server	6.72E-06
Total	2.13

Energy consumption for one hour active use of laptop computer (0.5)

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, acidification & eutrophication w/ o LT: 1.00E-02

Colo	Product	Quantity	Unit
	16 inch laptop computer [A	0.01	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, ecotoxicity w/ o LT: 0.03 points

Colo	Product	Quantity	Unit
	16 inch laptop computer [A	0.03	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, land occupation w/ o LT: 8.80E-03 points

Colo	Product	Quantity	Unit
	16 inch laptop computer [A	0.01	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, total w/ o LT: 0.05 points

Colo	Product	Quantity	Unit
	16 inch laptop computer [A	0.05	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, carcinogenics w/ o LT: 0.03 points

Colo	Product	Quantity	Unit
	16 inch laptop computer [A	0.03	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, climate change w/ o LT: 0.04 points

Colo	Product	Quantity	Unit
	16 inch laptop computer [A	0.04	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, ionising radiation w/ o LT: 4.75E-04 points

Colo	Product	Quantity	Unit
	16 inch laptop computer [A	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, ozone layer depletion w/ o LT: 1.50E-05 points

Colo	Product	Quantity	Unit
	16 inch laptop computer [A	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, respiratory effects w/ o LT: 0.14 points

Colo	Product	Quantity	Unit
	16 inch laptop computer [A	0.14	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, total w/ o LT: 0.20 points

Colo	Product	Quantity	Unit
	16 inch laptop computer [A	0.20	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, fossil fuels w/ o LT: 0.10 points				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.10	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, mineral extraction w/ o LT: 0.03 points				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.03	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, total w/ o LT: 0.13 points				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.13	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - total w/ o LT, total w/ o LT: 0.38 points				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.38	points

Desktop Computer	0.73
Laptop Computer	0.38
Tablet Computer	0.05
Self-printed LN	0.89
Printed Book of LN	0.14
Internet Access	0.00
Server	6.72E-06
Total	2.18

Lifetime of desktop computer (2)

LCIA Method: eco-indicator 99, (H,A) w/o LT - ecosystem quality w/o LT, acidification & eutrophication w/o LT: 9.91E-03

Colo	Product	Quantity	Unit
	desktop computer and acc	0.01	points

LCIA Method: eco-indicator 99, (H,A) w/o LT - ecosystem quality w/o LT, ecotoxicity w/o LT: 0.04 points

Colo	Product	Quantity	Unit
	desktop computer and acc	0.04	points

LCIA Method: eco-indicator 99, (H,A) w/o LT - ecosystem quality w/o LT, land occupation w/o LT: 0.02 points

Colo	Product	Quantity	Unit
	desktop computer and acc	0.02	points

LCIA Method: eco-indicator 99, (H,A) w/o LT - ecosystem quality w/o LT, total w/o LT: 0.07 points

Colo	Product	Quantity	Unit
	desktop computer and acc	0.07	points

LCIA Method: eco-indicator 99, (H,A) w/o LT - human health w/o LT, carcinogenics w/o LT: 0.03 points

Colo	Product	Quantity	Unit
	desktop computer and acc	0.03	points

LCIA Method: eco-indicator 99, (H,A) w/o LT - human health w/o LT, climate change w/o LT: 0.03 points

Colo	Product	Quantity	Unit
	desktop computer and acc	0.03	points

LCIA Method: eco-indicator 99, (H,A) w/o LT - human health w/o LT, ionising radiation w/o LT: 1.82E-03 points

Colo	Product	Quantity	Unit
	desktop computer and acc	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/o LT - human health w/o LT, ozone layer depletion w/o LT: 4.19E-05 points

Colo	Product	Quantity	Unit
	desktop computer and acc	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/o LT - human health w/o LT, respiratory effects w/o LT: 0.14 points

Colo	Product	Quantity	Unit
	desktop computer and acc	0.14	points

LCIA Method: eco-indicator 99, (H,A) w/o LT - human health w/o LT, total w/o LT: 0.20 points

Colo	Product	Quantity	Unit
	desktop computer and acc	0.20	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, fossil fuels w/ o LT: 0.15 points

Colo	Product	Quantity	Unit
	desktop computer and acc	0.15	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, mineral extraction w/ o LT: 0.03 points

Colo	Product	Quantity	Unit
	desktop computer and acc	0.03	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, total w/ o LT: 0.18 points

Colo	Product	Quantity	Unit
	desktop computer and acc	0.18	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - total w/ o LT, total w/ o LT: 0.45 points

Colo	Product	Quantity	Unit
	desktop computer and acc	0.45	points

Desktop Computer	0.45
Laptop Computer	0.40
Tablet Computer	0.05
Self-printed LN	0.89
Printed Book of LN	0.14
Internet Access	0.00
Server	6.72E-06
Total	1.92

Lifetime of laptop computer (0.75)

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, acidification & eutrophication w/ o LT: 0.01 poir				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.01	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, ecotoxicity w/ o LT: 0.04 points				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.04	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, land occupation w/ o LT: 0.01 points				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.01	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, total w/ o LT: 0.07 points				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.07	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, carcinogenics w/ o LT: 0.04 points				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.04	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, climate change w/ o LT: 0.05 points				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.05	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, ionising radiation w/ o LT: 7.55E-04 points				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, ozone layer depletion w/ o LT: 2.27E-05 points				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, respiratory effects w/ o LT: 0.18 points				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.18	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, total w/ o LT: 0.27 points				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.27	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, fossil fuels w/ o LT: 0.14 points				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.14	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, mineral extraction w/ o LT: 0.04 points				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.04	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, total w/ o LT: 0.18 points				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.18	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - total w/ o LT, total w/ o LT: 0.52 points				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.52	points

Desktop Computer	0.73
Laptop Computer	0.52
Tablet Computer	0.05
Self-printed LN	0.89
Printed Book of LN	0.14
Internet Access	0.00
Server	6.72E-06
Total	2.32

Print coverage in printed books (2)

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, acidification & eutrophication w/ o LT: 2.92E-03

Colo	Product	Quantity	Unit
	Script of lecture slides [A16	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, ecotoxicity w/ o LT: 2.73E-03 points

Colo	Product	Quantity	Unit
	Script of lecture slides [A16	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, land occupation w/ o LT: 0.05 points

Colo	Product	Quantity	Unit
	Script of lecture slides [A16	0.05	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, total w/ o LT: 0.05 points

Colo	Product	Quantity	Unit
	Script of lecture slides [A16	0.05	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, carcinogenics w/ o LT: 3.63E-03 points

Colo	Product	Quantity	Unit
	Script of lecture slides [A16	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, climate change w/ o LT: 9.09E-03 points

Colo	Product	Quantity	Unit
	Script of lecture slides [A16	0.01	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, ionising radiation w/ o LT: 5.98E-05 points

Colo	Product	Quantity	Unit
	Script of lecture slides [A16	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, ozone layer depletion w/ o LT: 2.79E-06 points

Colo	Product	Quantity	Unit
	Script of lecture slides [A16	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, respiratory effects w/ o LT: 0.05 points

Colo	Product	Quantity	Unit
	Script of lecture slides [A16	0.05	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, total w/ o LT: 0.06 points

Colo	Product	Quantity	Unit
	Script of lecture slides [A16	0.06	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, fossil fuels w/ o LT: 0.05 points				
	Colo	Product	Quantity	Unit
		Script of lecture slides [A16	0.05	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, mineral extraction w/ o LT: 1.15E-03 points				
	Colo	Product	Quantity	Unit
		Script of lecture slides [A16	0.00	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, total w/ o LT: 0.05 points				
	Colo	Product	Quantity	Unit
		Script of lecture slides [A16	0.05	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - total w/ o LT, total w/ o LT: 0.16 points				
	Colo	Product	Quantity	Unit
		Script of lecture slides [A16	0.16	points

Desktop Computer	0.73
Laptop Computer	0.40
Tablet Computer	0.05
Self-printed LN	0.89
Printed Book of LN	0.16
Internet Access	0.00
Server	6.72E-06
Total	2.23

Reading time (2) for desktop, laptop and tablet computer

Desktop computer

LCIA Method: eco-indicator 99, (H,A) w/o LT - ecosystem quality w/o LT, acidification & eutrophication w/o LT: 0.03 poir			
Colo	Product	Quantity	Unit
	desktop computer and acc	0.03	points

LCIA Method: eco-indicator 99, (H,A) w/o LT - ecosystem quality w/o LT, ecotoxicity w/o LT: 0.14 points			
Colo	Product	Quantity	Unit
	desktop computer and acc	0.14	points

LCIA Method: eco-indicator 99, (H,A) w/o LT - ecosystem quality w/o LT, land occupation w/o LT: 0.05 points			
Colo	Product	Quantity	Unit
	desktop computer and acc	0.05	points

LCIA Method: eco-indicator 99, (H,A) w/o LT - ecosystem quality w/o LT, total w/o LT: 0.22 points			
Colo	Product	Quantity	Unit
	desktop computer and acc	0.22	points

LCIA Method: eco-indicator 99, (H,A) w/o LT - human health w/o LT, carcinogenics w/o LT: 0.11 points			
Colo	Product	Quantity	Unit
	desktop computer and acc	0.11	points

LCIA Method: eco-indicator 99, (H,A) w/o LT - human health w/o LT, climate change w/o LT: 0.10 points			
Colo	Product	Quantity	Unit
	desktop computer and acc	0.10	points

LCIA Method: eco-indicator 99, (H,A) w/o LT - human health w/o LT, ionising radiation w/o LT: 3.76E-03 points			
Colo	Product	Quantity	Unit
	desktop computer and acc	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/o LT - human health w/o LT, ozone layer depletion w/o LT: 9.19E-05 points			
Colo	Product	Quantity	Unit
	desktop computer and acc	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/o LT - human health w/o LT, respiratory effects w/o LT: 0.48 points			
Colo	Product	Quantity	Unit
	desktop computer and acc	0.48	points

LCIA Method: eco-indicator 99, (H,A) w/o LT - human health w/o LT, total w/o LT: 0.68 points			
Colo	Product	Quantity	Unit
	desktop computer and acc	0.68	points

LCIA Method: eco-indicator 99, (H,A) w/o LT - resources w/o LT, fossil fuels w/o LT: 0.43 points				
	Colo	Product	Quantity	Unit
		desktop computer and acc	0.43	points
LCIA Method: eco-indicator 99, (H,A) w/o LT - resources w/o LT, mineral extraction w/o LT: 0.12 points				
	Colo	Product	Quantity	Unit
		desktop computer and acc	0.12	points
LCIA Method: eco-indicator 99, (H,A) w/o LT - resources w/o LT, total w/o LT: 0.56 points				
	Colo	Product	Quantity	Unit
		desktop computer and acc	0.56	points
LCIA Method: eco-indicator 99, (H,A) w/o LT - total w/o LT, total w/o LT: 1.46 points				
	Colo	Product	Quantity	Unit
		desktop computer and acc	1.46	points

Laptop computer

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, acidification & eutrophication w/ o LT: 0.02 poir				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.02	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, ecotoxicity w/ o LT: 0.07 points				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.07	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, land occupation w/ o LT: 0.02 points				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.02	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, total w/ o LT: 0.11 points				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.11	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, carcinogenics w/ o LT: 0.06 points				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.06	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, climate change w/ o LT: 0.08 points				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.08	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, ionising radiation w/ o LT: 1.43E-03 points				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, ozone layer depletion w/ o LT: 4.05E-05 points				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, respiratory effects w/ o LT: 0.28 points				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.28	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, total w/ o LT: 0.42 points				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.42	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, fossil fuels w/ o LT: 0.22 points				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.22	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, mineral extraction w/ o LT: 0.05 points				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.05	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, total w/ o LT: 0.28 points				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.28	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - total w/ o LT, total w/ o LT: 0.81 points				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.81	points

Tablet computer

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, acidification & eutrophication w/ o LT: 2.81E-03				
	Colo	Product	Quantity	Unit
		iPad [A137 (T19 -> RF)] (0.(	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, ecotoxicity w/ o LT: 6.92E-03 points				
	Colo	Product	Quantity	Unit
		iPad [A137 (T19 -> RF)] (0.(	0.01	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, land occupation w/ o LT: 1.78E-03 points				
	Colo	Product	Quantity	Unit
		iPad [A137 (T19 -> RF)] (0.(	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, total w/ o LT: 0.01 points				
	Colo	Product	Quantity	Unit
		iPad [A137 (T19 -> RF)] (0.(	0.01	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, carcinogenics w/ o LT: 7.17E-03 points				
	Colo	Product	Quantity	Unit
		iPad [A137 (T19 -> RF)] (0.(	0.01	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, climate change w/ o LT: 6.71E-03 points				
	Colo	Product	Quantity	Unit
		iPad [A137 (T19 -> RF)] (0.(	0.01	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, ionising radiation w/ o LT: 6.36E-05 points				
	Colo	Product	Quantity	Unit
		iPad [A137 (T19 -> RF)] (0.(	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, ozone layer depletion w/ o LT: 2.52E-06 points				
	Colo	Product	Quantity	Unit
		iPad [A137 (T19 -> RF)] (0.(	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, respiratory effects w/ o LT: 0.03 points				
	Colo	Product	Quantity	Unit
		iPad [A137 (T19 -> RF)] (0.(	0.03	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, total w/ o LT: 0.05 points				
	Colo	Product	Quantity	Unit
		iPad [A137 (T19 -> RF)] (0.(	0.05	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, fossil fuels w/ o LT: 0.03 points				
	Colo	Product	Quantity	Unit
		iPad [A137 (T19 -> RF)] (0.(	0.03	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, mineral extraction w/ o LT: 5.88E-03 points				
	Colo	Product	Quantity	Unit
		iPad [A137 (T19 -> RF)] (0.(	0.01	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, total w/ o LT: 0.04 points				
	Colo	Product	Quantity	Unit
		iPad [A137 (T19 -> RF)] (0.(	0.04	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - total w/ o LT, total w/ o LT: 0.10 points				
	Colo	Product	Quantity	Unit
		iPad [A137 (T19 -> RF)] (0.(	0.10	points

Desktop Computer	1.46
Laptop Computer	0.81
Tablet Computer	0.10
Self-printed LN	0.89
Printed Book of LN	0.14
Internet Access	0.00
Server	6.72E-06
Total	3.39

Amount of printed book of lecture notes (0.5)

LCIA Method: eco-indicator 99, (H,A) w/o LT - ecosystem quality w/o LT, acidification & eutrophication w/o LT: 1.17E-03				
	Colo	Product	Quantity	Unit
		Script of lecture slides [A16	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/o LT - ecosystem quality w/o LT, ecotoxicity w/o LT: 1.13E-03 points				
	Colo	Product	Quantity	Unit
		Script of lecture slides [A16	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/o LT - ecosystem quality w/o LT, land occupation w/o LT: 0.02 points				
	Colo	Product	Quantity	Unit
		Script of lecture slides [A16	0.02	points

LCIA Method: eco-indicator 99, (H,A) w/o LT - ecosystem quality w/o LT, total w/o LT: 0.02 points				
	Colo	Product	Quantity	Unit
		Script of lecture slides [A16	0.02	points

LCIA Method: eco-indicator 99, (H,A) w/o LT - human health w/o LT, carcinogenics w/o LT: 1.48E-03 points				
	Colo	Product	Quantity	Unit
		Script of lecture slides [A16	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/o LT - human health w/o LT, climate change w/o LT: 3.45E-03 points				
	Colo	Product	Quantity	Unit
		Script of lecture slides [A16	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/o LT - human health w/o LT, ionising radiation w/o LT: 2.45E-05 points				
	Colo	Product	Quantity	Unit
		Script of lecture slides [A16	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/o LT - human health w/o LT, ozone layer depletion w/o LT: 1.20E-06 points				
	Colo	Product	Quantity	Unit
		Script of lecture slides [A16	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/o LT - human health w/o LT, respiratory effects w/o LT: 0.02 points				
	Colo	Product	Quantity	Unit
		Script of lecture slides [A16	0.02	points

LCIA Method: eco-indicator 99, (H,A) w/o LT - human health w/o LT, total w/o LT: 0.02 points				
	Colo	Product	Quantity	Unit
		Script of lecture slides [A16	0.02	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, fossil fuels w/ o LT: 0.02 points				
	Colo	Product	Quantity	Unit
		Script of lecture slides [A16	0.02	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, mineral extraction w/ o LT: 4.29E-04 points				
	Colo	Product	Quantity	Unit
		Script of lecture slides [A16	0.00	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, total w/ o LT: 0.02 points				
	Colo	Product	Quantity	Unit
		Script of lecture slides [A16	0.02	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - total w/ o LT, total w/ o LT: 0.07 points				
	Colo	Product	Quantity	Unit
		Script of lecture slides [A16	0.07	points

Desktop Computer	0.73
Laptop Computer	0.40
Tablet Computer	0.05
Self-printed LN	0.89
Printed Book of LN	0.07
Internet Access	0.00
Server	6.72E-06
Total	2.14

Amount of self-printed lecture notes (0.5)

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, acidification & eutrophication w/ o LT: 7.44E-03

Colo	Product	Quantity	Unit
	printed paper [A67 (T17 ->	0.01	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, ecotoxicity w/ o LT: 0.02 points

Colo	Product	Quantity	Unit
	printed paper [A67 (T17 ->	0.02	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, land occupation w/ o LT: 0.11 points

Colo	Product	Quantity	Unit
	printed paper [A67 (T17 ->	0.11	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, total w/ o LT: 0.13 points

Colo	Product	Quantity	Unit
	printed paper [A67 (T17 ->	0.13	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, carcinogenics w/ o LT: 0.02 points

Colo	Product	Quantity	Unit
	printed paper [A67 (T17 ->	0.02	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, climate change w/ o LT: 0.03 points

Colo	Product	Quantity	Unit
	printed paper [A67 (T17 ->	0.03	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, ionising radiation w/ o LT: 1.44E-04 points

Colo	Product	Quantity	Unit
	printed paper [A67 (T17 ->	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, ozone layer depletion w/ o LT: 7.19E-06 points

Colo	Product	Quantity	Unit
	printed paper [A67 (T17 ->	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, respiratory effects w/ o LT: 0.12 points

Colo	Product	Quantity	Unit
	printed paper [A67 (T17 ->	0.12	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, total w/ o LT: 0.17 points

Colo	Product	Quantity	Unit
	printed paper [A67 (T17 ->	0.17	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, fossil fuels w/ o LT: 0.13 points				
	Colo	Product	Quantity	Unit
		printed paper [A67 (T17 ->	0.13	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, mineral extraction w/ o LT: 0.01 points				
	Colo	Product	Quantity	Unit
		printed paper [A67 (T17 ->	0.01	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, total w/ o LT: 0.14 points				
	Colo	Product	Quantity	Unit
		printed paper [A67 (T17 ->	0.14	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - total w/ o LT, total w/ o LT: 0.44 points				
	Colo	Product	Quantity	Unit
		printed paper [A67 (T17 ->	0.44	points

Desktop Computer	0.73
Laptop Computer	0.40
Tablet Computer	0.05
Self-printed LN	0.44
Printed Book of LN	0.14
Internet Access	0.00
Server	6.72E-06
Total	1.76

Reading time (0.5) for desktop, laptop and tablet computer

Desktop computer

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, acidification & eutrophication w/ o LT: 8.60E-03				
	Colo	Product	Quantity	Unit
		desktop computer and acc	0.01	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, ecotoxicity w/ o LT: 0.03 points				
	Colo	Product	Quantity	Unit
		desktop computer and acc	0.03	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, land occupation w/ o LT: 0.01 points				
	Colo	Product	Quantity	Unit
		desktop computer and acc	0.01	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, total w/ o LT: 0.06 points				
	Colo	Product	Quantity	Unit
		desktop computer and acc	0.06	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, carcinogenics w/ o LT: 0.03 points				
	Colo	Product	Quantity	Unit
		desktop computer and acc	0.03	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, climate change w/ o LT: 0.02 points				
	Colo	Product	Quantity	Unit
		desktop computer and acc	0.02	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, ionising radiation w/ o LT: 9.39E-04 points				
	Colo	Product	Quantity	Unit
		desktop computer and acc	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, ozone layer depletion w/ o LT: 2.30E-05 points				
	Colo	Product	Quantity	Unit
		desktop computer and acc	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, respiratory effects w/ o LT: 0.12 points				
	Colo	Product	Quantity	Unit
		desktop computer and acc	0.12	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, total w/ o LT: 0.17 points				
	Colo	Product	Quantity	Unit
		desktop computer and acc	0.17	points

LCIA Method: eco-indicator 99, (H,A) w/o LT - resources w/o LT, fossil fuels w/o LT: 0.11 points				
	Colo	Product	Quantity	Unit
		desktop computer and acc	0.11	points

LCIA Method: eco-indicator 99, (H,A) w/o LT - resources w/o LT, mineral extraction w/o LT: 0.03 points				
	Colo	Product	Quantity	Unit
		desktop computer and acc	0.03	points

LCIA Method: eco-indicator 99, (H,A) w/o LT - resources w/o LT, total w/o LT: 0.14 points				
	Colo	Product	Quantity	Unit
		desktop computer and acc	0.14	points

LCIA Method: eco-indicator 99, (H,A) w/o LT - total w/o LT, total w/o LT: 0.37 points				
	Colo	Product	Quantity	Unit
		desktop computer and acc	0.37	points

Laptop computer

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, acidification & eutrophication w/ o LT: 5.18E-03				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.01	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, ecotoxicity w/ o LT: 0.02 points				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.02	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, land occupation w/ o LT: 4.95E-03 points				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, total w/ o LT: 0.03 points				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.03	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, carcinogenics w/ o LT: 0.01 points				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.01	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, climate change w/ o LT: 0.02 points				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.02	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, ionising radiation w/ o LT: 3.58E-04 points				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, ozone layer depletion w/ o LT: 1.01E-05 points				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, respiratory effects w/ o LT: 0.07 points				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.07	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, total w/ o LT: 0.10 points				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.10	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, fossil fuels w/ o LT: 0.06 points				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.06	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, mineral extraction w/ o LT: 0.01 points				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.01	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, total w/ o LT: 0.07 points				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.07	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - total w/ o LT, total w/ o LT: 0.20 points				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.20	points

Tablet computer

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, acidification & eutrophication w/ o LT: 7.02E-04				
	Colo	Product	Quantity	Unit
		iPad [A137 (T19 -> RF)] (6.	0.00	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, ecotoxicity w/ o LT: 1.73E-03 points				
	Colo	Product	Quantity	Unit
		iPad [A137 (T19 -> RF)] (6.	0.00	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, land occupation w/ o LT: 4.45E-04 points				
	Colo	Product	Quantity	Unit
		iPad [A137 (T19 -> RF)] (6.	0.00	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, total w/ o LT: 2.88E-03 points				
	Colo	Product	Quantity	Unit
		iPad [A137 (T19 -> RF)] (6.	0.00	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, carcinogenics w/ o LT: 1.79E-03 points				
	Colo	Product	Quantity	Unit
		iPad [A137 (T19 -> RF)] (6.	0.00	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, climate change w/ o LT: 1.68E-03 points				
	Colo	Product	Quantity	Unit
		iPad [A137 (T19 -> RF)] (6.	0.00	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, ionising radiation w/ o LT: 1.59E-05 points				
	Colo	Product	Quantity	Unit
		iPad [A137 (T19 -> RF)] (6.	0.00	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, ozone layer depletion w/ o LT: 6.29E-07 points				
	Colo	Product	Quantity	Unit
		iPad [A137 (T19 -> RF)] (6.	0.00	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, respiratory effects w/ o LT: 8.35E-03 points				
	Colo	Product	Quantity	Unit
		iPad [A137 (T19 -> RF)] (6.	0.01	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, total w/ o LT: 0.01 points				
	Colo	Product	Quantity	Unit
		iPad [A137 (T19 -> RF)] (6.	0.01	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, fossil fuels w/ o LT: 8.21E-03 points				
	Colo	Product	Quantity	Unit
		iPad [A137 (T19 -> RF)] (6.	0.01	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, mineral extraction w/ o LT: 1.47E-03 points				
	Colo	Product	Quantity	Unit
		iPad [A137 (T19 -> RF)] (6.	0.00	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, total w/ o LT: 9.68E-03 points				
	Colo	Product	Quantity	Unit
		iPad [A137 (T19 -> RF)] (6.	0.01	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - total w/ o LT, total w/ o LT: 0.02 points				
	Colo	Product	Quantity	Unit
		iPad [A137 (T19 -> RF)] (6.	0.02	points

Desktop Computer	0.37
Laptop Computer	0.20
Tablet Computer	0.02
Self-printed LN	0.89
Printed Book of LN	0.14
Internet Access	0.00
Server	6.72E-06
Total	1.62

13.8 Appendix H – Umberto exports of alternative scenarios

$$Only\ desktop\ computer.\ Reference\ flow: \frac{460.07\ hrs}{4.84\ x\ (52-4)\ x\ 6\ x\ 5.52\ hrs}$$

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, acidification & eutrophication w/ o LT: 0.14 poir

Colo	Product	Quantity	Unit
	desktop computer and acc	0.14	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, ecotoxicity w/ o LT: 0.53 points

Colo	Product	Quantity	Unit
	desktop computer and acc	0.53	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, land occupation w/ o LT: 0.20 points

Colo	Product	Quantity	Unit
	desktop computer and acc	0.20	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, total w/ o LT: 0.87 points

Colo	Product	Quantity	Unit
	desktop computer and acc	0.87	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, carcinogenics w/ o LT: 0.42 points

Colo	Product	Quantity	Unit
	desktop computer and acc	0.42	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, climate change w/ o LT: 0.38 points

Colo	Product	Quantity	Unit
	desktop computer and acc	0.38	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, ionising radiation w/ o LT: 0.01 points

Colo	Product	Quantity	Unit
	desktop computer and acc	0.01	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, ozone layer depletion w/ o LT: 3.61E-04 points

Colo	Product	Quantity	Unit
	desktop computer and acc	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, respiratory effects w/ o LT: 1.88 points

Colo	Product	Quantity	Unit
	desktop computer and acc	1.88	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, total w/ o LT: 2.69 points

Colo	Product	Quantity	Unit
	desktop computer and acc	2.69	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, fossil fuels w/ o LT: 1.70 points				
	Colo	Product	Quantity	Unit
		desktop computer and acc	1.70	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, mineral extraction w/ o LT: 0.49 points				
	Colo	Product	Quantity	Unit
		desktop computer and acc	0.49	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, total w/ o LT: 2.19 points				
	Colo	Product	Quantity	Unit
		desktop computer and acc	2.19	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - total w/ o LT, total w/ o LT: 5.75 points				
	Colo	Product	Quantity	Unit
		desktop computer and acc	5.75	points

Only laptop computer. Reference flow: $\frac{460.07\ hrs}{4\ x\ (52-4)\ x\ 6\ x\ 7.62\ hrs}$

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, acidification & eutrophication w/ o LT: 0.02 poir

Colo	Product	Quantity	Unit
	16 inch laptop computer [A	0.02	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, ecotoxicity w/ o LT: 0.06 points

Colo	Product	Quantity	Unit
	16 inch laptop computer [A	0.06	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, land occupation w/ o LT: 0.02 points

Colo	Product	Quantity	Unit
	16 inch laptop computer [A	0.02	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, total w/ o LT: 0.09 points

Colo	Product	Quantity	Unit
	16 inch laptop computer [A	0.09	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, carcinogenics w/ o LT: 0.05 points

Colo	Product	Quantity	Unit
	16 inch laptop computer [A	0.05	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, climate change w/ o LT: 0.07 points

Colo	Product	Quantity	Unit
	16 inch laptop computer [A	0.07	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, ionising radiation w/ o LT: 1.24E-03 points

Colo	Product	Quantity	Unit
	16 inch laptop computer [A	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, ozone layer depletion w/ o LT: 3.51E-05 points

Colo	Product	Quantity	Unit
	16 inch laptop computer [A	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, respiratory effects w/ o LT: 0.25 points

Colo	Product	Quantity	Unit
	16 inch laptop computer [A	0.25	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, total w/ o LT: 0.36 points

Colo	Product	Quantity	Unit
	16 inch laptop computer [A	0.36	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, fossil fuels w/ o LT: 0.19 points				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.19	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, mineral extraction w/ o LT: 0.05 points				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.05	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, total w/ o LT: 0.24 points				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.24	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - total w/ o LT, total w/ o LT: 0.70 points				
	Colo	Product	Quantity	Unit
		16 inch laptop computer [A	0.70	points

Only tablet computer. Reference flow: $\frac{460.07\ hrs}{3.25\ x\ (52-4)\ x\ 6\ x\ 4.23\ hrs}$

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, acidification & eutrophication w/ o LT: 0.01 poir

Colo	Product	Quantity	Unit
	iPad [A137 (T19 -> RF)] (0.	0.01	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, ecotoxicity w/ o LT: 0.03 points

Colo	Product	Quantity	Unit
	iPad [A137 (T19 -> RF)] (0.	0.03	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, land occupation w/ o LT: 8.15E-03 points

Colo	Product	Quantity	Unit
	iPad [A137 (T19 -> RF)] (0.	0.01	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, total w/ o LT: 0.05 points

Colo	Product	Quantity	Unit
	iPad [A137 (T19 -> RF)] (0.	0.05	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, carcinogenics w/ o LT: 0.03 points

Colo	Product	Quantity	Unit
	iPad [A137 (T19 -> RF)] (0.	0.03	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, climate change w/ o LT: 0.03 points

Colo	Product	Quantity	Unit
	iPad [A137 (T19 -> RF)] (0.	0.03	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, ionising radiation w/ o LT: 2.91E-04 points

Colo	Product	Quantity	Unit
	iPad [A137 (T19 -> RF)] (0.	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, ozone layer depletion w/ o LT: 1.15E-05 points

Colo	Product	Quantity	Unit
	iPad [A137 (T19 -> RF)] (0.	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, respiratory effects w/ o LT: 0.15 points

Colo	Product	Quantity	Unit
	iPad [A137 (T19 -> RF)] (0.	0.15	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, total w/ o LT: 0.22 points

Colo	Product	Quantity	Unit
	iPad [A137 (T19 -> RF)] (0.	0.22	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, fossil fuels w/ o LT: 0.15 points				
	Colo	Product	Quantity	Unit
		iPad [A137 (T19 -> RF)] (0.	0.15	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, mineral extraction w/ o LT: 0.03 points				
	Colo	Product	Quantity	Unit
		iPad [A137 (T19 -> RF)] (0.	0.03	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, total w/ o LT: 0.18 points				
	Colo	Product	Quantity	Unit
		iPad [A137 (T19 -> RF)] (0.	0.18	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - total w/ o LT, total w/ o LT: 0.45 points				
	Colo	Product	Quantity	Unit
		iPad [A137 (T19 -> RF)] (0.	0.45	points

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LCIA Method: eco-indicator 99, (H,A) w/o LT - ecosystem quality w/o LT, acidification & eutrophication w/o LT: 0.04 poir				
	Colo	Product	Quantity	Unit
		printed paper [A67 (T17 ->	0.04	points
LCIA Method: eco-indicator 99, (H,A) w/o LT - ecosystem quality w/o LT, ecotoxicity w/o LT: 0.11 points				
	Colo	Product	Quantity	Unit
		printed paper [A67 (T17 ->	0.11	points
LCIA Method: eco-indicator 99, (H,A) w/o LT - ecosystem quality w/o LT, land occupation w/o LT: 0.60 points				
	Colo	Product	Quantity	Unit
		printed paper [A67 (T17 ->	0.60	points
LCIA Method: eco-indicator 99, (H,A) w/o LT - ecosystem quality w/o LT, total w/o LT: 0.75 points				
	Colo	Product	Quantity	Unit
		printed paper [A67 (T17 ->	0.75	points
LCIA Method: eco-indicator 99, (H,A) w/o LT - human health w/o LT, carcinogenics w/o LT: 0.12 points				
	Colo	Product	Quantity	Unit
		printed paper [A67 (T17 ->	0.12	points
LCIA Method: eco-indicator 99, (H,A) w/o LT - human health w/o LT, climate change w/o LT: 0.15 points				
	Colo	Product	Quantity	Unit
		printed paper [A67 (T17 ->	0.15	points
LCIA Method: eco-indicator 99, (H,A) w/o LT - human health w/o LT, ionising radiation w/o LT: 8.06E-04 points				
	Colo	Product	Quantity	Unit
		printed paper [A67 (T17 ->	0.00	points
LCIA Method: eco-indicator 99, (H,A) w/o LT - human health w/o LT, ozone layer depletion w/o LT: 4.03E-05 points				
	Colo	Product	Quantity	Unit
		printed paper [A67 (T17 ->	0.00	points
LCIA Method: eco-indicator 99, (H,A) w/o LT - human health w/o LT, respiratory effects w/o LT: 0.69 points				
	Colo	Product	Quantity	Unit
		printed paper [A67 (T17 ->	0.69	points
LCIA Method: eco-indicator 99, (H,A) w/o LT - human health w/o LT, total w/o LT: 0.96 points				
	Colo	Product	Quantity	Unit
		printed paper [A67 (T17 ->	0.96	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, fossil fuels w/ o LT: 0.71 points				
	Colo	Product	Quantity	Unit
		printed paper [A67 (T17 ->	0.71	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, mineral extraction w/ o LT: 0.07 points				
	Colo	Product	Quantity	Unit
		printed paper [A67 (T17 ->	0.07	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, total w/ o LT: 0.78 points				
	Colo	Product	Quantity	Unit
		printed paper [A67 (T17 ->	0.78	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - total w/ o LT, total w/ o LT: 2.49 points				
	Colo	Product	Quantity	Unit
		printed paper [A67 (T17 ->	2.49	points

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LCIA Method: eco-indicator 99, (H,A) w/o LT - ecosystem quality w/o LT, acidification & eutrophication w/o LT: 0.04 poir

Colo	Product	Quantity	Unit
	printed paper [A67 (T17 ->	0.04	points

LCIA Method: eco-indicator 99, (H,A) w/o LT - ecosystem quality w/o LT, ecotoxicity w/o LT: 0.10 points

Colo	Product	Quantity	Unit
	printed paper [A67 (T17 ->	0.10	points

LCIA Method: eco-indicator 99, (H,A) w/o LT - ecosystem quality w/o LT, land occupation w/o LT: 0.50 points

Colo	Product	Quantity	Unit
	printed paper [A67 (T17 ->	0.50	points

LCIA Method: eco-indicator 99, (H,A) w/o LT - ecosystem quality w/o LT, total w/o LT: 0.64 points

Colo	Product	Quantity	Unit
	printed paper [A67 (T17 ->	0.64	points

LCIA Method: eco-indicator 99, (H,A) w/o LT - human health w/o LT, carcinogenics w/o LT: 0.11 points

Colo	Product	Quantity	Unit
	printed paper [A67 (T17 ->	0.11	points

LCIA Method: eco-indicator 99, (H,A) w/o LT - human health w/o LT, climate change w/o LT: 0.14 points

Colo	Product	Quantity	Unit
	printed paper [A67 (T17 ->	0.14	points

LCIA Method: eco-indicator 99, (H,A) w/o LT - human health w/o LT, ionising radiation w/o LT: 7.52E-04 points

Colo	Product	Quantity	Unit
	printed paper [A67 (T17 ->	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/o LT - human health w/o LT, ozone layer depletion w/o LT: 3.67E-05 points

Colo	Product	Quantity	Unit
	printed paper [A67 (T17 ->	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/o LT - human health w/o LT, respiratory effects w/o LT: 0.63 points

Colo	Product	Quantity	Unit
	printed paper [A67 (T17 ->	0.63	points

LCIA Method: eco-indicator 99, (H,A) w/o LT - human health w/o LT, total w/o LT: 0.88 points

Colo	Product	Quantity	Unit
	printed paper [A67 (T17 ->	0.88	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, fossil fuels w/ o LT: 0.65 points				
	Colo	Product	Quantity	Unit
		printed paper [A67 (T17 ->	0.65	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, mineral extraction w/ o LT: 0.07 points				
	Colo	Product	Quantity	Unit
		printed paper [A67 (T17 ->	0.07	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, total w/ o LT: 0.73 points				
	Colo	Product	Quantity	Unit
		printed paper [A67 (T17 ->	0.73	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - total w/ o LT, total w/ o LT: 2.25 points				
	Colo	Product	Quantity	Unit
		printed paper [A67 (T17 ->	2.25	points

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LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, acidification & eutrophication w/ o LT: 0.04 poir				
	Colo	Product	Quantity	Unit
		Script of lecture slides [A16	0.04	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, ecotoxicity w/ o LT: 0.04 points				
	Colo	Product	Quantity	Unit
		Script of lecture slides [A16	0.04	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, land occupation w/ o LT: 0.69 points				
	Colo	Product	Quantity	Unit
		Script of lecture slides [A16	0.69	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - ecosystem quality w/ o LT, total w/ o LT: 0.77 points				
	Colo	Product	Quantity	Unit
		Script of lecture slides [A16	0.77	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, carcinogenics w/ o LT: 0.05 points				
	Colo	Product	Quantity	Unit
		Script of lecture slides [A16	0.05	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, climate change w/ o LT: 0.11 points				
	Colo	Product	Quantity	Unit
		Script of lecture slides [A16	0.11	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, ionising radiation w/ o LT: 7.65E-04 points				
	Colo	Product	Quantity	Unit
		Script of lecture slides [A16	0.00	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, ozone layer depletion w/ o LT: 3.74E-05 points				
	Colo	Product	Quantity	Unit
		Script of lecture slides [A16	0.00	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, respiratory effects w/ o LT: 0.60 points				
	Colo	Product	Quantity	Unit
		Script of lecture slides [A16	0.60	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - human health w/ o LT, total w/ o LT: 0.76 points				
	Colo	Product	Quantity	Unit
		Script of lecture slides [A16	0.76	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, fossil fuels w/ o LT: 0.59 points				
	Colo	Product	Quantity	Unit
		Script of lecture slides [A16	0.59	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, mineral extraction w/ o LT: 0.01 points				
	Colo	Product	Quantity	Unit
		Script of lecture slides [A16	0.01	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, total w/ o LT: 0.60 points				
	Colo	Product	Quantity	Unit
		Script of lecture slides [A16	0.60	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - total w/ o LT, total w/ o LT: 2.12 points				
	Colo	Product	Quantity	Unit
		Script of lecture slides [A16	2.12	points

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LCIA Method: eco-indicator 99, (H,A) w/o LT - ecosystem quality w/o LT, acidification & eutrophication w/o LT: 0.03 poir

Colo	Product	Quantity	Unit
	Script of lecture slides [A16	0.03	points

LCIA Method: eco-indicator 99, (H,A) w/o LT - ecosystem quality w/o LT, ecotoxicity w/o LT: 0.03 points

Colo	Product	Quantity	Unit
	Script of lecture slides [A16	0.03	points

LCIA Method: eco-indicator 99, (H,A) w/o LT - ecosystem quality w/o LT, land occupation w/o LT: 0.51 points

Colo	Product	Quantity	Unit
	Script of lecture slides [A16	0.51	points

LCIA Method: eco-indicator 99, (H,A) w/o LT - ecosystem quality w/o LT, total w/o LT: 0.57 points

Colo	Product	Quantity	Unit
	Script of lecture slides [A16	0.57	points

LCIA Method: eco-indicator 99, (H,A) w/o LT - human health w/o LT, carcinogenics w/o LT: 0.04 points

Colo	Product	Quantity	Unit
	Script of lecture slides [A16	0.04	points

LCIA Method: eco-indicator 99, (H,A) w/o LT - human health w/o LT, climate change w/o LT: 0.09 points

Colo	Product	Quantity	Unit
	Script of lecture slides [A16	0.09	points

LCIA Method: eco-indicator 99, (H,A) w/o LT - human health w/o LT, ionising radiation w/o LT: 6.70E-04 points

Colo	Product	Quantity	Unit
	Script of lecture slides [A16	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/o LT - human health w/o LT, ozone layer depletion w/o LT: 3.04E-05 points

Colo	Product	Quantity	Unit
	Script of lecture slides [A16	0.00	points

LCIA Method: eco-indicator 99, (H,A) w/o LT - human health w/o LT, respiratory effects w/o LT: 0.49 points

Colo	Product	Quantity	Unit
	Script of lecture slides [A16	0.49	points

LCIA Method: eco-indicator 99, (H,A) w/o LT - human health w/o LT, total w/o LT: 0.62 points

Colo	Product	Quantity	Unit
	Script of lecture slides [A16	0.62	points

LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, fossil fuels w/ o LT: 0.48 points				
	Colo	Product	Quantity	Unit
		Script of lecture slides [A16	0.48	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, mineral extraction w/ o LT: 0.01 points				
	Colo	Product	Quantity	Unit
		Script of lecture slides [A16	0.01	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - resources w/ o LT, total w/ o LT: 0.49 points				
	Colo	Product	Quantity	Unit
		Script of lecture slides [A16	0.49	points
LCIA Method: eco-indicator 99, (H,A) w/ o LT - total w/ o LT, total w/ o LT: 1.68 points				
	Colo	Product	Quantity	Unit
		Script of lecture slides [A16	1.68	points