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GREEN DESIGN

(UX) design know-how as the enabler of Green ICT

Faculty of information technology and communications
Bachelor’s thesis
May 2024, translated from Finnish April 2025

SUMMARY

Minnaleena Jaakkola: GREEN DESIGN – (UX) design know-how as the enabler of Green ICT
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The ICT industry has been long assumed to be a net positive force in fighting climate crisis. Even though digitalization can be a driving force in greening different industries, the environmental impacts of the ICT sector itself are comparable to those of countries. Causes behind the growing emissions of the ICT sector are among other things the fast-paced evolution of technology compared to the slow bureaucracy of legislation, culture of disposability as well as the highly influential position IT companies hold in societies. The industry, however, has many opportunities to do better.

This bachelor thesis has been conducted as a literary review. The aim of this thesis is to *scope different ways the holistic know how of (UX) designers can enable the green transition in the ICT sector.* All in all, the referenced material of the thesis paints a picture of a growing awareness towards the climate crisis and sustainability among different stakeholders in the ICT industry. On the other hand, there doesn't seem to be a clear consensus in the scientific community regarding the actual scope of the impacts of the ICT sector. Hence, more multidisciplinary research involving the subject is needed. Based on the referenced material, design has the potential to be a key element in enabling the green transition in the ICT sector. A holistic approach can help identify bottlenecks in the user experience of digital services as well as find ways to optimize the elements and features of digital services. Human centric approach that takes the whole lifespan of a product into consideration can help achieve both more sustainable and high-quality digital services.

A feasible green transition demands quick and all-encompassing changes into the way digital services are being developed and used. Both the users and developers seem to require leadership figures and clear guidance to support them in the up-coming transition. With designers, their holistic, multidisciplinary know-how and versatile soft skill sets are integral to enabling sustainable choices both in the design process and use of a digital service. Outside of organizations, the green transition requires the prioritization of sustainability through legislation and procurement processes, as well as raising awareness about the physical resources required for digital services.

Keywords: digital sustainability, user experience, Green ICT, Green Design, green transition

The originality of the Finnish version of this thesis has been checked with Turnitin OriginalityCheck –software.

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1 Introduction

United Nations (UN) has declared human caused global warming as the biggest threat humanity will ever face (UN, 2021). The effects of the climate crisis are already visible in our day to day lives through extreme weather events, energy crises, disruptions in food distribution systems and as overall political unrest in societies. The information and communication technology (ICT) sector is typically thought of as non-physical, yet it is one of the world's largest polluters. It is estimated that the ICT sector releases 2-3 % of the global carbon (CO2) emissions. Additionally, the ICT sector uses up a massive 4-10 % of the global energy supply, 8-10 % on the European Union (EU) level. If the ICT industry was a country, it would be the seventh most polluting country in the world. (Ojala & Oksanen 2021; Ojala et al, 2020)

As a counter force to the staggering climate impact of the ICT industry and the traditional "move fast and break things" way of thinking, there's the social movement of Green ICT. This global collective of ICT professionals and researchers aims to bring sustainability into a central part of the technology and software development. (Murugesan, 2008; Perèa et al, 2023; TIEKE, 2023) There's also several initiatives in the legislative level regarding sustainability, such as mandatory reporting and circular design directives (EUR LEX, 2023). Legislation, however, advances slowly while the ICT industry evolves at a faster pace year by year. At the moment, many companies, individual ICT professionals and organisations, such as the Finnish Information Society Development Centre (TIEKE) and the European Green Software Foundation (GSF) aim to advance various sustainability initiatives and practices through different publications (TIEKE, 2023; GSF, 2023a).

The European Eco-design Directive claims up to 80 % of a products carbon footprint is determined through the decisions made in the design phase (European Commission, 2022). Correspondingly, according to TIEKE, a software designed to be green can consume up to 30-90 % less energy compared to a traditional software (TIEKE, 2023). In this literary review, I aim to answer the following research question: *how can the holistic design know-how of designers enable the sustainability of digital services?"* In the literary review, I aim to uncover what is the climate impact of the design choices in digital service development and what are the actions designers can take to reduce the climate impact of digital services and the hardware they're used on. This literary review also attempts to find out how the holistic design know-how can enable overall green software development practices and how the holistic Green ICT subcategory Green Design method can affect different parts of the digital service.

The literary review is divided into six parts. The research methods and process of gathering references is covered in part two. In part three, I go through the different elements of the design process and their contributions to the carbon footprint of a digital service. Part four includes mirroring the topic in a wider societal frame and some speculation about future scenarios. In part five, I gather similarities and conclusions based on the reference materials. Finally, part six is a summary of the literary review.

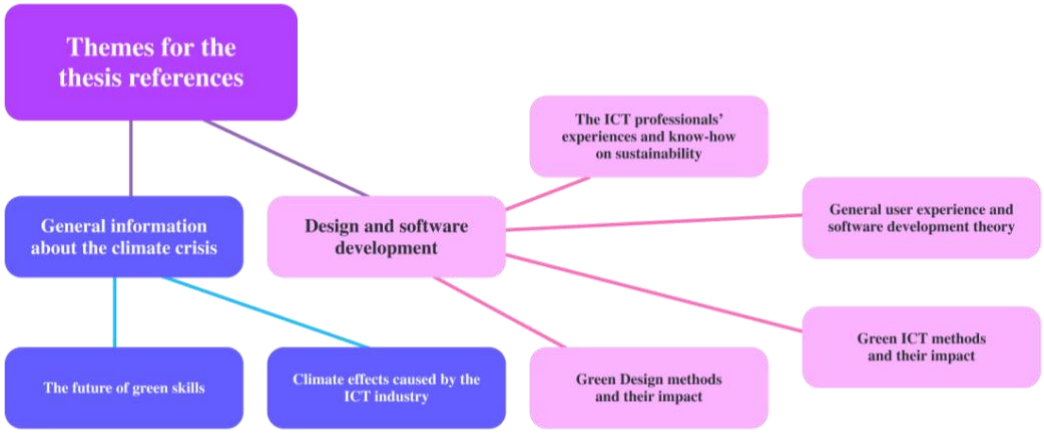
2 Methods

This bachelor thesis is conducted as a literary review. References have been searched primarily through academic databases (ACM, Proquest, Springer) as well as contemporary publications (Journal of User Experience, Quality of User Experience, UX Magazine). Some references were found through the references listed in other scientific articles. In addition to academic papers, research material also includes governmental or scientific organisations (TIEKE, Finnish State Council, UN) publications, legislative texts and relevant, respected professional publications (Greenwood, Macleod, Nielsen). Tampere University library services were also utilized in the process. Search was conducted with 1-3 conditions per search phrase. The parameters are listed in table 1.

Table 1: Search parameters used in the research phase of this thesis.

PARAMETERS 1	PARAMETERS 2	PARAMETERS 3
Sustainab*	AND (design OR UX)	OR ICT
(usability OR UX)	AND sustainab*	
Green (design OR ICT)		
(”user experience” OR UX)	AND ”carbon footprint”	
ICT	AND ”carbon emissions”	OR ”carbon footprint”
Digitalisation	AND ”circular design”	
”service design”	AND sustainab*	
”UX design”	AND electricity	OR emissions

Referenced materials include publications in Finnish and English. Additionally, the themes of materials and the relevance of said themes influenced the selection. To avoid straggling in the approach to the topic, the concept of climate impacts is only discussed in a general level and e.g. climate impacts of AI has been intentionally left out of the analysis. The reference materials have been evaluated and selected by dividing them into different themes depicted in picture 1.



Picture 1: Categories for the thesis reseach material.

In this literary review, the reliability and topicality of the used references has been enabled by prioritizing academic, peer reviewed articles as well as those materials published after the year 2020. The exception to this are the sources for relevant usability and sustainability related terms Brundtland (1987), Carroll (1997), Nielsen (1994a) and Murugesan (2008). The most important scientific references for this literary review were Bernataviciute & Balough (2022), Brundtland (1987), Freitag et al. (2021), GarcíaBerná et al. (2021), Nielsen (1994a) and Ojala et al (2020). The most important professional publications used as references in the literary review were Green Software Foundation (2023), Greenwood (2021), TIEKE (2023) and World Wide Web Consortium Group (W3C, 2024). Those selected as most important were either the most referenced in this literary review or they included some of the most relevant information to the topic.

In this literary review, I use the term *sustainability* and *sustainable development*, to describe the product development process that is executed following the guidelines of sustainable development. The topic is approached specifically from the standpoint of the ICT sector and the development of digital services. The term sustainability includes the scope of economic, social, and environmental sustainability. Corresponding terms are e.g. *green* and *responsible* development. In the ICT industry, sustainable development approach is also referred to as *Green IT / ICT, digital sustainability* and *Green Design*. (Murugesan 2008; Perea et al 2023; TIEKE 2023) With the term digital service, the literary review refers to a service, website or platform operating on or offline and used on a digital device. The literary review uses established industry term *UX / UI design/designer* to describe the process or the person behind the design of a digital service (Nielsen 1994). The literary review also uses a broader, established industry term *design* to describe all the decisions in the design process that require design know how. The terms and acronyms used in this literary review are described in more detail in table 2.

Table 2: Terms and acronyms used in the thesis.

TERM	**EXPLANATION**	NOTE
Deceptive UX	A practice where a part of a digital service is designed purposefully in a way that confuses or misleads a user.	Previously referred as "dark UX"
Green, 'vihreä' ICT	A movement or principle in the ICT industry that advances more sustainable practices.	Please see "ICT"
Green, 'vihreä' UX	A movement or principle of sustainable design among UX-designers.	Please see "UX"
Green transition	The process of transforming the economy into a sustainable system that is not based on overconsumption or the use of fossil fuels.	
HCI	'*Human-Computer Interaction'*, the science of usability and user experience	

HTI	'*Human-Technology Interaction'*, the science of usability and user experience	
ICT	'*Information & Communication Technology'*	
Irtikytkentä, 'decoupling'	Intentional and strategic change in policy and practice where the goal is to adopt circular and sustainable frameworks.	
Kestävä digitaalisuus, 'digital sustainability'	Digital development that follows the principles of circularity and sustainability	
KgCo2e	*'carbon dioxide equivalent',* The scientific measurement that expresses the environmental effects of a product, event, company etc. relative by comparing the emissions from various greenhouse gases on the basis of their global-warming potential (GWP), by converting amounts of other gases to the equivalent amount of carbon dioxide with the same global warming potential.	
SHCI	'*Sustainable Human-Computer Interaction'*	ks. HCI
UI	'*user interface'*	
UX	'*user experience'*	

Conclusions in this literary review have been reached by critical study of reference materials and reviewing their finding in relations to each other and the wider societal framework. Netum Business Lead Designer Marjut Pietarlehto has served as the pre-reader of the Finnish version of this literary review. The English version of this literary review has been translated by the author.

3 Results – Green Design and the process of designing sustainable UX

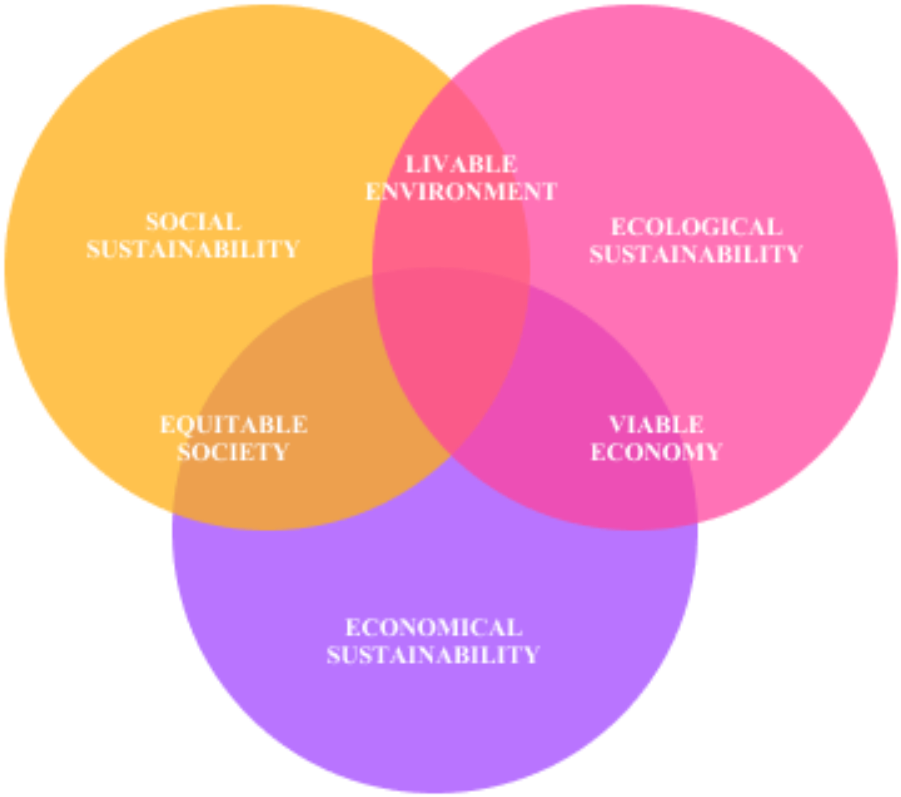
In this third part of this literary review, I go through the definition of digital sustainability. Additionally, this part clarifies the design practices that can help reduce the climate impact of both the digital service design process as well as the use of the service.

3.1 Digital sustainability

In 1987 the Brundtland report Our Common Future, defined sustainability as follows: "*Sustainable development is development that meets the needs of the present without*

compromising the ability of future generations to meet their own needs" (Brundtland 1987)

In the Brundtland report (1987), the concept of sustainability was divided into three overlapping scopes, economic, social and ecological sustainability (picture 2). Since all three scopes are interconnected, ecological sustainability cannot be addressed as an individual problem, but rather it's intertwined with larger, societal elements and phenomenon. Transitioning to the sustainable economic model envisioned in the Brundtland report (1987) is called the green transition (Ojala & Oksanen, 2021). The definition of sustainability has also been used to further developed new sustainability related terminology. Guillard (2021) defines the concept of digital sobriety as "a lifestyle that involves not just consuming better but also, and critically, consuming less". Kotlarsky et al (2023) have similarly further narrowed down a ICT-field focused version of Brundtland's (1987) definition of sustainability called digital sustainability. By introducing this term, they aim to better describe the obscured relations between technology and climate crisis. Researchers also think that in order to answer to the climate crisis effectively, it's essential that Green ICT covers all three scopes of sustainability. (Kotlarsky et al, 2023)



Picture 2: Three scopes of sustainability and their confluences
(adapted from Brundtland 1987)

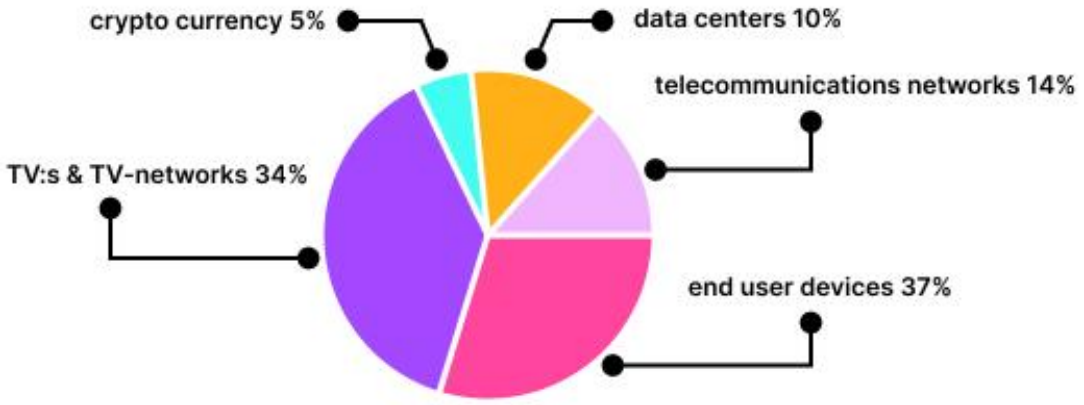
The digital world has long been thought of as non-physical with endless capacity for growth. This assumption, however, is false. Even if the ICT sector can enable the green transition in other industries, it desperately needs to transition to more sustainable practices as well. (Freitag et al, 2021) The greenhouse gas emissions produced by the ICT

industry is estimated to be around 2-5% of the global emissions and additionally it's assumed to hog 4-10% of all globally produced electricity (Ojala et al, 2020; TIEKE, 2023). Freitag et al (2021) summarised and analysed different estimates of the ever-growing
carbon footprint and energy consumption of the ICT sector in order to create prediction models of the industry's consumption trends. Regardless, research shows the emissions of digitalisation are not going to reduce on its own and they cannot be solved just by utilizing regenerative energy production methods. The currently devised action plans are therefore inefficient to curb the environmental effects of the ICT industry.

The increasing demand of physical world's resources like water, electricity and metals to make the digital world go around, as well as the tech industry's strong influence in societies is a dangerous combination that can result in the ICT sector growing at the expense of the growth of other industries (Freitag et al, 2021). Some researchers have even questioned if the effects of the green transition enabled by digitalization will be gobbled up by the growing resource use of the ICT sector. As a solution, researchers have suggested a type of conscious *decoupling* which would result in the transition from overconsumption to circular economy models in the ICT sector. One example of circular business models is the 2013 founded Dutch electronics company Fairphone that focuses on modular smartphones. (van der Velden, 2018)

3.2 Design know-how as a key component in enabling the green transition

Many consumers are not aware of the environmental consequences of their technology use (Santarius et al, 2023). Out of the carbon footprint of the internet 37 %, even 57% according to some estimates is contributed by end user devices (Freitag et al, 2021; Berners-Lee, 2021). Image 3 depicts the different contributors towards the carbon footprint of the internet and in it, the share of end-user devices is marked as 37%. The average life span of an end-user device such as laptops is 3-8 years and 2,5 years with smartphones (TIEKE, 2023; Santarius et al, 2023). Smart devices have also been associated with an unecological and hyper consumerist phenomenon, *planned obsolescence*. As a result of this phenomenon, users buy new devices before the natural end of its lifespan. (Taffel, 2022) Most of the carbon footprint of a device is attributed to its manufacturing phase so by extending the lifespan of a device, its relative climate impacts can be significantly lowered (GSF, 2023c; Lovehagen et al, 2023; Santarius et al, 2023). Device lifespan can be extended by lowering the strain on the battery, central memory unit and screen during use as well as enabling the compatibility of digital services and software with older devices (Santarius et al, 2023). This is why design solutions that support resource efficiency and longer device lifespans in digital services are essential in transitioning to more digitally sustainable practices.



Picture 3: Elements that contribute to the carbon footprint of the internet
(adapted from Berners-Lee 2021)

Circular economy practices are applicable to not only devices, but also software itself. The European Commission Eco-Design Directive estimates that up to 80% of the carbon footprint of a product is determined by the choices made in the design phase (European Commission, 2022). Similarly, TIEKE claims that a software that's designed with green principles could save 30-90% in energy consumption (TIEKE, 2023). Design has also been noted in European Centre for the Development of Vocational Training's report on the development of the ICT industry as one of the essential future skills (CEDEFOP, 2023).

One great example of the ballooning use of resources in digital services is the gaming industry. The massive hardware requirements to download games and long installing times have been raising eyebrows among consumers in recent years. (Evanson, 2023) Some argue this is only natural due to more detailed HD graphics and cheap data storage. The above mentioned as well as the fast paced "crunch" timelines of the game development industry can also contribute to the large size of new releases. One such example is Cities: Skylines 2, which performed badly despite quality hardware. (Huhtala, 2023) A Finnish software engineer Paavo Huhtala combed through the game's files in order to find out the reason for its lagging. Atop of some technical issues, he found out that the game developers had used the same rendering model for both playable character and the non-playable characters (NPC's). This resulted in every NPC having fully rendered features, complete with individual hair strands and teeth, regardless of how far away they were from the player's view. This caused severe overload to the system and slowed downloading. Situations like these could be prepared for or avoided altogether by applying holistic, sustainable design decisions.

In addition to design related knowledge, designers often possess so called *soft skills* that centre around communication and empathy. Soft skills are essential in user-oriented design processes, but they also enable relaying difficult, abstract information to different stakeholders in a more easily digestible format. (Crause & Rosala, 2020) This way designers who advocate for sustainability can use communication skills to persuade different stakeholders into being more susceptible to adopting more sustainable practices.

3.3 High-quality UX-design serves as the base for sustainability

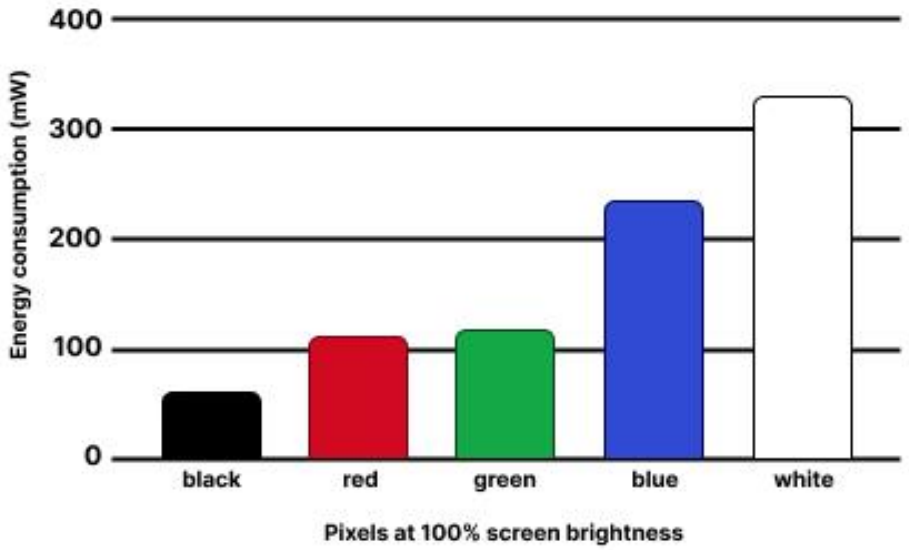
In a holistic design process, the whole life cycle of the product is taken into consideration, not just the immediate user experience. The pioneer of usability Jacob Nielsen (1994a) determined ten different elements of high-quality user experience, dubbed '*usability heuristics*'. Among others, these include minimalistic visuals, efficient navigation, minimizing user errors as well as clear and efficient communication between the user and the system (Nielsen Norman Group, 2024). There's a lot of overlap between usability and sustainability. For example, when you compare the Nielsen (1994a) heuristics and for example the sustainability guidelines by the World Wide Web Consortium Sustainable Web Design Community Group, you can find significant similarities (Nielsen 1994a; Nielsen Norman Group, 2024; W3C, 2024). Researchers García-Berná et al, (2021) also found that user interface design and usability in personal e-health web services were directly connected to the energy consumption of said services. They utilized Nielsen (1994a) heuristics in their evaluation. As a result, the team discovered several connections between high quality user experience and the energy consumption of the services. Key elements effecting the energy consumption seemed to be minimalistic UI and preventing user error. The time in which the users were able to complete tasks seemed to also correlate with the compliance of heuristics in the service design. (García-Berná et al, 2021)

As a matter of principle, UX designers are expected to avoid unethical, deceptive UX methods. These manipulative *dark patterns* are for example often used to obscure or hide options to unsubscribe or cancel a service or alternatively to increase the time users spend in the service. (Rosala, 2023) Deceptive UX typically boosts revenue at the users' expense. It is seen as not only unethical but also considered to lower the usability and accessibility of a service (W3C, 2023). Additionally, since deceptive patterns encourage users to linger in services longer than necessary, they add to the energy use of the service. (Greenwood, 2021; W3C, 2024).

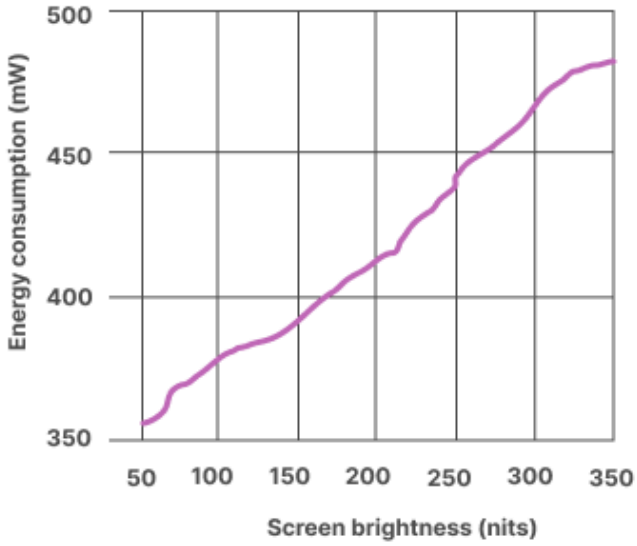
In addition to service design methods, Green Design approach also provides opportunities for optimizing the energy consumption of the UI itself. The visual elements such as images and videos can be set to a fixed size and quality in the design phase depending on the use case. Media elements can also be set to download only when they enter the user's view – a technique called *lazy loading*. (Greenwood, 2021) For example, it's near impossible to differentiate a high (4K) and medium (1080px) quality images on an older device with a smaller screen and there is no point in enabling surround sound without the appropriate speakers. When designers use predetermined settings on UI elements such as maximum height for images, it's also easier to hand over project to the developers. This practice also supports the *responsivity* of a service, making it automatically adaptable to different sized screens. It is also useful to determine the scope of utilizing different resource libraries beforehand; if for example only one version of a font is used in a service, is there any point in downloading the whole selection of it? Instead, designers should utilize system fonts whenever possible. (Greenwood, 2021; W3C, 2024)

These days, many smart devices have OLED-screens that use more electricity depending on the colours of the UI. This is because in OLED-screens, every pixel corresponds with a tiny light – simplified, if the pixel is black, it means the light is off and therefore the device uses less energy. (Greenwood, 2021) This was also noted in a 2018 demonstration

at Google, where they found significant differences between different UI colours. The comparison demonstrated the most energy hogging colour was white, then blue, then green and red and finally black as most energy efficient (picture 4). Additionally, the screen brightness has been found to affect device energy use (picture 5). The demonstration also featured a comparison between light and dark mode in streaming service Youtube, which showed a whopping 60% difference in energy use between the two versions (figure 3, picture 6). (Burns, 2018)



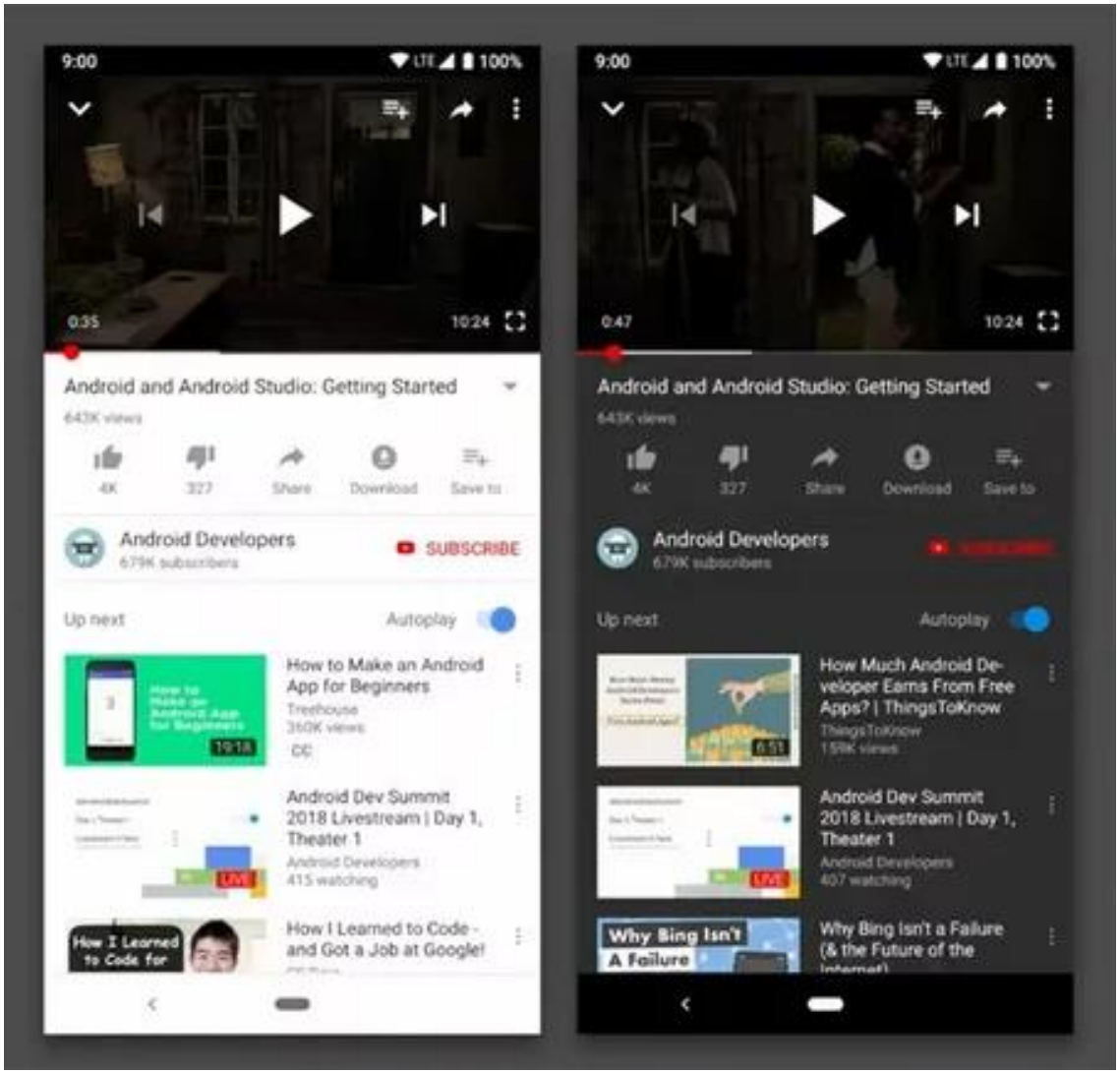
Picture 4: Comparison of the energy consumption of a smart device screen divided by pixel colours (adapted Banes & Viverette, according to 2018 Burns, 2018).



Picture 5: Graph depicting the correlation between screen brightness and energy consumption (adapted Banes & Viverette, according to 2018 Burns, 2018).

Table 3: Comparison of the energy consumption of a paused Youtube video when comparing light and dark mode (adapted Banes & Viverette, according to 2018 Burns, 2018)

Screen brightness	Light mode	Dark mode	Effect
50 %	93 mA	80 mA	- 14 %
100 %	239 mA	96 mA	- 60 %



Picture 6: Youtube-video paused in light mode (left) and dark mode (right)
(adapted Banes & Viverette, according to 2018 Burns, 2018).

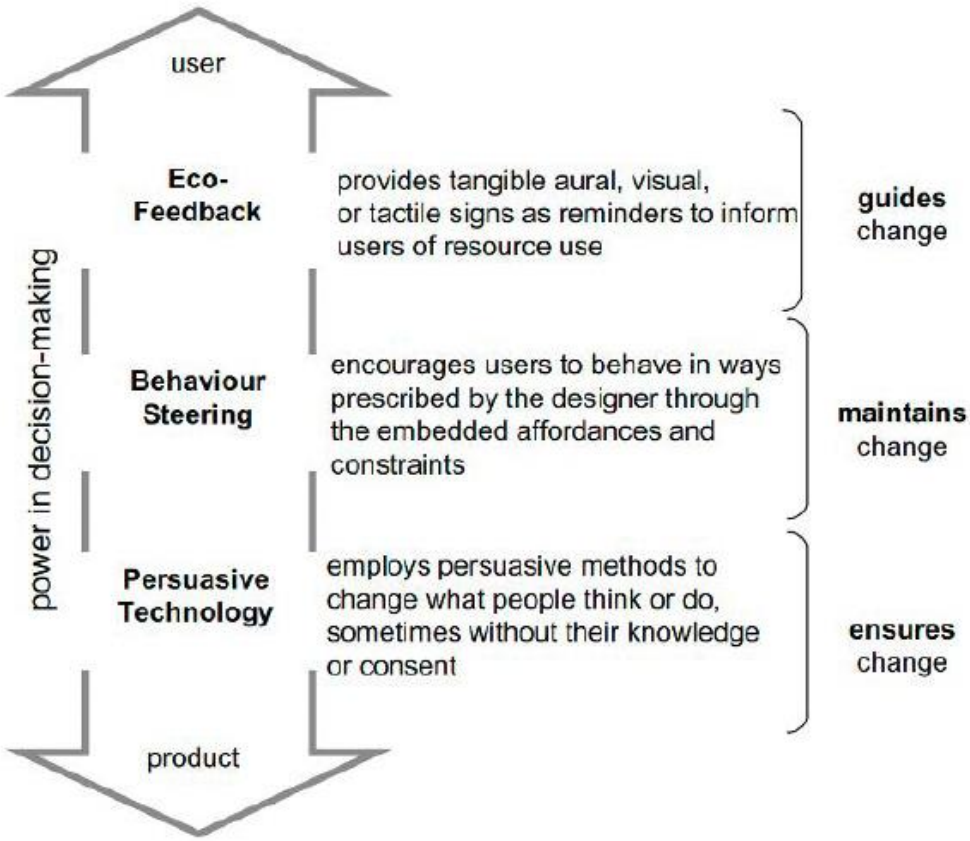
When using dark color palettes in UI design, it's easier to achieve high contrast elements. This enables a more accessible user experience for all users, because high contrast content is easier to interact with in low light situations and with lower screen brightness. (W3C, 2023; W3C, 2024) Including dark mode as a default feature thus not only benefits all user groups but can also be seen as a design feature that extends a devices lifespan.

All in all, it seems that the core of Green Design is the following: the lighter the technical elements of the design and the faster, effortless and streamlined user experience, the more

high-quality and sustainable the service will be. However, each design project has a myriad of influencing factors. For example, even if green and red are more energy efficient than blue, using them in a UI can decrease the usability of the service for color blind individuals. This is why it's imperative that designers utilize their know-how to determine what is prioritized to find comprehensive solutions for sustainability that don't compromise the usability of the services.

3.4 Choices and consent at the core of designing sustainable digital services

One of the most fundamental heuristics is supporting the users' sense of agency. By supporting users' agency, they are able to complete tasks independently and feel in control of their own user experience. Loss of control often causes users to become frustrated and can lead to abandoning tasks. (Nielsen, 1994b; Nielsen Norman Group, 2024) This is why visualizing information clearly and especially explaining the decisions behind sustainable design choices to the users is incredibly important. Influencing user behaviour (*nudging*) has been found to be a useful tool for encouraging change towards a more sustainable habits. Nudging can be covert, such as highlighting or prioritizing sustainable options in the UI, or it can be clearly communicated, such as listing the environmental effects of different choices next to them (picture 7). (Bernataviciute & Balogh, 2022)



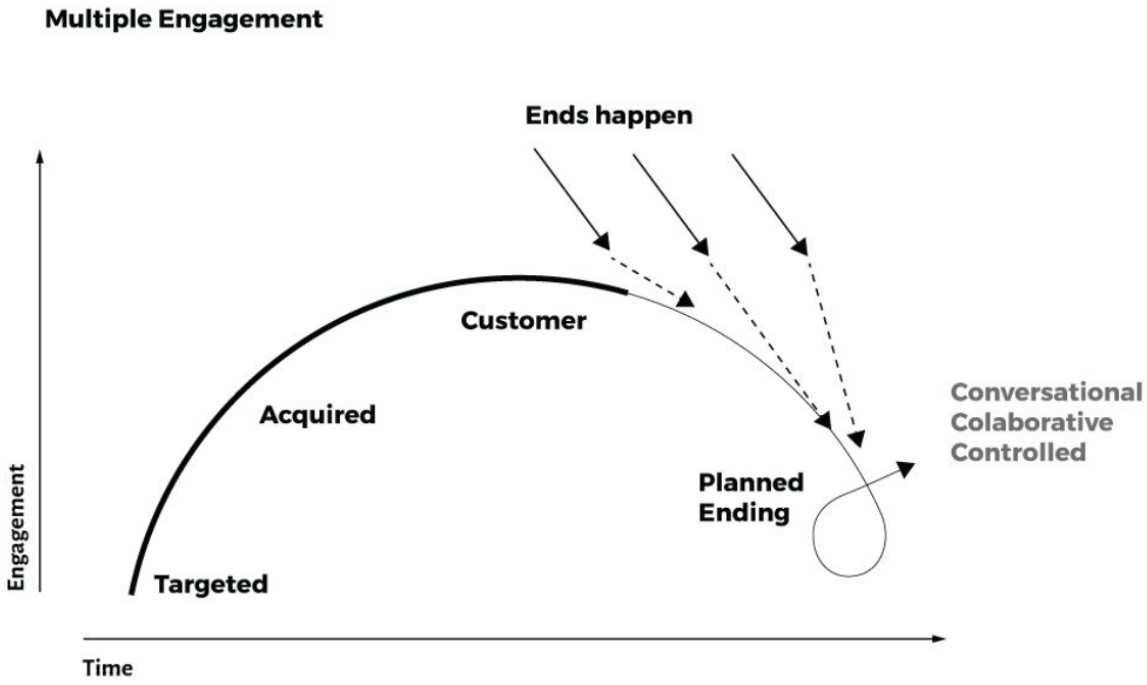
Picture 7: Strategy diagram for designing more sustainable user behaviour
(adapted Lilley 2009, according to Bernataviciute & Balogh, 2022)

At the moment, a staggering 80% of online traffic can be attributed to video streaming. In terms of data transfer, it seems that using mobile networks eat up resources multiple

times more than wi-fi transfer. (Hanhivaara, 2022) Even though end-user devices use up only a fraction of the emissions of ICT-sector, the data transferred through the devices is a significant factor (Freitag et al, 2021). In the process of designing a service, the designer has the power to decide e.g. when files, search results or alternative views are downloaded. This directly contributes to the amount of data transfer caused by the service. Greenwood (2021) has suggested that in order to utilize as much renewable energy as possible, the developers of digital services should develop energy aware processes and schedule their resource intense workloads to times when the grid is under least amount of pressure and renewable energy is abundant. Scheduling the processes in a service – such as "download only through wi-fi" – could be either a predetermined filter in the service preferences or an option under every user choice – such as initiating a video stream instead of using autoplay. Data traffic caused by media streaming could be decreased further by providing users text summaries or shortened segments of the contents. This way the user can decide whether the content is relevant and worthy of downloading. Freedom of choice in downloading content also supports the user's agency. (Greenwood, 2021; W3C, 2024)

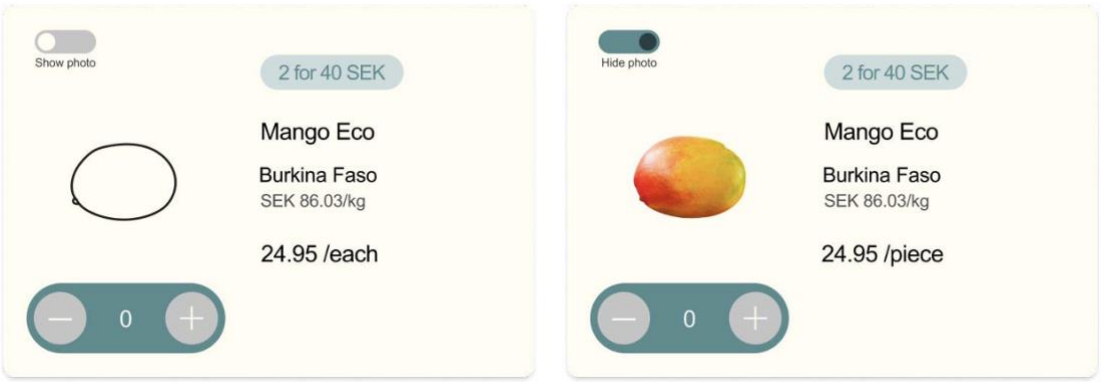
Handling and preserving data increases the carbon footprint of the ICT-sector and it is estimated that the amount of data preserved doubles every other year (Freitag et al, 2021; GSF, 2023c). Out of this data, 90% is said to be unnecessary, and it's never accessed again after the initial save (Macleod, 2021). According to Google's estimate, the carbon footprint of idle data preservation is up to 600 000 kgCo2e a year (Talbott & Conkling, 2021). Through holistic design approach, digital services could include elements that could communicate with users about the emissions caused by their data handling and enable more intentional data handling practices instead of merely suggesting more cloud space. Not only would a more conscious data handling increase sustainability, it would also enable a more secure user experience.

Due to the recent rise of *attention economy* many digital services encourage their users to spend more and more time scrolling. This is managed by deceptive design patterns, frequent push-notifications, endless scrolling and carousels as well as recommendations based on user data. (Santarius et al, 2023) In his book *Endineering.*, Joe Macleod (2021) explains the process of *off-boarding* in the context of digital service development. He claims that one way to enable the transformation to a more circular economy would be through focusing on endings – guiding the users from one experience to another instead of encouraging continuous use (picture 8). There are several different types of endings, both during and at the end of a user experience such as finishing a task (e.g. payment process) or relocating out of the reach of the service (e.g. moving to another city). Paradoxically, by enabling the users to let go of the service, Macleod claims designers can actually increase user satisfaction and revenue. This is due to the *peak-end-rule* where the most intense part of the experience as well as its ending is the most memorable to the user. (Macleod, 2021) By focusing on endings and avoiding coerced lingering in the service, designers can enable a more conscious use of the service and therefore more sustainable and ethical digital service design.



Picture 8: Timeline depicting user commitment during user experience (Macleod, 2021)

Bernataviciute & Balogh (2022) conducted a study on how low carbon UI designs correlated with user satisfaction. They designed an imaginary e-commerce website prototype in which they included different low carbon design elements and gathered data on how users reacted to them. The design choices included for example a toggle to swap the product image to a vector graphic (picture 9). Users reacted positively to the more minimalistic low-carbon UI and on the contrary felt it supported a more intentional use of the service. (Bernataviciute & Balogh, 2022) Low-carbon UI's could be a welcomed option for users whose internet connection is weak or those with difficulties navigating highly stimulating UI's. If Green Design -approach gains traction in the future, it could lead to the popularization of a more situationally aware, flexible user experience. Soon, the concept of responsivity might also include adapting to not just screen variations, but to the energy grid and data traffic as well.



Picture 9: Product card from the imaginary web-shop prototype, depicting a low carbon version (left) and a high carbon version (right) (Bernaviciute & Balogh, 2022)

4 Results – The future development of Green ICT

Part of this thesis aims to estimate the possible evolution of Green ICT and the challenges those practicing it might face.

4.1 Green ICT is a foundation for the future – not a trendy phase

The ICT-sector can enable other industries to decrease their carbon footprint through digitalization (Ojala et al, 2020). Busk et al (2023) also estimate that the number of potential jobs created by the green transition in the technology industries are higher than average. Sustainable Green ICT skills are much like accessibility, most likely soon recommended, or even expected of industry graduates.

The ICT sector can't however lull itself with the potential influence of the industry, and must find solutions to reign in its own, rapidly soaring carbon footprint. Due to *Jevon's paradox* – a phenomenon where absolute use of a technology increases along with its efficiency – the industry can't rely on optimization alone. (Freitag et al, 2021) That's why Freitag et al (2021) urges legislators and public procurement to limit the ICT companies freedom to define their own rules and force corporations to set environmental preservation above short-term profits. Legal limitations are typically seen as the most effective way to encourage a more sustainable way of production (Péréa et al, 2023). It is also possible that in the coming years the finite resources of the physical world start to affect technological advancements. Prioritizing sustainability could show up as carbon budgets and sustainable quality assurance metrics in projects and procurement plans.

4.2 Visions of the future of sustainable digital services in the societal frame

Bremer et al. (2022) pondered the evolution of sustainable human-computer interaction (SHCI) and the critique the field has faced in the last 15 years. According to them, research in the field has turned towards a more holistic, multidisciplinary angle, where climate crisis is approached from a system-oriented view instead of the traditional individualism. In their paper however, Bremer et al (2022) also state that the awareness and skills of ICT professionals can't compensate for the lack of regulation and proper policy. Elgaaied-Gambier et al (2020) came to a similar conclusion – they claim that users of digital services expect governmental figures or ICT companies themselves to influence the emissions caused by technology, instead of attempting to alter their own habits. Therefor instead of relying on individuals changing their habits, a successful green transition would require management on a societal level. But what makes it so hard to utilize sustainable design know-how in the development process of digital services?

In 2023, the Green Software Foundation published the "State of Green Software" -report, in which they conducted surveys concerning the attitudes, know-how and experiences of ICT professionals regarding sustainable software development initiatives in their work. In light of the results of this report, it seems that sustainable software development initiatives often fall on independently educated individual employees who are passionate about the sustainability. According to the survey, many software professionals are interested in sustainable development but lack the appropriate know-how and organizational support frameworks to concretize their passion. Over half of respondents represented companies who had not set any concrete sustainability targets. (GSF, 2023a) Leaving the concretization of sustainability as a company value up to the individual

employees seems to hinder forming any meaningful companywide policies and sharing relevant know-how over unit lines. This can also cause burnout to those passionate employees who end up carrying the brunt of the unofficial effort and pressure of advancing sustainability in their workplace. Posch & Speckbacher (2017) observed that middle management would seem to play a crucial part in advancing sustainability strategies. In their survey conducted in over 134 companies, they noticed that middle level managers served as a type of relay between the lofty strategic goals of the higher management and concrete everyday tasks of employees. (Posch & Speckbacher (2017))

5 Conversation

Part five of this thesis attempts to summarise and present conclusions based on the previous chapters. Additionally, it aims to identify potential future areas of research.

The goal of this thesis was to map out the ways (UX) designers can utilize holistic design know-how to enable the sustainability of digital services. Based on the gathered materials, design know-how has the potential to serve as a key element in the green transition of the ICT-sector (European commission, 2022; García-Berná et al 2021; Macleod, 2021; van der Velden 2018). As a result of this thesis, it seems that a holistic approach that's typical in design, can help identify bottlenecks in services, optimize the service functions and help prolong the lifespans of end-user devices (Greenwood, 2021; Lovehagen et al 2023; W3C, 2024). Additionally, a service that's comprehensively designed following green design principles, would seem to have a higher quality, more secure and accessible user experience (W3C, 2023; W3C, 2024). Utilizing user data in the design process as well as designers skilful interaction with different stakeholder groups will most likely result in higher quality and more intentional user experience. This can also help drive the whole production team towards more sustainable workflows. (Bremer et al, 2022; Crause & Rosala, 2023). Digital service development however has a variety of both direct and indirect influencing factors, including limited resources, which demands designers to utilize their professional know-how to identify and prioritise the sustainability development aspects case by case.

All in all, the research material of this thesis communicates an increasing awareness about the climate crisis and the role of the ICT sector in it among industry professionals. Even if there's no consensus among the scientific community on the exact numbers of emissions caused by the ICT sector, it is clear that digitalization is one of the significant contributors of the strain on the environment (Freitag et al, 2021; GSF 2023b; Lovehagen et al, 2023; Ojala et al, 2020; TIEKE, 2023). The exact emissions caused by different processes are hard to verify for example because of numerous indirect influencing factors and lack of transparency among other things. On the other hand, considering the rapid growth of the emissions and energy consumption, waiting for comprehensive, exact statistics could hinder enacting change and tie too much of the available resources to bureaucracy instead of action.

One of the factors complicating Green ICT research is the powerful social status of ICT companies and their lack of transparency. A lot of the information regarding the emissions of digital services has been classified as trade secrets. In general, the green transition is being led by economic ideals and investments in technology products development,

which can in turn affect research through the popularity of certain research topics as well as directing and rationing of funds to certain topics. Many of the people producing research in the field of Green ICT – such as TIEKE (2023), Greenwood (2021) – are either working in close collaboration with commercial actors or serve as consultants in the ICT industry. The connection with commercial or political actors can lead to incomplete information, cause biases in the produced materials or lead the research towards the interests and in favor of the industry. The green transition is in itself a politically loaded topic which can in turn for example effect research and its trends and the attitudes of industry professionals.

All in all, the results of this thesis are somewhat applicable to researching and developing more sustainable digital services. The research materials of the thesis are high quality scientific references searched through appropriate databases, and the contemporary professional literature has been produced by respectable industry actors. The references of this thesis also contain up-to-date information. Conclusions in this thesis have been drawn through a critical thought process, and they're backed by the reference materials. The thesis is, however, only a bachelor level literary review, so it is just a relatively short overview of the topic. The number of references is also fairly limited and consists of materials released in either English or Finnish. The thesis could have achieved more in-depth conclusions by including sources written in for example German, French or Spanish. These notions should be considered when applying the results of this thesis.

There is a clear potential for utilizing Green ICT and Green Design in both commercial product development as well as independent scientific research. Especially multidisciplinary collaboration among humanities and STEM could produce comprehensive studies on the subject. This thesis identified at least the following as potential research subjects:

- Researching the experiences of design professionals in the ICT industry on what is enabling or hindering advancing sustainability in their work, possibly through surveys and interviews.
- Researching the effects of data transfer to the lifespan of the end-user devices through user testing: integrating different offline solutions as a part of digital service user journeys in for example file management.
- Studying the way emissions and their environmental effects could be communicated to the end users of digital services and researching how this could influence user behaviour through user testing and interviews.
- Studying how different low carbon modes affect the emissions of digital services and how users interact with them or feel about them.

Through the research materials, it is clear that a reliable, realistic green transition demands quick and comprehensive changes in the way we develop and use digital services. Both the end-users and industry professionals seem to need leadership figures and clear guidance in the transition towards more sustainable digital services (GSF, 2023a; Greenwood, 2021; Posch & Speckbacher, 2017). By utilizing their holistic, multidisciplinary know-how and interpersonal skills, designers can be key players in encouraging more sustainable use of digital services among end-users. This can be further enabled by efficiently communicating the emissions of the service to the user but also by

designing the user journey to encourage the sustainable choices subconsciously (Bernataviciute & Balogh, 2022; W3C, 2024). There should also be efforts towards developing flexible, low carbon UI modes to enable more sustainable use of digital services. Utilizing low-carbon UI modes, services could decrease the amount of energy consumption and data transfer (Greenwood, 2021; Hanhivaara 2022).

Outside the scope of individual organisations, green transition should be enabled through prioritizing sustainability as a societal goal through legislation and increased awareness of the physical resources consumed by the ICT industry (Freitag et al, 2021). ICT industry professionals should be offered support and resources to learn new green skills and knowledge. The future societies function largely dependent on digital infrastructure which makes it essential for those developing and procuring it to prioritize producing responsible and sustainable solutions.

6 Conclusions

The ICT industry is still often thought to be immaterial and its effects to the climate are challenging to verify accurately. Technology and digital services are however huge contributors to the climate crisis and digitalization is expected to only increase in the coming decades. Luckily, the Green ICT phenomenon has brought the topic of sustainable digitalization to the forefront of the industry and the methods of green digital service development are becoming the norm in both Finland and globally. With appropriate legislative actions and support to the industry professionals, the sorely needed, quick green transition is still possible.

The use of digital services causes both direct and indirect emissions. A large contributor to the emissions caused by the ICT industry is the manufacturing process of end-user devices and therefore design choices that prolong the device lifespan are essential in transitioning to a circular economy. Those designing digital services have several ways to affect the emissions caused by the service. In addition to optimizing the technical elements of UI's, designers can enable digital circular economy by focusing on endings in the user journeys, avoiding design choices that enable the attention economy and by developing different low-carbon modes. Additionally, designers can encourage more sustainable choices through the design of the UI elements and functions.

The approach and methods of both Green ICT and its subcategory Green Design enable the transition towards a more circular economy in the ICT industry. The lighter the technical elements of the design and the faster, effortless and streamlined user experience, the more high-quality and sustainable the service will be. Aiming to produce as high quality, user-centered experience seems to be the most sustainable choice.

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