The sustainability of digitalization: Methods for the analysis of digital processes.

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Abstract

Two major themes of the modern world in all industries include sustainability and digitalization. The impacts digital processes have on sustainability goals have been evaluated in many studies focusing on different aspects of sustainability. However, the overall picture considering the enablers and challenges digitalization conveys on sustainability, still requires more analysis.

Five significant themes collecting together the impacts of digitalization on sustainability are identified in this thesis. These themes are identified through the analysis of the enablers and challenges of digitalization regarding the UN Sustainable Development Goals. Namely the themes are Accessibility and Equitability, Economy, Education, Environment, and Strong Institutions. Together these five themes form a basis for analyzing the sustainability of digital processes introduced in this thesis. The resulting pipeline can be used to analyze the sustainability of new or existing digital processes to develop them to become more sustainable.

This thesis aims to identify methods for analyzing the sustainability of digital processes through a literature review studying the essence of the interlinkage between digitalization and sustainability.

The pipeline suggested in this thesis approaches the sustainability of digital processes from two different angles. Firstly, the pipeline for each theme includes a step evaluating whether the process at hand can be described as a process for sustainability, meaning that the process itself furthers sustainability goals. This section of the pipeline for each theme could be further developed into another tool for supporting the establishment of new innovations for sustainability. The second part studies the sustainability of the process regardless of whether the process itself is meant for forwarding sustainability. However, the second part has limited coverage due to the large size of both themes, sustainability and digitalization, and could also be developed through more extensive literature reviews.

When applied to digital processes, the pipeline has the potential to further sustainability goals through digitalization and enable curbing challenges that digitalization opposes for sustainable development. This conclusion was demonstrated through a case study considering a digital archiving tool, Arkki. Through the case studies, strengths and weaknesses of the digital process were identified, and future considerations for developing the strategy to become more sustainable were established.

This demonstration supports the conclusion that the aim of the thesis was met, and the results formed in the thesis can be used to analyze the sustainability of digital processes, resulting in the more sustainable development of the digital world. Yet the pipeline could be further developed through more profound studies of the interlinkages between sustainability and digitalization, and it should be developed as new impactful technologies emerge.

Keywords Sustainability, Digitalization, Sustainable Development, Digital Processes, UN Sustainable Development Goals, Sustainability Frameworks, Accessibility, Equitability, Economy, Education, Environment, Strong Institutions

Preface

First and foremost, I would like to thank my supervisor Dr. Ivan Vujaklija and my advisor Nathalie Kuosa. Thank you for your insightful feedback, and fruitful conversations, for cheering me on through the whole process, and for believing in me and my topic. I would like to thank Evitec for supporting me with this thesis and especially Marko Väisänen for your dependable support in the sustainability analysis of Arkki.

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Espoo, 29.5.2023

Emmaleena Ahonen

Contents

Abbreviations and Terms

Abbreviations

AI	Artificial Intelligence
ESG	Environmental, Social, Governance
EU	European Union
GDP	Gross domestic product
GHGs	Green House Gases
GRI	Global Reporting Initiative
ID	Identification
KPI	Key Performance Indicator
R&D	Research and Development
SDGs	Sustainable Development Goals
SMEs	Small and medium-sized enterprises
UN	United Nations
UN GC	United Nations Global Compact

Term Definitions

Arkki	Digital archiving solution by Evitec Ltd.
Biodiversity	All different forms of life present in some area.
Digital Natives	People born into the digital era and perceive digital processes as a natural part of everyday life, embracing them effortlessly.
Digital Platform	A software-based network that enables interaction between users and streamlining business operations.
Equitability	Providing opportunities that enable anyone to succeed.
Gender Gap	Systemic differences as to how different gendered people are treated.
Global South	Refers to the developing countries of Latin America, Asia, Africa, and Oceania.
Green Coding	Coding in an environmentally conscious manner, considering the energy efficiency of the code.
Jevons paradox	A situation where advances in technology lead to higher efficiency and savings in resources, but this also leads to higher demand and consumption.
Just transition	Refers to developing towards a climate-neutral economy while mitigating the challenges, including employment and sustenance of people and communities.
Open Data	Data available for anyone free of charge.
SDGs	17 global goals set by the UN for a more sustainable world.
Tax-base erosion	Using financial tools and tax planning to minimize taxes companies need to pay.
Transversal Skills	Skills essential for employment.

1 Introduction

Digitalization is no new concept; even the exploration of using digitalization as a tool for a more sustainable future has been prospering for a while [11]. It has become widely accepted that digitalization is a tool that can be used as one measure in sustaining many of the United Nations' Sustainable Development Goals (SDGs). Yet digitalization also opposes challenges when considering sustainability and the SDGs [10]. For people to be able to develop a more sustainable future through digitalization, the challenges and threats of digitalization must also be recognized and weighed against the positives.

Digitalization has been noticed to enable increasing numbers of people to access services and information, building towards a more socially equal world [24]. Furthermore, digitalization enables the optimization of many processes and modeling and planning of others, possibly reducing greenhouse gas (GHG) emissions [33]. Digitalization can also be utilized to promote optimization growth [33] [26]. Digitalization, therefore, has the potential to open many doors to a more sustainable future.

Nevertheless, there are opposing sides to digitalization concerning sustainability [10]. The challenges of digitalization are often forgotten when striving towards a more sustainable world through digitalization. Even though digitalizing services and information can lead to a more vast audience being able to reach the services and information but simultaneously, as the number of physical or live services lessens, some people might be left troubled, for example, due to a lack of knowledge on how to use digital services [11]. Algorithms have been noticed to raise productivity, but algorithms may often reflect the views of the person behind them and even unintentionally end up discriminating against a particular group of people [37].

Algorithms and other digital services can also be severely energy consumption, wise heavy solutions, and tremendous computational resources are necessary. This leads to high GHG emissions, possibly more significant than the good that the digital transformation has done [34]. Digitalized products and solutions may also lead to Jevon's paradox and over-consumerism. Artificial Intelligence (AI) and customer targeting solutions could also lead to overconsumption. [11] [34]

Economically speaking, digital solutions might also be highly expensive for poorer countries and regions [11]. Moreover, the automatization of processes could lead to the loss of some jobs, leading to a heightened need for re-educational opportunities [23] and just transition [74], and push more profits to business owners instead of the created value being equally distributed among the workforce [10]. However, views on this matter differ [11].

When companies and organizations seek ways to utilize digitalization to reach sustainability targets, both positive and negative sides should be considered equally to ensure that digitalization leads to the greater good rather than negative results. Organizational digital strategy should therefore include discussion on both aspects. Unfortunately, though sustainability and digitalization are both topical and universal themes, currently, there are no universal guidelines for building a sustainable digitalization strategy. In my thesis, I aim to investigate possible means for analyzing the sustainability of digitalization and thereafter seek to further tools companies need to

build strategy towards sustainable digitalization.

The ultimate goal is to assemble a pipeline, which companies could use to analyze the sustainability of their digital processes. As has been established, digitalization has the potential to forward progress toward global sustainability goals, but it also opposes some threats to sustainability. Both opportunities and threats are distributed throughout different sustainability themes, and it can be challenging to grasp all different areas without a structured framework. The aim is to provide such a framework in the form of a pipeline. This way, companies can analyze the effects of their digital processes on sustainability, covering a range of critical themes. After running a digital process through the pipeline, the company would also have concrete concepts for further developing this digital process to support sustainable development.

In this thesis, I will first discuss sustainability and the existing frameworks to portray its different aspects. I will then analyze and identify digitalization's positive and negative sides from the sustainability perspective. This will be followed by the introduction of a pipeline that I propose for the study of the sustainability of digital processes. Finally, I will present a case study's findings to which the proposed pipeline was applied.

By reading this thesis, you can gain a good understanding of the interlinkage between sustainability and digitalization, the key possibilities and challenges digitalization opposes to sustainability, and the tools for deciding how the sustainability of digital solutions can be evaluated.

2 Sustainability Frameworks

Sustainability is a broad topic that consists of several different aspects. This has led to the creation of many different frameworks for studying sustainability. In this section, I will analyze a few of the most widely recognized frameworks to conclude which framework suits the study of digitalization the best.

Perhaps one of the most common ways of dividing sustainability into separate sections is through the triple bottom line framework published by John Elkington in 1994 [1]. This framework can be used to identify, assess and integrate a company's Environmental, Social, and Governance impacts. The abbreviation ESG is often used for these three pillars of sustainability. [2] The environmental aspect covers energy efficiency, emissions, waste, climate change, biodiversity, and other environmental issues [1] [2]. The social aspect analyzes responsibilities concerning human rights, employee rights and well-being, and product liability [1] [2]. Finally, governance analysis handles topics such as policies around corruption and bribery, paying taxes, procedures for appointing board members and CEO, and board activities [2].

The triple bottom line framework may be beneficial in the creation of company sustainability strategy, KPIs, and reporting [1]. ESG evaluation of companies, funds, and investments has also become a central tool for sustainable investing and risk analysis [2]. Nevertheless, the framework also imposes challenges. Some sustainability efforts and risks, for example, cannot be classified only under one of the three aspects of ESG. Clean water, for example, is an environmental issue and a basic human right. The model has also been criticized for separating governance and, thereby, economy and economic gain from the environment and social issues. [1]

The United Nations (UN) launched Sustainable Development Goals (SDGs) in 2015 for a more prosperous world by 2030 [1]. These SDGs are a set of 17 different global goals, which aim to end poverty, promote economic growth, and better societies by addressing topics such as education, health, social protection, and job opportunities, prevent climate change, and enforce environmental protection [3].

The 17 SDGs are:

- GOAL 1: No Poverty
- GOAL 2: Zero Hunger
- GOAL 3: Good Health and Well-being
- GOAL 4: Quality Education
- GOAL 5: Gender Equality
- GOAL 6: Clean Water and Sanitation
- GOAL 7: Affordable and Clean Energy
- GOAL 8: Decent Work and Economic Growth
- GOAL 9: Industry, Innovation, and Infrastructure

- GOAL 10: Reduced Inequality
- GOAL 11: Sustainable Cities and Communities
- GOAL 12: Responsible Consumption and Production
- GOAL 13: Climate Action
- GOAL 14: Life Below Water
- GOAL 15: Life on Land
- GOAL 16: Peace and Justice Strong Institutions
- GOAL 17: Partnerships to achieve the Goal

These universal goals also have 169 sub-goals, most directly related to business. The SDGs framework recognizes how sustainability issues or goals are integrated and enable a clear measurement of sustainability. [4]

The UN Global Compact (UN GC) is a framework that can be seen as a lighter version compared to the SDGs but more concrete than the triple bottom line approach. The UN GC was formed already in 1999 and, at that moment, included nine principles. Today, the Compact is based on ten principles all participants must adhere to. [1] These principles are divided under four categories, namely, human rights, labor, environment, and anti-corruption, and are as follows [5]:

Human Rights

- Principle 1: Businesses should support and respect the protection of internationally proclaimed human rights; and
- Principle 2: make sure that they are not complicit in human rights abuses.

Labour

- Principle 3: Businesses should uphold the freedom of association and the effective recognition of the right to collective bargaining;
- Principle 4: the elimination of all forms of forced and compulsory labour;
- Principle 5: the effective abolition of child labour; and
- Principle 6: the elimination of discrimination in respect of employment and occupation.

Environment

- Principle 7: Businesses should support a precautionary approach to environmental challenges;
- Principle 8: undertake initiatives to promote greater environmental responsibility; and

- Principle 9: encourage the development and diffusion of environmentally friendly technologies.

Anti-Corruption

- Principle 10: Businesses should work against corruption in all its forms, including extortion and bribery.

The Global Reporting Initiative (GRI) is another sustainability framework mainly used in sustainability reporting. The GRI focuses on communication and helps companies demonstrate accountability for their impacts on the triple bottom line or ESG. The initiative publishes extensive sustainability reporting standards, covering all aspects of ESG in-depth, including topics such as biodiversity, waste, emissions, diversity, equality, health, safety, and tax. The initiative aims to provide tools for better transparency and communication between companies and their stakeholders. [6]

The International Organization for Standardization (ISO) has also published some standards on sustainability. Two perhaps most important ones from the sustainability viewpoint are ISO 14001 and ISO 26000. ISO 14001 offers practical tools for the management of environmental aspects of sustainability, and ISO 26000 provides guidance on social responsibility beyond legal compliance. [7] [8] Cyber security is continuously being considered a more critical aspect of sustainability as well, which leads to ISO 27001, which is a standard for information security management systems a relevant standard as well [9]. There are also plenty of other ISO standards which offer guidance on, for example, the governance side of sustainability.

All these frameworks mentioned above provide different approaches to the study of sustainability. (Their scopes have been summarized in 1.) Of course, there are also plenty of other frameworks, but these were chosen to be evaluated in this thesis for their international and wide recognition and use.

The triple bottom line framework or ESG seems to provide the basis for many of these other frameworks, making it possibly the most universal one. Nevertheless, this approach is a very broad one and lacks the specificity this thesis requires to analyze the interlinkages between digitalization and sustainability.

Both the GRI and the ISO frameworks provide a vast amount of information and guidelines on different aspects of sustainability. Yet the information is scattered into different standards and guides and therefore does not support the intent of this master's thesis as evaluating the role of digitalization in all these different standards and principles would not fit in the scope of the thesis.

The UN Global Compact (UN GC) and the UN Sustainable Development Goals (SDGs) portray abundant similarities, which is unsurprising as they have both been created by the UN. According to the UN GC website, the compact's ten principles also aim to advance the SDGs [5]. The UN GC can almost be seen as a light version of the SDGs. Because the SDGs possess more details and practicalities, especially through their sub-goals, they provide a better framework for studying sustainable digitalization in this thesis.

Table 1: Sustainability Frameworks

Sustainability Framework	Scope
The Triple Bottom Line	Three pillars: Environmental, Social and Governance
UN Sustainable Development Goals (SDGs)	17 goals of sustainable development for a more prosperous world by 2030
The UN Global Compact (UN GC)	10 sustainability principles concerning human rights, labour, environment and anti-corruption
Global Reporting Initiative (GRI)	Guidelines, which support companies reporting on their sustainability work based on The Triple Bottom Line
International Organization for Standardization (ISO)	The ISO has implemented several standards for developing more sustainable initiatives

3 Possibilities and Challenges Digitalization opposes to Sustainability

3.1 Sustainable Digitalization

Digitalization can be defined as the transformation of business models through the application of digital technologies, possibly resulting in increased revenue and added value [10]. Furthermore, it is widely accepted that digitalization may pave the way towards sustainability as it may provide solutions to issues such as poverty [13], equality [14], education [12], health care [11] and better environmental conservation [33]. This wave of digitalization can even be described as The Fourth Industrial Revolution, and the way of the revolution is paved by the accelerated development of technologies such as artificial intelligence (AI), robotics, biotechnology, nanotechnology, and more [33]. Yet digitalization also brings with it challenges for sustainable development [11], and the positive impacts should be weighed with the negative impacts.

Digitalization can be seen as a force boosting communication and confluence amid digital and physical environments. Digitalization can be divided into three sub-sections. The first section consists of data, meaning digital information. [34] Data has become a powerful tool in the digitized world, and often data is referred to today as the modern day's oil. The parties which own data also own power. [44] Access to data should be opened so that people globally would be able to benefit from it for digitalization to become more sustainable. Open data practices could, for example, lead to better economic inclusivity and growth [26]. Additionally, such methods enable the creation of stronger societies and institutions and lead to sustainable innovation [41].

A second aspect of digitalization is analytics, which can be used to evaluate and understand data [34], and AI, which can be used to optimize processes and create solutions for sustainability [33]. This aspect can be used to support better policy-making based on the analysis of vast amounts of scientific data [34] and to create a range of different types of innovations supporting universal sustainability goals [33]. Yet many challenges are associated with analytics and AI, and their ethics should be considered [37].

The third aspect of digitalization is connectivity. Connectivity covers the communication of data among people and machines, including communication among machines without human interaction. [34] Connectivity facilitates global communication, data sharing, and access to data and services unimaginable in an un-digitized world [17]. The challenge is ensuring equitable access to digitized services for everyone around the globe [24].

In the software industry, experts have divided research on the sustainability of software into two segments, namely, 'sustainable software' and 'software for sustainability' [30]. Another way of dividing the study of the sustainability of digitalization into more approachable entities is by utilizing a similar form and considering it from the approaches of 'sustainable digitalization' and 'digitalization for sustainability.' Sustainable digitalization can be described as a sum of digital

processes which have been developed in a sustainable manner. This could include topics such as energy efficiency considerations [45], accessibility considerations [62], and cyber security considerations [27]. Digitalization for sustainability, on the other hand, could be described as a sum of processes that themselves enable progress for sustainability goals. For example, such methods could include processes optimizing other processes to consume fewer resources, be it energy, water, or something else [33] or procedures that enable better financial inclusivity, such as open data practices and systems [41].

The evermore digitalizing world is developing into previously unimaginable directions and lengths due to the expeditious development of an array of groundbreaking technologies, which enable increased speed, better intelligence, and higher efficiencies [33]. The links of digitalization to the development of a more sustainable world are vast, and digitalization leads to both enablers [27] and challenges [11].

3.2 UN Sustainable Development Goals (SDGs)

The United Nations Sustainable Development Goals (SDGs) consist of 17 goals which altogether have 169 sub-goals [4]. 126 of these goals are classified as outcome targets [3]. This section will analyze the links between these outcome targets and digitalization.

3.2.1 #1 No Poverty

Digitalization seems to have the power of both possibly assisting the eradication of poverty [13], but also further widening the gap between the wealthy and the poor [11]. A trend can be identified where new digital innovations are usually invented by the wealthy and, perhaps due to this, serve the wealthy in the first place. Only after these innovations become average everyday goods do they usually spread to poor societies. [15] This trend results in new technologies first causing more significant wage gaps between the wealthy and the poor, but possibly later bringing the two closer together.

It should also be recognized that new innovations and technologies only have a penetration of 25% in developing countries, where poverty is at large [15]. This could result in digitalization worsening or at least not alleviating the situation of extreme poverty. Yet, according to studies, digital technologies and enabling access to the internet could bear even more significant tools for development in the Global South compared to conventional methods [54].

Examples of technologies relying on digitalization that have the potential of reducing poverty include genomics and robotics, which could reduce healthcare costs and culminate to better care [11], digital identification [13], and digital finance [16], which could make banking and insurance more accessible to people experiencing poverty [11] [13] [16].

As an example, digital identification, and especially biometric identification, through the use of, for example, fingerprints, could provide banks the reassurance they are seeking to be able to serve customers better. Currently, financial institutions must be cautious, for instance, in the signing of loans, since there are plenty of fraudsters, and these fraudsters are challenging to catch. But if biometric identification was required to conclude business, these fraudsters could be detected easily, opening opportunities to the honest and diligent. [16] According to studies, the establishment of mobile banking in developing countries has enabled better access to basic financial systems, enabled easier development of small-scale businesses, and better investing opportunities into, for example, good health and education [15]. Digital ID and connectivity could also enable more equitable land and other possession ownership as these could be registered more accessibly and affordably. In India, for example, the launch of internet booths enabled increased land rights of people living in poverty [54].

Poverty is also being alleviated through different types of assistance programs. Digital identification and the linkage of factors such as property, paid taxes, and earnings to digital ID could ensure that these assistance programs reach the correct targeted people and prevent corruption. [13]

Digital platforms are another example of a double-edged sword. The challenge arises from huge companies such as Google, Facebook, Airbnb, and Uber gaining monopolistic positions as digital platform providers. They can utilize the winner-takes-all logic, which leads to owners making unjustifiably great profits compared to the workforce. [10] Though others argue that Internet-based technologies usually transfer value to end users even to the extent of two-thirds of the value being created ending up benefiting the consumer [11]. As a definite benefit for sustainability, these digital platforms provide an easily accessible way for people to start their own businesses or find work [10].

A case study of rural Malawi concluded that: "On average, it takes 87 minutes to travel to a bank branch in rural areas (versus 27 minutes in urban areas). In addition, on average, it costs MK 801 to pay for public transportation to the bank. Opening a bank account costs 2 percent of average monthly income. Eligibility and affordability are major barriers to accessing credit, while affordability is the biggest obstacle to getting insurance." [16] Digital finance could offer a solution for more accessible banking and insurance and enable competitive tendering of banking and insurance solutions as people would not be bound to choose the service closest to them location-wise.

In the context of Goal #1 'No Poverty', digital tools and processes can be used as means for attaining the sustainable development targets set for the goal, which means that in this case, we can talk about digitalization for sustainability. There are though also ways of assuring the sustainability of any digital tools and processes in the context of 'No Poverty' of which the most important one is assuring that the digitalization of these products and processes does not prevent people with existing access to previous products and processes from having this access. Though the subgoals under goal #1 are mostly focused on developing countries, the same principle could be applied in developed countries. Companies should put thought into how the digitalization of their solutions or products could grow accessibility for people experiencing poverty of the society the company acts in. Therefore, to measure how well a company's digitalization strategy and efforts support sustainable development, the company should aim to measure the accessibility of its product.

It seems that it is possible that the newest technology is not always accessible to people experiencing poverty. This would mean for example that when a new software update is made for a mobile phone, upkeeping of old versions should be kept intact in case this update was not available for older phone models still in use. Unavailable access to digitalization is by far the biggest threat of digitalization for 'No Poverty' as unavailable access could lead to the widening of wealth gaps between the poor and the rest of society, so it is definitely something to be considered in the development of digital processes.

1.1 By 2030, eradicate extreme poverty for all people everywhere, currently measured as people living on less than $1.25 a day

Based on my analysis of the interlinkage between digitalization and the goal of no poverty, it seems that digitalization could provide assistance in decreasing the number

of people living in poverty. Nevertheless, the biggest challenge would be reaching people living in extreme poverty with the benefits of digitalization. Therefore, I would classify digitalization as a challenge for eradicating extreme poverty.

1.2 By 2030, reduce at least by half the proportion of men, women, and children of all ages living in poverty in all its dimensions according to national definitions

Digitalization can lead to better and cheaper access to financial institutions and other important platforms for accumulating wealth. Though these solutions do not provide a cumulative silver bullet solution for ending poverty for all, they should be able to provide assistance to many. Therefore digitalization can be used as a tool for reaching sub-goal 1.2.

1.3 Implement nationally appropriate social protection systems and measures for all, including floors, and by 2030 achieve substantial coverage of the poor and the vulnerable

Digital ID could be used as a tool for achieving substantial coverage of the poor and the vulnerable. Whether digital solutions would truly reach all by 2030 which is the goal for the SDGs is yet highly unlikely. Nevertheless, digital solutions offer tools and solutions for reaching sub-goal 1.3 at least to an extent, and naturally should be supported by other means of achieving the goal.

1.4 By 2030, ensure that all men and women, in particular the poor and the vulnerable, have equal rights to economic resources, as well as access to basic services, ownership and control over land and other forms of property, inheritance, natural resources, appropriate new technology and financial services, including microfinance

Digital ID could be used to measure instances such as property, inheritance, the use of natural resources, and others. Biometric ID could also enable banks to offer more possibilities for more people. Digital banking could make banking and insurance more accessible to a larger audience and offer people options to select their preferred services and price ranges. This does yet require that equipment for the use of digital systems must be provided to the use of everyone.

Though there are challenges to achieving the distribution of equipment necessary for the use of digital services, digitalization offers means for reaching sub-goal 1.4.

1.5 By 2030, build the resilience of the poor and those in vulnerable situations and reduce their exposure and vulnerability to climate-related extreme events and other economic, social, and environmental shocks and disasters

Digital solutions can be used to predict climate-related extreme events and other economic, social, and environmental shocks and disasters and digital solutions can also be used to spread information about such events. The means for this are discussed in more depth in later sections.

3.2.2 #2 Zero Hunger

Technology and digitalization have already enabled some improvements in hunger crises globally, nevertheless, much more could be done to boost productivity and produce more nutritious and sufficient food through the means of digitalization [17]. Solutions already in use in developed countries must be further developed to meet the needs of the developing world [19].

The developed world including Europe experienced serious malnutrition in the 1960s and 70s. This period of time is referred to as the Green Revolution of Europe. Technology was used as a tool to fight this epidemic of malnutrition and insufficient food supplies and some key discoveries were made. These included enhanced plant breeding, heightened utilization of pest control and fertilizer chemicals, and amplification of irrigation efforts. The use of these tools transformed farming methods and schemes initially in developed countries and later they have been adapted around the world. [17] Yet there are still areas around the world, which the Green Revolution has not reached [19].

AI-based solutions could be used to optimize food distribution networks to minimize spoilage and to distribute nutritional food equally [22]. Technologies utilizing AI can even predict yields of farming seasons, optimize the use of fertilizers, enable better weather forecasting, and predict extreme weather conditions for better preparation in these situations [33].

Though digitalization brings great assets to farming and there on to fighting the hunger crises, there are substantial challenges to it as well. These include access to digital farming solutions [18], the balancing of different sustainability goals [19], the distribution of wealth [17], and climate change [19].

One huge challenge is the fact that digital farming solutions may not reach the populations which are suffering most from hunger and malnutrition. Farmers in developing countries are having a hard time accessing digital farming solutions and, even at the point where access may be possible, many of these farmers lack digital literacy and are not able to use the solutions due to a lack of education or training. [18] Digital farming solutions also require fast development, the adoption of constantly evolving technical solutions, and often also regulation and policies, making it very costly for small farmers. This shifts profits and gains most likely to large organizations. [17] Knowledge connectivity could be the tool needed to partially fight these challenges. Enabling access to digital solutions for all could bridge knowledge gaps and enable a more equitable environment also for farming as more people would have access to farming solutions and the training required to understand and utilize them. [20]

An increasing number of digital farming solutions are designed in a way that enables access to poorer populations and small-scale farmers as long as the prerequisite of access to digitalization or the internet is met [22]. Many of these technologies utilize AI and can for example identify plant deterioration early enough for crops to be saved [33]. AI can work more efficiently than humans in many cases and in this case as well, which could lead to great savings [22]. Similar technologies can also be used to track farm animals' health and well-being [33]. Technologies like this develop

possibilities of access to even the poorest farmers. [22]

Sustainability is a broad topic and even a goal such as 'Zero Hunger' must be balanced with other sustainability goals. When discussing food production and farming it should also be recognized that food systems create complex links between many factors starting from the production and finally leading to consumption and nutrition. Therefore agricultural, health, nutritional, economic, and environmental factors must be balanced. [19] More specific examples include the environmental safety, good health, and well-being of farmers, the ecological and economic sustainability of farming systems, the health and nutrition security of consumers, conserving the balance between local trade and imports, and biosecurity [20]. New technologies in farming require regulation and policies to support them and to ensure that the intended goals are met [20], especially as new technologies can often have unexpected consequences [19].

Under the Sustainable Development Goal (SDG) #2 'Zero Hunger' digitalization can be used as a tool for achieving sustainable development, though digitalization also brings challenges with it, concerning especially accessibility. Nevertheless, by designing accessible digital processes and products many of these challenges can be fought to maximize the positive sides digitalization brings with it. The most central themes arising under this SDG relating to digitalization seem to be the accessibility of information and better productivity, which can lead to less hunger, but can also lead to small-scale farmers suffering from job loss.

The potential of Artificial Intelligence (AI) should also be considered in solving challenges under this SDG. According to some research, the amount of food currently produced should also be able to nutritiously feed a greater amount of people than what it currently does due to unequally distributed wealth. AI-based solutions could offer some solutions for better-optimized nutrition distribution. Small-scale farmers could also enjoy the benefits of digitalization as long as access to the internet is first guaranteed.

2.1 By 2030, end hunger and ensure access by all people, in particular, the poor and people in vulnerable situations, including infants, to safe, nutritious, and sufficient food all year round.

As discussed technology and digitalization have enabled new developments in farming methods and therefore helped fight hunger crises, but there are many places where these developments have not yet been utilized. Much more could be done through digital solutions though there are some challenges to this and these digitalization tools require other tools such as education to support them.

AI-based solutions can also be used to fight hunger by for example minimizing food spoilage, distributing food more equally, optimizing water use in irrigation, and more as long as access to the internet is first enabled for everyone.

2.2 By 2030, end all forms of malnutrition, including achieving, by 2025, the internationally agreed targets on stunting and wasting in children under 5 years of age, and address the nutritional needs of adolescent girls, pregnant and lactating

women, and older persons.

Digital solutions have already been used successfully to fight malnutrition at least in the EU. Similar technologies could possibly be used as a cure also in developing countries. Digitalization also enables better global information sharing on the type of nutrition people need at different moments of their lives.

2.3 By 2030, double the agricultural productivity and incomes of small-scale food producers, in particular women, indigenous peoples, family farmers, pastoralists, and fishers, including through secure and equal access to land, other productive resources and inputs, knowledge, financial services, markets and opportunities for value addition and non-farm employment.

It seems that digitalization can well be used to increase farming productivity and improve the quality of work being done, but this raise in productivity could lead to lost jobs of small-scale food producers. It seems that the enablers brought to farming by digitalization are being reaped by larger organizations rather than small-scale farmers since the application of digital solutions often requires fast implementation and substantial investments.

Digital IDs discussed under goal #1 could though bring more transparency to land ownership and eradicate corruption. In this sense, digitalization requires policies and social programs to make digitalization a tool for equitability and to fight the monopolization of farming.

Finally, again many digital solutions are designed to benefit the poor and small-scale farmers, but for these benefits to be achieved, as discussed internet access must first be guaranteed.

2.4 By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality.

Digital solutions can be utilized to not only predict extreme weather but also communicate warnings to wider populations. “Smart” solutions can also be used to produce more resilient agricultural practices, boost productivity and production and safeguard ecosystems. Simultaneously new farming methods may also be a threat to the environment and ecosystems, especially as all consequences of new technologies are not always clear or predictable. As discussed earlier, solutions that might work towards some sustainability goals such as ending hunger, could potentially threaten other goals such as protecting ecosystems, and the diverse effects which different digital solutions have should be considered and weighed from many different standpoints.

2.5 By 2020, maintain the genetic diversity of seeds, cultivated plants and farmed and domesticated animals and their related wild species, including through soundly

managed and diversified seed and plant banks at the national, regional and international levels, and promote access to and fair and equitable sharing of benefits arising from the utilization of genetic resources and associated traditional knowledge, as internationally agreed.

As discussed an important benefit, which digitalization enables is connectivity. Connectivity enables globalization which makes international cooperation easier than before. Lots of genetic information of seeds etc can be easily stored and made accessible internationally via the internet.

3.2.3 #3 Good Health and Well-being

Technological advances through digitalization offer many possibilities for future health care ranging from the accessibility of health care to new and improved ways of treating illnesses and injuries. One important aspect which should be considered is how digitalization can prevent illness and other health hazards in the first place through knowledge sharing, preventative care, and education [11] [17]. Yet digitalization may also result in the misuse of new technologies such as gene sequencing to build biological weapons (though traditional tools such as hammers can similarly be used for building something or to destroy something or hurt someone) [53] or digital patient records may be breached for financial gain [27] or discrimination [27].

Digital healthcare data can benefit especially developing countries in abundant ways. Healthcare supplies can for example be distributed in the areas where they are required through access to patient data [11] and distribution can be optimized through the use of AI [33]. A digital collection of data can enable faster, cheaper, and remote health care through the use of technical advances such as different sensors. Healthcare data can also be supported by other data collected from social media, telecommunications, geospatial data, and others for example to conclude illness transmission patterns. [22] Finally digital data can be analyzed by AI to discover different healthcare patterns and possible treatments [24].

Other technologies enabling remote health care or illness prevention and thereafter cheaper and more accessible health care include connectivity [24] [17], more ways of utilizing AI [22] and omics and molecular technologies such as genomics [21]. Connectivity for example enables better education on health care for issues such as malaria and malnutrition [11] and preventative care and remote access to health care professionals and databases [17] [22]. Connectivity paired with robotics can even enable remote care and remote video communication with doctors. Such robots carrying tablets for video connection between doctors and their patients have even been tested during the COVID-19 pandemic. [52] AI can be utilized through for example remote visual diagnosis of images of wounds or other defects to determine whether further examination is needed or even if skin lesions for example may be cancerous [22]. An example of where genomics can be used to prevent illness is the case of malaria. Researchers have found ways of modifying malaria-carrying insects' genes to disable them from spreading the disease. [21]

AI truly is a tool from which health care could benefit greatly [24]. Diagnosis supported by AI can be a lot faster and more accurate when used as a tool by doctors, compared to human diagnosis alone [24] [22]. Additionally, AI enables the automation of many tasks which enables professionals to concentrate on tasks that cannot be atomized [24]. One example is the optical analysis of doctors' handwriting and health care history hard copies to transfer notes into a digital and accessible format for patients [22]. As an example, the Helsinki Metropolitan Area Hospitals (HUS) use speech recognition programs in some of their health care units to save doctors' time [51].

Global health issues such as diabetes could also be treated using a combination of AI and sensors, as these sensors could spot early stages and enable faster care and better results compared to traditional methods. This type of technology may be quite expensive though, but if prices were shifted down low enough according to studies over 400 million people could be assisted. [22]

AI can also be used to assist visually impaired people access more services and environments, enabling them to for example work and navigate their surroundings better. According to estimates, the worldwide economic significance of untreated and unsupported vision impairments is over $42 billion. [22]

The use of digital identification has been linked to better access to and monitoring of medications and vaccines from a young age [27]. Additionally, access to healthcare itself has also been linked to lessened drug abuse [56] and as digital solutions can be used to provide more accessible healthcare [11] [22] [33], it could also lead to decreasing harmful substance abuse.

All these solutions do though require access to the internet and most even access to smart devices, which may be a challenge for people living in poverty [22]. Nevertheless, phones could also be used for many other functions in health care, including contacting medical professionals, getting notifications about health checkups and more [15]. Therefore access to phones and the internet should be advanced on a global scale.

For educational purposes, AI has already been developed to recognize patterns signifying student distress faster than what teachers can notice. Tools such as this one could be utilized to spot early signs of mental distress or even illnesses, which enables preventative care. [22] Preventative care could lead to great socio-economic benefits ranging from economic savings and a rise in GDP, even to smaller environmental impacts [55].

Just through using AI in health care has been estimated to be able to lead to economic savings which could make way for investments generating anywhere from $250 billion to $420 billion in global GDP by 2030 [24].

As has been evident under the study of previous Sustainable Development Goals, achieving the benefits of digitalization requires global access to the internet. Though it could be tempting to invest available funds into conventional methods of alleviating poverty and introducing health care, providing Internet access to all could result in even greater results in the development of poor countries and enable leapfrogging [54].

Conclusively, digitalization could be seen as a tool for achieving sustainability goals related to 'Good Health and Well-being'. Digital processes seem to have a big

impact on improving access to healthcare services and connected enablers for wide audiences and provide means for furthering even economic goals consequently. Some of the enabling technologies include artificial intelligence, connectivity, and genomics. To achieve these enablers, economic investments are needed especially in introducing internet access for all. If such investments are made, they can though be expected to pay themselves back.

3.1 By 2030, reduce the global maternal mortality ratio to less than 70 per 100,000 live births. & 3.2 By 2030, end preventable deaths of newborns and children under 5 years of age, with all countries aiming to reduce neonatal mortality to at least as low as 12 per 1,000 live births and under-5 mortality to at least as low as 25 per 1,000 live births.& 3.7 By 2030, ensure universal access to sexual and reproductive health-care services, including for family planning, information and education, and the integration of reproductive health into national strategies and programmes.

As discussed and will be discussed in more depth under the next section 3.2.4 '#4 Quality Education', digitalization has ways of leading to better education which could be benefited from in education on prenatal care, which could lead to better birthing outcomes both for parent and child. Remote checkups could also make prenatal more accessible to larger populations, while AI accompanied by a variety of sensors could make checkups cheaper and more accessible.

Remote care and digital education could also be used as a way of enabling access to reproductive health care and education on the subject and other related themes.

3.3 By 2030, end the epidemics of AIDS, tuberculosis, malaria and neglected tropical diseases and combat hepatitis, water-borne diseases and other communicable diseases.

As discussed digitalized education and meetings make education and health care more accessible to a larger population. Education on these different diseases could provide relief to transmission numbers and to the curing or alleviating of symptoms. Other digital technology solutions could also be used. As an example, Malaria was discussed and it was concluded that through for example genomics the spread of malaria could be minimized. Another example could be using AI to pinpoint disease transmission patterns and thereafter take action where necessary. And a third example could be using health data to provide medication, vaccination, and cures to the areas where these are needed most.

A challenge that might arise from databases with peoples' health data meant for the prevention of the transmission of diseases and other positive enablers of better health, could be used against people if this data were to end up in the wrong hands. This could result in discrimination or even biological weapons.

3.4 By 2030, reduce by one third premature mortality from non-communicable diseases through prevention and treatment and promote mental health and well-being.

Better accessibility to education on the prevention and treatment of non-communicable could again be strengthened by digital solutions. Mental health hotlines could also provide help in moments of crisis through mobile phones and the internet.

As discussed, AI-driven solutions to diagnose mental illnesses at an early stage are also being developed. This could enable preventative care which could lead to socio-economic benefits including economic savings.

3.5 Strengthen the prevention and treatment of substance abuse, including narcotic drug abuse and harmful use of alcohol.

Digital ID could make it harder for people to claim medications that they are not meant to have. Education through digital solutions could also lead to a better understanding of consequences.

Access to healthcare has been linked to lessened abuse of drugs. As digitalization enables more accessible healthcare, a trend of decreasing drug abuse can be expected as digital healthcare becomes more widely available.

3.6 By 2020, halve the number of global deaths and injuries from road traffic accidents.

Many people globally lack digital identification as will be discussed in later sections. This lack of identity also affects access to driver's licences. Digital ID could lead to improvements in accessibility to digital ID and thereafter to driver's licences. As having a driver's licence would become easier, it could also become expected from drivers which would make it easier to monitor whether drivers have licences and sufficient skills for driving in the first place, lessening the number of people driving without a licence and thereafter also traffic accidents.

Another means for prevention of roadside accidents could come from "smart" cars which could for instance communicate with other cars or sense obstacles in their way and break before the driver has time to react.

As mentioned before, education through digital solutions could also lead to more accessible training and a better understanding of traffic rules and better access to attaining a driver's licence.

Remote care and connectivity could also enable better on-scene treatment of the injured even by nonprofessionals arriving at the accident site first.

3.8 Achieve universal health coverage, including financial risk protection, access to quality essential health-care services and access to safe, effective, quality and affordable essential medicines and vaccines for all.

Remote access, digital education tools, and digital identification discussed above can also be used as tools to achieve universal health coverage and further access to quality medical services. Remote access to medical personnel such as doctors could enable patients to receive referrals to the correct medications, treatments, and vaccines. Digital education tools could then enable more locals to become qualified

in the distribution of medication, some care, and vaccines, and digital identification could enable people to receive the correct medication.

Digital identification can also enable better universal health coverage through financial risk protection as the procurement of insurance could become more accessible as already discussed under section 3.2.1 '#1 No Poverty'.

3.9 By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination.

To reduce the number of deaths and illnesses from hazardous chemicals and air, water, and soil pollution and contamination, the root causes should be fought and ways to do this are discussed in other later sections of this thesis. To reduce existing health issues, educational digital solutions could be used as a supportive tool as well as remote access to medical personnel.

3.2.4 #4 Quality Education

Quality education and access to it are key measures needed in the implementation of other UN SDGs as can be noticed from the discussion under different goals. The United Nations has also made a similar conclusion and listed digital inclusion as a fundamental enabler of quality education [27] and just transition [74]. Digitalization provides tools for making education more accessible and efficient to larger populations [22] [11]. Automized language translation could for example make educational materials accessible to a wider audience. Adaptive learning technology on the other hand can be used to personalize education and thereafter increase productivity. Students struggling with learning and people with disabilities could also be supported with the use of digital tools. [22] Connectivity and open data practices could also lead to better information-sharing practices [14] [41].

Education can be personalized through the use of adaptive learning technologies [22]. Digitalization enables also new, more personalized learning and teaching methods such as classroom flipping. Flipping refers to flipping usual class activities into homework and traditional homework into class-based activities. For example, lectures could be listened to before class at home through smart devices and information gained from the lectures could be applied to assignments and group work during class. [35] Such technologies paired with mobile computing could substantially increase learning productivity [11]. Higher productivity could lead to smaller costs and lead to better accessibility regardless of economic status.

Through case studies utilizing digital technologies, it has been estimated that the use of digital tools in and outside of classes could lead to 5-15% greater graduation rates for under-college-aged students in only a few years from the point when digital tools are taken into use in education. In college and university studies as well as workplace education these numbers are expected to be even higher. It is estimated that in such higher education opportunities, digital tools could increase learning productivity by 10-30%. [11]

Digitalization offers tools that make education more accessible to all people [22]

[11]. The role digitalization plays in eradicating gender disparities is further discussed in the next section 3.2.5 '#5 Gender Equality'. In short, automation will replace abundant numbers of jobs and consequently, many women are at risk of losing their jobs [33], but the new career opportunities enabled by digitalization are expected to pay better if access to the proper education is reached [23]. Smartphones have for example been noticed to promote learning and even basic phone models have been noticed to thereafter promote entrepreneurship among women [15].

People suffering from different types of disabilities may also be supported by digitalization when considering education. People with physical disabilities such as visual impairment can be supported in education through AI-based tools. Mental health issues and learning disabilities on the other hand can also be identified through the use of other types of AI-based tools. After the identification of such issues, adaptive learning technologies enable better support for these students. These tools have been developed to the degree that they can notice student discomfort in learning already before teachers, enabling early-on support. Yet tools such as these which can identify learning disabilities and others should be closely monitored as they oppose risks concerning data privacy. [22]

As for other people in vulnerable situations such as immigrants, refugees, and others suffering from language barriers in education, they can be supported by digital tools such as automatic language translation to make education more accessible. [22]

The effects and goals of quality education should also be considered. Better education naturally leads to better job opportunities and can be seen as the overreaching goal behind goal #4 Quality Education. As digitalization offers better tools and more accessibility for education [22] [11], it may also be considered to have a positive effect on employment. Additionally, ways through which digital education can be used to boost transversal skills, which are essential for employment, have been investigated. These studies show that for example playing digital games can boost transversal skills already in primary education leading to better employment opportunities. [36]

From this section, it can be concluded that many digital tools exist, which could be used to further the goal of 'Quality Education'. The focus has been on digital tools for sustainability rather than sustainable digital tools. Nevertheless, many of these digital educational tools for sustainability can be applied to digital tools to boost these tools' sustainability. For example, a game that boosts transversal skills and on its own is a tool for sustainability could be enhanced by adding speech recognition and audio qualities to it. In this case, two tools for sustainability are merged to create sustainable tools for sustainability so to say. Yet, though there are recognizable benefits to the digitalization of education, challenges exist as well. Even though digitalization boosts accessibility to education, access to the internet and smart devices are first necessary in order to achieve these benefits. Data security should also be considered when applying some of the discussed digital technologies to education. Nevertheless, altogether based on this discussion, digital tools can be used to boost the sustainability goals under 'Quality Education', when applied considering challenges.

4.1 By 2030, ensure that all girls and boys complete free, equitable and quality

primary and secondary education leading to relevant and effective learning outcomes & 4.2 By 2030, ensure that all girls and boys have access to quality early childhood development, care and pre-primary education so that they are ready for primary education & 4.3 By 2030, ensure equal access for all women and men to affordable and quality technical, vocational and tertiary education, including university & 4.6 By 2030, ensure that all youth and a substantial proportion of adults, both men and women, achieve literacy and numeracy

Digitalization offers tools that make education more accessible and affordable for a wider audience furthering goals 4.1., 4.2., 4.3. and 4.6. More effective outcomes can also be reached through the individualized approach which digital tools offer to education.

4.4 By 2030, substantially increase the number of youth and adults who have relevant skills, including technical and vocational skills, for employment, decent jobs and entrepreneurship

Digitalization may lead to losses in jobs due to the automation of many traditional jobs as discussed in later sections including 3.2.8 '#8 Decent Work and Economic Growth'. Yet digitalization also creates new jobs which are estimated to have better pay associated with them compared to the ones that are lost. This leads to good job opportunities, especially for youth, but also for adults as long as the education required for these new jobs is accessible. Fortunately, digitalization also offers tools that make education more accessible and affordable for a wider audience, which could lead to digitalization enabling more job opportunities and the education required for the jobs, therefore, furthering goal 4.4. Technologies that could directly increase job opportunities include digital games which boost transversal skills and which can be played already at a young age to help people develop skills needed in the ever-changing working environment.

4.5 By 2030, eliminate gender disparities in education and ensure equal access to all levels of education and vocational training for the vulnerable, including persons with disabilities, indigenous peoples and children in vulnerable situations

The effects of digitalization on gender disparities are further discussed in the next section 3.2.5 '#5 Gender Equality'. In this section, the way through which digitalization offers means for making education more accessible and affordable for a wider audience was discussed. Considering people in vulnerable situations, digitalization has the means to make education more accessible to people with disabilities. For example, people suffering from visual impairments could benefit from AI-based "smart" learning tools which digitalization enables. As discussed, digital tools, which identify student learning difficulties at an earlier stage than at which teachers may be able to notice them, have been developed. Such tools could be used to identify learning disabilities and better support these students.

4.7 By 2030, ensure that all learners acquire the knowledge and skills needed to promote sustainable development, including, among others, through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship and appreciation of cultural diversity and of culture's contribution to sustainable development

Digitalization offers tools that make education more accessible and affordable for a wider audience furthering goal 4.7.

3.2.5 #5 Gender Equality

Digital solutions could enable women to take part in more businesses, and provide improved rights including for example property rights, increased knowledge of rights, and improved education among others. According to studies, knowledge sharing is an essential tool for welding the gender gap. Digitalization through the internet and other technologies such as phones and radios enable such knowledge sharing. [20] Digitalization can lead to higher remuneration of women [23] and digital ID could bring with it many benefits and rights [27].

Digitalization does bring challenges with it as well though. Automation is replacing many jobs and with this effect, lots of women are at risk of losing their jobs [33]. According to estimates, 40-160 million women may face the need of changing career paths and re-educating or training themselves before 2030[23] for just transition to prevail [74]. These new careers are mostly ones that require a vast understanding of new fields of study for the affected women, which opposes a threat and an opportunity. The threat is that not everyone might learn the required skills. Yet, the opportunity is that with jobs requiring higher skill sets, the pay can also be expected to be better. [23] Good education opportunities can therefore be seen as key to maximizing the opportunity and minimizing the threat.

The good news is that as discussed before, digitalization brings with it many opportunities for quality improved, more efficient, and more accessible learning opportunities [22] [11]. Smartphones could be used to promote learning. Even basic phone models have also been noticed to promote entrepreneurship among women and offer a way for women to call for help when experiencing distressing situations [15]. Internet access enables access to many free online courses, including ones designed especially for women looking for economic empowerment, such as the ones introduced by the UN Women Training Centre [57].

Open data or information sharing can also be used as a tool for boosting gender equality [20]. The benefits and the challenges of open data are further analyzed under section 3.2.15 '#16 Peace, Justice and Strong Institutions', but in short open data can be used to further for example financial inclusion, benefiting not only women, but everyone in vulnerable situations [26].

According to valuations, there are currently about one billion people around the world who do not have any legal identification. Naturally, this number of people contains many women to it. In developing countries as many as 45 % of women 15 years old and up lack legal identification, while only 30 % of men of the same age

lack similar documentation. [27] Digital identification and biometric identification could be gateways for many of these people to reach many new benefits [16] [13] [27]. As discussed earlier digital ID could open doors to financial inclusion [16], social assistance programs [13] and other integral government and economic solutions and services [27].

As discussed further under other sections, mainly 3.2.15 '#16 Peace, Justice and Strong Institutions', digital identification brings its share of challenges with it in addition to the benefits. In brief, data collected through digital identification systems could for example be misused for harmful purposes such as persecuting minorities, affecting electoral results, or fraud. [27] This is a very important question to be considered especially when considering equality. Strong cyber security programs and strong policies and laws must be considered and implemented simultaneously with digital ID to enable benefits while evading threats [27].

Conclusively, digitalization opposes many opportunities in mending gender imparities, but also a few challenges and threats. The opportunities include better-paying jobs and improved rights and laws to support all genders. Threats digitalization opposes include job loss due to automation and data security issues. Both can though be fought with other digital tools such as digital education and data security policies and laws.

5.1 End all forms of discrimination against all women and girls everywhere & 5.4 Recognize and value unpaid care and domestic work through the provision of public services, infrastructure and social protection policies and the promotion of shared responsibility within the household and the family as nationally appropriate

Ending all forms of discrimination against all women and girls everywhere is a broad goal and includes many different aspects to it. Digitalization offers some tools for ending such discrimination. Information sharing and more accessible and free education through digital platforms could lead to better awareness of women's rights and improved laws and rights concerning women.

On another front, helplines set up through digital platforms could enable women to call for help or support in discriminatory situations. This is enabled by connectivity, which also enables many new information channels and platforms for innovation, which have been noticed to boost entrepreneurship among women.

Entrepreneurship can lead to better pay, more respect, and rights, but so do other jobs. In this section, it was discussed how digitalization can lead to more equal pay through the development of new jobs. This could again result in more equal rights. Simultaneously many existing jobs are disappearing as automation takes over, which causes a threat to women's position, but as discussed access to quality education could turn the situation into an opportunity for better-paying jobs.

Finally, also digital ID could enable better rights for women as discussed above, but digital identification comes with threats of its own discussed in more detail in later sections, mainly section 3.2.15 '#16 Peace, Justice and Strong Institutions'.

5.2 Eliminate all forms of violence against all women and girls in the public and

private spheres, including trafficking and sexual and other types of exploitation

Globalization could be one answer to the question of how to stop violence such as trafficking. Better communication channels between cities, states, and countries could make information sharing and the tracking of traffickers easier.

Digital ID could also make it easier to find and identify abducted people in addition to making fraudulent IDs used in trafficking harder to attain.

5.3 Eliminate all harmful practices, such as child, early and forced marriage and female genital mutilation

Information sharing and better access to education through digitalization could work towards ending harmful practices towards women as better awareness of rights and healthy ways of living are gained. Digital identification could also be utilized in ending child, early, and forced marriage at least in countries where legislation banns such acts.

5.5 Ensure women's full and effective participation and equal opportunities for leadership at all levels of decision making in political, economic and public life

Digital identification could enable equal opportunities for women in many forms of decision-making. Having legal identification can be a prerequisite for voting and even for gaining a job, so the furthered accessibility to legal ID brought by digitalization could better women's equal rights in decision-making.

5.6 Ensure universal access to sexual and reproductive health and reproductive rights as agreed in accordance with the Programme of Action of the International Conference on Population and Development and the Beijing Platform for Action and the outcome documents of their review conferences

As discussed, digitalization enables more accessible education and better information sharing. These tools could be used to provide information about reproductive health and rights.

Better reproductive health care could also be enabled by digitalization through advances such as remote healthcare, further discussed under section 3.2.3 '#3 Good Health and Well-being'.

3.2.6 #6 Clean Water and Sanitation

The World Economic Forum suggests that AI could be utilized to enable water security and healthy oceans. They list the following as AI-based tools that may be used to ensure water security [33]:

- Water supply monitoring and management

- Water quality simulation & data alerts
- Self-adaptive water filtration
- Asset maintenance on critical water and wastewater expenditures
- Drones and AI for real-time monitoring of river quality
- Ensuring adequate sanitation of water reserves
- Real-time monitoring and management of household water supply
- Residential water use monitoring and management
- Optimisation of industrial water use
- Predictive maintenance of water plants
- Early warning system for water infrastructure
- Detect underground leaks in potable water supply systems
- Smart meters in homes
- Harmful algal blooms detection and monitoring

The same study suggests that AI can be used to prevent ocean pollution, protect ocean habitats and species, and prevent climate change [33].

Yet, even though AI-based solutions may be ones to forward the UN SDG #6 Clean Water and Sanitation, AI is not a straightforward solution. AI solutions require considerable amounts of training data with the amount depending much on the solution being developed [31] and this process can be quite resource intensive [58]. This could lead to causing more harm than what the solutions revamp, which means that developers of such technologies must be careful in the execution. Additionally, AI-based solutions can end up making more mistakes than trained personnel would [31]. Therefore precision and validation of results also play a big role in the development process.

To keep water resources clean, robots and AI could be used for improved recycling and different process optimization [22] [33].

The need for internet access globally as a means for reaching the enablers that digitalization has the potential of leading to has been discussed in previous sections. The same dilemma applies here as well. For the sustainable development of water availability and security, and sanitation conventional tools may lead to more concrete and faster results compared to developing internet access. Yet, access to the internet could enable development not only towards this goal but many other sustainability goals as well. For the best results, conventional methods and digitalization should both be advanced to enable leapfrogging towards better wholesome sustainability. [54]

Conclusively, digitalization offers tools for advancing the Sustainable Development Goal #6 'Clean Water and Sanitation'. Many of these tools utilize AI and great development can be expected through the implementation of these methods. The environmental impacts of AI should nevertheless be considered as AI-based solutions can be resource intensive. It is also worth noting that for digitalization to solve challenges under the goal, conventional methods are needed to support it and investments should be allocated to both conventional methods and digitalization.

6.1 By 2030, achieve universal and equitable access to safe and affordable drinking water for all & 6.4 By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity & 6.5 By 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate

AI-based solutions for real-time water supply monitoring and management, filtration, and more could go a long way in ensuring universal and equitable access to safe and affordable drinking water. Yet AI-based solutions require lots of work which could result in the need for substantial initial investments.

Connectivity brought by gadgets such as mobile phones could also be utilized for enhanced transboundary cooperation.

6.2 By 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations

Having clean water available for sanitation could further the goal of adequate and equitable sanitation and hygiene for all. As discussed, clean water accessibility then again could be bettered with AI-based solutions, even though not without challenges.

6.3 By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally

AI-based solutions could be used to observe and manage water reserves, making it easier to keep reserves clean and pollution free. Such solutions could also be used to identify emission origins and intervene. Yet as discussed, these solutions can pollute themselves as well, so developers must take care of minimizing the emissions of the solutions.

Using machines to evolve recycling procedures and using AI to optimize water use in industry could also go a long way to further sub-goal 6.3.

6.6 By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes

AI can be used to prevent ocean pollution, protect ocean habitats and species and prevent climate change. The extent of this is further discussed under later goals of #14 Life Below Water and #15 Life on Land.

3.2.7 #7 Affordable and Clean Energy

Accomplishing affordable and clean energy for all people requires digitalization as an enabler for optimal results. Digital tools such as AI and digital ID can be used to facilitate the affordability of energy [27] [33]. The cleanliness of energy can also be supported with tools such as smart digital solutions including AI [22] [29]. Additionally, digitalization enables many ways of increasing energy efficiency [23] [24].

Access to clean energy is a universal necessity and many kinds of digital tools are being developed to support the energy transition from fossil-fuel-based energy to affordable renewable energy. Smart solutions can be used to enable clean energy [22]. For example, different parts of existing infrastructure could be connected to enable the collection and utilization of waste heat [29] or the forecasting of solar flares to protect smart grids [33].

AI-based solutions and digital innovations such as digital ID can be utilized in ensuring accessible and affordable energy [27] [22]. The lack of identification has led to corrupt business also in the energy sector. Yet studies have proven that the introduction of digital ID has been able to eradicate corruption in some instances and enable great governmental savings as energy access-related aid reaches the people who are most in need. This naturally has led to more affordable and accessible energy for larger populations. [27]

Other AI-based solutions enabling more affordable and especially clean energy systems include the better modeling of different components of energy systems such as batteries and renewable energy system sites, and smarter communication between different parts of energy networks. [33]

Efficient use of energy can also drive energy prices down and lead to less emissions. Optimization of power consumption can lead to greater efficiency [23] and constant innovation is driving costs down, efficiency up [24], and additionally accessibility up as mobile pay-as-you-go payment models for renewable technologies such as solar panels are being introduced [27]. More technologies supporting end-users consuming energy at convenient times are constantly being introduced. For example, Finland's transmission system operator, Fingrid, provides users with their free application information on the following day's electricity prices. This enables users' financial savings and the shifting of consumption to hours of high production. [59]

Finally, efficiency, affordability, and renewable solutions are all factors contributing to the reliability of energy systems. Digitalization-enabled forecasting for energy consumption is being developed [28] and this type of forecasting can also be used to enable better reliability. Optimized energy systems and networks could lead to better efficiency and thereafter affordability and accessibility to increase reliability on their part [33].

As different digital tools are applied to energy systems and as they become

connected, this naturally leads to the systems facing the risk of cyber security attacks and threats such as geomagnetic storms. Complete nullifying of cyber security risks and other digital risks is impossible with any level of anticipation, but these risks can be mitigated. Good cyber security policies and actions, and partnerships between governments and companies must be put into place to protect energy systems vital for people's everyday life from cyber security threats. [34]

As a whole, it seems that digitalization is a great asset for affordable and clean energy through tools that boost efficiency, accessibility, affordability, and environmental friendliness. Naturally, the use of digital ID may always result in breaches in information security, but this is quite a small risk, (which can be mitigated,) compared to the positive sides digitalization has on affordable and clean energy. A bigger risk is the possibility of cyber security threats on whole energy systems, but this risk can be mitigated through the use of cyber security policies and actions to enable the positives digitalization facilitates for energy systems and markets.

7.1 By 2030, ensure universal access to affordable, reliable and modern energy services

Digitalization enables many tools which can be utilized to enable universal access to affordable, reliable, and modern energy solutions. These include the optimization of different components and whole energy systems, better energy forecasting, and more efficient use of energy through energy-efficient products and through consumer actions. Nevertheless, there are cyber security challenges and digital risks such as the risk of geomagnetic storms to be considered as more digital tools are applied to energy systems to reach the substantial enablers.

7.2 By 2030, increase substantially the share of renewable energy in the global energy mix

Digital solutions can be used to better utilize renewable and waste energy, growing their part in the global energy mix. Renewable energy solutions can also be better optimized and modeled through the use of AI to make their utilization more efficient and easier. The forecasting of energy supply gained from renewables can also be developed to become more reliable and accurate through the use of digital technologies to make the commissioning of renewables more attractive.

7.3 By 2030, double the global rate of improvement in energy efficiency

There is a lot of innovation going on toward identifying new digital solutions and enhancing old ones to support energy efficiency. Energy efficiency gains brought by digitalization are discussed in more detail under the later sections of 3.2.9 '#9 Industry, Innovation and Infrastructure', 3.2.11 '#11 Sustainable Cities and Communities' and 3.2.12 '#12 Responsible Consumption and Production'.

3.2.8 #8 Decent Work and Economic Growth

Digitalization brings with it several tools which may have a vast impact on the economy. Both enablers and challenges may be recognized, but the number of positives seems to trump the number of negatives. Some major digital tools which may enable great, inclusive economic growth include digital identification [16], digital finance [11], and open data sharing [26]. Challenges include the distribution of the technology needed to gain these benefits [11], education on how to use the benefits [22], and the shift in employment that digitalization and automation bring with them [11].

Open data systems are believed to be a tool that could benefit both financial institutions and customers. According to estimates adopting open data culture in the financial sector could result in a rise of 1-1.5 % in GDP in the European Union and even 4-5 % in India. This suggests that even though perhaps the most developed countries might benefit from open data systems, the greatest benefits could be reaped by developing countries. The same study also suggested that open data systems in the data industry would have positive effects on all sizes of organizations ranging from single persons and micro-sized organizations to medium-sized and up. [26] There are also challenges and risks associated with the use of open data, including extending the quantities of open data [41] issues concerning data privacy, user consent, and cybersecurity [26]. These issues must be addressed for the effective utilization of the enablers. [26] More discussion on open data can be found under section 3.2.15 '#16 Peace, Justice and Strong Institutions'.

Digital solutions in other sectors are also expected to result in large gains in GDP. For example in medicine digital technologies could result in $250 billion to $420 billion rise in global GDP by 2030 [24] as discussed under the section of 3.2.3 '#3 Good Health and Well-being'.

Digitalization and the internet offer people who have never had access to basic aspects of society such as education or financial inclusion, the possibility of becoming a part of global economies [11]. Digital identification as discussed in several of previous sections enables the possibility of having a great inclusive impact on the financial sector as well [16]. Financial services ranging from insurance to mobile banking could be reached by over 1 billion people who currently miss out on these benefits due to not having any legally recognized ID [27]. As discussed before, if biometrics were applied to digital IDs even more benefits could be achieved. This is because digital ID would make it easier for banks to for example trust clients with loans and more credit, as fraudsters could be caught easily through the use of digital ID. [16] Digital ID could even be used to fight child labor and human trafficking. [27]

Yet as mentioned, there are also challenges to digitalization when paired with inclusively growing economies. Job loss is one big threat of digitalization [11]. As discussed under the section of 3.2.5 '#5 Gender Equality', 40-160 million women may lose their jobs due to the automation of their tasks [23]. This number can be presumed to be even bigger if it were to include men as well. Nevertheless, other studies show that for every job that the internet makes invalid, it creates about 3.2

new working positions in developing countries [11]. This supports the ideology that through access to education, job loss could lead to new jobs and even better-paid ones as suggested in earlier sections [23]. The emergence of digitalization-based jobs could also benefit youth referred to as 'digital natives'. 'Digital natives' are people who have been born into the digital era and see digital processes as a natural part of everyday life. They are used to the accelerating development of technologies and can effortlessly embrace them. This gives youth an edge in the digital job market. [60] The digital reform of the job market could also lead to less hazardous jobs. Robots are taking over occupations, which can be quite dangerous for humans, while the new jobs created by digitalization are not. This can lead to better occupational safety. [61]

The effective reaping of the benefits of digital finance does also require financial institutions to take action in building the necessary infrastructure and decide to educate customers on the ways of digital economies [22]. For example, for the effective utilization of open data systems, institutions must address questions about data standardization, the comprehensiveness of open data and more [26].

The digital landscape is constantly evolving and effective utilization of the enablers linked to digitalization requires constant development. It is for example expected that AI might become a divider in company economies. Companies that find AI-based solutions and innovations first could find great economic from the technologies, while companies that struggle to adapt to the new technologies take a hit economically. [33]

As increasingly more enterprises become digital ones and more traditional platforms become digital ones, not only do corporations need to be ready for the changes but governments must also adapt. Taxation for example is a subject that needs to be discussed and developed in the digital era, since as the outlook of businesses changes through digitalization, so should taxation. A challenge governments may face due to digitalization, is tax-base erosion, which could lead to delays in progress towards sustainable development goals as well if not kept in check. [33]

To conclude it can be established that the economic impacts of digitalization on sustainability and economies of all sizes are vast and cannot be fully predicted. Sustainable digitalization from the perspective of the economy could be seen as digitalizing the economy in a long-lasting manner, considering the environment [47] and the fact that on a global scale, local economies range diversely and the effects of digitalization can differ considerably [11]. Digitalization offers great advances for different-sized economies, but simultaneously also opposes some challenges ranging from the automation of jobs to possible tax base erosion and the adoption of many new methods for financial institutions, governments, companies, and single persons. Yet the enablers seem to outweigh the risks and challenges as digitalization is predicted to grow in global economies and GDPs greatly and the financial inclusivity of all people is furthered significantly.

8.1 Sustain per capita economic growth in accordance with national circumstances and, in particular, at least 7 per cent gross domestic product growth per annum in the least developed countries

Open data practices are believed to result in great growth of GDP in developing countries. Other digital solutions are also driving GDP up through other sectors such as the medical industry. The new jobs created by digitalization can also be expected to raise GDP.

8.2 Achieve higher levels of economic productivity through diversification, technological upgrading and innovation, including through a focus on high-value added and labour-intensive sectors

Digitalization is a great driver of technological upgrading and innovation. As digitalization automates many manual jobs it enables better economic productivity especially if the jobs digitalization creates are capitalized on. The automation of jobs does nevertheless cause job loss for millions or even hundreds of millions of people and this risk should be considered. On the bright side, estimates expect digitalization to create more jobs than what it replaces.

8.3 Promote development-oriented policies that support productive activities, decent job creation, entrepreneurship, creativity and innovation, and encourage the formalization and growth of micro-, small- and medium-sized enterprises, including through access to financial services

Mobile financial services could give a boost to financial inclusion for the smallest enterprises which might be struggling the most to reach traditional financing methods. As discussed earlier, open data systems in the financial sectors also support all sizes of organizations as they do individuals, but also require policies to support them. Digital ID could be used to support policies and formalization necessary for the sustainable digitalization of economies.

8.4 Improve progressively, through 2030, global resource efficiency in consumption and production and endeavour to decouple economic growth from environmental degradation, in accordance with the 10-year framework of programmes on sustainable consumption and production, with developed countries taking the lead

Responsible consumption and production practices that increase efficiency and enable the protection of the environment are discussed in detail under later sections of 3.2.9 '#9 Industry, Innovation and Infrastructure', 3.2.11 '#11 Sustainable Cities and Communities' and 3.2.12 '#12 Responsible Consumption and Production'. In short, digitalization can be used to optimize and raise the efficiency of many processes and products, enabling savings in energy and resources and further resulting in less environmentally harsh consumption and production patterns.

8.5 By 2030, achieve full and productive employment and decent work for all women and men, including for young people and persons with disabilities, and equal pay for work of equal value

Digitalization provides new jobs for many. Yet as discussed, digitalization makes many jobs unnecessary as automation takes over, resulting in job loss. Nevertheless, digitalization has the potential of creating many more new jobs than what it eradicates. Good educational opportunities are key here as people who lose their jobs may need re-education. As the new jobs created by digitalization require more know-how also pay should be better. This can be seen as an enabler of equal pay and value.

Digitalization also provides the opportunity for many who have not been able to work before to gain jobs. As an example from section 3.2.3 '#3 Good Health and Well-being' namely digital aid to visually impaired people can open up job opportunities for them.

8.6 By 2020, substantially reduce the proportion of youth not in employment, education or training

As discussed, digitalization creates new jobs which are estimated to have better pay associated with them compared to the ones that are lost due to their digitalization. This leads to good job opportunities, especially for youth with the prerequisite that the education required for these new jobs is available. Fortunately, as discussed under section 3.2.4 '#4 Quality Education' digitalization also offers tools which make education more accessible and affordable for a wider audience, and therefore better job opportunities. Digital tools enabling better transversal skills such as games developed to boost these skills can also promote employment among the youth. Additionally, the 'digital native' youth who have been born in the digital era can absorb new technologies fast, which gives them an edge in the digital job market.

8.7 Take immediate and effective measures to eradicate forced labour, end modern slavery and human trafficking and secure the prohibition and elimination of the worst forms of child labour, including recruitment and use of child soldiers, and by 2025 end child labour in all its forms

Digital identification could be used to enforce policies which eradicate forced labour, modern slavery and human trafficking.

8.8 Protect labour rights and promote safe and secure working environments for all workers, including migrant workers, in particular women migrants, and those in precarious employment

A better economic stance for migrants could be gained through better international communication enabled by connectivity and digital identification. Digital tools such as translation software could also be utilized to better understand local economies and related subjects such as taxation and to be able to work a wider variety of different jobs.

Digital tools offer means for more accessible and better education which could lead to better work safety. Digital can also enable safer infrastructure as discussed

under the following section 3.2.9 '#9 Industry, Innovation and Infrastructure', which could lead to safer working environments.

The digitalization of the job market can also lead to fewer hazardous occupations being available as robots take these jobs over. The jobs created consequently by new needs lead by digitalization contrarily are ones where human health is not jeopardized to such an extent.

8.9 By 2030, devise and implement policies to promote sustainable tourism that creates jobs and promotes local culture and products

Accessible means of education could lead to more sustainable tourism. Discussion concerning the effects digitalization has on the accessibility of education can be found under section 3.2.4 #4 'Quality Education'.

8.10 Strengthen the capacity of domestic financial institutions to encourage and expand access to banking, insurance and financial services for all

Digital identification and banking and insurance accessible through the Internet can boost financial inclusion drastically. Biological traits immersed in digital ID could lead to better credit, loan, and other banking service opportunities for all people as they provide financial institutions more security.

3.2.9 #9 Industry, Innovation and Infrastructure

Modern-day industries have enabled the development of societies as we have come to know them and brought with them innovations important in everyday life. Yet industrialization is a big factor behind many challenges we are facing today, including climate change, biodiversity loss, and more [33]. Nevertheless, focusing on sustainable infrastructure, innovation, and industry has the potential of undoing some of the harm caused and leading to a more accessible, equitable, and environmentally friendly world of industry and infrastructure. In fact enhancing and developing infrastructure, especially in developing countries, is essential for connecting all people and for the creation of a more equitable and accessible world [24].

Accessibility of digital solutions can be boosted with standards and policies shaped by the developers of the technologies, researchers, in some cases government organizations, and others [34]. Communication is key here and as it has been discussed earlier, digitalization drives better connectivity, leading to more accessible and effortless communication.

Standards for connected infrastructure are central to the sustainability goals being reached, as standardization of different technologies and products enables them to be interlinked. Standards can also improve user experience and ease of use, which eventually can even lead to shorter operational times and energy savings. [34]

Digital technologies can boost accessibility and equitability of infrastructure also through the financial aspect [33]. Digitalization is for example driving lower maintenance costs and improving energy efficiency, leading to smaller energy costs

[34]. Additionally, as discussed in earlier sections, digitalization has the potential of offering more people financial inclusion and the possibility of becoming a part of global economies [11] [16]. Financial services ranging from insurance to mobile banking could be reached by over 1 billion people who currently miss out on these benefits due to not having any legally recognized ID [27]. Especially with biometric digital IDs could make it easier for banks to trust clientele with loans and credit, as biometric digital IDs would lessen the amount of corruption and possibilities for fraud. [16]

Nevertheless, initial investments in these digital technologies and infrastructure can sum up to considerably large numbers, which could slow down progress and achieve the enablers of digitalization. Different kinds of financial support programs must be enabled by governments and other operators to maximize the benefits of digitalizing infrastructure. [33] Even then, developing countries should aim to utilize the developments made in developed countries and 'cherry-pick' opportunities best suited for them. Conventional methods paired with digitalization could result in great economic savings and added value. [54]

An interesting tool that could be used to enable limited access to infrastructure such as mobile networks at a smaller price is "network slicing". Through the possibility of live monitoring the use of infrastructure, infrastructure operators could provide different deals for different users. Cost-sensitive consumers could be offered limited access deals, while agents consuming vastly more of the products are billed higher. [24]

As mentioned, digital technologies are paving the way for more sustainable and energy-efficient infrastructure. Some technologies driving this change are automation [32], data analytics, connectivity [34], demand response compatibility, and artificial intelligence [33]. In the transportation industry for example a combination of these technologies is facilitating the construction of aircraft, ships, trucks, and others to optimize routes, speed, fuel use, and more [34]. Jevons paradox should though be realized here. Naturally, more accessible infrastructure will also result in more infrastructure and to continue the example of the transportation industry, more cars, aircraft, ships, and others could also lead to even greater net emissions than before even though unit emissions are minimized [33].

Additionally, the process of digitalization is expected to result in great rises in different countries' GDPs as discussed in previous sections including '#3 Good Health and Well-being'. [24]

It is crucial to notice that not only emissions and energy efficiency can be considered when evaluating the environmental effects of industry and infrastructure. Biodiversity and ecosystems must also be considered. Modern-day power lines have for example been shown to cause huge numbers of bird deaths. Fortunately, ways for making such infrastructure more animal friendly are in progress and researchers are for example looking into how changing the height of power lines and adding blinking LEDs to them might help birds navigate around them. [31]

Digital tools are also enabling safer infrastructure [34]. The opportunity of building predictive maintenance systems, for example, can lessen the number of flaws and malfunctions in these systems [22].

To enable all the opportunities digitalization brings to the sustainability of industry and infrastructure, new innovations are still needed and scientific research around infrastructure is required. Though digitalization brings with it some threats to sustainability, with proper research these threats can be evaded and enablers can be maximized.

9.1 Develop quality, reliable, sustainable and resilient infrastructure, including regional and transborder infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all

Digitalization can definitely be used as a tool to build new and develop current infrastructure in a more quality-oriented, reliable and resilient manner and with focus on affordability and equitability, as well as optimizing usage and maintenance to prevent flaws. There are several ways through which this can be done including boosted accessibility through cheaper consumer prices attained from optimized efficiency or through other tools such as network slicing. Human well-being on the other hand can be boosted for example through better safety procedures enabled by better modelling of risks.

Standardization of technologies and connectivity enabled by digitalization also enable better transborder communication and through this also infrastructure.

9.2 Promote inclusive and sustainable industrialization and, by 2030, significantly raise industry's share of employment and gross domestic product, in line with national circumstances, and double its share in least developed countries & 9.3 Increase the access of small-scale industrial and other enterprises, in particular in developing countries, to financial services, including affordable credit, and their integration into value chains and markets

Digital tools open the way for more inclusive and sustainable industrialization and according to research will be able to boost the economies and GDPs of many countries. Nevertheless, initial investment costs can rise to be quite high, and governmental or other types of aid are needed for sustainable industrialization to reach all. One way of enabling small-time users of infrastructure access to it is through "network slicing". Developing countries also possess the opportunity of 'leap frogging' their progress to the level of developed countries by evading and learning from mistakes made by others and capitalizing on the successes.

Digital and biometric ID will also make it easier for small businesses and entrepreneurs to reach financing opportunities, insurance, and credit.

9.4 By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities

As discussed, digitalization can go a long way in providing more environmen-

tally friendly infrastructure both emission and energy consumption-wise but also ecosystem-wise if the proper research is done in the development of the industry. Yet Jevons paradox comes into question and as mentioned, further accessibility may lead to higher usage of technology and even though these technologies have been developed to be as environmentally friendly as possible through digital tools, emissions might rise due to the rise in use.

9.5 Enhance scientific research, upgrade the technological capabilities of industrial sectors in all countries, in particular developing countries, including, by 2030, encouraging innovation and substantially increasing the number of research and development workers per 1 million people and public and private research and development spending

More and enhanced scientific research is also needed in the aspect of digitalization to reach all the enablers that digitalization provides for sustainable development.

3.2.10 #10 Reduced Inequalities

A big part of reducing inequalities under the UN's SDG #10 revolves around the financial inclusivity of the poor and of developing countries. The effects of digitalization on financial inclusivity were discussed in more depth under the section 3.2.1 '#1 No Poverty', but are summed up here as well. The UN has classified digital inclusivity as a major facilitator of the sustainable development of global economies. [27]

As discussed earlier digitalization seems to have the power of playing an important role in the eradication of poverty [13], but as in many other cases, digitalization brings challenges with it as well and results in the threat of further widening the gap between the wealthy and the poor [11]. Usually, new technologies first reach the wealthy [15] causing greater wage gaps between the wealthy and the poor, but can later bring the two closer together if the technologies reach poorer societies. Additionally, some technologies such as digital platforms can be seen as double-edged swords, which may result in owners making unjustifiably great profits compared to the workforce transfer [10] but may also shift value to end users even to the extent of two-thirds of the value being created ending up benefiting the consumer [11] and provide an easily accessible way for people to start own businesses or find work [10].

Digital innovations which can indirectly aid financial inclusivity include genomics and robotics, which could reduce health care costs and culminate to better care [11] while technologies such as digital identification [13], digital finance and biometric identification [16], could make banking and insurance more accessible to the poor and have a direct impact. These technologies also have the potential of leading to more accessible documents such as driver's licenses [22], more inclusive voting rights and accessibility, and eradicating corruption [27].

Yet again another substantial benefit of digitalization is connectivity. Studies of history imply that as innovative communications solutions have arisen, new social movements are born and today's connectivity brought to us by mobile phones has for example played a big role in the Black Lives Matter Movement [14]. With this

said, it should also be noted that technologies such as artificial intelligence can also cause great harm to equality [22] [25] [33]. Precarious historic data resulting from factors such as non-inclusive samples [22] and the way in which AI may often end up preferring only those variables which further their predictive certainty [25] may easily result in bias. As an example historic data concerning American criminal institutions may be biased towards different groups such as African Americans and an AI system interpreting this data can end up in even further heightened bias and discrimination [22].

As usual, there are some conflicting studies about the bias AI causes for decision making and some studies suggest that AI can also be used to lessen bias, as AI-based decisions can be evaluated in an easier manner than human decisions [25]. Yet in cases where AI-based solutions are aimed to make better, more equitable, and inclusive decisions, the data with which the solution has been trained should at least be studied carefully to avoid bias.

There are AI-based technologies that can also directly result in better inclusivity. An example of such innovative technology is that of Affectiva. Their technology helps autistic people recognize others' emotions and suggests ways of understanding social situations around them. [22]

Another challenge opposed by digitalization relates to job loss as discussed before for example in section 3.2.5 '#5 Gender Equality'. Automation may result in smaller numbers of employment in fields such as transportation, manufacturing, farming, service, and more which may cause further inequality [33]. As discussed earlier this causes a great threat to some marginalized groups and for example women might be hit hard by the eradication of these jobs. Yet according to estimates, digitalization brings more new jobs with it than what is lost. These jobs enable higher salaries as long as the qualifications needed for the jobs are met. [23] Luckily, digitalization does bring new, more accessible learning tools with it as well and training to reach these new job requirements is therefore also becoming more accessible [22] [11] [15] leading to a more equitable and inclusive world.

Building more equitable governance, policies and more can also be boosted by digitalization. As an example, connectivity, which was already mentioned earlier, enables faster more personal ways of organizing movements and getting minorities' voices heard, while also providing a more economically viable platform for rallying for poorer societies. [14]

Social media can also provide a platform for anyone to have their voice heard and social media channels have been utilized to create demonstrations, which have led to more equal legislation. Nevertheless, even social media does not come without threats. The spread of misleading or even false information is also easier in the connected world. Another possibly harmful effect that has come out of social media is the free rider issue. Simply put, people show their support for minorities' rights and other issues on social media, then feel that they have done their part, feel content, and as a result, do not perform actions to actually further the rights they have shown their support for on social media. [14]

This chapter has so far focused on digital solutions which can boost accessibility and therefore reduce inequalities. It is worth noting that digital processes should

also be designed considering the aspect of equitability and accessibility. There are different methods that can be utilized to make digital interfaces as approachable as possible for all users. [62] Some on these include vocal recognition [63], customizable text [64], clear layout and design [65], and using colors with good contrast [66]. Standards such as ISO/IEC 30071-1:2019 can be utilized to ensure accessibility and equitability of digital design [62].

Altogether there are many positive outcomes, which can be derived from digitalization, including more accessible jobs, better pay for marginalized groups, better access to financing, insurance, and voting for all, and more opportunities to get your voice heard. These are 'digital tools for sustainability'. Nevertheless, challenges arise simultaneously and bias caused by AI must for example be monitored closely, and means for better and more accessible education must be enabled to support people whose jobs may be lost due to digitalization. Finally, the accessibility of digital products including user interfaces should be considered for digitalization to be sustainable from the viewpoint of 'Reduced Inequalities'.

10.1 By 2030, progressively achieve and sustain income growth of the bottom 40 per cent of the population at a rate higher than the national average

Digitalization brings with it better and more accessible ways of reaching financial institutions such as banking and insurance which enables bettered financial inclusion of the poor. Digitalization may eradicate many jobs that are currently necessary, but will also create more new jobs with possibly higher pay. Digital platforms may enable easier ways for entrepreneurship and finding jobs, but might also lead to owners making unjustifiably large profits compared to the value gained by end users.

10.2 By 2030, empower and promote the social, economic and political inclusion of all, irrespective of age, sex, disability, race, ethnicity, origin, religion or economic or other status & 10.3 Ensure equal opportunity and reduce inequalities of outcome, including by eliminating discriminatory laws, policies and practices and promoting appropriate legislation, policies and action in this regard & 10.4 Adopt policies, especially fiscal, wage and social protection policies, and progressively achieve greater equality & 10.7 Facilitate orderly, safe, regular and responsible migration and mobility of people, including through the implementation of planned and well-managed migration policies

Digital ID can be utilized to enable and promote more accessible voting rights for all deriving furthered political inclusion. Digital ID also furthers the goal of economic inclusion. Political inclusion can also be driven by connectivity as technologies such as social media enable more affordable, more personal, and larger scale rallying and more for political rights and more inclusive legislation.

Social inclusion can also be driven by specific digital innovations. Take the example of the tool discussed earlier, which enables people with autism to interpret social situations around them easier.

Yet there are also issues and challenges that digitalization opposes to reducing

inequalities. The free rider effect and the spread of untrue information are examples of such issues that should be considered.

10.5 Improve the regulation and monitoring of global financial markets and institutions and strengthen the implementation of such regulations

Digital identification for one may be used to fight corruption and build stronger regulation.

10.6 Ensure enhanced representation and voice for developing countries in decision-making in global international economic and financial institutions in order to deliver more effective, credible, accountable and legitimate institutions

Connectivity can enable hearing the voices of those coming from developing countries.

3.2.11 #11 Sustainable Cities and Communities

Digital technologies are enabling innovations for safer, more accessible, and energy-efficient solutions [34] for the building of sustainable cities. Many of such technologies have been discussed in previous sections and include automation [32], data analytics, connectivity [34], and artificial intelligence [22]. In this section, the focus is on how these technologies can enable the sustainable development of cities and communities.

The smart design of city and community human settling and infrastructure could get a boost from AI-based analytics and automation [33].

Many of the previous sections have concluded that digital tools could enable great advances in sustainable development as long as access to digital tools and especially the Internet is available. This observation leads to the thought that public spaces could include access to the internet, boosting connectivity and facilitating the enablers of digitalization. Therefore public spaces with access to the Internet could boost city and community sustainability.

Accessibility to housing could be boosted by decreased expenses of maintenance. Specifically, autonomous intelligence systems running on AI-based solutions and sensors could adapt to real-time data, enabling savings [33]. For example, moments of high demand and therefore high costs in heating or electricity consumption can be adapted to and even predicted [34] without human-made decisions [33].

Demand-response and smart grids are a key part of the development of environmentally sustainable cities and communities [33].

Accessibility, for example, for people with disabilities could be boosted through auditory responsive lighting and heating systems [33].

AI paired with automation could also be used for more efficient and better recycling and recycling robots could be trained to identify recyclable materials in city waste [22] [33].

Transportation systems are also a big part of sustainable cities and communities and digitalization does offer tools for developing these transportation systems in a

sustainable manner. A combination of automation [32], data analytics, connectivity [34] and artificial intelligence [33] is expediting the development of aircraft, ships, trucks, and others to optimize routes, speed, fuel use, and more [34]. In addition to savings in energy consumption, these solutions carry the potential of yielding savings, leading to more affordable transport and boosting accessibility [34]. Finally, also the safety of transportation systems can be boosted via digital solutions [33], which for example enable predictive care and predict which components might fail [22].

Autonomous vehicles could also boost energy savings [33], but factors such as the ethical side of autonomous vehicles should first be evaluated.

The sustainability of digital platforms has been touched upon in earlier sections (mainly under section 3.2.1 '#1 No Poverty') and both enablers and challenges have been identified. The biggest challenge seems to be the possibly unfair distribution of economic gains enabled by digital platforms [10], though others also argue that nevertheless, end-users end up realizing most of the value created [11]. For transportation systems digital platforms could have the potential of enabling sharing platforms [34], which could make transportation yet again more environmentally friendly and more accessible. This would also slow down the effect caused by Jevons paradox, discussed under the earlier section of 3.2.9 '#9 Industry, Innovation and Infrastructure', as less production could satisfy a larger customer base [33].

In addition to the means of transportation, transportation systems include transportation routes and those must also be developed to enable sustainable transportation. AI-based technology combined with traffic light networks can for example be used to optimize traffic [22] and better efficiency [34] reducing emissions. Simultaneously, AI can also be utilized in parking systems, to enable similar advantages [33].

According to estimates, when pairing digitalization with electrification, transportation emissions could even be cut by half if correct supporting actions such as supporting policies are set up, but these may also result in greater emissions if supportive actions are not attended to [34].

Air quality can also be bettered with digital technology. For example, AI-based optimized sensor-based air purifying systems help keep city air quality at a good level. [33]

Countries especially in the Global South are prone to natural disasters [67] and cities and communities must have harm-preventative plans and actions in place for such cases. Digital solutions offer solutions both for fighting natural disasters and their effects and for warning and therefore saving people [22] [20] [33]. As an example, applying AI technologies to the analysis of satellite data can be used to predict and evaluate disaster development, such as wildfires and fight them by for example placing firefighting units in the right locations [22]. As another example, extreme weather events and droughts can be predicted, and simulated and impacts can be assessed using AI [33]. Communication-wise, the internet, radio, and mobile phones on the other hand are an example of how information about such catastrophes can be shared quickly to prevent loss of life and save people [20]. Technologies such as AI can also be utilized to build more natural disaster-resilient buildings and infrastructure [33].

According to estimates, digital solutions could enable energy-based savings of

about 10% by 2040, especially through smart solutions in heating and cooling, and lighting. Nevertheless, higher accessibility and the new applications enabled by digitalization could result in digitalization leading to higher net energy consumption. Unfortunately, this is not the only challenge in way of maximizing the advantages of digitalization. Ethical issues include the issue of data privacy and security of smart buildings which make buildings and cities vulnerable to cyber security threats. [34] Economical viability must also be considered and finance must be directed at innovation for sustainable digitalization [33]. Ready-made solutions can boost savings, but initial investments needed can be sizeable [34]. According to the World Economic Forum, when considering AI such investments could include "large-scale basic and applied R&D investment that bridges the technology and environmental disciplines, impact capital directed at technology solutions, specialized venture and growth capital, and government financial instruments that catalyze private sector innovation, for example through innovation accelerators, price support mechanisms and targeted patient capital" [33]. Similar investments can be deduced to be necessary also for other technologies being developed to ensure sustainable development.

Conclusively, many digital technologies already enable and have an even greater potential of saving energy and other resources. These technologies also enable better access to many aspects of sustainable cities and communities. Additionally, safety can be boosted through technologies that grow resilience against natural disasters. Yet there are challenges to consider when deploying new technologies and they range from ethical considerations to financial ones. The ethics of AI should for example be considered. On the financial aspect the large sizes of initial investments needed for the development of sustainable technologies must be considered as financial benefits can only be gained after initial investments are made. These challenges can though be mitigated through partnerships, innovations, and more. Perhaps a larger challenge with less precise predictability is the one opposed by Jevon's paradox. As accessibility to technologies grows, the savings made in efficiency may be trumped by the growing usage. Technology developers should keep in mind that savings brought by efficiency are not directly proportional to net energy usage, but production numbers should also be taken into account.

11.1 By 2030, ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums & 11.3 By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries & 11.7 By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities

When set up, digitalization-enabled solutions have the potential of leading to lower costs in housing maintenance, leading to more accessible housing, but initial investments must be made and these investments might be quite sizeable. Smart use of analytics could be used for resourceful urban planning and mapping. Participatory planning could also gain a boost from access to the Internet, which as discussed could be made available in public spaces.

11.2 By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons

Transportation systems can definitely be developed to become more accessible, safer, and more energy efficient via digital tools. Nevertheless, Jevon's paradox and ways of fighting over-consumption must be considered.

11.4 Strengthen efforts to protect and safeguard the world's cultural and natural heritage & 11.6 By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management

Smart analytics utilizing urban mapping could enhance the protection and safeguarding of cultural and natural heritage. More energy-efficient infrastructure, buildings, and cities are all enabled by digital solutions, which could lead to reduced per capita environmental impacts. Yet, digitalization may also lead to more infrastructure and buildings and more comforts which result in greater total energy consumption. AI-based solutions could also be utilized to better air quality.

11.5 By 2030, significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations

Digital tools offer many ways into preventing damage caused by natural disasters, reduce the number of related deaths, and fight natural disasters. These tools include better warning systems reaching larger populations and better modeling and prediction of disasters.

3.2.12 #12 Responsible Consumption and Production

Under the theme of Responsible Consumption and Production, sustainable digitalization should be reviewed from two different viewpoints. Firstly, the ways in which digital solutions can be utilized to reach responsible consumption and production patterns and goals should be addressed. And secondly, sustainable consumption and production of digitalization should be considered. This section will first analyze the impacts of the first viewpoint and then the second one.

Responsible consumption and production can be facilitated through AI-based optimization of different production processes and digital twins can for example be used for lifespan performance optimization. [33]

Sustainable procurement methods can be supported with AI solutions as AI enables better monitoring and transparency of supply chains [33]. This can be

followed by the use of software for sustainability [30] for reporting purposes. Today there are several different kinds of digital sustainability reporting tools available such as EcoVadis [77], which enable transparent and standardized means for sustainability reporting.

Responsible production and consumption of nutritious foods is a great, important part of reaching the UN SDGs including this one [3]. As discussed under the goal of 'Zero Hunger', AI can, for example, be used to detect early signs of crop damage enabling actions before all food being produced gets wasted [22] and food distribution can be optimized [33]. Digitally optimized transportation [34] could also pave the way for reduced food spoilage.

Recycling and the sorting of waste is also an important sustainability goal [3] and as discussed in earlier sections, AI combined with automation could enable robots that could detect recyclable materials and sort them accordingly [22] [33]. Optimization with AI [33] could also enable less use of harmful substances.

Additionally, better education on responsible production and consumption and sustainable lifestyle and access to it are enabled by digital tools to larger populations [22] [11].

To summarize, digital solutions can be used to create and support sustainable production and consumption patterns. Additionally, digitalization also enables substitutes for some emission-intensive matters. For example, holding work-related meetings online enables meetings on a global scale without the emissions caused by flying [30]. This could also be a lucrative option from the financial point of view, though the benefits of live meetings should also not be forgotten [68].

Yet as increasingly more devices are connected each year, the energy consumption of digital solutions can also be expected to grow [34]. Streaming video content for example is growing insistently and about 70% of current internet traffic consists of video streaming [24]. Yet according to estimates, the gains met in energy efficiency improvements via digital solutions could keep the current energy consumption pattern steady [34], and the development of more renewable energy sites could satisfy this need at least partially [11], but the sustainability of digital solutions should be analyzed.

Digital solutions should be designed so that they are as energy efficient as possible. Recently green coding practices have become an area of interest for software houses and companies [73] such as GFT Technologies [45] and Exove [46] are building their own handbooks for green coding. Some basic principles for green coding include choosing energy-efficient programming languages [69], reusable output [45], energy-efficient file formats, considering the effects of data processing [70], and even considerations concerning the hardware the code is being run on [76]. Additionally, digital industry leaders such as Microsoft are providing free courses for learning about sustainable software engineering [75].

Conclusively, digitalization can be used to drive responsible consumption and production patterns, but responsible consumption and production practices should be considered when designing any type of digital tool. As technologies become more accessible, their use will grow and therefore the sustainable design of these products is essential. An example of sustainable design would be using green coding

methods in software programming. Designing digital processes to support responsible consumption and production patterns is also possible and desirable. An example of this could be sustainability software meant for the analysis of supply chains.

12.1 Implement the 10-Year Framework of Programmes on Sustainable Consumption and Production Patterns, all countries taking action, with developed countries taking the lead, taking into account the development and capabilities of developing countries

Software for sustainable consumption and production could be utilized in the design of sustainability programs. Analytics could be applied to identify the best courses of action and transparency could be gained through the use of supply chain software. Progress could be measured and reported using standardized sustainability reporting software for even higher transparency and as a means of communicating about processes found to have the best results for sustainability and the ones which might not have led to the expected results, increasing information sharing and open data.

12.2 By 2030, achieve the sustainable management and efficient use of natural resources & 12.4 By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment

Optimization of consumption with AI-based tools could lessen the use of scarce resources and harmful substances and optimize resource management.

12.3 By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses

AI-based solutions could lead to lessened food spoilage through for example identifying crop damage at an early stage when actions can still be put into motion to save the crops in question. Optimized solutions for the transportation of food supplies could also diminish food waste.

12.5 By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse

Optimization with AI could lead to less waste and AI combined with automation could lead to robots capable of sorting and handling recyclable materials.

12.6 Encourage companies, especially large and transnational companies, to adopt sustainable practices and to integrate sustainability information into their reporting cycle

There is a lot of software for sustainability that enables transparent and accessible

ways of performing sustainable procurement and other sustainability-related reporting in a standardized manner. Such software could be utilized by companies of different sizes to adopt sustainability reporting practices.

As discussed under section 3.1 'Sustainable Digitalization' more sustainability-related actions and reporting are also being required especially from large companies by laws and directives. These policies could be enforced through the use of software for sustainability.

12.7 Promote public procurement practices that are sustainable, in accordance with national policies and priorities

Promoting public, sustainable procurement practices could be advanced through sustainable procurement education. As discussed further under section 3.2.4 '#4 Quality Education' digitalization makes education more accessible and effective for larger populations and digital learning platforms could be utilized in this instance as well.

12.8 By 2030, ensure that people everywhere have the relevant information and awareness for sustainable development and lifestyles in harmony with nature

Similarly, as for sub-goal 12.8, digital tools provide better and more accessible education sustainable development, and responsible consumption and production patterns, promoting better awareness.

3.2.13 #13 Climate Action

UN Sustainable Development Goal #13 Climate Action focuses on information sharing, smart information application in policies and planning, and developing resilience towards climate-related disasters. Digitalization can be used as a tool for the collection and analysis of relevant information, the sharing of such information for example in the form of education, and for designing ways of mitigating the impacts of climate-related disasters.

With climate change, the number of climate-related disasters is also expected to grow [71]. Digital solutions offer solutions both for fighting natural disasters and their effects and for warning and therefore saving people [20] [22] [33]. As explained in more detail under goal #11 Sustainable Cities and Communities, digital solutions can for example be used to fight forest fires [22], to simulate, predict and assess damages from extreme weather and droughts, to share information about disasters faster [20] and to build more natural disaster resilient developments [33].

Naturally, as climate change increases the number of climate-related disasters, fighting climate change is a good way of also indirectly fighting natural disasters by aiming to prevent them. Ways for mitigating climate change have been collected under several of the other SDGs and are discussed for example under '#9 Industry Innovation and Infrastructure', '#11 Sustainable Cities and Communities', and '#12 Responsible Consumption and Production'. To add to these, one method for

alleviating climate change, which has not yet been discussed is carbon capture. At this point, it could be mentioned that carbon capturing can also be optimized using digital solutions such as AI [33]. Yet digitalization may also have adverse effects on climate change if proper precautions and consideration are not carried through. As discussed in the previous section 3.2.12 '#12 Responsible Consumption and Production', digital products also have a growing environmental footprint and it should be mitigated for example through the use of green coding.

More information can also be collected and analyzed about the climate using AI and thereafter better modeling and predictions can be made [33]. Policymakers can also utilize this type of information for better climate-related policy [34] concerning for example greenhouse gas emissions [33].

Better and more accessible education on climate change and how to act against it is also enabled by digital tools to larger populations [11] [22]. Additionally, there are many specific "deeper dive" courses for experts such as conservation biologists concerning the use of AI in conservation efforts [31].

Conclusively, the UN SDG #13 Climate Action, can be supported with digital methods and tools. Climate-related disasters can be fought and mitigated with digital tools and so can climate change which is causing increasingly more climate hazards. Climate action awareness can be grown through the use of digital education tools and better policies and actions can be designed by supporting the development processes with AI-based modeling and optimization. Nevertheless, the negative impact of digitalization on climate change should also be considered and digital process developers should aim to design digital processes to be as efficient and environmentally conscious as possible for example through the use of green coding methods.

13.1 Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries

More natural disaster-resilient developments are enabled by AI. Real-time communication of natural disasters is another advantage of digitalization. Natural disasters can also be predicted, and simulated and damages can be assessed using AI-based solutions.

Perhaps the best way for fighting climate-related hazards is the prevention of climate change. As discussed digital tools and processes have the potential of fighting climate change and reducing emissions, but the proper considerations must be made in the design of digitalization to ensure that the environmental footprint of digitalization does not surpass the positive effects.

13.2 Integrate climate change measures into national policies, strategies and planning

Better modeling of climate change and related topics can enable the construction of more competent policies for fighting of climate change.

13.3 Improve education, awareness-raising and human and institutional capacity

on climate change mitigation, adaptation, impact reduction and early warning

Better and more accessible education on climate change and ways of preventing it is available to a larger population through digital means. Additionally, more specialist information and education for professionals such as conservation biologists is available through online platforms.

3.2.14 #14 Life Below Water & #15 Life on Land

Digitalization offers a diverse set of tools for combating challenges faced by ecosystems both on land and below water. These range from the monitoring and safeguarding of these ecosystems [33], to the conservation of plants and animals [31]. Illicit activities such as prohibited logging [22], poaching, or overfishing [33] can be monitored and mitigated through digital tools and more. Yet there are challenges that arise with the utilization of these digital tools. The information collected could result in more illicit activities in the wrong hands and the development of these digital processes can require lots of energy [31] to mention a few. These challenges should be considered to enable the benefits brought by digitalization while mitigating the risks.

Monitoring the health of ecosystems can be expedited through digitalization. AI combined with other digital technologies such as satellite imagery or drones can for example be used to identify and monitor ecosystem plants and animals and their health and possible diseases. AI can even be used to simulate and evaluate animal and habitat interplay. By monitoring ecosystem health actions can be put into play when problems are detected. For example, to save diminishing plant bases drones could be used for automized pollination. [33]

Ocean acidification and pollution are listed under the UN SDG #14 Life Below Water, as integral issues which should be fought to reach the sustainable development targets [3]. Digitalization paired with sensors enables live observation of ocean temperature, pH levels, phytoplankton distribution, pollution, and litter. By adding robotics to the mix, digitalization can also be used to fight these by for example deploying robotic fish to combat pollution. [33] An important aspect of fighting ocean acidification comes from more sustainable farming methods. Farming is discussed in more depth under section 3.2.2 '#2 Zero Hunger', but at this point, it can be added that as digital farming methods enable the lessened use of pesticides and more sustainable irrigation [20] (discussed later in this section), they also work as a tool for fighting ocean acidification and pollution.

Under section 3.2.9 '#9 Industry, Innovation, and Infrastructure', the case of how power lines affect birds negatively and cause huge numbers of bird deaths was considered [31]. In that context, the design of animal-friendly infrastructure was considered, but also the location of such infrastructure could be optimized using AI. The habitat and migration patterns of birds can be anticipated using AI and thereafter better locations for infrastructure can be applied. [33]

For better-concentrated conservation efforts, scientists can also benefit from a type of software for sustainability. Many software platforms have been developed to support conservation efforts. One example is a platform, Wildbook, which detects

and counts animals in photos and can even identify individual animals. [31] [72] Drones equipped with AI can be used to monitor the health and movement of endangered species such as some whales to predict their movements and enable the best conservation efforts. For the best results in ecosystem conservation results, AI could be used also to model the threats and possible spread of invasive species [33].

Yet AI-based real-time data and future predictions of animal routes and locations [33] should be safeguarded, as in the wrong hands' such data could be used for illicit actions such as poaching. On the bright side, poachers and traffickers of marine and land-based animals can be caught and brought to justice to protect endangered species using digital solutions [22]. AI can for example be utilized in analyzing online social media pictures of animals on sale to identify whether they are concluding business legally or whether the animals in question are for example protected [31]. Image classification and object detection can be used to identify poachers and animals at night time using drone video [22]. AI analysis of satellite images can be used to identify routes used by illegally operating fishermen or poachers [22] [33].

Overfishing can also be controlled using automized systems that detect overfishing patterns and alert the fishermen and if necessary alert authorities. Based on marine ecosystem monitoring, AI could even be applied to create automized fishing quotas based on current information. [33]

To fight deforestation AI could again be utilized [22]. Automized programs identifying transitions in land usage could be applied and ecosystem fees could be initialized [33]. Audio sensor data and its analysis through AI for its part can be used to detect prohibited logging and fight deforestation [22].

Human-caused natural catastrophes such as oil spills can also be detected through the use of digital tools. Automated systems analyze satellite imagery and enable the identification of spills in real time, giving the correct authorities more time to react and contain the situation. [32]

For effective and equitable use of biological and biomimetic resources, AI could be used to monitor and register related commerce [33]. Digital technologies such as genomics and information technology enable the growing of crops suitable for the local weather and ground conditions which further enables more environmentally conscious farming through the lessened use of pesticides, smarter irrigation, and more. Such types of new technologies do though require regulation and policies to support their sustainable use. [20] This is especially essential as new technologies can often have unexpected and even undesired consequences [19].

Nevertheless, most of the solutions discussed in this section rely at least partially on AI for the most effective results and it is necessary to realize that for these solutions to function properly, they must be well-trained, and training of AI requires massive amounts of data and thereafter energy. Even when trained, AI-based tools are usually more exposed to flaws compared to human experts and samples, and testing of models is strongly recommended. [31]

To summarize, digitalization provides many tools for safeguarding Life on Land and Life Below Water. Digital solutions enabling this protection and harboring range from AI to genomics and information technologies and require support from technologies such as robotics and satellite imagery. AI is used in many of these

solutions and the challenges related to AI should be considered when deploying these solutions, weighing the positive enablers against negative side-effects such as energy intensity. When utilized properly, digitalization can be used to protect ecosystems and fight illicit actions and human-caused catastrophes.

14.1 By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution & 14.3 Minimize and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels

Digital technologies can be used to support polluting industries such as the farming sector to develop solutions that cause less pollutants and litter to end up in oceans, leading to reduced marine pollution and acidification. When combined with robotics, digital innovations such as robotic fish collecting pollution and litter from oceans can be deployed.

To fight human-caused natural disasters, AI can for example be paired with satellite imagery to create autonomous systems which can for example identify oil spills and sound an alarm to the appropriate authorities, yet again reducing marine pollution.

14.2 By 2020, sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, including by strengthening their resilience, and take action for their restoration in order to achieve healthy and productive oceans & 15.1 By 2020, ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands, in line with obligations under international agreements & 15.4 By 2030, ensure the conservation of mountain ecosystems, including their biodiversity, in order to enhance their capacity to provide benefits that are essential for sustainable development & 15.5 Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species

Digital tools are enabling many ways of safeguarding ecosystems both on land and under water. Ecosystems and habitats can be better monitored including the health of animals and plants. When issues are noticed other solutions paired with for example robotics can be used to mitigate disruptions. Animal detection and identification software can be used to identify which species need protection and whether protection methods are yielding results. Additionally, foreign species can be identified and returned to their natural habitats.

14.4 By 2020, effectively regulate harvesting and end overfishing, illegal, unreported and unregulated fishing and destructive fishing practices and implement science-based management plans, in order to restore fish stocks in the shortest time feasible, at least to levels that can produce maximum sustainable yield as determined by their biological characteristics & 14.6 By 2020, prohibit certain forms of fisheries

subsidies which contribute to overcapacity and overfishing, eliminate subsidies that contribute to illegal, unreported and unregulated fishing and refrain from introducing new such subsidies, recognizing that appropriate and effective special and differential treatment for developing and least developed countries should be an integral part of the World Trade Organization fisheries subsidies negotiation & 15.7 Take urgent action to end poaching and trafficking of protected species of flora and fauna and address both demand and supply of illegal wildlife products

Poachers and illegal fishermen can be caught through the use of digital technologies such as through analyzing imagery to identify their possible routes and locations. As another example, traffickers can also be caught selling their illegally obtained animals on social media.

Overfishing can also be monitored and mitigated through digitalization and fishermen and authorities can be warned of overfishing through AI-based warnings based on live data.

14.5 By 2020, conserve at least 10 per cent of coastal and marine areas, consistent with national and international law and based on the best available scientific information

Monitoring and analyzing ecosystems and animal and plant habitats through the use of digital processes provides important information on ways of conserving these ecosystems and on the success of conservation efforts. Collected data can be analyzed with AI solutions to identify which areas are in the biggest need of conservation efforts and the areas at which conservation efforts could provide the best assistance to ecosystems.

14.7 By 2030, increase the economic benefits to Small Island developing States and least developed countries from the sustainable use of marine resources, including through sustainable management of fisheries, aquaculture and tourism

As more software for sustainability is developed, this software may also lead to new conservation jobs being created, boosting economic benefits. Also, the development of such software and other related tools could provide a business supporting Small Island Developing States.

Data collected from the observation of marine ecosystems could also lead to a better understanding of the needs of the ecosystems and enable the development of better policies and means for fisheries, aquaculture, and tourism.

15.2 By 2020, promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests and substantially increase afforestation and reforestation globally

Illegal logging can be used by analyzing audio-sensory data with AI-based tools to fight deforestation and tariffs could be set for logging.

15.3 By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world

Ecosystem monitoring can provide the necessary information for possible ways of protecting land and enabling the combating of desertification and restoring degraded land and soil.

15.6 Promote fair and equitable sharing of the benefits arising from the utilization of genetic resources and promote appropriate access to such resources, as internationally agreed

Genomics and information technologies are enabling the development of processes and methods which enable more sustainable and more economically viable farming methods. AI-based solutions could be used to monitor the equitable sharing of such information.

15.8 By 2020, introduce measures to prevent the introduction and significantly reduce the impact of invasive alien species on land and water ecosystems and control or eradicate the priority species

Digital technologies can be used for the detection of foreign species so that they can be returned to their natural habitats. The detection of animals and live information on animal location and predictions on their routes could though result in for example poachers finding their prey easier if the data were to end up in the wrong hands.

15.9 By 2020, integrate ecosystem and biodiversity values into national and local planning, development processes, poverty reduction strategies and accounts

Digitalization enables a better understanding of ecosystems and biodiversity and the modeling of these systems. This can help in giving insight and finding the best solutions for what should be integrated into policies and plans and how this should be done.

3.2.15 #16 Peace, Justice and Strong Institutions

There are many digital products that can be used to further the goals under UN SDG '#16 Peace, Justice and Strong Institutions', but simultaneously it must be ensured that these products which digitalization enables are such that they do not create new issues larger than the ones they solve. Under many, even most, of the previous goals, the potential of using AI as a tool to advance the goals. AI is a good example of a technology, in which ethics must be discussed before implementing all possible solutions. Another key enabling technology under the previous goals has been the introduction of digital and biometric ID. This section will study these two

technologies in more depth.

Digital and biometric ID, as discussed in earlier sections, has the potential of expediting global financial inclusivity by making banking and insurance more accessible for everyone [16]. It also enables more accessible legal identity documents [27], for example, driver's license [22], while simultaneously making forgery harder [27]. Also, more inclusive voting rights can be promoted through digital identification and electoral integrity can be heightened [16].

Fighting fraud and corruption is also made easier through the use of biometric identification as fraudsters could be caught with less effort, resulting in more opportunities for the honest and diligent [16]. Fraud and misuse of financial alleviation programs can also be fought by using digital identification and programs can reach the correct audiences in an easier manner [13].

Strong institutions can be built on digitalized financing and ID and can lead to great savings inside of governments and other organizations. Ghost employees can be eradicated. [16]

Yet though a strong case can be built for supporting digital identification, there are also risks or challenges which arise with it. The data collected through digital identification systems could for example be misused for harmful purposes such as persecuting minorities, affecting electoral results, or fraud. Strong cyber security programs and strong policies and laws are therefore necessary for digital identification systems. As with all technical systems, possibilities for technical malfunctions are a threat always and the effects of such errors should be weighed and policies should be built also for these situations. [27]

As with all digital processes and products, as we have come to see, the benefits that they bring with them can only be enabled if people have access to digital services and especially the Internet. As long as not everyone has access to the internet, there must be some alternatives also for the digital ID. [27]

Open data is another term, that has already been mentioned under other sections and was deduced to be an important factor in reaching the goals set under SDG #8 Decent Work and Economic Growth. The Finnish Innovation Fund Sitra defines open data as "raw data collected by public administration entities, businesses organizations and private individuals that are or can be, made freely available to everyone to use" [41].

As discussed earlier open data systems could boost financial inclusion and spur economic growth resulting in a rise of 1-1.5 % in GDP in the European Union and even 4-5 % in India by 2030 [26]. Additionally and importantly, open data sharing practices could help shape stronger societies and institutions and develop existing and create new more sustainable services [41]. Effective data sharing would have the potential of benefiting a range of parties extending from all sizes of organizations and institutions to single persons. Examples of how individuals could benefit from open data include better access to financial institutions and their services, better user experience, and larger product and service options, enabling for example financial savings. For larger establishments such as financial institutions, open data could lead to benefits such as higher operational efficiency, better identification of illicit or wrongful actions, and advanced personnel allocation. Having all documentation in a

digitized, structured, and consistent format could not only lead to financial savings but also enable the assumption of fitting technologies, and boost transparency and customer satisfaction through better organization of customer information. [26]

The positive outcomes of open data sharing are extensive, but some challenges still prevail in front of successful data sharing culture [26] [41]. First off extending the quantities of open data is a fundamental challenge. Currently much data is located in countless separate spaces and players in the field ranging from businesses to public sector actors have their own ways, formats, and spaces for collecting and storing data. [41] Other open data-related challenges include issues concerning data privacy, user consent, and cybersecurity. [26]

Innovation and standardization are needed for overcoming the challenges listed [26]. Collective schemes are needed to break so-called data containers and form open data-sharing practices. An example of how this might be achieved is through international, cross-boundary legislation, such as the European Directive on open data, launched by the EU in 2019 [42] or the later proposed Data Act [43]. Such legislation can be used to encourage the open sharing and re-use of information [42] and can for example support the negotiation power of SMEs [43]. A range of diverse actors can contribute to the overcoming of the discussed challenges [34] and players can extend from large financial institutions to technology companies especially in the field of fintech as they realize the advantages and their own strengths in achieving these enablers [26]. By defeating all these challenges, innovation will be likely to grow to extents unforeseeable in the present [26].

In the discussions under most of the UN Sustainable Development Goals analyzed in this thesis, artificial intelligence has played a big role in enabling many facilitators of sustainable development. Yet, some challenges have also been identified in the use of AI in different systems, and for the development of Strong Institutions, these challenges and risks should be considered in a bit more depth.

Already today AI and algorithms can be found all around everyday life and they are shaping the way we act, the way we see the future, and even our well-being. They touch upon a range of social aspects and influence for example politics, which begs to make the conclusion that such technologies are not only that, technologies, but have become a social development. [37] Algorithms act with each other and have been noticed to be able to develop languages for conversing, which humans cannot understand. As humans become more distanced from AI-based decision-making, this leads to the question of who assumes final responsibility and to ethical considerations. [33]

In the digitalized world, algorithms have been given the power to control what information we come across and in what way the information is portrayed leading to algorithms having the capability of influencing our opinions and emotions towards different subjects. [37] The nature of algorithms evolves around simplifying large quantities of information and therefore the information fed to the algorithms is essential. This simplifying nature and the fact that the initial data might be flawed can lead to biased results. Studies have for example shown that algorithms can easily become biased towards gender or race. A classic example is that search engines suggest jobs with better salaries and higher decision-making power to men rather

than others. [39] As algorithms grow their impacts on the human world, the question of assumed responsibility rises. AI has already led to the collapses of institutions and for example, in 2010 AI-based technologies conversing with one another resulted in a financial crash. [33]

Some areas of AI strongly linked to the UN SDG #16 Peace, Justice, and Strong Institutions, are surveillance AI, AI used in weaponry, and AI in political decision-making. AI-based security and surveillance systems are constantly becoming more common globally [38]. Subjects such as this one raise questions about privacy concerns [33] and concerns about basic human rights and freedoms [38]. Already today autonomous weapons exist [37] which result in risks around larger and faster-escalating conflict situations, with serious humanitarian and environmental consequences [33]. Concerning politics, as already discussed algorithms have great power over the content we read online and this can lead to them influencing human decision-making in many areas including politics. It is believed that algorithms have already had a part to play in several political instances and studies point at algorithms influencing decision-making around for example the US presidential campaign of 2016 and the victories of politicians around the world. [37]

Altogether the ethics of AI should be considered from at least three different viewpoints. Firstly, the data being fed to the algorithms to teach them should be studied to make sure the data is not biased. Second, responsibility for the actions put in motion by AI should be considered. Third, the role of human decision-making and role in the supervision of AI functionalities should be given thought. The consideration of these subjects is essential for the development of fair and responsible societies. [33]

To mitigate the ethical concerns which arise with the use of AI, companies, governments, and all institutions should come together to consider the risks and how to alleviate them [34]. Innovation is required and the possibility of algorithms overseeing other algorithms and checking them for example for biases is a possibility [40]. Even in such situations, the human role should nevertheless be evaluated [40] and questions around responsibility answered [33]. The human supervision of AI-based tools is especially important as AI is usually more exposed to flaws compared to human experts. Human-guided sampling and testing can be used to reduce the risks of flaws. [31]

A couple of other concerns other than ethics-based risks should also be evaluated when working with AI. AI provides a powerful tool for doing good, but if AI-based information ends up in the wrong hands, consequences can be severe. Under the previous section 3.2.14 discussing goals '#14 Life Below Water' and '#15 Life on Land' the example of how animal tracking data made available by AI could in the hands of poachers lead to dangerous repercussions for those animals. [33] Hacking of data related to autonomous cars [33], weapons [37] and other AI-based tools could in a similar way lead to catastrophes [33] and good cyber security actions should be put in place [34]. AI-related issues linked to job loss are studied under '#8 Decent Work and Economic Growth', but in short the jobs being replaced by digitalization should be substituted by even more jobs [11] possibly with higher pays [23]. Nevertheless, access to these new jobs should be considered.

The environmental consequences of using all technologies discussed in this section should also be considered. Training AI for example requires a considerably large amount of data, which leads to great amounts of energy being consumed [31]. The environmental impacts of digitalization are further discussed under previous sections and especially section 3.2.12 '#12 Responsible Consumption and Production'.

Conclusively, the digital technologies discussed in this section could have great positive effects on the sustainable development aimed at achieving the UN SDG '#16 Peace, Justice and Strong Institutions'. Yet cross-boundary cooperation [33], and policies and standards concerning factors such as cybersecurity and data privacy are needed [34] in order to reach the benefits brought by digital tools, while avoiding risks and challenges.

16.1 Significantly reduce all forms of violence and related death rates everywhere

In previous sections including section 3.2.5 '#5 Gender Equality', digital tools have been discussed which have the possibility of reducing violence. Nevertheless, threats should also be considered and a large threat to peace and violence is constituted by autonomous weapons, which as stated may escalate conflict situations into larger ones at a quick pace.

16.2 End abuse, exploitation, trafficking and all forms of violence against and torture of children

The use of digital identification and perhaps also the development of open data platforms could be used to fight exploitation and other forms of violence against all people including children. Surveillance paired with artificial intelligence could also be used to monitor such instances and intervene, but the repercussions of such surveillance on human rights and freedoms should be evaluated.

16.3 Promote the rule of law at the national and international levels and ensure equal access to justice for all

Digital identification could go a long way in making institutions including law at different levels accessible to larger populations, as identification can be a prerequisite for many such services.

16.4 By 2030, significantly reduce illicit financial and arms flows, strengthen the recovery and return of stolen assets and combat all forms of organized crime & 16.5 Substantially reduce corruption and bribery in all their forms & 16.6 Develop effective, accountable and transparent institutions at all levels

As discussed in this section, the use of digital identification and open data can be used to fight fraud and other illicit actions such as corruption and bribery effectively. The storing of the necessary data comes with risks including privacy, but with standardized cybersecurity policies and actions such issues can be mitigated. These

actions can also contribute to the building of strong and transparent institutions at all levels.

When considering the transparency and especially the accountability of institutions, the role of AI in communities should be considered. As discussed AI can lead to biased decision-making and questions about the assumption of responsibility of AI-made decisions. International, cross-boundary conversations are needed on such topics to mitigate risks.

16.7 Ensure responsive, inclusive, participatory and representative decision-making at all levels & 16.9 By 2030, provide legal identity for all, including birth registration

Digital identification provides access to identification and much decision-making to people currently lacking ID and therefore rights to contribute to public decision-making. Yet the role of AI should be considered and conversations raised about the role AI has in such decision-making and how it should be monitored to ensure inclusive decision-making.

16.8 Broaden and strengthen the participation of developing countries in the institutions of global governance

Information sharing and open data platforms could be used to moderate the playing field for different countries in decision-making. The EU Data Act has been designed to pave the way for SMEs. Similar acts could be put in place to support developing countries.

16.10 Ensure public access to information and protect fundamental freedoms, in accordance with national legislation and international agreements

Public access to information can be enhanced effectively with the use of open data systems. To protect fundamental human freedoms, the risks associated with AI, which have been discussed in the section, should be considered.

3.2.16 #17 Partnerships for the Goals

The United Nations' Sustainable Development Goal #17 focuses on building global partnerships to enable development under all previous goals and to especially support developing countries. Technology and digitalization play a big role in this development as is stated under the sub-goals of Goal #17 such as sub-goal 17.8: *"Fully operationalize the technology bank and science, technology and innovation capacity-building mechanism for least developed countries by 2017 and enhance the use of enabling technology, in particular information and communications technology"*. The time frame for this goal has been overrun, but there is still much to be done under it.

Based on this thesis and the UN SDG sub-goals, it can be deduced that data sharing and connectivity are two of the perhaps most important aspects around

digitalization that have the potential of truly forwarding all goals and thereafter also Goal #17.

Never before in human history have we had the same possibilities concerning global connectivity that we have access to today. Digitalization has enables global networking, data sharing, and the analysis of all interlinked data in a revolutionary manner. [17] The challenge arises from making sure that all people on our planet are able to participate in this network of information and connections. According to estimates from 2020, it is likely that 80% of the global population will have internet access by 2030 [24]. This is an admirable number when considering that in 2020 40% [24] of the global population were still offline. Nevertheless, the ultimate goal should be full connectivity and access to the internet for all people globally. This will require innovative solutions for more affordable and accessible connectivity.

The SDG #17 also evolves around better policy and less corruption. As discussed under many of the goals above, digitalization provides a multitude of solutions to further these aims. One solution which recurred in discussions under almost every goal was digital and biometric identification. To summarize, bio-metric digital ID could provide solutions for more accessible financing, insurance, political rights, fight human trafficking and much more resulting in the eradication of corruption and organized crime.

All institutions have the possibility of furthering Goal #17 through partnerships, working to build cross-sectoral policies, supply chain analysis, and more. To reach the full potential of digitalization as a means to reach the UN's SDGs this is necessary. Another technology that has been present throughout this thesis is AI and all AI-based solutions. If AI is taken as an example here, it can be stated that people working in tech, policy-makers, many different specialists and possibly even philosophers, and probably many more must come together to optimize AI-based solutions and reach the full potential AI has in advancing sustainable development while dealing with the challenges it brings with it [33]. One more recurring theme in this thesis has been education and the bettered accessibility to education that digitalization brings with it. If this theme is considered, again we see that academic and research institutions, innovators, and many more are again needed to take AI [33] and many other technologies and themes present in this thesis forward.

4 The Pipeline for analyzing the Sustainability of Digitalization

The aim of this thesis was to identify methods for the analysis of digital processes. Based on the research conducted in the earlier section 3 'Possibilities and Challenges Digitalization opposes to Sustainability', the pipeline introduced in this section was formed to answer the goal of the thesis. The pipeline consists of five separate question trees which can be used as tools to analyze the sustainability of a digital process from the viewpoint of five different themes namely, Accessibility & Equitability (view Figure 1), Education (view Figure 2), Economy (view Figure 3), Environment (view Figure 4) and Strong Institutions (view Figure 5). All these five aspects of the pipeline should be utilized in analyzing any digital process with it, but the order in which this analysis is concluded is up to the user.

All question trees, which together form the pipeline, consist of three to four levels of questions, which include evaluation from two perspectives, firstly, digitalization for sustainability, and secondly, the sustainability of digitalization. The first level of questions always evaluates digitalization for sustainability and the later ones concentrate on sustainable digitalization. There is one exception to the structure of the question trees under the theme of Strong Institutions, where the question tree has been divided into two separate trees for smoother use of the pipeline. The other question tree under strong institutions focuses on the effects of AI and the other one considers other aspects of Strong Institutions.

The themes and questions portrayed through the pipeline are broad and not at all all-encompassing. Though all questions can be answered with a 'Yes' or a 'No', it might not be a simple decision at every step to decide which answer is the correct one. Yet this is an essential part of the evaluation process, as it leads the evaluator to consider ways that would enable the complete appreciation of the depth and breadth of the different themes and broad questions associated with them. The evaluator may also find it useful to follow both paths separately when a decision between the answers is challenging to make. The thoughts presented in the conclusions of both paths can be combined into an action plan of how to proceed in developing the process at hand into a more sustainable one. It is advisable to keep the questions visible in this action plan for cases of further development and to raise more thoughts and innovations. Own notes of the evaluator are also strongly encouraged as the nature of the questions is one which aims to raise thoughts.

It is good to note that while we refer to the user of the pipeline in the singular form in this thesis, a group of evaluators may also use the pipeline. As many digital processes are complex, they usually have many experts for them. In a case where a team of evaluators is needed for the use of the pipeline, I suggest a project manager is chosen to keep the results orderly and to collect the thoughts of other experts together. I believe that in this way the most coherent results will be obtained and these results will then be in a form easy to apply for future development and reference.

The pipeline (view Figures 1, 2, 3, 4 and 5) introduced in this section is a solution that focuses on growing the sustainability hand print of a digital solution and on

identifying the risks the digital process opposes to sustainability to be able to mitigate them. This solution can be used either for the evaluation of a new process idea or for the evaluation of an existing one. Especially at the beginning of a digital solution ideation process, the first level of questions, meaning questions concerning digitalization for sustainability could be used to foster innovation for sustainability.

This solution is not one to be used to analyze the full sustainability of any process. The purpose is to use it to weigh the different aspects of sustainability for a digital solution. Even then it is not an absolute model for the analysis of the process, but only the digital aspects of it. As an example of the process to fully support all sustainability goals listed under the UN SDGs, the process should adhere to anti-corruption & due diligence laws. Yet this solution only weighs the impact of the digital process on transparency and strong institutions, which link to anti-corruption. For the complete analysis of sustainability digital tools such as EcoVadis [77], which was discussed earlier under section 3.2.12 '#12 Responsible Consumption and Production', can be utilized.

Based on the research and discussions conducted in this thesis, one conclusion that can be deduced is that sustainability is a very broad field of study and the interlinkage between sustainability and digitalization is strong and also quite broad, giving the study even more aspects and perspectives to it. With that said, it can be derived that not all possible interlinkages were most likely identified and more research could be concluded on the subject. From the analysis of the literature utilized in this thesis, it can be noticed that most of it considers digitalization as more of an asset than as a threat to sustainability. Therefore, especially the threats and challenges could be given more thorough thought.

Yet, as a whole, the pipeline introduced in this thesis could well be used as a tool for analyzing the sustainability of digitalization. Conclusively, the pipeline can be utilized to point to some even major ways of evaluating and improving the sustainability of digital processes.

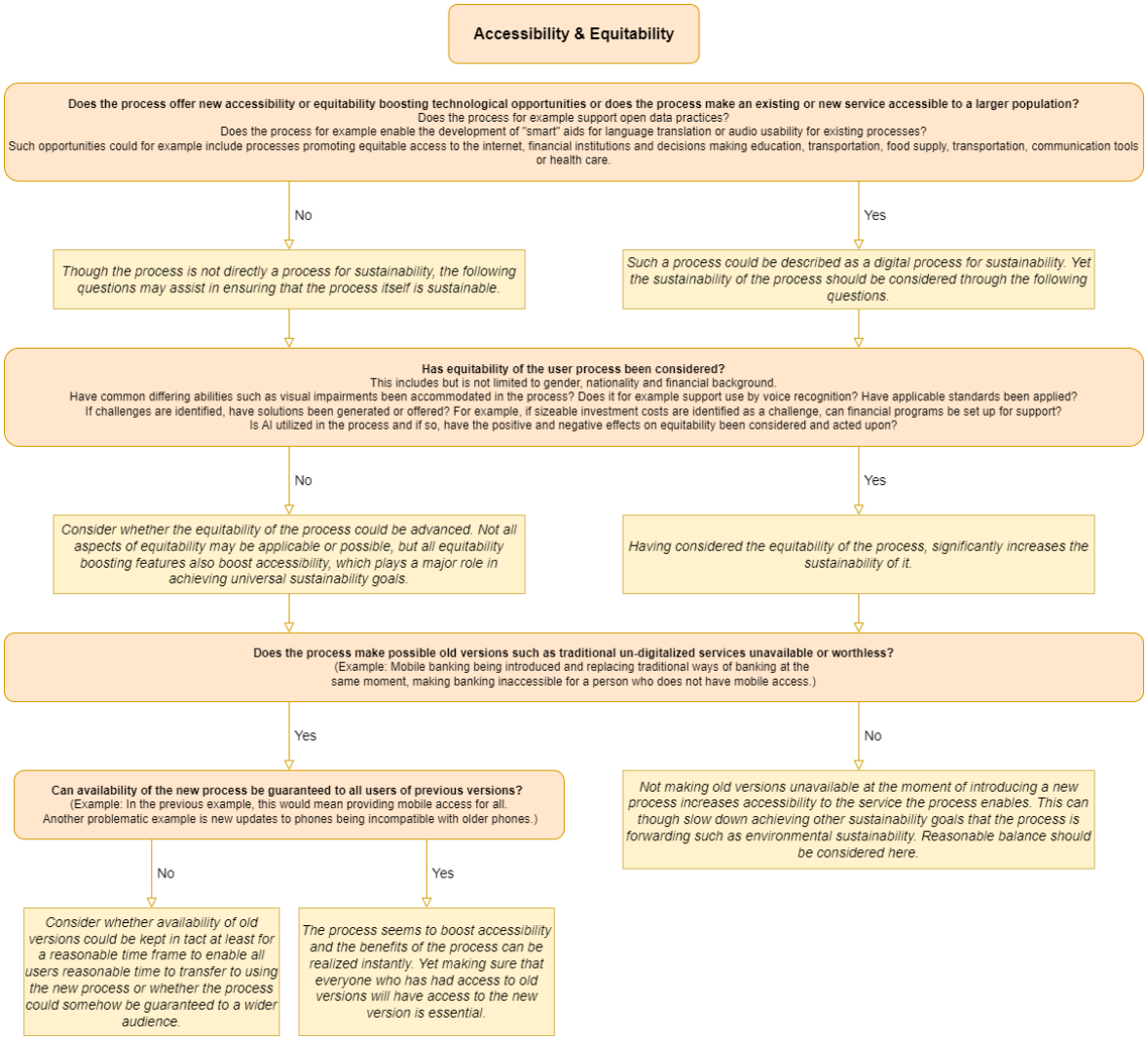

Figure 1: Pipeline for analyzing the effects of a digital process on Accessibility & Equitability.

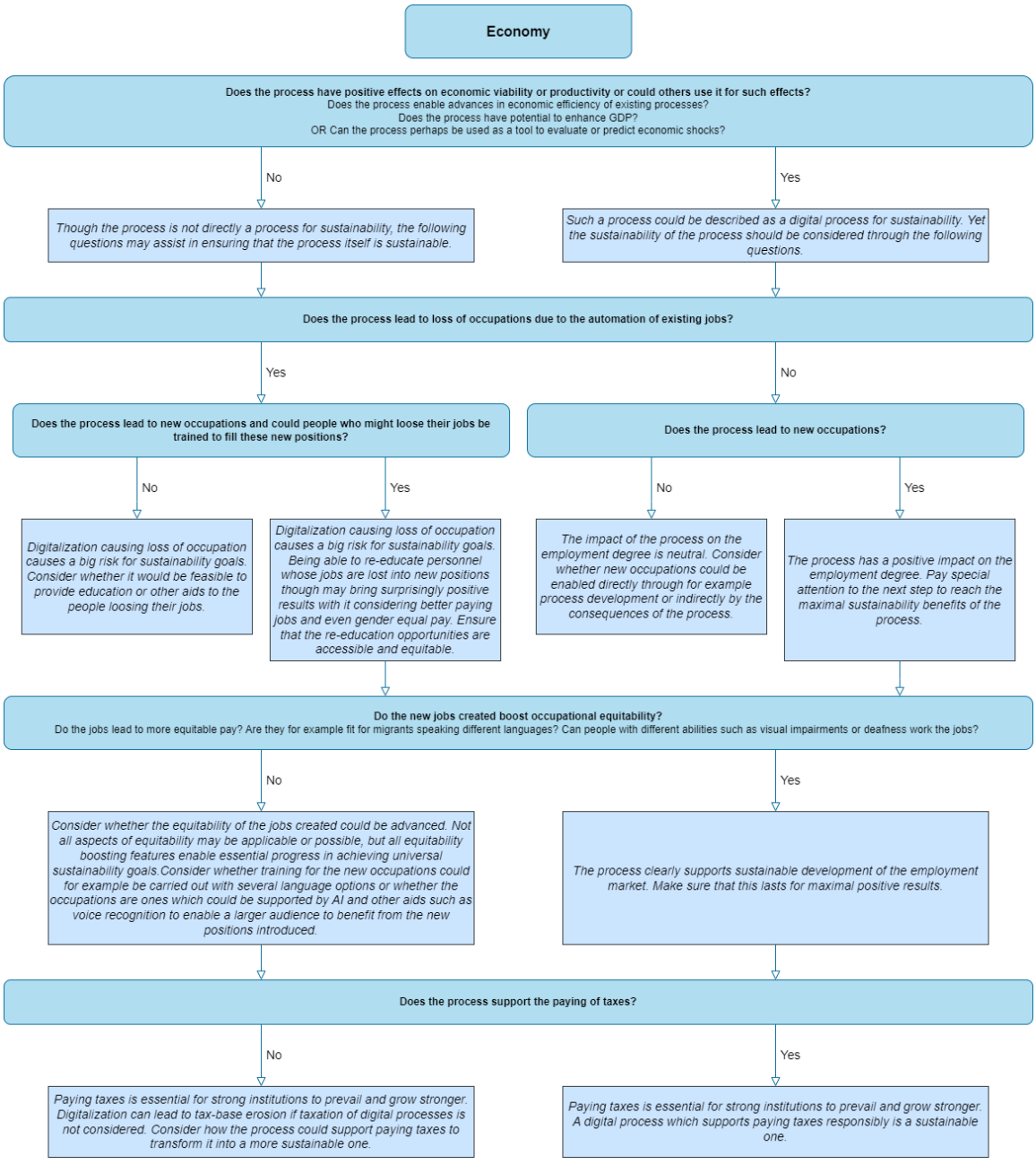

Figure 2: Pipeline for analyzing the effects of a digital process on the Economy.

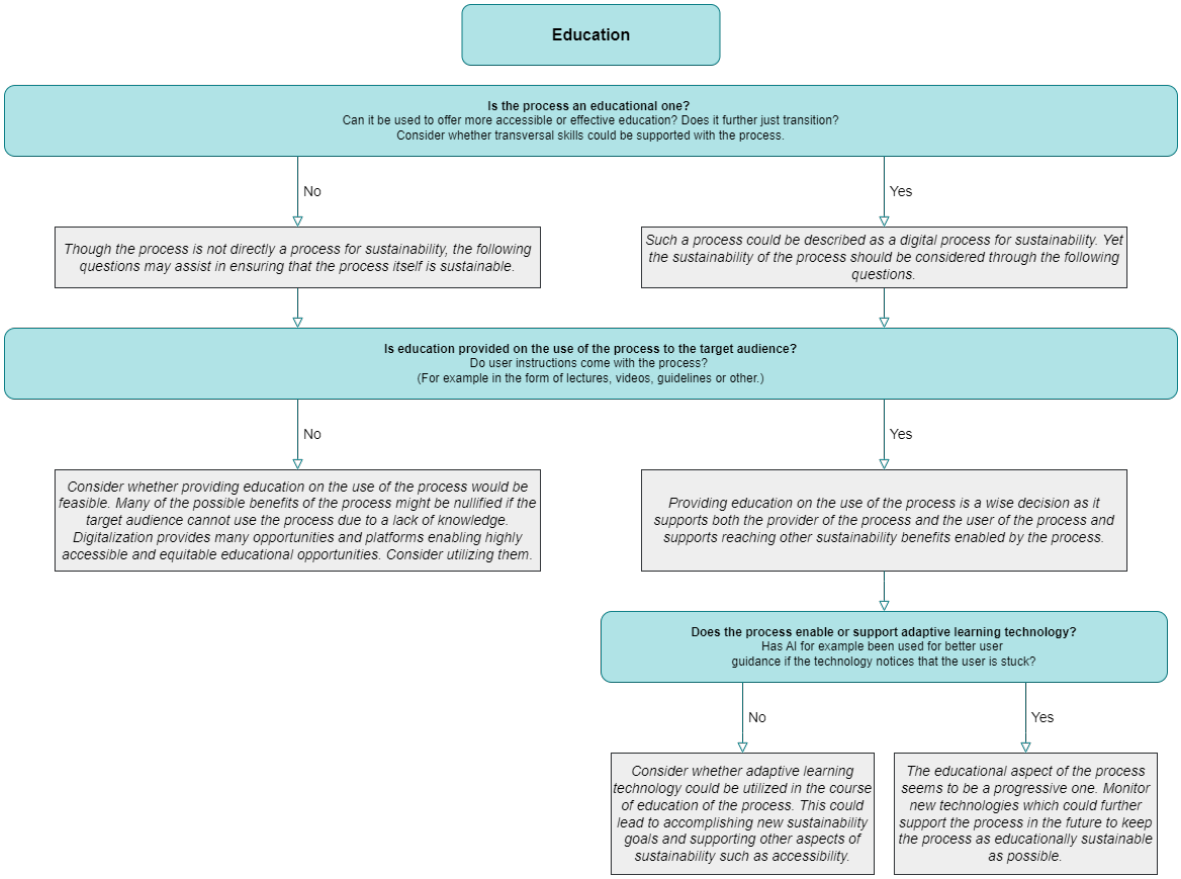

Figure 3: Pipeline for analyzing the effects of a digital process on Education.

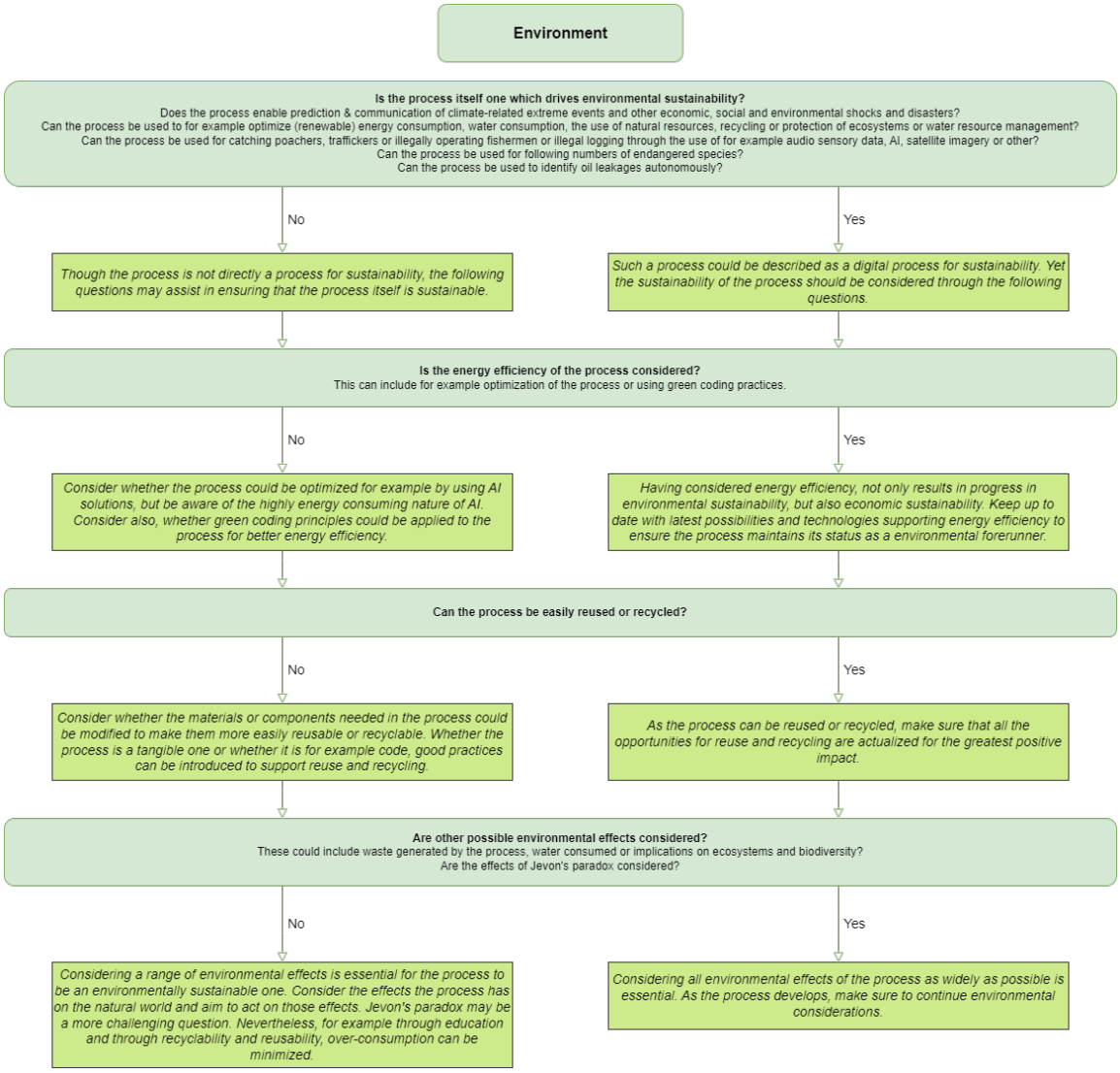

Figure 4: Pipeline for analyzing the effects of a digital process on the Environment.

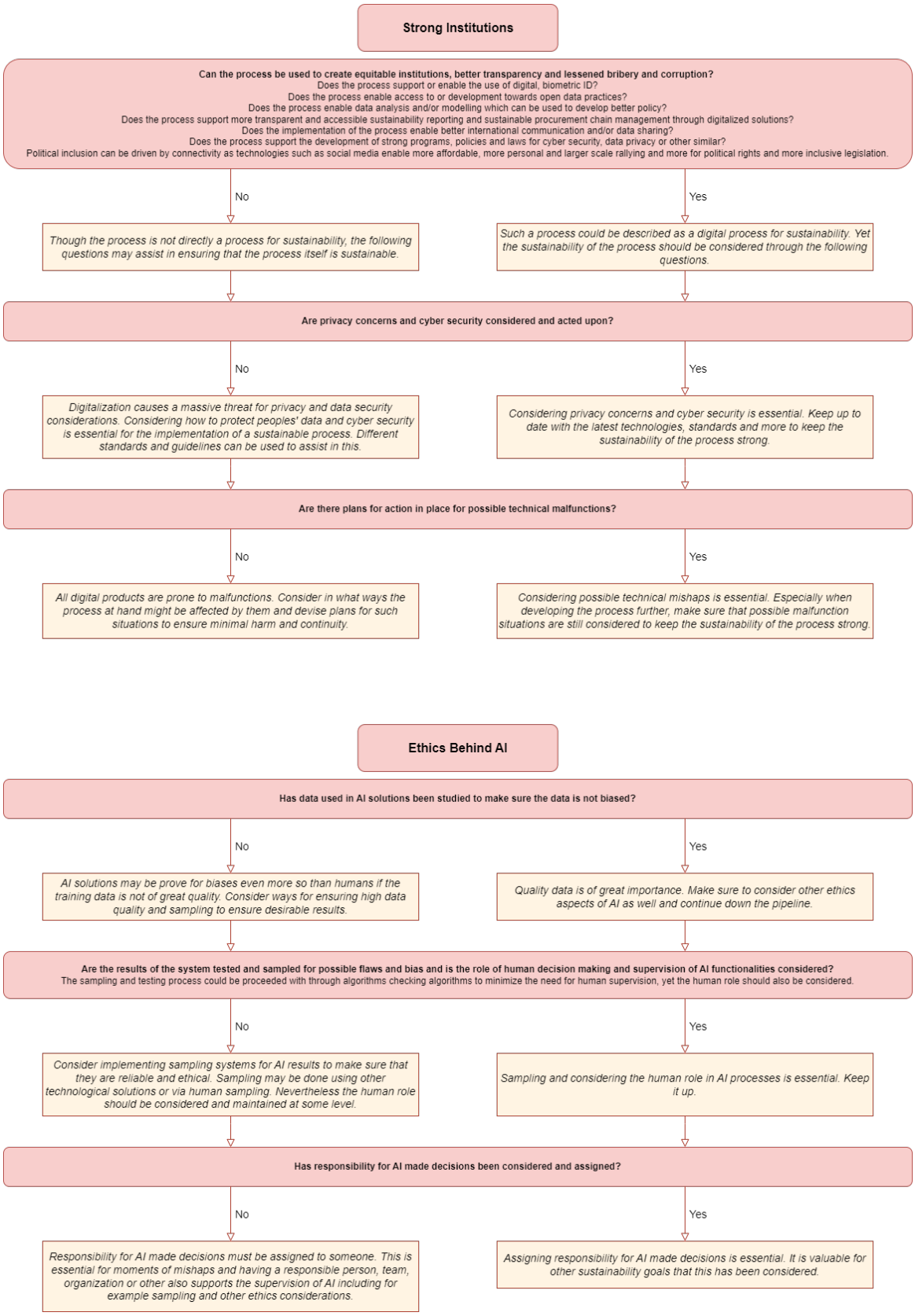

Figure 5: Pipeline for analyzing the effects of a digital process on Strong Institutions.

4.1 The Formulation of the Pipeline

The abovementioned pipeline was formulated using the literature review from section 3. Based on the discussion in the area in question, I aimed to identify and list all enablers and challenges which digitalization leads to in the light of sustainability. This evaluation resulted in collectively identifying 89 enablers and 44 risks and challenges.

Analysis of the listed enablers, risks, and challenges leads to the identification of initial themes which could be used as umbrellas to classify all the different enablers, risks, and challenges. Through this process, a list of 5 themes was created, and these themes led to the idea of shaping the contents of the themes into decision trees. First, some enablers, risks, and challenges were merged under the different themes as I developed the enabler and risk and challenge propositions into questions.

After the questions were shaped, I realized that some questions under different themes closely corresponded to one another, after which I decided to merge some of the initial themes into new ones to prevent excessive repetition. This led to the identification of the final five themes of Accessibility & Equitability, Education, Economy, Environment, and Strong Institutions.

Subsequently, after the themes and questions were set, the order of the questions was developed. To gain a consistent and comprehensive form, I decided to start each question tree with a set of questions concerning digitalization for sustainability, which evolves into questions about sustainable digitalization. After answering the questions of the decision tree, the evaluator ends up with brief conclusions summarizing what might be good with the current process and what might be improved. These conclusions are based on the question tree questions and the information gained from the literature view of this thesis.

The pipeline aims to challenge the current process being evaluated and to lead the user of the pipeline to think about ways through which the process could be made more sustainable. Both the questions and the conclusions address and build on this aim.

4.2 Themes of the Pipeline

As discussed, five collective themes for analyzing the sustainability of digital methods were identified in the evaluation of the literature review. These five themes and their contents are discussed further in this section.

The themes form the basis for the whole pipeline. They are one of the central findings of this thesis, so understanding these themes is essential for applying this pipeline to any digital process. This required understanding can be gained by studying this section.

4.2.1 Accessibility & Equitability

Accessibility became a keyword in the literature review already at an early stage, and the term "access" and/or its inflected forms can be found under each section discussing a UN Sustainable Development Goal (SDG).

To begin with, in the process of forming the pipeline, accessibility, and equitability were treated as separate topics, and separate question trees were designed initially for the two. Yet later, after a more thorough evaluation, it became evident that the two are closely interlinked and advancing the other, had direct impacts on the other, and the same applied to negative impacts. As a result of this realization, the two question trees were merged into one.

The question tree considering Accessibility & Equitability can be viewed under the earlier section 4 in Figure 1. The first question of the pipeline is one which encourages the user to reflect on whether the process is one for sustainability, meaning whether the process itself directly contributes to reaching sustainability goals. Supporting questions have been listed under the main question to support the evaluation process. The aim is to understand the big picture.

The following questions focus on the sustainability of the process, in this case meaning that the focus is on making the user process as equitable and thereafter as accessible as possible. The questions also support the pipeline user in evaluating whether the process might cause momentary set-backs in accessibility due to new technologies not being available for all. Finally, the conclusions gained from answering the questions support the user in developing the process to become more accessible and equitable.

4.2.2 Economy

Economic feasibility is a basis that any digital or other process requires for it to succeed. Under the literature review, it became abundant that the largest concerns related to digitalization and economic sustainability evolve around employment [33] [23]. These concerns were discussed mainly under sections 3.2.5 '#5 Gender Equality' and 3.2.8 '#8 Decent Work and Economic Growth'. Therefore, the emphasis of the theme of Economy is on employment and job opportunities.

As with other themes, the first question of the Economy pipeline focuses on digitalization for sustainability (see Figure 2). The aim of answering the question is to evaluate the large-scale impact of the process itself on sustainability.

The second part of the Economy pipeline, meaning the rest of the questions associated with it, focuses on economically sustainable digitalization and here the emphasis is on employment. As digitalization progresses, some occupations are bound to be replaced by digital solutions [33] [23]. Nevertheless, as discussed in the literature review under sections 3.2.5 '#5 Gender Equality' and 3.2.8 '#8 Decent Work and Economic Growth', digitalization has the potential of creating more new jobs than what are eradicated [23]. Positively, these jobs may also be ones that are more equitable and thereafter more accessible to a wider population and they have the potential of mending gender-based wage gaps [23] [22]. Additionally to employment, this part holds one question about taxation. Digitalization was found to be a threat to responsible tax-paying, possibly leading to tax-base erosion in section 3.2.8 '#8 Decent Work and Economic Growth'. The final question of this section therefore encourages the user of the pipeline to consider what effect their digital process has on taxation. The questions and conclusions obtained from the second part encourage the user to think about how the process can support employment opportunities and how these opportunities created can support a more equitable economy.

4.2.3 Education

The theme of Education has a strong interlinkage to the other sustainability goals and themes. As concluded in the literature review under section 3.2.4 '#4 Quality Education', education is a key component necessary for realizing the benefits of other sustainability goals. Therefore education can be seen as an important tool for sustainability and as a major theme.

As usual, the first question of the Education section focuses on digitalization for sustainability (see Figure 3). The goal of the question is to lead the user to think about whether the process at hand is one that advances sustainability goals and whether it could be developed further to do so.

Similarly to the other themes, the second part focuses on the sustainability of the digital process. In this case, this means educational sustainability. This part consists of only two questions, which summarize the need for education on the process. Firstly, the availability of education is considered. The goal is to make sure that an educational process is set in place or if not then that the user is guided towards setting one up. The following question focuses on adaptive learning technologies, which in the literature review were identified as ones that could well support other goals [22]. The goal here is to get the user to consider means through which adaptive learning technologies could be adopted to support their process.

4.2.4 Environment

The theme of Environment portrays a large part of sustainability and is also highly present in the UN Sustainable Development Goals (SDGs) with several of them focusing on environmental sustainability. Through the literature review especially under sections 3.2.11 '#11 Sustainable Cities and Communities', 3.2.12 '#12 Responsible Consumption and Production', 3.2.13 '#13 Climate Action', and 3.2.14

'#14 Life Below Water & #15 Life on Land', it became obvious that environmental sustainability is also closely interlinked with digitalization enabling positive progress, but also causing some threats.

It became evident through examples reviewed under SDG studying that there is much potential for developing digitalization for sustainability to harbor the environment through innovations ranging from optimizing energy efficiency [33] to catching poachers [22]. Therefore, as for the other themes, the pipeline considering environmental aspects begins with a question considering whether the process at hand forwards environmental sustainability (see Figure 4).

The rest of the questions under the theme of Environment focus on sustainable digitalization. The first question in this set of questions challenges the user to think about the energy efficiency of the process and aims to make sure that energy consumption and ways for minimizing it are considered. The second question is one directly related to the UN SDG #12 Responsible Consumption and Production and questions the reusability or recyclability of the process. Whether the process is a physical product that utilizes digitalization or whether the process is purely a digital one, this question is a relevant one. The gist of the question is to encourage the user to rethink the process and consider whether the degree of reusability or recyclability of the process can be heightened. The final question of this section directs the user to think about other possible environmental effects of the process. This includes effects on biodiversity, water sources, and more. One of the sub-questions of this question also challenges the user to think about Jevon's paradox and about whether it is possible that the enablers of the process are consumed by over-consumption. It is a broad question, but it gives the user space to reflect on a wide subject and leaves room and hopefully guides towards new innovation and process development.

4.2.5 Strong Institutions

The theme of strong institutions stemmed from the realization that digital processes are already shaping the world around us and simultaneously the institutions in it [37]. This theme aims to challenge the user to consider the large-scale implications of the process at hand on the institutions around us and calls for developers to consider responsibility. The pipeline for this theme (visible in Figure 5) differs from the other four in the sense that a separate sub-section was built in conjunction with the main line of questions to discuss the role and effects of AI. This separate piece is only meant to be used when evaluating processes that currently utilize AI or processes which are being developed toward utilizing AI.

The main question tree under the theme of Strong Institutions starts off in a similar way as other themes' pipelines, with a question about digital processes for sustainability. This question challenges the user to consider whether the process has a broad, direct effect on sustainability goals or whether it ultimately could. This is followed by two questions relating to the sustainability of digitalization. The first one of these two questions requires the user to think about the data privacy and cyber security aspects of the process being evaluated. Based on the literature review, this may in fact be one of the most essential aspects of study in the line of field

of sustainable digitalization [26] [34] [38] and this is emphasized in the conclusions following the question. The final question of this section leads the user of the pipeline to consider moments of technical malfunctions, which are a threat to any digital system [27]. The goal behind this question is to prepare the user for such situations and to encourage them to devise plans as to how to proceed in such situations to ensure minimal damages or risks.

The separate question tree considering the ethics of AI under the theme of Strong Institutions consists of three questions. The first question about the quality of data used to train the AI solution aims at ensuring that the data is inclusive and that the AI does not learn biases because of the data [39] [40]. The second question challenges the user to consider sampling of the data being used and the results the AI solution devises [31], and the human role in decision making [33]. The final question links strongly to the previous one, inviting the user to consider which party takes responsibility for decisions made by the AI solution. This is a question that aims to firstly, make sure that there in fact is a responsible party, but secondly, having a responsible party may also lead to better practices and follow-ups on ethics as responsibility for the doings of the AI is allocated to someone [33].

5 Case Study: Arkki

Digitalization and sustainability are both huge fields of study and relevant themes in all industries universally. Yet studies focusing on the interlinkages between the two are scattered and there have not been structured solutions for sustainability analysis of digitalization. This thesis aimed to solve this issue and based on a literature review a pipeline for analyzing the sustainability of a digital process was introduced. To test the viability of the solution proposed, a case study was performed on a digital archiving system, Arkki.

The pipeline introduced in this thesis under section 4 'The Pipeline for analyzing the Sustainability of Digitalization' in Figures 1, 2, 3, 4 and 5 consists of five separate components. These five sections are based on themes collecting together enablers, and risks and challenges, which digitalization portrays on sustainable development. These themes are namely Accessibility & Equitability (view Figure 1), Economy (view Figure 2), Education (view Figure 3), Environment (view Figure 4) and Strong Institutions (view Figure 5). In the analysis of the literature review discussing the interlinkages between the UN Sustainable Development Goals and digitalization, all identifiable impacts of digitalization on sustainability were analyzed and listed. Under further review of these impacts, the 5 collecting themes introduced were identified. Based on the impacts listed under each theme pipelines consisting of questions are answers were formed. This process as a whole resulted in a pipeline that analyzes both digitalization for sustainability and sustainable digitalization.

To test the pipeline introduced, a test case was carried out on a digital product called Arkki. Arkki is a digital, scalable archiving system [48] and was chosen as the center of study due to a need for understanding the sustainability impacts of the product. The aim was to identify both strengths and weaknesses to be able to further develop the system in a more sustainable direction.

The impacts Arkki has on sustainability were successfully evaluated and the aim of the case study was reached. Conclusively, based on the study Arkki was found to be 'a digital solution for sustainability' as it advances goals under several of the themes of the pipeline. Yet the 'sustainability of digitalization' should be considered more thoroughly and several suggestions were made to improve the sustainability of the process.

5.1 Evitec Arkki - A Data Archiving Solution

Evitec Ltd (https://evitec.com/) is a Nordic expert in software solutions and consultation services for the finance sector. Analytics and data management services are available across multiple sectors. Arkki is one of Evitec's products for better data management. Arkki is a digital, scalable archiving solution for a range of different systems. [48]

Governments and other legal entities set archiving requirements for different types of data, but maintaining legacy systems to fulfill these requirements can be expensive. As historic systems are shut down, data archiving must often be solved due to legal or other requirements and systematically tended to in order to fulfill requirements such as the ones introduced by GDPR. [48]

The Arkki solution enables data archiving to cloud or on-premises archives and is customizable for differing needs. The solution can be utilized to archive data from both active and historic systems. The deployment of the system is designed to be easy and fast and it can be implemented in only a few weeks. Utilizing the Arkki solution for archiving is estimated to save up to 70-90% more time compared to developing a new archiving solution. The Arkki-system can be integrated into other existing systems and finally, it enables quick data searches even on sizeable sets of data. [48]

In the sustainability analysis of Arkki and in the process of applying the pipeline introduced in this thesis to it, I was supported by an Arkki expert, Marko Väisänen.

For more information on the Arkki-solution, visit: https://evitec.com/solutions/evitec-arkki/.

5.2 Analyzing the Sustainability of the Arkki Solution using the Pipeline

As the Arkki-solution was analyzed using the pipeline introduced under section 4, key impacts the solution has on sustainability were identified. Significant findings were made both while analyzing whether the system is a 'digital process for sustainability' and while evaluating the 'sustainability of the process'. The process was found to be one for sustainability under several of the themes introduced under section 4 'The Pipeline for analyzing the Sustainability of Digitalization'. Yet several improvement areas were also identified under the different themes while considering the sustainability of the process.

To summarize, Arkki was found to be a 'process for sustainability' mainly due to it constituting a way for concretely furthering open data practices. This furthers the goals under the themes of Accessibility & Equitability and Strong Institutions. The fact that the system can be utilized to maintain good governance for example by supporting GDPR requirements, also supports goals under the theme of Strong Institutions. Additionally, as the system can lead to economic savings, it can also be classified as a 'process for sustainability' under the theme of Economy. Whether Arkki is a 'process for environmental sustainability' is slightly more complex. The process enables savings in materials compared to traditional archiving systems, but the energy efficiency of the system could be further investigated to evaluate whether it also saves energy compared to up-keeping legacy systems or utilizing other archiving methods.

To boost the 'sustainability of the process', several suggestions were made. Under the theme of Accessibility & Equitability, more equitability-boosting properties were recommended. Under the theme of Education, adaptive learning technologies were suggested to boost learning. When considering the theme of Environment, the application of green coding practices was recommended. Finally, under the theme of Strong Institutions, it was noted that Arkki does not utilize AI, but includes opportunities for it. Therefore the recommendation was made that if these opportunities are seized, AI ethics should be considered and developers should re-evaluate the results of the pipeline.

5.2.1 Accessibility & Equitability

Digitalization for Accessible & Equitable Sustainability

The first question of the pipeline for the section of Accessibility & Equitability (visible in Figure 1 under section 4 'The Pipeline for analyzing the Sustainability of Digitalization') focuses on digitalization for sustainability and asks *"Does the process offer new accessibility or equitability boosting technological opportunities or does the process make an existing or new service accessible to a larger population?"*. In the literature review it was deduced that open data systems and practices are one important area of digital innovation for better accessibility and equitability enabling further financial and institutional inclusivity globally [26] [41]. It has also been listed

as one of the supporting sub-questions for this main question.

As a digital archiving system that enables easy and fast data searches from large amounts of data [48], Arkki can be seen as a system that in fact can be used to drive open data practices and searches forward. This makes it evident that Arkki can be classified as a digital process for accessible & equitable sustainability.

Accessible & Equitable Digitalization

The second part of the pipeline considering Accessibility & Equitability (visible in Figure 1 under section 4 'The Pipeline for analyzing the Sustainability of Digitalization') focuses on sustainable digitalization. The first question asks: *"Has equitability of the user process been considered?"*. Efforts have clearly been invested in developing an easily understandable user process that supports effortless training and learning. The system also supports the use of several different languages. Yet, the ultimate answer to this question is *"No"*. The reason for this is that the system is lacking support for the most common disabilities. To accommodate people with differing sight abilities, the system could benefit from a user portal that is designed to the needs of the visually impaired or even vocal recognition to be accessible even for visually impaired people [22] [33]. The implementation of vocal recognition may be slightly more consuming, but the possibility could be kept open in case a customer was to wish for such a solution. Re-designing the user interface of the system to support people with limited sight [49] could though be a feasible solution for the backlog considering the close future. Standards [62] discussed under section 3.2.10 '#10 Reduced Inequalities' could be utilized. With this addition, the answer to this particular question in hand could be changed to *"Yes"*.

Yet, some decisions, which affect the accessibility of the user interface are made by the customer. For example, one way of bettering the user interface for partially visually impaired people is through the coloring of the interface and/or by enabling several coloring options [49]. Nevertheless, usually, customers of the Arkki solution wish to apply company brand colors. In such cases, color options could be made available for the user if the customer would agree.

The following question asks the evaluator: *"Does the process make possible old versions such as traditional un-digitalized services unavailable or worthless?"*. The answer to this question is *"No"*, resulting in the following conclusion: *"Not making old versions unavailable at the moment of introducing a new process increases accessibility to the service the process enables. This can though slow down achieving other sustainability goals that the process is forwarding such as environmental sustainability. A reasonable balance should be considered here."* Shutting down old systems containing the data moved to Arkki, is up to the upkeeper of those systems. Environmental benefits may be gained if the upkeeper decides to shut those systems down, but these benefits are discussed further under the theme of Environment. This concludes the line of questions under Accessibility & Equitability.

5.2.2 Economy

Digitalization for Economic Sustainability

As for the other themes, the first question at hand under the pipeline considering the theme of Economy focuses on 'digitalization for sustainability' and in this case economic sustainability (visible in Figure 2 under section 4 'The Pipeline for analyzing the Sustainability of Digitalization'). The question asks: *"Does the process have positive effects on economic viability or productivity or could others use it for such effects?"*. One of the supporting questions for this main question asks: *"Does the process enable advances in the economic efficiency of existing processes?"*. According to the Arkki-experts, substantial financial savings can be gained from shutting down legacy systems and migrating the existing data to Arkki to be stored. This suggests that Arkki can also provide a digital solution to furthering economic sustainability.

Economically Sustainable Digitalization

The questions following the first section under the theme of Economy consider economically sustainable digitalization (visible in Figure 2 under section 4 'The Pipeline for analyzing the Sustainability of Digitalization'). The first question asks: *"Does the process lead to loss of occupations due to the automation of existing jobs?"*. The answer to this question is *"No"*, leading to the following question: *"Does the process lead to new occupations?"*. The product itself does not lead to new job opportunities. Even though the development of the process may provide some occupations, as the product itself does not result in them, the answer to this question is also *"No"*. This leads to the following conclusion: *"The impact of the process on the employment degree is neutral. Consider whether new occupations could be enabled directly through for example process development or indirectly by the consequences of the process."* Further thought could be given to new employment opportunities down the line, but at the moment the impacts on employment seem to be quite neutral.

The final question is about taxation and asks: *"Does the process support the paying of taxes?"*. Taxes are paid throughout the development process of Arkki and when in use through maintenance fees, so the answer to this question is *"Yes"*. This leads to one more conclusion: *"Paying taxes is essential for strong institutions to prevail and grow stronger. A digital process which supports paying taxes responsibly is a sustainable one."*

5.2.3 Education

Digitalization for Education

The first question for the theme of Education (visible in Figure 3 under section 4 'The Pipeline for analyzing the Sustainability of Digitalization') focuses on digitalization for education and asks the evaluator: *"Is the process an educational one?"*. The answer to this question is *"No"*, which leads to the conclusion that Arkki is not a

digital process forwarding educational goals under sustainability as a product itself.

Educational Digitalization

The second line of questions under the theme of Education (visible in Figure 3 under section 4 'The Pipeline for analyzing the Sustainability of Digitalization'), focuses on educational digitalization. The first question asks the evaluator: *"Is education provided on the use of the process to the target audience?"*. The answer to this question is *"Yes"*, leading to the following conclusion: *"Providing education on the use of the process is a wise decision as it supports both the provider of the process and the user of the process and supports reaching other sustainability benefits enabled by the process."*

The next question then asks the user: *"Does the process enable or support adaptive learning technology?"*, to which the answer is *"No"*. This leads to the following proposition: *"Consider whether adaptive learning technology could be utilized in the course of education of the process. This could lead to accomplishing new sustainability goals and supporting other aspects of sustainability such as accessibility."* Adding some adaptive learning technology through utilizing AI could be possible to enable the process to become a more sustainable one from the point of view of the theme of Education [22]. This concludes the line of questions under this section.

5.2.4 Environment

Digitalization for Environmental Sustainability

Similarly as with the pipelines considering other themes, also the pipeline evaluating environmental aspects begins with a question about 'digitalization for sustainability', in this case, environmental sustainability (visible in Figure 4 under section 4 'The Pipeline for analyzing the Sustainability of Digitalization'). The first question asks the user: *"Is the process itself one which drives environmental sustainability?"*. This is a question that would require slightly more investigating. Theoretically, being able to shut down large legacy programs and archiving the data in Arkki should provide a more environmentally sound option for storing data. Archiving data in a digital format enables less consumption of paper which is also positive. Yet digitally stored data also requires different kinds of material and energy and for example, whether the data is stored locally on-premises or in the cloud results in different kinds of emissions [50]. These effects should be further investigated. Additionally, the energy consumption of the Arkki system could be investigated to better compare the results to other forms of archiving, such as traditional paper-based solutions.

To conclude, it could be beneficial to investigate this question further, but it seems that by concluding this type of investigation and by acting on the results of the investigation, Arkki could form a digital process for environmental sustainability.

Environmentally Sustainable Digitalization

The second area of investigation under the theme of Environment, evolves around environmentally sustainable digitalization. The first question (visible in Figure 4 under section 4 'The Pipeline for analyzing the Sustainability of Digitalization') asks the evaluator: *"Is the energy efficiency of the process considered?"*. For Arkki, the energy efficiency of the code base has currently not been thoroughly considered. As the conclusions of the pipeline suggest, by adding green coding practices to the development of Arkki and its code base, the energy efficiency of the system could be advanced.

The second question under this section asks: *"Can the process be easily reused or recycled?"*. The answer to this question is *"Yes"*. The system is easily customizable for different purposes and can therefore be reused easily. Recycling of code is also simple. This leads to the following positive conclusion: *"As the process can be reused or recycled, make sure that all the opportunities for reuse and recycling are actualized for the greatest positive impact."*

The final question of this section asks: *"Are other possible environmental effects considered?"*. The effect of saving paper and therefore having a positive impact on forests has been considered, but the effects of new resources, which support digital archiving have not been considered. Considering Jevon's paradox, there is the possibility that having a tool such as Arkki could possibly lead to more data being stored than necessary, due to the storing of the data being so easy. Yet, this can be classified as quite a small threat compared to the advantages. Altogether, this question requires slightly more research to be fully answered.

5.2.5 Strong Institutions

Digitalization for Strong Institutions

In a similar manner as with other sections of the pipeline for different themes, also the Strong Institutions -themed pipeline begins with evaluating digitalization for sustainability (visible in Figure 5 under section 4 'The Pipeline for analyzing the Sustainability of Digitalization'). The first question asks the evaluator: *"Can the process be used to create equitable institutions, better transparency, and lessened bribery and corruption?"*. One of the sub-questions supporting the main questions asks: *"Does the process enable access to or development towards open data practices?"*. As discussed earlier, as Arkki is a digital archiving system that enables easy and fast data searches from large amounts of data, Arkki can be seen as a system that in fact can be used to drive open data practices and searches forward. This makes it evident that Arkki can be classified as a digital process for strong institutional sustainability.

Additionally, one other supporting question is related to Arkki, This question asks: *"Does the process support the development of strong programs, policies, and laws for cyber security, data privacy, or other similar?"* Arkki supports storing data according to legal requirements such as GDPR, giving it another perspective supporting sustainability goals.

Strong Institutions wise Sustainable Digitalization

The first question considering strong institutions wise sustainable digitalization (visible in Figure 5 under section 4 'The Pipeline for analyzing the Sustainability of Digitalization') asks the evaluator: *"Are privacy concerns and cyber security considered and acted upon?"*. For Arkki the answer to this question is *"Yes"*. The system includes possibilities for creating different kinds of user profiles with different access to data. Cyber security has also been considered. This leads to the following conclusion: *"Considering privacy concerns and cyber security is essential. Keep up to date with the latest technologies, standards, and more to keep the sustainability of the process strong."* The conclusion works as a reminder to keep updating cyber security and data privacy programs to keep them up to date.

The final question asks: *"Are there plans for action in place for possible technical malfunctions?"*. The risk for technical malfunctions has been considered for Arkki and plans have been devised for these situations, therefore the answer is *"Yes"*, and therefore the conclusion that is obtained says: *"Considering possible technical mishaps is essential. Especially when developing the process further, make sure that possible malfunction situations are still considered to keep the sustainability of the process strong."* This again serves as a good reminder.

The Ethics of AI

Unlike the other themes, the pipeline for Strong Institutions includes an additional separate pipeline for a relevant technology, namely AI (visible in Figure 5 under section 4 'The Pipeline for analyzing the Sustainability of Digitalization'). The reason that this section is kept separate from the main decision tree is to make the pipeline easier to use. If the process at hand does not have AI-based features, then this piece of the pipeline can be omitted.

In the case of Arkki, this section is not relevant to the current implementation. Nevertheless, AI-based features such as adaptive learning features suggested earlier could be added to Arkki. If such decisions are made, then coming back to this section of the pipeline is advisable.

6 Summary

The purpose of this thesis was to examine sustainable digitalization and identify ways for analyzing the sustainability of digital processes. In the constantly digitalizing world, digital technologies are being developed at an accelerating pace [33] and digital processes are shaping the way we perceive the world around us [37]. The link between digitalization and sustainability is evidently a strong one no matter whether considering digitalization from an environmental [33], social [14] or governance [41] point of view.

The aim of the thesis was achieved through the implementation of a pipeline, which can be utilized to analyze the different sustainability aspects of a digital process. When applied to the design and the development of digital processes, the pipeline can be used to identify both strengths and weaknesses of the process at hand sustainability-wise. This enables further sustainable development of either new or existing processes. The pipeline supports the development of progress towards the UN Sustainable Development Goals (SDGs) and by applying the pipeline to digital processes and acting on the results obtained from the analysis, impacts on sustainable development can be extensive.

The pipeline was tested through a case study concerning a digital archiving system called Arkki. Arkki is one of Evitec's solutions meant for digitally archiving data from active or legacy systems. The analysis lead to findings, which indicate that Arkki can be perceived as a digital solution for sustainability. The sustainability of the digital process was identified to have some areas for improvement and the analysis led to concrete suggestions for how to improve in these areas.

The pipeline consists of five separate segments which all portray a theme essential for the sustainability analysis of digital processes. These five themes are Accessibility & Equitability, Economy, Education, Environment, and Strong Institutions. Each of these segments can be described as a question tree, which entails 3-5 levels of questions each.

The questions under the question trees are ones with options of 'Yes'/ 'No' answers, but the answer may not always be clear to the user of the pipeline as some of the questions are essentially broad. The reason as to why broad questions were used instead of long lists of more compact questions were used is that the questions aim to lead to even complex thought processes which give more depth to the analysis. The broadness of the questions also enables the use of the process on practically any digital process.

The questions are supported with sub-questions. These sub-questions aim to broaden the user's thought process and give depth or guide the analysis without having to gain expertise in all areas of sustainability of digitalization.

All questions are followed by either detailing questions or conclusions, but ultimately all questions lead to a set of conclusions. As discussed, the questions themselves aim to lead to thought processes about ways of developing the sustainability of the process at hand, but these conclusions aim to further support the questions and the evaluation process.

Each question tree can ultimately be divided into two separate sections. The

first section of each question tree or pipeline segment consists of one question which aims to study whether the process at hand is one for sustainability. A digital process for sustainability is one which has a purpose that directly forwards sustainability goals. The second section of each pipeline segment focuses on the sustainability of the process. This is whether the process has been developed in a way that is sustainable and supports universal sustainability goals.

This thesis has shown that the fields of sustainability and digitalization are huge ones and their interlinkages are vast. The scope of these areas can make it daunting for innovators and developers of digital processes to establish solutions fixing all sustainability issues or solutions which consider all aspects of sustainability whether while finding new digital solutions or while developing existing solutions. Nevertheless, as is said small streams can create a large river. The pipeline introduced in this thesis can be utilized to identify and further support such 'small streams' to turn them into 'larger rivers'.

Digitalization has the potential of enabling much progress for universal sustainability goals, but it also introduces significant risks. Using methods such as the pipeline introduced in this thesis is essential for sustainable digital development.

As mentioned, the field of sustainability is huge and so are the numbers of possibilities and challenges digitalization enables and opposes for sustainable development. This thesis has merely touched upon some examples and many more could and should be considered. Future works could focus on diving deeper into all different UN SDGs and their links to digitalization. Each one of the SDGs provides areas for such future research linked to digital processes.

Though all SDGs were found to be essential in the study between sustainability and digitalization a central theme within all these themes could be identified. The very key behind all seems to be accessibility. Digitalization is taking over many traditional aspects of society and we should make sure that everyone has equitable access to the 'digitalization train', which can offer great successes for sustainable development concerning health, economic equitability, and plenty more. Digitalization can be seen as an enabler for practically all sustainable development goals and it can enable even fast-tracking of many of these goals. Yet there is still lots to be done for example with making the Internet and other digital tools accessible for all. Therefore special attention should be allocated to the accessibility of digitalization in future research.

The pipeline introduced in this thesis is one which can be used for qualitative analysis as was demonstrated in the Arkki-case study. Nevertheless, it could be useful for experts to be able to analyze the sustainability of digital processes quantitatively as well. This pipeline paired with further research could provide solutions for such KPIs.

An interesting realization I made while developing the pipeline was that one more way of developing it could be using it as a basis for creating a tool for sustainable innovation. If the focus was directed into the aspects of the pipeline concentrating on 'digitalization for sustainability', these elements could be combined and further developed into a tool, which could be used to boost the ideation process for digital innovation for sustainability.

Finally, based on the studies concluded in this thesis, I see that the field of

sustainability is the future and there is no long-term viable field without it supporting sustainable development. This includes the field of digitalization. Sustainability analysis and considerations of digital processes may not be a norm today and can even be seen as a selling point at the moment. Yet, the future is about sustainability and to stay relevant, players in the field of digitalization must consider sustainability from the viewpoint of 'digitalization for sustainability' and the other viewpoint of 'sustainable digitalization'. I believe that companies looking for ways to develop their digital processes in a sustainable direction can benefit from using the pipeline introduced in this thesis to do so, as was demonstrated through the Arkki-case study. I hope that by doing so this thesis leads to new sustainable development of digitalization and sustainable digital innovation.

References

[1] T. Koipijärvi and S. Kuvaja, "Yritysvastuun johtaminen," in *Yritysvastuu 2.0, Johtamisen uusi normaali,* 2nd ed. Kauppakamari, 2020, pp. 22-24, 56-59.

[2] H. Sivola and T. Landau, "Vastuullisen sijoittamisen periaatteet," in *Vastuullisuudesta ylituottoa sijoituksiin,* 1st ed. Helsinki, Finland: Alma Talent, 2019, ch. 1, pp. 15-31.

[3] "Sustainable Development Goals." Sustainable Development Goals homepage. https://www.un.org/sustainabledevelopment/ (retrieved 16.01.2023).

[4] A. Martinuzzi and N. Schönherr, "Introduction: The Sustainable Development Goals and the Future of Corporate Sustainability." in *Business and the Sustainable Development Goals,* 1st ed. Palgrave Pivot Cham, 2019, ch. 1, pp. 1-17. [Online]. Available: https://doi-org.libproxy.aalto.fi/10.1007/978-3-030-16810-0_1

[5] "The Ten Principles of the UN Global Compact." United Nations Global Compact. https://www.unglobalcompact.org/what-is-gc/mission/principles (retrieved 16.01.2023).

[6] "Global Reporting Initiative." GRI homepage. https://www.globalreporting.org/ (retrieved 16.01.2023).

[7] "ISO 14001 and related standards." ISO. https://www.iso.org/iso-14001-environmental-management.html (retrieved 16.01.2023).

[8] "ISO 26000:2010 Guidance on social responsibility." ISO. https://www.iso.org/standard/42546.html (retrieved 16.01.2023).

[9] "ISO/IEC 27001 Information security management systems." ISO. https://www.iso.org/standard/27001 (retrieved 16.01.2023).

[10] V. Pardia, "Digitalization," in *Addressing SOCIETAL CHALLENGES,* 1st ed. Luleå, Sweden: Luleå University of Technology, 2018, pp. 29-38. [Online]. Available: https://www.diva-portal.org/smash/get/diva2:1191622/FULLTEXT02.pdf

[11] J. Manyika, M. Chui, J. Bughin, R. Dobbs, P. Bisson, A. Marrs, *Disruptive technologies: Advances that will transform life, business, and the global economy* McKinsey Global Institute, 2013, pp. 9, 11, 26-28, 33, 35, 38. [Online]. Available: https://www.mckinsey.com/~/media/mckinsey/business%20functions/mckinsey%20digital/our%20insights/disruptive%20technologies/mgi_disruptive_technologies_full_report_may2013.pdf

[12] U. E. Nabahany, A. Mosbech, M. Mgeni, S. Yunuspp, "A transformation into Digitally Supported Education: Case from the State University of Zanzibar" in *Sustainable ICT, Education and Learning,* A. Tatnall and N. Mavengere,

Eds, IFIP Advances in Information and Communication Technology, vol 564, Springer, Cham, 2019, pp. 16-23. [Online]. Available: https://doi.org/10.1007/978-3-030-28764-1_3

[13] E. Asiedu and A. Baku, "Social Protection in Ghana—History, Equity-Driven Reforms, Financing and Sustainability," in *Transitioning to No Poverty,* I. Günther and R. Lahoti, Eds, Transitioning to Sustainability Series 1. Basel, Switzerland: MDPI, 2021, pp. 190. [Online]. Available: https://mdpi.com/books/pdfview/edition/1404

[14] R. Brescia, *The Future of Change : How Technology Shapes Social Revolutions,* Ithaca: Cornell University Press, 2020, ch. intro, 9, pp. 3, 163-167, 172, 178-180. [Online]. Available: https://ebookcentral.proquest.com/lib/aalto-ebooks/detail.action?docID=5964948

[15] J. James, *The Impact of Mobile Phones on Poverty and Inequality in Developing Countries,* Tilburg, The Netherlands: Springer, 2016, pp. 29-30, 43, 71. [Online]. Available: https://link-springer-com.libproxy.aalto.fi/content/pdf/10.1007/978-3-319-27368-6.pdf

[16] A. Dabalen, A. Fuente, A. Goyal, W. Karamba, N. T. V. Nguyen and T. Tanaka, *Pathways to Prosperity in Rural Malawi.* Washington DC, USA: World Bank Publications, 2017, pp. 16, 110. [Online]. Available: http://ebookcentral.proquest.com/lib/aalto-ebooks/detail.action?docID=4913547

[17] J. Dörr, M. Nachtmann, et al. *Handbook Digital Farming; Digital Transformation for Sustainable Agriculture,* Springer, 2022, ch. 1,6, pp. 17, 31, 343. [Online.] Available: https://doi.org/10.1007/978-3-662-64378-5

[18] H. Baumüller and M. M.O. "Going Digital," in *Transforming Agriculture in Southern Africa,* R. A. Sikora, et al, Eds, Abingdon, Oxon Kah, England: Routledge, 2020, ch. 20, pp. 179. [Online]. Available: https://library.oapen.org/bitstream/handle/20.500.12657/41244/9781138393530_text.pdf;jsessionid=42881A75180FD96DB7A8ABC2B1A9DE57?sequence=1

[19] K. F. Davis, C. Dalin, M. Kummu, L. Marston, P. Pingali and M. Tuninetti, *Beyond the Green Revolution : A roadmap for sustainable food systems research and action,* Environmental Research Letters , vol. 17 , no. 10 , 100401. 2022. [Online]. Available: https://doi.org/10.1088/1748-9326/ac9425

[20] M. S. Swaminathan, "Can Science and Technology feed the World in 2025?," in *Science And Sustainable Food Security: Selected Papers Of M S Swaminathan,* M. S. Swaminathan, Eds, World Scientific Publishing Company, 2009, pp. 93-105. [Online]. Available: https://ebookcentral.proquest.com/lib/aalto-ebooks/detail.action?docID=1679369

[21] J. Remes, K. Linzer, S. Singhal, M. Dewhurst, P. Dash, J. Woetzel, S. Smit, M. Evers, M. Wilson, K. Rutter and A. Ramdorai, "Ten innovations that can improve global health," McKinsey Global Institute, 2020. [Online]. Available: https://www.mckinsey.com/industries/healthcare-systems-and-services/our-insights/ten-innovations-that-can-improve-global-health

[22] M. Chui, M. Harryson, J. Manyika, R. Roberts, R. Chung, A. van Heteren, P. Nel, "NOTES FROM THE AI FRONTIER: APPLYING AI FOR SOCIAL GOOD," McKinsey Global Institute, 2018, pp. 3, 6-7, 11-13, 18, 22, 36,39. [Online]. Available: https://www.mckinsey.com/~/media/mckinsey/featured%20insights/artificial%20intelligence/applying%20artificial%20intelligence%20for%20social%20good/mgi-applying-ai-for-social-good-discussion-paper-dec-2018.pdf

[23] A. Madgavkar, J. Manyika, M. Krishnan, K. Ellingrud, L. Yee, J. Woetzel, M. Chui, V. Hunt and S. Balakrishnan, "The future of women at work: Transitions in the age of automation," McKinsey Global Institute, 2019, pp. 8. [Online]. Available: https://www.mckinsey.com/~/media/mckinsey/featured%20insights/gender%20equality/the%20future%20of%20women%20at%20work%20transitions%20in%20the%20age%20of%20automation/mgi-the-future-of-women-at-work-report-july-2019.pdf

[24] F. Grijpink, E. Kutcher, A. Ménard, S. Ramaswamy, D. Schiavotto, J. Manyika, M. Chui, R. Hamill and E. Okan, "Connected world: An evolution in connectivity beyond the 5G revolution," McKinsey Global Institute, 2020, pp. 4, 20, 24-27, 48, 61, 67-68. [Online]. Available: https://www.mckinsey.com/~/media/mckinsey/industries/technology%20media%20and%20telecommunications/telecommunications/our%20insights/connected%20world%20an%20evolution%20in%20connectivity%20beyond%20the%205g%20revolution/mgi_connected-world_discussion-paper_february-2020.pdf

[25] J. Silberg and J. Manyika, "Notes from the AI frontier: Tackling bias in AI (and in humans)," McKinsey Global Institute, 2019, pp. 2-3. [Online]. Available: https://www.mckinsey.com/~/media/mckinsey/featured%20insights/artificial%20intelligence/tackling%20bias%20in%20artificial%20intelligence%20and%20in%20humans/mgi-tackling-bias-in-ai-june-2019.pdf

[26] O. White, A. Madgavkar, Z. Townsend, J. Manyika, T. Olanrewaju, T. Sibanda and S. Kaufman, "Financial data unbound: The value of open data for individuals and institutions," McKinsey Global Institute, 2021. [Online]. Available: https://www.mckinsey.com/industries/financial-services/our-insights/financial-data-unbound-the-value-of-open-data-for-individuals-and\-institutions#/

[27] O. White, A. Madgavkar, J. Manyika, D. Mahajan, J. Bughin, M. McCarthy and O. Sperling, "Digital identification: A key to inclusive growth," McKinsey Global Institute, 2019, pp. 2-4, 6-7, 23, 25. [Online]. Available: https://www.mckinsey.com/~/media/mckinsey/business%20functions/mckinsey%20digital/our%20insights/digital%20identification%20a%20key%20to%20inclusive%20growth/mgi-digital-identification-report.pdf

[28] A. T. Eseye, M. Lehtonen, T. Tukia, S. Uimonen and R. J. Millar, "Day-ahead Prediction of Building District Heat Demand for Smart Energy Management and Automation in Decentralized Energy Systems," in *Proceedings of the 17th IEEE International Conference on Industrial Informatics, INDIN 2019 : Industrial Applications of Artificial Intelligence . IEEE International Conference on Industrial Informatics,* Helsinki-Espoo, Finland: IEEE, 2019, pp. 1694-1699. [Online]. Available: https://doi.org/10.1109/INDIN41052.2019.8972297

[29] A. Khosravi, T. Laukkanen, V. Vuorinen, and S. Syri, "Waste heat recovery from a data centre and 5G smart poles for low-temperature district heating network," in *Energy,* vol. 218, 119468, 2019, pp. 23-24. [Online]. Available: https://doi.org/10.1016/j.energy.2020.119468

[30] P. Lago, R. Verdecchia, N. Condori-Fernandez, E. Rahmadian, J. Sturm, T. van Nijnanten, R. Bosma, C. Debuysscher, and P. Ricardo, "Designing for Sustainability: Lessons Learned from Four Industrial Projects," in *Advances and New Trends in Environmental Informatics,* A. Kamilaris, V. Wohlgemuth, K. Karatzas, I.N. Athanasiadis, Eds, Progress in IS, Springer, Cham, 2021, pp. 3-4, 11. [Online]. Available: https://doi.org/10.1007/978-3-030-61969-5_1

[31] R. Kwok, "AI empowers conservation biology," Nature, 2019, Vol. 567, pp. 133-134. [Online]. Available: https://doi.org/10.1038/d41586-019-00746-1

[32] I. Keramitsoglou, C. Cartalis, C. T. Kiranoudis, "Automatic identification of oil spills on satellite images", in *Environmental Modelling & Software,* 2006, Vol. 21, Issue 5, pp. 640-652, ISSN 1364-8152. [Online]. Available: https://doi.org/10.1016/j.envsoft.2004.11.010.

[33] "Harnessing Artificial Intelligence for the Earth," in *Fourth Industrial Revolution for the Earth Series,* World Economic Forum, 2018, pp. 1-28. [Online]. Available: https://www3.weforum.org/docs/Harnessing_Artificial_Intelligence_for_the_Earth_report_2018.pdf

[34] "Digitalisation and Energy," IEA, Paris, 2017, pp. 21-145. [Online]. Available: https://www.iea.org/reports/digitalisation-and-energy

[35] A. A. Carvalho, "Using Mobile Devices and Online Tools to Promote Students' Learning," in *Sustainable ICT, Education and Learning,* A. Tatnall, Nicholas Mavengere, Eds, SUZA 2019. IFIP Advances in Information and Communication

Technology, vol 564. Springer, Cham. pp. 9. [Online]. Available: https://doi-org.libproxy.aalto.fi/10.1007/978-3-030-28764-1_2

[36] R. Bottino, A. Chioccariello, L. Freina, M. Tavella, "Digital Games in Primary Schools for the Development of Key Transversal Skills," in *Sustainable ICT, Education and Learning,* A. Tatnall, Nicholas Mavengere, Eds, SUZA 2019. IFIP Advances in Information and Communication Technology, vol 564. Springer, Cham. pp. 55-63. [Online]. Available: https://doi-org.libproxy.aalto.fi/10.1007/978-3-030-28764-1_2

[37] S. Quadflieg, K. Neuburg, S. Nestler, "(Dis)obeying Algorithms? Introductory Thoughts on the Power of Algorithms and the Possible Necessity of Resisting it," in *(Dis)Obedience in Digital Societies: Perspectives on the Power of Algorithms and Data,* Edinburgh: transcript Verlag, 2022. pp. 7-21. [Online]. Available: https://doi-org.libproxy.aalto.fi/10.1515/9783839457634

[38] J. Mellentin, F. Schmidt "Surveillance, Artificial Intelligence and Power," in *(Dis)Obedience in Digital Societies: Perspectives on the Power of Algorithms and Data,* S. Quadflieg, K. Neuburg, S. Nestler, Eds, Edinburgh: transcript Verlag, 2022. pp. 48-66. [Online]. Available: https://doi-org.libproxy.aalto.fi/10.1515/9783839457634

[39] K. Dill, "When Search Engines Discriminate: The Posthuman Mimesis of Gender Bias," in *(Dis)Obedience in Digital Societies: Perspectives on the Power of Algorithms and Data,* S. Quadflieg, K. Neuburg, S. Nestler, Eds, Edinburgh: transcript Verlag, 2022. pp. 227-244. [Online]. Available: https://doi-org.libproxy.aalto.fi/10.1515/9783839457634

[40] F. Lütz, "Discrimination by Correlation: Towards Eliminating Algorithmic Biases and Achieving Gender Equality," in *(Dis)Obedience in Digital Societies: Perspectives on the Power of Algorithms and Data,* S. Quadflieg, K. Neuburg, S. Nestler, Eds, Edinburgh: transcript Verlag, 2022. pp. 251-286. [Online]. Available: https://doi-org.libproxy.aalto.fi/10.1515/9783839457634

[41] "Open Data," Sitra. https://www.sitra.fi/en/topics/information-society/ (Retrieved 10.04.2023).

[42] "European legislation on open data," European Comission. https://digital-strategy.ec.europa.eu/en/policies/legislation-open-data (Retrieved 10.04.2023).

[43] "Data Act: Commission proposes measures for a fair and innovative data economy," Brussels: European Comission, 2022. https://ec.europa.eu/commission/presscorner/detail/en/ip_22_1113 (Retrieved 10.04.2023).

[44] "The world's most valuable resource is no longer oil, but Data," The Economist, 2017. [Online]. Available: https://www.economist.com/leaders/2017/05/06/the-worlds-most-valuable-resource-is-no-longer-oil-but-data (Retrieved: 15.04.2023).

[45] "Green Coding," GFT Technologies. https://www.gft.com/be/en/dam/jcr:03015de2-79bd-4444-b62c-25a9e8cfc0f5/gft-thought-leadership-greencoding-en.pdf (Retrieved: 15.04.2023).

[46] "Green Code," Exove. [Online]. https://www.exove.com/green-code/ (Retrieved: 15.04.2023).

[47] "What is Sustainable Digitalisation?," European Digital SME Alliance, 2021. https://www.digitalsme.eu/what-is-sustainable-digitalisation/ (Retrieved: 01.04.2023).

[48] "Evitec Arkki," Evitec. https://evitec.com/solutions/evitec-arkki/ (Retrieved: 28.04.2023).

[49] R. Navarrete, M. Peñafiel, M. Tenemaza, and S. Luján-Mora, "Towards an Accessible UX for People with Disabilities in Open Educational Resources Websites," in *Advances in usability and User Experience*, T. Ahram and C. Falcão, Eds, Washington DC, USA: Springer International Publishing, 2020, pp. 77–69. [Online]. Available: https://doi-org.libproxy.aalto.fi/10.1007/978-3-030-19135-1_7

[50] S. G. Monserrate, "The staggering ecological impacts of computation and the cloud," The MIT Press Reader, 2022. [Online]. Available: https://thereader.mitpress.mit.edu/the-staggering-ecological-impacts-of-computation-and-the-cloud/ (Retrieved: 04.05.2023).

[51] K. Pärssinen, "Lääkärisaneluissa Koeteltu SpeechLive Oppi Suomea Ja Tuli Puhelimiin," Mikrobitti, 2017. https://www.mikrobitti.fi/uutiset/laakarisaneluissa-koeteltu-speechlive-oppi-suomea-ja-tuli-puhelimiin/de304600-1f18-300d-b919-02c3eb6a611d (Retrieved: 05.05.2023).

[52] A. Trafton, "The (robotic) doctor will see you now," MIT News, 2021. https://news.mit.edu/2021/robotic-doctor-will-see-you-now-0304 (Retrieved: 05.05.2023).

[53] J. B. Tucker, "Introduction," in *Innovation, dual use, and security: Managing the risks of emerging biological and chemical technologies*, Cambridge, MA: MIT Press, 2012, pp. 2–3 [Online]. Available: https://ebookcentral-proquest-com.libproxy.aalto.fi/lib/aalto-ebooks/reader.action?docID=3339418#

[54] J. James, "Re-estimating the difficulty of closing the digital divide," in *Digital Interactions in developing countries: An economic perspective,* London, England: Routledge, 2013, pp. 83–98 [Online]. Available: http://ebookcentral.proquest.com/lib/aalto-ebooks/detail.action?docID=1108573

[55] "Economic benefits of prevention," The Prevention Centre. https://preventioncentre.org.au/about-prevention/what-are-the-economic-benefits-of-prevention/ (Retrieved: 06.05.2023).

[56] "Health care systems and substance use disorders," in *Facing addiction in America: The surgeon general's report on Alcohol, Drugs and health*, Washington, D.C., U.S.A: U.S. Department of Health; Human Services, Office of the Surgeon General, 2016 [Online]. Available: https://www.ncbi.nlm.nih.gov/books/NBK424848/

[57] "UN Women Course Catalog," UN Women Training Centre, 2022. https://portal.trainingcentre.unwomen.org/ (Retrieved: 07.05.2023).

[58] J. Saul and D. Bass, "Artificial Intelligence Is Booming—So Is Its Carbon Footprint," Bloomberg.com, 2023 [Online]. Available: https://www.bloomberg.com/news/articles/2023-03-09/how-much-energy-do-ai-and-chatgpt-use-no-one-knows-for-sure#xj4y7vzkg (Retrieved: 08.05.2023).

[59] "Tuntihinta-sovellus," Fingrid. https://www.fingrid.fi/sahkomarkkinat/markkinoiden-yhtenaisyys/sahkomarkkinoiden-kehityshankkeet/tuntihinta-sovellus/ (Retrieved: 08.05.2023).

[60] A. Dingli and D. Seychell, "Who Are the Digital Natives?," in *The new digital natives: cutting the chord*, Berlin, Germany: Springer, 2016 [Online]. Available: https://link-springer-com.libproxy.aalto.fi/book/10.1007/978-3-662-46590-5

[61] "How robots are taking on the dirty, dangerous, and Dull Jobs," Automate, 2019 [Online]. Available: https://www.automate.org/blogs/how-robots-are-taking-on-the-dirty-dangerous-and-dull-jobs (Retrieved: 09.05.2023).

[62] "ISO/IEC 30071-1:2019," ISO. https://www.iso.org/standard/70913.html (Retrieved: 09.05.2023).

[63] "Speech Recogniton," Web Accessibility Initiative WAI. https://www.w3.org/WAI/perspective-videos/voice/ (Retrieved: 09.05.2023).

[64] "Customizable Text," Web Accessibility Initiative WAI. https://www.w3.org/WAI/perspective-videos/customizable/ (Retrieved: 09.05.2023).

[65] "Clear Layout and Design," Web Accessibility Initiative WAI. https://www.w3.org/WAI/perspective-videos/layout/ (Retrieved: 09.05.2023).

[66] "Colors with Good Contrast," Web Accessibility Initiative WAI. https://www.w3.org/WAI/perspective-videos/contrast/ (Retrieved: 09.05.2023).

[67] R. McKenzie, “In the Global South, climate change already kills,” Tribune, 2021. https://tribunemag.co.uk/2021/11/climate-change-global-south-asia-africa-heatwave-cyclone-natural-\disasters-cop26-glasgow (Retrieved 10.05.2023).

[68] J. Adams, "Advantages and Disadvantages of Virtual Meetings," DisplayNote, 2022. https://www.displaynote.com/blog/advantages-and-disadvantages-of-virtual-meetings/ (Retrieved 10.05.2023).

[69] R. Pereira, M. Couto, F. Ribeiro, R. Rua, J. Cunha, J. P. Fernandes and J. Saraiva, "Energy Efficiency across Programming Languages: How Do Energy, Time, and Memory Relate?," in *Proceedings of 2017 ACM SIGPLAN International Conference on Software Language Engineering (SLE'17)*, New York, NY, USA: Association for Computing Machinery, 2017, pp.256–267. [Online]. Available: https://doi.org/10.1145/3136014.3136031

[70] M. Koljonen, "Vihreä koodi – mitä on Green Coding?," CGI, 2022. https://www.cgi.com/fi/fi/blogi/mita-green-coding-on (Retrieved 11.05.2023).

[71] V. Thomas, "The Rising Threat of Climate-Related Natural Disasters," in *Climate Change and Natural Disasters,* New York, NY, USA: Taylor & Francis, 2017 pp. 31-46. Available: https://directory.doabooks.org/handle/20.500.12854/32340

[72] "Study, identify, and protect the Iberian Lynx!," Wildbook. https://lynx.wildbook.org/ (Retrieved 11.05.2023).

[73] "Green Coding yleistyy – energiankulutukseen kiinnitetään nyt huomiota ohjelmistokehityksessä," TIVI, 2022. [Online]. Available: https://www.tivi.fi/kumppanisisallot/cgi/green-coding-yleistyy-energiankulutukseen-kiinnitetaan-nyt\-huomiota-ohjelmistokehityksessa/ (Retrieved 11.05.2023)

[74] "Socially just transition towards sustainable development: The role of digital technologies on social development and well-being of all”," United Nations: Department of Economic and Social Affairs Social Inclusion, 2020. [Online]. Available: https://www.un.org/development/desa/dspd/2020-meetings/socially-just-transition-digital-technologies.html (Retrieved 14.05.2023)

[75] "The Principles of Sustainable Software Engineering," Microsoft. https://learn.microsoft.com/en-us/training/modules/sustainable-software-engineering-overview/?ocid=AID3038246&WT.mc_id=green-9537-cxa (Retrieved 15.05.2023)

[76] "Principles of Green Software Engineering," Principles.Green. https://principles.green/ (Retrieved 15.05.2023)

[77] "The World's Most Trusted Business Sustainability Ratings," EcoVadis. https://ecovadis.com/ (Retrieved 15.01.2023)