Reyhaneh Raja Beheshti

The Role of Digitalization in Transition Towards Circular Economy in Organizations

June 2021

NTNU
Norwegian University of
Science and Technology
Faculty of Engineering
Department of Mechanical and Industrial Engineering

Master's thesis

2021

Reyhaneh Raja Beheshti

Master's thesis

NTNU
Norwegian University of
Science and Technology

NTNU
Norwegian University of
Science and Technology

NTNU
Norwegian University of
Science and Technology

The Role of Digitalization in Transition Towards Circular Economy in Organizations

Reyhaneh Raja Beheshti

TPK4920 - Master's thesis in Project Management
Submission date: June 2021
Supervisor: Nora Johanne Klungseth

Norwegian University of Science and Technology
Department of Mechanical and Industrial Engineering

Preface

This master thesis was written by Reyhaneh Raja Beheshti, a master's student in Project Management, during the Spring of 2021. It was carried out to satisfy the requirement of the course TPK4920 – Master's Thesis in Project Management, specialization of Production and Quality Engineering, at the Department of Mechanical and Industrial Engineering at the Norwegian University of Science and Technology (NTNU).

The topic of this master thesis stemmed from my passion for circular economy and sustainability. Some parts of the theory section, especially in the Digitalization section contains text from an earlier work written for TPK4520 – Project and Quality Management, Specialization Project with a topic about digitalization and sustainability.

Being 30 credits assigned to this master thesis, it was a huge and time-consuming task. However, I received valuable information during this study from both my supervisor and other interview objects. Our discussions on this subject and beyond were greatly useful for writing this master thesis.

My deep gratitude and appreciation goes to my supervisor Nora Johanne Klungseth, for her rich feedback and supportive guidance throughout the process of writing this thesis. I would also like to sincerely thank all the interviewees from different companies and organizations for their participation and valuable inputs.

Lastly, I would like to thank my family and my boyfriend, Daniel, for all the love, support, and encouragement during the whole process of writing my master thesis.

Reyhane Raja Beheshti
Trondheim, June 30, 2021

Abstract

This master thesis is conducted based on an in-depth study on literature as well as several interviews about the concept of digitalization and circular economy in organizations. The aim was to find out the role of digitalization and digital tools in transition towards circular economy in organizations.

In order to fulfill this aim, four research questions were formulated. One as the main research question (Main RQ) and three sub-research questions. The first sub-research question (RQ1), elaborated the concept of circular economy and the main possible areas for circular economy practices in organizations. RQ 2 narrowed down the ways and fields that organizations can practice circular strategies to be able to move towards a more circular economy. And, RQ 3 covered some of the barriers and challenges that organizations can face throughout their transition process. The outcomes of these sub-research questions helped to answer the main research question and accomplish the aim of this master thesis.

To answer these research questions, a qualitative research approach based on a combination of theoretical literature and interviews was chosen. Initially, more than 2000 materials such as articles, books, and conferences were extracted from the search engines. The primary literature was extracted from 28 relevant articles aligned with the three key search strings, namely: Circular economy & Digitalization, Circular economy & Organization, and Digitalization & Organization. Moreover, a number of 13 interview objects were selected based on a non-random purposive interview sampling according to their profession and relevance of position to the subject of this master thesis. The findings of the interview were beneficial for arguments in the discussion section.

The outcome of this master thesis showed that digitalization can facilitate the transition to circular economy in many ways from resource management to waste management as well as data collection and analysis. However, implementing circular economy strategies in organizations is an emerging subject and organizations need to enrich their knowledge about circular economy, change their mindsets, make collaboration, overcome the barriers, and prepare themselves for this transition. Therefore, in the early stages, they can begin with their existing tools and technologies or use simple tools such as apps and platforms for this purpose because buying expensive and complex technologies can sometimes bring more challenges to these organizations.

Sammendrag

Denne masteroppgaven er gjennomført basert på en dyptgående litteraturstudie, samt flere intervjuer rundt begrepet digitalisering og sirkulær økonomi hos organisasjoner. Målet med masteroppgaven var å finne ut hvilken rolle digitalisering og digitale verktøy spiller i overgangen til sirkulær økonomi hos organisasjoner.

For å undersøke dette konseptet ble det utformet fire forskningsspørsmål, hvorav ett hovedspørsmål (Main RQ) og tre underbyggende spørsmål. Det første spørsmålet (RQ 1) utdyper begrepet rundt sirkulær økonomi, og undersøker de vanligste områdene sirkulær økonomi praktiseres i organisasjoner. RQ 2 begrenser måter og felt som organisasjoner kan praktisere sirkulære strategier for å bevege seg mot en mer sirkulær tilnærming. RQ 3 dekker noen av barrierene og utfordringene som organisasjoner kan møte gjennom hele overgangsprosessen. Resultatene av disse underspørsmålene bidro til å svare på hovedspørsmålet og oppnå målet med denne masteroppgaven.

For å svare på disse forskningsspørsmålene ble det valgt en kvalitativ forskningstilnærming basert på en kombinasjon av teoretisk litteraturfordypning og utføring av intervjuer. Opprinnelig ble mer enn 2000 materialer som artikler, bøker og konferansejournaler lastet ned og undersøkt. Primærlitteraturen ble hentet fra 28 relevante artikler tilpasset de tre viktigste søkeordene: Sirkulær økonomi & Digitalisering, Sirkulær økonomi & Organisasjon og Digitalisering & Organisasjon. I tillegg ble det valgt ut et antall på 13 intervjuobjekter basert på en bestemt seleksjon i henhold til deres yrke og relevans for emnet til denne masteroppgaven. Oppdagelsen i intervjuene var fordelaktige for argumentasjonen i diskusjonsdelen.

Resultatet av denne masteroppgaven viste at digitalisering kan lette overgangen til sirkulær økonomi på mange måter fra ressursfordeling til avfallshåndtering samt datainnsamling og analyse. Imidlertid er implementeringen av sirkulærøkonomiske strategier i organisasjoner et voksende tema, og organisasjoner trenger å berike sin kunnskap om sirkulær økonomi, endre sitt tankesett, samarbeide og overvinne barrierer for å forberede seg på denne overgangen. Derfor kan de i de tidlige stadiene begynne med eksisterende verktøy og teknologier eller bruk enkle verktøy som apper og plattformer for å nå dette målet, ettersom dyre og komplekse teknologier ofte kan gi langt flere utfordringer for disse organisasjonene en hva som først er tiltenkt.

Abbreviations

CE - Circular Economy
IoT - Internet of Things
AI - Artificial Intelligence
ML - Machine Learning
RFID - Radio-frequency identification
CPS - Cyber-physical system
ICT - Information and Communications Technology
EU - European Union
CEAP - The European Circular Economy Action Plan
EESC - European Economic and Social Committee
EC - European Commission
EAA - European Environmental Agency
CD - Compact Disk
WHO - World Health Organization
BSI - The British Standards Institution
RRFW - Resource Recovery From Waste
RIS - Research Information Systems
NSD - Norsk Senter for Forskningsdata
PBL - Planbureau voor de Leefomgeving (Netherlands Environmental Assessment Agency)

Contents

List of Figures

List of Tables

Chapter 1

Introduction

Humans' harmful actions to the environment and consumption of finite resources is accelerating beyond the capacity of planet Earth. The world has set a new record in the history of material consumption by the global economy and has passed the amount the 100 billion tonnes. Yet, only 8.6% of these massive amounts of materials are recycled back to the economy (Circularity Gap Report, 2020). According to the United Nations estimation, although the fertility level may decline in the future, the global population size would preserve a continuous upward trend and is expected to reach 9.8 billion by 2050 (United Nations, 2019). It is also anticipated that if the current consumption level continues, by 2050 the oceans will be filled with plastic and the number of plastics will be more than fishes in the ocean (World Economic Forum, 2016).

Circular Economy

For many years the global consumption and material use followed an economy model of "take-make-dispose", but in recent years, there has been a growing movement from this linear model to a more circular one. The concept of circular economy has gained a lot of attention as a source of solutions for some of the most important and challenging problems related to sustainable development (Hoosain et al., 2020).

In 2015, the European Union agreed on a circular economy policy package known

as the European Circular Economy Action Plan (CEAP) which mapped 54 actions for Europe to move towards a circular economy and reach that by 2030 and 2035 (Ellen MacArthur Foundation, 2020).

According to (Ellen MacArthur Foundation, 2013b), "circular economy is an industrial system that is restorative or regenerative by intention and design. It replaces the end-of-life concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse and return to the biosphere, and aims for the elimination of waste through the superior design of materials, products, systems, and business models"[p 7].

Circular economy focuses on making the full benefits out of the available resources while ensuring value creation and sustainability in the short and long term. In fact, the aim is to close the material loops so that the resources would not be lost or wasted (Jahren et al., 2020). Circular economy ideas can be summarized in 10 "R" frameworks or "Rs" as Refuse (R0), Rethink (R1), Reduce (R2), Reuse (R3), Repair (R4), Refurbish (R5), Remanufacture (R6), Repurpose (R7), Recycle (R8) and Recover (R9) as energy (Potting et al., 2020). These frameworks or concepts are interconnected and can affect each other (Demestichas & Daskalakis, 2020).

Organization transition

The linear economy and business models can bring profit to organizations, but it may only last for a short time. In a larger period of time, the linear models can bring operational, market, legal, and business risks to the organizations (Circle Economy, 2018). Companies and organizations should have actions in place and try to avoid these risks and transform them into a more circular business model. The transition from the linear model towards a more circular economy model is estimated to create $4.5 trillion by 2030 (Jose et al., 2020), create more job opportunities and result in a more resilient economy (World Economic Forum, 2014).

The COVID-19 pandemic has severely affected the financial markets in the world and resulted in an economic disaster across the borders. Many people lost their jobs and many businesses registered a drop in revenues. Researchers have claimed that after COVID-19 the best way to recover the world's economy is implementing

and adopting circular economy strategies and putting an end to the linear economy practices (Ibn-Mohammed et al., 2021).

Although the circular economy can bring opportunities to organizations and create value and growth for them , the transition to a circular model is challenging and not straightforward and requires changes in business models, strategies, and policies (WBCSDa, 2017). Organizations should have a common approach and regardless of their size or sector, speak the same language to be able to achieve the best result (WBCSDb, 2019). The British Standard has introduced BS 8001:2017 standard and provided some guidelines for organizations in the transition towards circular economy and more sustainable operations as "Framework for implementing the principles of the circular economy in organizations" (Niero & Rivera, 2018; BSI, 2017).

Digitalization

The fourth industrial revolution started some years ago and today, we are standing at the cusp of it. A lot of digital tools and technologies such as Information and communication technology (ICT), Robotics, Machine learning (ML), Big data, the Internet of Things (IoT), Blockchain, Artificial intelligence (AI), Cloud computing, 3D technologies, and many more have assisted people in different situations and has become the solutions to many of the world's problems (Hoosain et al., 2020). Circular economy is no exception and has also been influenced by advanced technologies.

Digital tools and solutions are paving the way towards a circular economy (Demestichas & Daskalakis, 2020). They help companies and organizations to foster circular economy business models and close the loop material, slow it down, and narrow it by efficient use of resources (Bocken et al., 2016). In the circular economy-based business models, the key is to lease, rent or share products instead of buying or selling them and digitalization is one of the facilitators of this process (Ellen MacArthur Foundation, 2013a). It also enables data transparency and makes it possible for businesses and industries to track their material and product flow which would ultimately increase the networking and collaboration across the industry and make decision making and resource management easier

for them.(Antikainen et al., 2018; Kristoffersen et al., 2020a).

1.1 Aim of the study

The circularization of organizations, especially public organizations, has not gained much attention in the circular economy researches (Klein et al., 2020). Most of the researches focus on industries and product manufacturing companies, while many other organizations such as public sectors exist that are just service provider, consumer, purchaser, or user of the product and services and do not produce a physical product themselves. On the other hand, digital technologies are considered as enablers of circular economy but there is little understanding of how these tools and technologies can assist circular economy.

The purpose of this master thesis is to address these gaps and find how digitalization and digital tools can play a role in facilitating the transition to a circular economy in organization. This purpose would be fulfilled by studying different literature and by answering the research questions mentioned below.

1.2 Research questions

How digital technologies can support the transition to a circular economy? (Main RQ)
This is the main question in this master thesis. The answers to the three other questions will build up to answer this main question. The advance of technology during recent years has contributed to the invention of different digital tools and smart solutions that can accelerate reaching circular economy. In this question, a range of new technological solutions will be introduced.

What is the concept of circular economy? (RQ1)
To be able to further understand the key terms and the aim of this thesis, the concept of circular economy needs to be elaborated and thoroughly defined. This question will fulfill this purpose.

How can organizations practice circular economy? (RQ2)
Circular economy strategies are mostly practiced in industries and manufacturing units, while there are very little researches and literature about the implementation of circular economy in organizations. This question would explore the way organizations can move towards a more circular economy.

What are the barriers and challenges to circular economy implementation in organizations? (RQ3)
The transition from linear economy towards circular economy can be challenging and businesses and industries can face different barriers in this process. The purpose of this question is to cover some of these challenges and barriers.

1.3 Structure of the study

This master thesis consists of six parts. Introduction, theory, methodology and research approach, and empirical results ending with the discussion and conclusion part. This current chapter, introduction, provides an overview of the concept of circular economy and digitalization and the organizational transition. Chapter two includes the theoretical background of the circular economy and digitalization. This part functions as a basis for the empirical results as well as the discussion and conclusion section of the thesis. The theory part is backed up with several interviews with experts in the field of circular economy and digitalization both in private and public companies. Chapter three is about the methodology used in this thesis. The chapter begins with a short introduction to different types of literature review and later the research approach and data collection methods will be discussed. The thesis and the study will be conducted based on a qualitative method by using literature review and interviews in collaboration with some experts from the public and private organizations. The results of these interviews will be collected, summed up, and analyzed in chapter four, empirical results, which will support the purpose of the thesis in the best way. The last two chapters, discussion, and conclusion will analyze the results and gaps of the conducted research from different aspects and generate the most important outcomes of the thesis.

Chapter 2

Theory

This section covers three scopes, namely: Circular economy, Organization transition, and Digitalization. Firstly, a deeper literature review is conducted and related concepts and definitions about circular economy are represented. Later, the processes and models that organizations can use to reach a circular economy are explained. Finally, the contribution of digitalization and digital tools in achieving circular economy, specifically in organizations, will be discussed.

2.1 Circular economy

2.1.1 Background

The origin or originator of the circular economy (CE) is not clearly proved and documented (Winans et al., 2017), but it seems that the term was used in the 1990s drawn from two scientific works as " *The Economics of the Coming Spaceship Earth*" by Boulding (1966) and "*Closed-loop Economy*" by Mulvey (1976). However, the mainstream of the circular economy concept in the European policy was in the 2010s with the first report from the Ellen MacArthur Foundation in 2013 (Kovacic et al., 2019). This report, entitled as "*Towards the Circular Economy*", showed the advantages of circular business models and the pathways for taking action and moving towards circular economy (Ellen MacArthur Foundation, 2013a).

In 2014, the concept of circular economy was officially used in the European

Union policy. The European Commission approved a Circular Economy Package which included a communication on the transition to circular economy and revision of some waste legislation (Eisenriegler, 2020). However, this package was reviewed later in the new commission, by President Jean-Claude Juncker who took office later that year. He wanted to make sure that the package is coherent with the new priorities of EU policy. As the result of misconception about the circular economy and considering it as a pure environmental policy, the European Commission withdrew its proposals on waste in 2014 and promised to deliver a new and more ambitious proposal in 2015 (Kovacic et al., 2019; Ellen MacArthur Foundation, 2020).

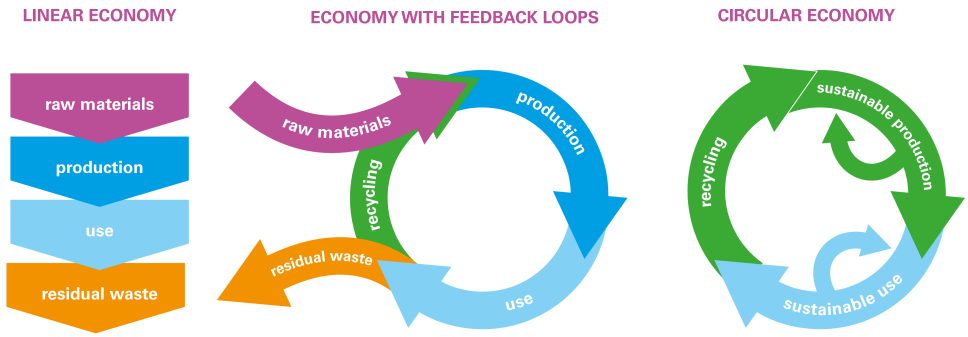

Figure 2.1: Linear economy vs Circular economy (Council for the Environment and Infrastructure (Rli), 2015)

In 2015, at a conference called "*Closing the loop*", the European Commission presented the "*Circular Economy Action Plan*". The difference between this Communication and the previous one is that the main focus of the second one is on economic growth and circularly while the first Communication was perceived as a more environmental policy. The definition of circular economy in the second Communication shows that the economy was actually circular but the idea was to make it more circular:

> *"The transition to a **more circular** economy, where the value of products, materials and resources are maintained in the economy for as long as possible, and the generation of waste minimized, is an essential contribution to the EU's efforts to develop a sustainable, low carbon, resource-efficient and competitive economy"(European Com-*

mission, 2015)[p2].

In 2016, a scoreboard of 24 indicators was introduced by the European Commission. One of the aims was to monitor the development of circular economy. This time a new economic sector, as the raw material sector, was focused. The sector consisted of both extractive industries (such as forestry or mining), and the construction or manufacturing sectors which made use of raw materials in their production (Kovacic et al., 2019). By the end of 2016, the "*Ecodesign Working Plan 2016 - 2019*" was introduced, as a part of the package "*Clean Energy for all Europeans*". This plan contributed to the Action Plan for CE with a focus on the design of the product and making the products more durable, with less toxic materials, and easier reuse or recycle ways (European Commission, 2016).

According to European Commission (2017), the year 2017 became an important year for the European Commission. "*The Circular Economy Finance Support Platform*" was launched and EC introduced the " *European Circular Economy Stakeholder Platform*" in collaboration with the European Economic and Social Committee (EESC). The purpose was to involve all the stakeholders and make better partnerships to scale up circular economy all over the Europe and make it happen faster and come up with new solutions for challenges.

In 2018, the European Commission published a monitoring framework for the circular economy to measure the progress and effectiveness of the circular economy actions. This framework adopted some indicators to cover the circular economy in its different phases. The main indicators include production and consumption, waste management, secondary raw materials, and competitiveness and innovation (European Commission, 2018).

The European Commission released a comprehensive report on the Circular Economy Action Plan implementation in 2019 and announced that all 54 actions under the action plan were completed and delivered or are being implemented (Ellen MacArthur Foundation, 2020). In the next year, 2020, the European Commission introduced a new Circular Economy Action plan which was one of the main blocks of Europe's new agenda for sustainable growth entitled as "*European Green Deal*" (European Commission, 2020). The European Green Deal was introduced

in 2019 and provided an action plan to reach a climate-neutral circular economy and to make Europe's economy more sustainable by 2050 (European Commission, 2019). The main focus of the new Circular Economy Action Plans was on design, sustainable consumption, product durability and reusability, and restriction of single-use products (Ekern, 2020).

A summary of the Circular Economy timeline is illustrated in the figure below.

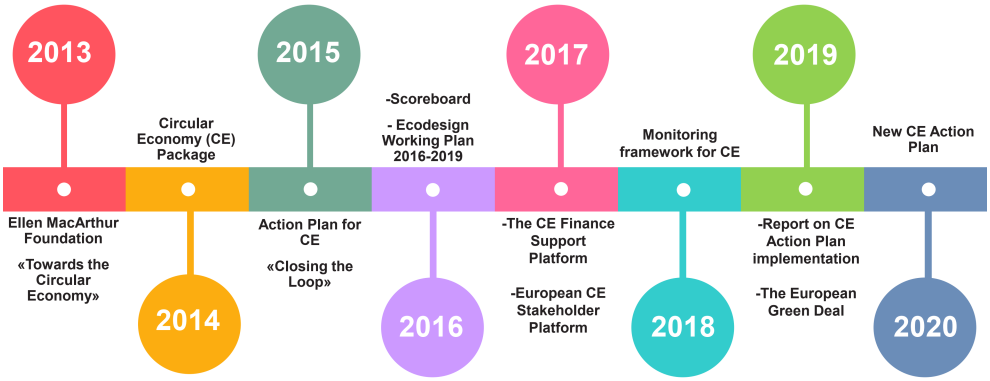

Figure 2.2: Timeline of Circular Economy (own production)

2.1.2 Definition

There has been a lot of attempts to define circular economy and many authors have tried to introduce their own definition or interpretation of circular economy. Preston (2012) believes "*circular economy is an approach that would transform the function of resources in the economy. Waste from factories would become a valuable input to another process – and products could be repaired, reused or upgraded instead of thrown away*" [p 1]

According to Ellen MacArthur Foundation (2013a, 2013b), CE is "*an industrial system that is restorative or regenerative by intention and design. It replaces the 'end-of-life' concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse, and aims for the elimination of waste through the superior design of materials, products, systems, and,*

within this, business models" [p 7]. The overall objective is to "*enable effective flows of materials, energy, labor, and information so that natural and social capital can be rebuilt*" [p 26]. In fact, the aim is to keep the products and their materials always at a high level of utility and value (Homrich et al., 2018).

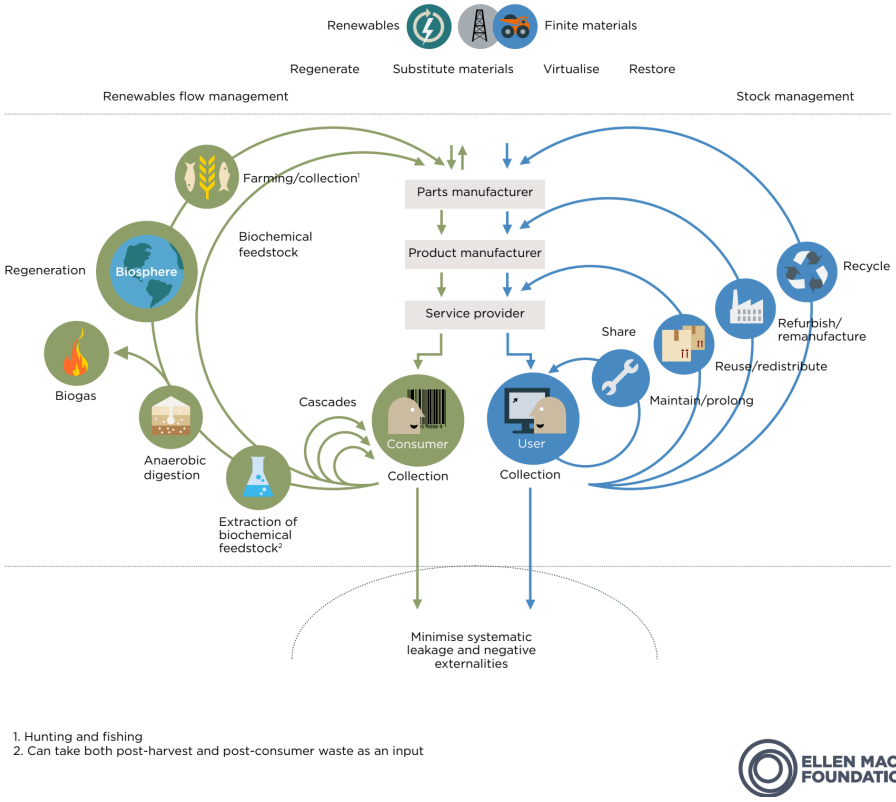

Figure 2.3: Outline of a Circular Economy (Ellen MacArthur Foundation, 2019a)

In a report released by EEA (2014), the concept of circular economy "*refers mainly to physical and material resource aspects of the economy – it focuses on recycling, limiting, and re-using the physical inputs to the economy, and using waste as a resource leading to reduced primary resource consumption*" [p 11]. A later report by EEA (2016) stated that "*a circular economy provides opportunities to create well-being, growth, and jobs while reducing environmental pressures. The concept can, in principle, be applied to all kinds of natural resources, including biotic and abiotic materials, water, and land*" [p 9].

For WRAP (n.d) circular economy is "*an alternative to a traditional linear economy (make, use, dispose) in which we keep resources in use for as long as possible, extracting the maximum value from them whilst in use, then recovering and reusing products and materials*". They believe in order to reach a Net Zero future we should accelerate the transition to a circular economy that is sustainable and more resource-efficient.

According to Sauve et al. (2016), circular economy is related to "*production and consumption of goods through closed-loop material flows that internalize environmental externalities linked to virgin resource extraction and the generation of waste (including pollution)*" [p 49]. In this definition, the focus is on the life cycle of the products and the reduction of waste and pollution, besides cutting the resource consumption (Rizos et al., 2017).

In another article related to circular economy, Murray et al. (2017) claims that "*the CE is an economic model wherein planning, resourcing, procurement, production and reprocessing are designed and managed, as both process and output, to maximize ecosystem functioning and human well-being*" [p 377]. They believe that circular economy is a young field and needs careful and comprehensive definition, which will allow the emerging of real benefits for the environment and society.

Based on the previous definitions of circular economy, Geissdoerfer et al. (2017) define CE as "*a regenerative system in which resource input and waste, emission, and energy leakage are minimized by slowing, closing, and narrowing material and energy loops. This can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling*" [p 759].

An article by Korhonen et al. (2018) defines the circular economy as "*a sustainable development initiative with the objective of reducing the societal production-consumption systems' linear material and energy throughput flows by applying materials cycles, renewable and cascade-type energy flows to the linear system. CE promotes high-value material cycles alongside more traditional recycling and develops systems approaches the cooperation of producers, consumers, and other societal actors in sustainable development work*" [p 547].

Despite the variety of schools of thought about circular economy, Zink & Geyer (2017) claims that in the practical terms, "*the core of the circular economy refers to three activities: reuse at the product level (such as 'repair' or 'refurbishment'); reuse at the component level (e.g., 'remanufacturing'); and reuse at the material level ('recycling')*". [p 594]

Eiroa et al. (2019) proposed a definition for circular economy as it "*is a regenerative production-consumption system that aims to maintain extraction rates of resources and generation rates of wastes and emissions under suitable values for planetary boundaries, through closing the system, reducing its size and maintaining the resource's value as long as possible within the system, mainly leaning on design and education, and with the capacity to be implemented at any scale"* [p 958]. This definition focuses on the operational model of circular economy and introduces seven operational principles.

Based on Sverko Grdic et al. (2020), the linear production model used currently is an "extract-produce-use-dump" method which is an unsustainable model and uses a lot of energy during the production. The negative environmental impacts of this linear production model have resulted in developing the idea of circular economy concept. They claimed that a circular economy "*enables an economic system in which raw materials circulate and are transformed from one form into another, resulting in no or minimal waste generation*" [p 1].

According to Deloitte (2020), transition to renewable energy and energy efficiency is becoming very important. Therefore, transition to renewable energy has become a part of their circular economy transition plan. They believe "*in the circular economy, all resource extraction will be minimized – whether this is for material use or energy purposes – and will take place in a manner which ensures equal access to resources and ecosystem services for future generations. This will be done through optimal utilization of the resources already extracted, and by avoiding activities that generate pollution and emissions/discharges*" [p 3].

Table 2.1 summarises the definitions of circular economy presented in this section.

Table 2.1: Summary of definitions (own production)

Author	Definition
Preston (2012)	CE is a concept that seeks to change the way resources are used in the economy. Factory waste would become a beneficial contribution to another operation, and items could be restored, reused, or upgraded rather than discarded.
Ellen MacArthur Foundation (2013b; 2013a)	CE is a restorative or regenerative industrial system. In this concept the focus in on restoration, using greener energies, removing the use of hazardous chemicals, and more specifically eliminating the waste. It also seeks an overall aim to rebuild on the environmental and social aspects through better and more effective use of information and data, labor, energy, and resources.
European Commission (2015)	The EU's attempts to create a green, sustainable and competitive environment include a transition to a more circular economy, in which the value of resources are sustained for a long time and waste production is reduced.
European Environmental Agency (EEA)(2014)	CE emphasizes recycling, reducing and reusing physical inputs to the economy, and using waste as a good source for decreasing the primary resource use.
EEA(2016)	CE can generate job opportunities, bring development and well-being, and at the same time reduce the environmental effects. The term can also be extended to any kind of natural resource.
WRAP (n.d)	CE is opposed to the traditional linear model of take, make, dispose. In the circular model, the resources are used for a longer period of time with maximum value use and ultimately reused and recycled for further use.
Sauvé et al. (2016)	CE is related to closed-loop material use which helps to reduce the material extraction and waste or pollution generation in the consumption and production process.
Murray et al. (2017)	Circular Economy is mostly known as an economic model which seeks to utilize the ecosystem and developing well-being by good and effective planning and management of the whole procurement, design, and production processes.
Geissdoerfer et al. (2017)	CE is a regenerative system that aims to reduce the use of resources and energy as inputs and also minimize the emission and waste generation by slowing, closing, and narrowing the loops. In order to reach this, actions such as recycling, reusing, repairing, remanufacturing, etc can be taken.

Author	Definition
Korhonen et al. (2018)	CE is "a sustainable development initiative" based on the cooperation of all actors which tries to promote using more renewable types of energy and efficient material cycles besides the traditional recycling methods in the production-consumption linear systems.
Suarez-Eiroa et al. (2019)	CE "is a regenerative production-consumption system" with the purpose to keep resource extraction rates and waste and emission generation rates within acceptable limits by closing the material loops and preserving the value of resources for a longer period in systems, mostly by design and education, and with the ability to be applied in different scales.
Sverko Grdic et al. (2020)	CE can create an ecosystem that circulates and transfers the materials from one formation to another so that minimum or no waste is generated.
Deloitte (2020)	The idea behind circular economy is to minimize the material or energy extraction and use the extracted resources in an optimal way with minimum emission so that the future generations would have equal access to all the resources.

2.1.3 Circular Strategies

The main ideas of the circular economy are summarized into different "R" frameworks. The most popular R frameworks for circular economy are 3R, 4R, 6R, and 9R (Matova et al., 2019). The 3R framework is connected to "Reduce", "Reuse", and "Recycle" which are usually interconnected. It means that reusing a product or useful components and materials of that product through recycling can result in less raw material use. In the 4R framework, the fourth R as "Recover" is added to the previous one to emphasize the importance of energy recovery from waste. Later, two more Rs as "Redesign" and "Remanufacture" were added and created the 6R framework. Finally, the 9R framework completed the 4R model with adding "Rethink", "Repair", "Refurbish", "Remanufacture"(same as the 6R framework), and "repurpose" (Demestichas & Daskalakis, 2020). Each of these frameworks has a hierarchy such that each R is prioritized over the next R. For example in the 4R framework, "reduce" is prioritized over "reuse', and "reuse" over "recycle", and "recycle" over "recover" (Kirchherr et al., 2017).

The 9R model is also known as the PBL circularity ladder which focuses more on the circularity in the products chain. (Potting et al., 2017). There are actually 10 Rs in this ladder starting from the R0: Refuse. These different Rs are illustrated in the Figure 2.4.

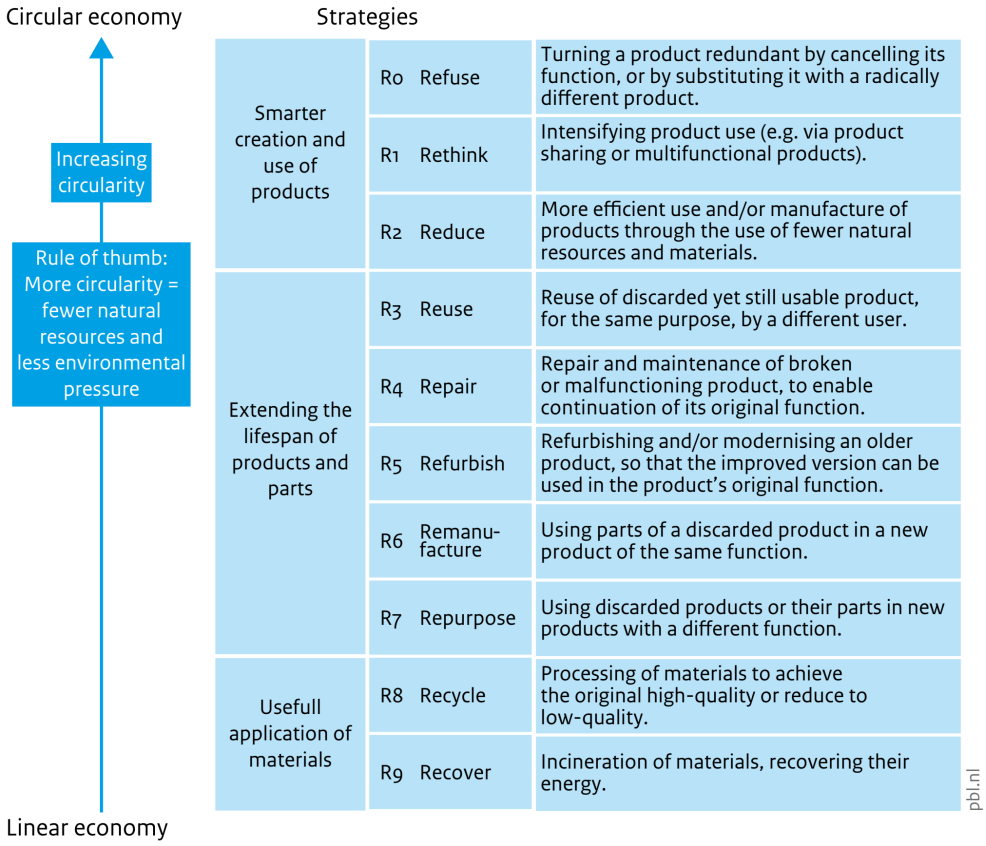

Figure 2.4: Order of priority for circularity strategies in the product chain (Council for the Environment and Infrastructure (Rli), 2015); adaptation by PBL.nl

Refuse (R0):

It is related to declining the use of certain raw materials or hazardous materials in a product, as well as making a product redundant either by canceling the product's function or by using the same function in a different product (Morseletto, 2020).

Rethink (R1):
In order to make a product more circular, we need to reconsider the use of the product. Products can be use-intensive by making them multi-functional or through product sharing (Potting et al., 2017).

Reduce (R2):
Reduce refers to using fewer natural resources which will result in less use of energy, extracting fewer raw materials, and producing less waste. Reduce is also related to the efficient use of products so that there would be fewer demands for new products (Morseletto, 2020).

Reuse (R3):
Reuse can be referred to second or more further use of a product by other users again and again. It can be achieved by, for example, relocating or reselling the product. It is important here that the products still be in a good condition and manage to function as good as the original product (Morseletto, 2020; Ghisellini & Ulgiati, 2020).

Repair (R4):
It is usually defined as adjustment and maintenance of a product that is damaged, broken, or decayed and needs to be fixed or replaced in order to function well again (Potting et al., 2017). With this aim, the so-called "repair cafes" are spreading in the world where they repair different products or devices and also offer repair courses (Ghisellini & Ulgiati, 2020).

Refurbish (R5):
Refurbishing is related to upgrading or modernizing a product function (Morseletto, 2020). It is usually connected to replacing some parts and it does not involve in disassembly. Therefore, refurbishment is usually called "light" manufacturing (Ferguson, 2010).

Remanufacture (R6):
Remanufacturing or second life production is referred to reusing different parts of a discarded or abandoned product in a new product or device with the same function (Morseletto, 2020). Remanufacture is also called rebuild, remould, or

rewound (Charter & Gray, 2008). Jawahir & Bradley (2016) also, state that remanufacturing refers to restoring the used product's part and components to their prior state without any negative effect on their functionality.

Repurpose (R7):
Repurpose is about using the discarded products or their spare parts in the form of new products that have a different function than the prior one. Repurposing can sometimes become difficult because many products can not be repurposed (Morseletto, 2020).

Recycle (R8):
Recycling is about the process of returning the raw materials or secondary materials of a product to the economy (EEA, 2016). These secondary materials can be upcycled and converted into higher quality materials or in the opposite direction, downcycled (Morseletto, 2020).

Recover (R9):
According to Jawahir & Bradley (2016), recover "involves the collection of products at the end of the use stage, their disassembling, sorting, and cleaning for utilization in subsequent life-cycles of the product" [p 105].

2.1.4 Circular Economy & Sustainability

Natural resources are finite and, over-consumption of people and other destructive actions of human beings toward nature has threatened the life of other creatures on the planet as well as the existence of the next generations. In order to stop this crisis and save the planet for future generations and also provide peace and prosperity for the planet and remaining creatures, in 2015 about 150 European authorities and politicians agreed on 17 sustainable development goals (SDGs) as an urgent call for action to be achieved by 2030 (United Nations, 2015).

Sustainable development is usually defined as "*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*" (WCED et al., 1987) [p 16]. Circular economy can act as a facili-

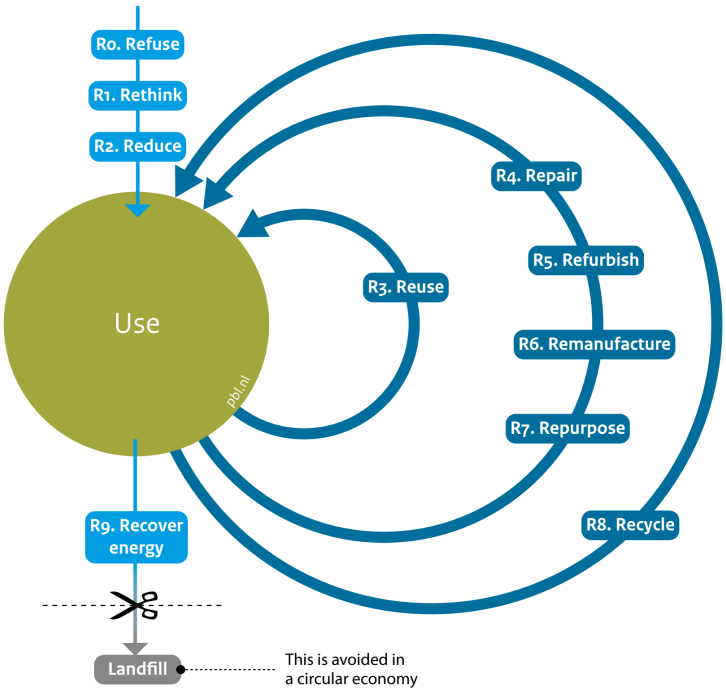

Figure 2.5: Circular economy: more than recycling. Source: PBL.nl

tator and tool for businesses to achieve sustainable development across all sectors (Geissdoerfer et al., 2017; Sauve et al., 2016) and is in correlation with many of the SDGs (van Kruchten & Eijk, 2020; Haywood et al., 2019). Most literature admits the close relationship between the concept of sustainability and circular economy, however, there are still doubts about the role of circular economy in the sustainable development framework (Eiroa et al., 2019).

On the other hand, scholars and literature also refer to some differences between these two concepts. Geissdoerfer et al. (2017) provided some of these differences as shown in the Table 2.2. As we can see sustainability and circular economy have a range of differences in their origins, primary goals, main motivations, priorities of the system, institutionalizations, potential beneficiaries, time frame of changes, perceptions of their responsibilities, and their commitments and interests.

Based on the information provided in this table, it seems that the circular econ-

omy term has recently emerged while the concept of sustainability is an older term emerged by environmental movements and especially after the Brundtland report (Keeble, 1988). Moreover, sustainability is more open-ended and has a large number of goals, while the circular economy mainly focuses on closing the loop, minimizing the input resources, and eliminating waste (Ellen MacArthur Foundation, 2013b; Geissdoerfer et al., 2017).

The motivation behind sustainability is quite diverse and diffused and can be adapted to different concepts. In contrast, the motivation behind circular economy is mainly shifting from a linear economy to a circular one (Geissdoerfer et al., 2017; Upadhayay & Alqassimi, 2019). Moreover, the agency in sustainability is quite diffused and stakeholders define the priorities, while the emphasis of the circular economy is on governments and companies.

The responsibility of shifting to a circular economy usually lies with policymakers, regulators, and businesses but in sustainability, the responsibilities are usually shared and not defined clearly. Also, circular economy is more focused on bringing financial advantages to the businesses and companies, while sustainability focuses on interest alignment among stakeholders (Geissdoerfer et al., 2017).

2.1.5 Circular economy and Covid-19

In March 2020, the World Health Organization (WHO) declared a global pandemic called Covid-19. The virus spread quickly across the world and the governments in almost all countries implemented strict rules and regulations to limit and control the transmission of the virus. These regulations and measures shattered the economy and caused a huge economic recession in the world. Many people lost their lives and jobs and it had a significant impact on financial markets and the supply chain.

Moreover, the current situation has shown the shortcomings and vulnerability of our current linear system. Naidoo & Fisher (2020) claimed that it is no longer practical or realistic to rely on economic growth and globalization to achieve green and sustainable development or investment. But adoption of other solutions such

Table 2.2: Differences between Sustainability and Circular Economy (Geissdoerfer et al., 2017)

	Sustainability	Circular Economy
Origins of the term	Environmental movements, NGOs, non-profit and intergovernmental agencies, principles in silviculture and cooperative systems	Different schools of thought like cradle-to-cradle, regulatory implementation by governments, lobbying by NGOs like the EMF, inclusion in political agendas, e.g. European Horizon 2020
Goals	Open-ended, multitude of goals depending on the considered agent and her interests	Closed loop, ideally eliminating all resource input into and leakage out of the system
Main motivation	Diffused and diverse reflexivity and adaptive→ past trajectories	Better use of resources, waste, leakage (from linear to circular)
What system is prioritised?	Triple bottom line (horizontal)	The economic system (hierarchical)
To whose benefit?	The environment, the economy, and society at large.	Economic actors are at the core, benefitting the economy and the environment. Society benefits from environmental improvements and certain add-ons and assumptions, like more manual labour or fairer taxation
How did they institutionalise (wide diffusion)?	Providing vague framing that can be adapted to different contexts and aspirations.	Emphasising economic and environmental benefits
Agency (Who influences? Who should influence?)	Diffused (priorities should be defined by all stakeholders)	Governments, companies, NGOs
Timeframe of changes	Open-ended, sustain current status “indefinitely”	Theoretical limits to optimisation and practical ones to implementation could set input and leakage thresholds for the successful conclusion of the implementation of a Circular Economy
Perceptions of responsibilities	Responsibilities are shared, but not clearly defined	Private business and regulators/policymakers
Commitments, goals, and interests behind the use of the term	Interest alignment between stakeholders, e.g. less waste is good for the environment, organisational profits, and consumer prices	Economic/financial advantages for companies, and less resource consumption and pollution for the environment

as circular economy seems to be a viable and practical solution to this crisis. The current pandemic is the best time to consider how useful the principles of circular economy can be to recover our global economy (Ibn-Mohammed et al., 2021).

2.1.5.1 Closing, narrowing and slowing loops

In the circular economy concept, the products used today are used as raw materials for other products in the future. This is how making cycles and closing the loops happen (PWC, 2018). The recent pandemic has helped to close material loops, especially in the medical sector. The urgent shortage of materials and inputs obliged companies and individuals to make, for example, face masks from leftovers of textiles or produce alcohol-based sanitizers or disinfection liquids from the remaining products in the breweries factories (Wuyts et al., 2020). While the circular economy has been a good solution to tackle the shortcomings of input resources under the Covid-19 crisis, waste management due to the generation of a lot of waste and hazardous materials, is turning into a serious problem in the world (GGKP, 2020).

Slowing the material loops is related to processes such as remanufacturing, repurposing, or refurbishment of products and goods so that they can last longer, and narrowing the material loops is referred to as resource efficiency in the consumption and production processes (Jensen, 2018; Wuyts et al., 2020). The recent crisis has encouraged a lot of people and stakeholders to practice circular economy approaches such as repairing, sharing, and refurbishing the devices.

2.1.5.2 Climate mitigation

Researches show that despite the lockdown during the pandemic and restrictions on transportation, mobility, and a lot of activities, there has been only 8% reduction in carbon emissions and it is still 92% of what we used to emit during the last years (Gates, 2020). Therefore other solutions and approaches are required to tackle the climate change issues. Circular economy can help to tackle climate change and meet climate-related targets by changing our production and consumption patterns. Renewable energy and energy efficiency solutions can address about 55% of the green gas emissions, and circular economy can be the solution to the remaining 45% (Ellen MacArthur Foundation, 2019b). According to OECD (2020), in order

to reach a low-carbon recovery after the Covid-19, there is a need to both removing the fuel subsidies and also putting carbon pricing in place. These decisions made by policymakers are aligned with circular approaches and highlight the importance of circular economy after the pandemic recovery period.

2.1.5.3 Opportunities of CE in different sectors

In many countries, especially undeveloped countries, nonstandard and poor-quality houses and buildings, insufficient ventilation systems, not following the social distancing regulations due to the design problems, have increased the risk of spreading the virus. Innovation, redesign, and renovation of buildings and reusing the building materials, and adaptation of the circular economy strategies in the building and construction industry can both prevent the problems related to the pandemic and also reduce the greenhouse gas emissions produced by this sector (Ibn-Mohammed et al., 2021).

Covid-19 has released the vulnerability of our food system. Restrictions on transport and economic activities have resulted in significant increases in food loss and waste in the world (FAO, 2020). If we continue our linear approaches, we would turn out of food in the near future. Circular economy strategies can contribute to establishing a better food industry and moving towards a more resilient food system. Regenerative agriculture, smart production and manufacturing, food waste management, and effective food distribution systems are among circular examples that can tackle the food crisis during the pandemic.

The transport industry was among the sectors that were significantly impacted by the recent pandemic (Ibn-Mohammed et al., 2021). Circular economy approaches and adopting strategies such as using shared mobility, autonomous vehicles, and material selection in the transportation infrastructure can both provide effective mobility and contribute to lower CO2 emissions.

2.1.6 Challenges and barriers of circular economy

Circular economy has received a lot of attention among the public and also scholars. However, the implementation of circular economy did not have a lot of

progress due to the variety of barriers (Kirchherr et al., 2018). Some of these barriers and challenges are introduced below. They are described in five different categories such as Financial and economic, Cultural and behavioral, Organizational, Technological, and Policy and regulatory barriers. Some of the main barriers related to each category are illustrated in the Table 2.3.

2.1.6.1 Financial and economic barriers

Scholars and literature emphasize the important role of financial and economic barriers in the implementation of circular economy (Kirchherr et al., 2018). Existing economic models can also be a barrier to circular economy. In the linear business models, the costs are usually covered by the upcoming revenue, while in the circular business models, businesses and organizations need to invest upfront and the revenue can come after months or even years (Tura et al., 2019). Therefore not a lot of businesses are willing to risk their money and support the transition financially (Bressanelli et al., 2018).

2.1.6.2 Cultural and behavioural barriers

Cultural barriers can be referred to as organizational and customer culture which are one of the main barriers to circular economy (Kirchherr et al., 2018). In many organizations and businesses, circular economy is not a part of their strategy, mission, or goal yet. Circular economy should find a place in the company's goal and strategies and they should have enough incentives to move their business and approaches towards circularity (Pheifer, 2017). Other important relative cultural barriers to circular economy are that organizations and businesses are not willing to change and would like to continue their linear approach (Kirchherr et al., 2018).

2.1.6.3 Organizational barriers

Organizational barriers are one of the other important challenges in implementing circular economy business models. Many organizations and businesses suffer from a lack of knowledge and information in transforming their business or firm operations and strategies. This can hinder applying circular economy approaches and

Table 2.3: Circular economy barriers (own production)

Category	Barriers	References
Financial & economic	• Existing economic models • Lack of investment or limited funding • Lack of financial support • Financial Risks • Lack of willingness to pay	Ormazabal et al. (2018); Hedberg et al. (2019); Kirchherr et al. (2018); Agyemang et al. (2019); Rizos et al. (2015, 2017); Ritzen & Sandstrom (2017); Bressanelli et al. (2018)
Cultural & behavioural	• Lack of incentives • Lack of cooperation and trust • Lack of willingness to collaborate • Resistance to change • Environmental culture • Conflicts with existing business culture	Hedberg et al. (2019); Tura et al. (2019); Pheifer (2017); Antikainen et al. (2018); Zhang et al. (2019); Kirchherr et al. (2018); Agyemang et al. (2019); Rizos et al. (2015)
Organizational	• Lack of information and knowledge • Lack of expertise • Lack of resources • Lack of collaboration • Existing linear targets • Organizational hierarchy • Lack of management support	Agyemang et al. (2019); Hedberg et al. (2019); Rizos et al. (2015, 2016); Tura et al. (2019); Pheifer (2017); Bressanelli et al. (2018)
Technological	• Privacy and security problems • New and complex technologies • Digital infrastructure • Lack of proper technology • Lack of digital and technical skills	Demestichas & Daskalakis (2020); Ormazabal et al. (2018); Tura et al. (2019); Hedberg et al. (2019); li et al. (2015); Rizos et al. (2017); Ritzen & Sandstrom (2017); Rizos et al. (2016)
Policy & regulatory	• Legislations • Lack of standardization • Conflicting regulations • Lack of supporting policies • Laws and regulations against CE • Lack of government support • Complex and overlapping regulations	van Eijk & Acceleratio (2016); Rizos et al. (2015); Hedberg et al. (2019); Pheifer (2017); Kirchherr et al. (2018); Rizos et al. (2016); Agyemang et al. (2019); Tura et al. (2019)

the adoption of circular business models (Tura et al., 2019). Strong organizational hierarchy can also make it difficult to transfer the change ideas from one level to another level of organization and can sometimes lead to a lack of collaboration or managerial support to implement circular economy, business models (Pheifer, 2017; Tura et al., 2019).

2.1.6.4 Technological barriers

Technology is a prerequisite in the transition to circular economy (Pheifer, 2017; Kirchherr et al., 2018). However, there are a lot of technical barriers that still need to be overcome. Data privacy and security are some of the technological problems that can limit the usage and access to digital tools and technologies (Hedberg et al., 2019). Having a good digital infrastructure and proper digital tools and technologies can also facilitate the transformation to circular economy (Rizos et al., 2017; Ritzen & Sandstrom, 2017; Hedberg et al., 2019). However, only having the technology in place is not enough. Organizations should have good digital and technical skills to be able to take the most advantage out of available technologies (Rizos et al., 2015; Hedberg et al., 2019).

2.1.6.5 Policy and Regulatory barriers

A lot of regulatory barriers are presented in different literature. One of these barriers refers to the lack of supportive policies from the governments and policymakers such as funding opportunities or proper taxation policies (Rizos et al., 2015). There are also preventing and conflicting laws and regulations in the implementation of circular economy such as waste management regulations or material use policies (Kirchherr et al., 2018). Moreover, governments can play as an enforcement tool to move the organizations towards a more circular and sustainable business (Rizos et al., 2015).

2.2 Transition to circular economy

2.2.1 Principles of circular economy in organizations

According to the British Standards Institution, circular economy is a difficult and complex concept with a lot of theoretical information to understand. Therefore they introduced six principles of circular economy as a framework to help and give guidance to organizations to create long-term values through sustainable resource management. Organizations should apply at least these principles or additional principles for transition to circular economy. These six principles are illustrated in the Figure 2.6.

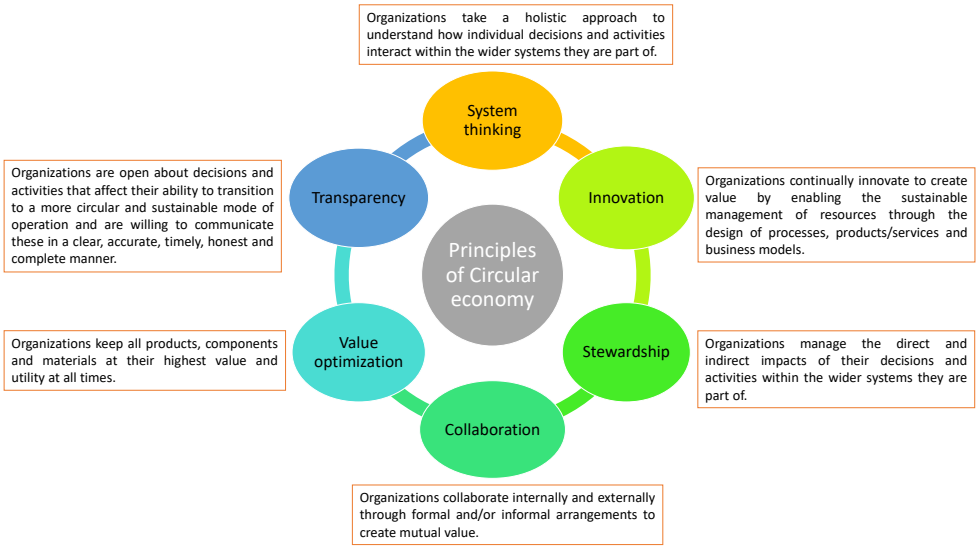

Figure 2.6: Principles of circular economy- modified from BSI (2017)

System thinking:

System thinking is "*a set of synergistic analytic skills used to improve the capability of identifying and understanding systems, predicting their behaviors, and devising modifications to them in order to produce desired effects. These skills work together as a system*"[p 675] (Arnold & Wade, 2015). According to BSI (2017) system thinking "*is about understanding the complex, non-linear and in-*

terconnected nature of any system in which an organization sits" [p28]. Each organization is a part of a system and finding out about this system and the relations that an organization has in this system is important for transition to more sustainable resource management. System environments like the market that the organization is in, are not always predictable and their behavior can vary over time. Therefore system thinking would help organizations to manage the changes in the system and make good decisions. In the Figure, 2.7 an organization system with the internal and external components is illustrated.

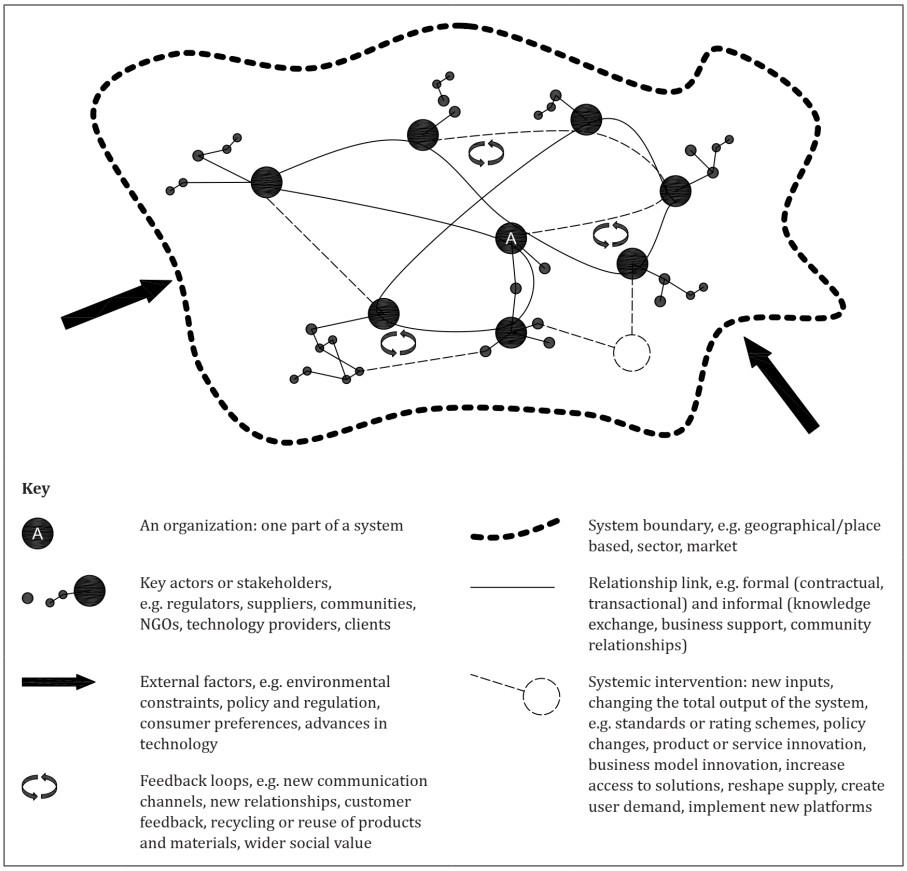

Figure 2.7: General concept of an organizational system with intervention highlighted BSI (2017)

Innovation:
The world is constantly changing and all businesses and organizations need to adapt to these changes in order to remain profitable and survive in the competitive market. Innovation refers to doing things differently from what others usually do. It can be innovation in product, in services, or in processes. This innovation usually results in saving money, time, and resources and also bring competitive advantages to the organization (Purcell, 2019). Transition to circular economy also requires innovation. It is about a new way of production and consumption and challenges the organizations' business practices. Innovation can for example help organizations extract value from waste or create more sustainable resource management (BSI, 2017; Sharma et al., 2020).

Stewardship:
According to BSI (2017), "*stewardship means an organization is responsible for the management of all facets of its decisions and activities, from inception through to fulfillment and end-of-life"*[p 29]. These aspects could include what's going on in the company's supply chain and consumer base, as well as current and predicted economic, environmental, and social concerns in the future. For example a product development case, consists of all aspects from minimizing the extraction of raw material and using chemical substances, to respect human rights, human health, or even creating employment opportunities. Implementing the circular economy approaches in organizations also requires taking both environmental and social aspects into account.

Collaboration:
Transition to circular economy in organizations requires collaboration. As mentioned before, organizations need system thinking to achieve circular economy. They need to have cooperation and collaboration within the organization as well as between other organizations. Businesses and companies are dependent on each other and if, for example, the value of the materials is lost in a chain, the whole chain would suffer (Het Groene Brein, 2017). The collaboration can be between businesses, customers, society, academia, or government. However, the organizations' culture should be aligned with this collaboration and support it. Lack of transparency between the organizations and unwillingness to share data and

information can become a significant collaboration barrier in achieving circular economy in organizations (BSI, 2017).

Value optimization:
According to BSI (2017) circular economy aims to create and optimize value through rethinking about what may be considered as waste and the identification of new opportunity. The benefit is that it can save costs (through access to cheaper material and a reduction in costs related to waste management) or create new income sources (through supplies of supplementary goods, parts, and materials), or improve the customer relationship.

Transparency:
Transparency and traceability, and trust are three key factors in collaboration and achieving circular economy. Traceability and transparency of, for example, materials and substances used in a product can make the organizations and their circular economy models more feasible and viable (Tan, 2018). However, transparency does not mean making all the proprietary data and information of an organization public to access. It is all about efficient collaboration build on trust to eliminate waste, and extraction of natural resources to ensure a more circular economy and ultimately a more sustainable world (BSI, 2017).

2.2.2 The circular maturity levels

According to Taival (2020), "*Generally, a maturity model is a qualitative metric that assesses and guides best practices in organizational maturity and process capability"* [p 6]. It helps to recognize the capacity of an organization to improve continuously. This can be achieved by assessing the maturity of a company's processes for a specific topic and defining effective and proven business practices.

The circular maturity model is designed based on research and interviews with experts. It has been built based on the classic Porter Value Chain Model with some activities added such as Network Management. The Figure 2.8 illustrates different levels of circular maturity. Each company or organization can find their current

state in this circular maturity model so that they can plan better for transition to circular economy. This insight can also help them gain value from their actions and operations and save time and money in their transition process to a more circular economy (Cramer, 2020).

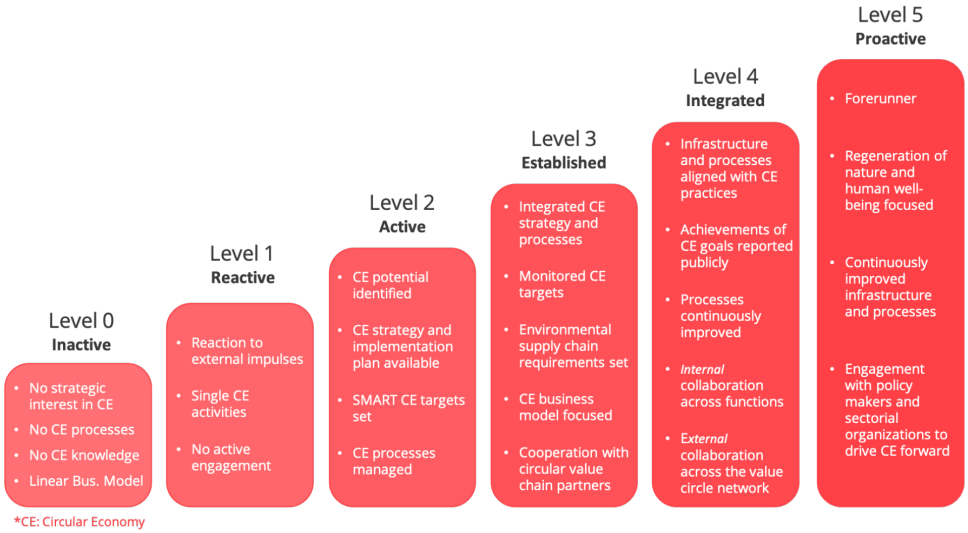

Figure 2.8: Summarized maturity level definition across the business activities (Taival, 2020)

Level 0- Inactive:
At this level, the organization does not have any special knowledge about circular economy and is not really aware of that. Therefore they do not have any strategy to become more circular and keep following their linear business models.

Level 1- Reactive:
In level one, organizations try to apply some single activities just to respond to the customers' demands or other external legal requirements. Therefore, the activities are not really aligned with circular strategies or do not have active engagement or communication with circular economy.

Level 2- Active:
Organizations have a certain circular economy strategy and plan at this level and

identify goals and targets to cut the costs and improve their product and services. At this level, the employees have insight and are aware of the circular economy practices in their organization. Organizations fulfill all the legal requirements at this level.

Level 3- Established:
At this level, organizations integrate the circular economy into their strategies and processes. All activities, processes, business models, and products or services are aligned with circular economy principles and supported by the management. They cooperate with internal and external stakeholders and partners and try to enforce further voluntary guidelines which are usually stricter than the legal requirements.

Level 4- Directed:
The organizations try to continuously improve their processes and have more collaboration internally and externally. Circular economy is implemented and embedded in the organizations' goal and purpose. They report their achievements to their partners and stakeholders and engage in making possible changes in legislation.

Level 5- Proactive:
At this level, organizations play a role as forerunners in circular economy. They try to move the circular economy forward by engaging and actively collaborating with policymakers, senatorial organizations, and other activities across the industry. They go beyond their own businesses and focus on maximizing human well-being as well as ecosystem and nature protection. They surpass the general legal requirements and work on anticipating future changes in these legal rules and legislation (Taival, 2020).

2.2.3 Circular Business Models

There are five circular economy business models that were introduced by Accenture (2020). These five models were developed based on a case study of 120 companies that were practicing and improving productivity in their resources in an innovative way. These models are good options for those companies and businesses

that want to practice transition to circular economy and maximizing their benefits. In all these models, the key is to use the maximum value out of the available products and reduce extracting new resources (Veolia, 2020). These five models are summarized in the Figure 2.9.

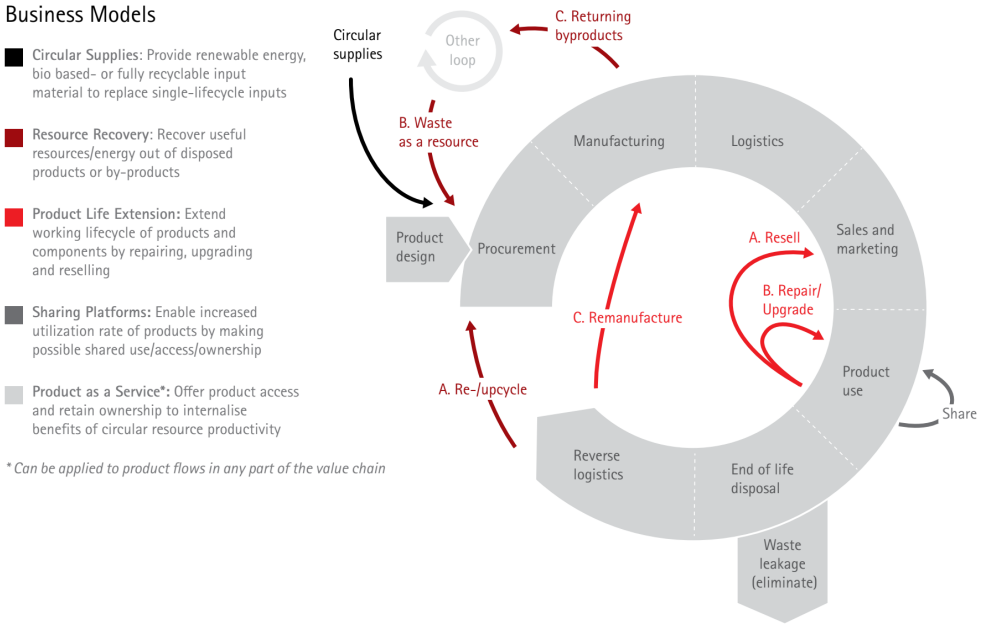

Figure 2.9: Five circular business models (Accenture, 2020)

2.2.3.1 Circular supplies

The circular supplies model is based on eliminating linear approaches and the use of materials that come from virgin materials and resources and instead, using renewable energy or bio-based, recovered, and recyclable materials. This is a good and powerful model for companies with a high environmental footprint and scarce commodities. Reusing the materials can help them reduce their dependency on new resources (Accenture, 2020; Veolia, 2020). This model helps businesses and companies to have a more sustainable business and fulfill the customers' demand and desire of having environmentally friendly products that use clean energy and produce less pollution.

2.2.3.2 Resource recovery

As it is obvious from the name of this model, the resource recovery model attempts to reuse and recover the resources at the end of the product life-cycle and use them as input of other products in the chain. This model also promotes using innovative and advanced technological methods to transfer wastes into resources and create value out of them. It is a good model for companies with environmentally conscious customers that care about the product and services that receive and want the companies to recover the waste more and stop using the virgin resources. Other models such as closed-loop recycling and Cradle-to-Cradle are useful methods for recovering the resources (Accenture, 2020; Veolia, 2020). In circular economy approaches, implementing the resource recovery from waste (RRFW) requires cooperation and collaboration across different sectors such as industries, communities, politicians, academia, and NGOs (Lag-Brotons et al., 2020).

2.2.3.3 Product Life Extension

The product life extension model focuses on the length of the product's life and the importance of extending the time that a product can be used. Every time that customers or manufacturers throw a product away, they potentially lose all the energy and resources that were used in the production process of that product (Lee, 2019). One of the ways to apply it to the life-extension model is remanufacturing product components (Veolia, 2020). In this way, companies can prevent losing the value of the wasted product and try to maintain them instead of dumping them into landfills. Online marketplaces are good platforms that users can buy and sell products so that the value of the products is not wasted and their life is extended during their life cycle (Accenture, 2020).

2.2.3.4 Sharing Platforms

Sharing platforms are collaboration platforms for both users and organizations to share their products and services (Accenture, 2020). Airbnb and Uber are good examples of this type of platform. The difference between the sharing platform models and the leasing approach is that in the sharing platform models the number

of users is very high but at the same time the duration of using shared services or products is very short (Veolia, 2020). The importance of digitalization in circular economy has also affected the sharing platform models and as we see today, the digital sharing platforms are becoming very famous and have outgrown the business practices (Schwanholz & Leipold, 2020).

2.2.3.5 Product as a Service

Product as service models are based on selling the services and solutions to customers and users instead of tangible or physical products to fulfill their needs (Aubertin, 2019). Philips is one of the companies that is changing their strategies from selling lamps to customers to selling light to them so that the products are used through the pay-for-use or leasing agreements (Goedkoop, 2016). Other than the economic advantages that this model can bring to people and organizations, Sakao & Webster (2020) mention the environmental and social benefits of this model. One of the examples of this model can be leasing or renting cars instead of buying your own car. Users can at the same time save money and have access to brand-new cars. This can also contribute to lower greenhouse gas emissions. From the social aspect, this service can create new job opportunities for a lot of people.

The effective role of digitalization and new technologies in business development and growth is inevitable. Digitalization can also bring strategic benefits to organizations and businesses by making things faster, cheaper, and more effective for them. Internet of things, cloud computing, sensor technology, data analytics, and even mobile devices are technologies that everyone hears a lot about these days. In the next section, the concept of digitalization, different digital tools and technologies, and the application of these tools in circular economy are investigated.

2.3 Digitalization

Today, technology is affecting different accepts of people's life. The environment and social characteristics have been influenced by the industrial revolution in the last three centuries. Economic systems were enormously affected by this revolution. (Jovanovic et al., 2018).

About 10,000 years ago, people experienced a substantial shift in their life. As the result of this revolution, humans and animal efforts were merged and helped better communication, transportation, and production. This improvement also facilitated urbanization and population growth. The first industrial revolution took place from 1760 until around 1840.

During this period, the steam engine was invented and railroads were constructed. The second industrial revolution occurred between the late 19th and the early 20th. Mass production became feasible with the advent of assembly lines and electricity. In the 1960s, the third revolution began and computers and the internet emerged in this period. Therefore, the third revolution is also known as the digital revolution or computer revolution (Schwab, 2017). The last revolution that has occurred until today and we are still in the middle of it, is the fourth revolution. The 'digital technology' term covers different new technologies namely, Big data, Internet of Things (IoT), and Artificial intelligence (AI). These technologies made a revolution in industrial production, called 'Industry 4.0' or the 'Fourth Industrial Revolution'. There are also other digital technologies related to the concept of digitalization such as Cloud Computing, Blockchain, and Cyber-Physical Systems (Kristoffersen et al., 2020b).

2.3.1 Digitization

Converting analog data and information to a digital format is mainly known as "digitization". The digital data or information generated from digitization have different applications in many ways and in different systems and on various materials (Brennen & Kreiss, 2016). Converting the analog data like paper archives to high-resolution scanned documents (600 dpi or more) can be a good example of digitization. (Savic, 2019) The digitization process encodes the signals into 1s

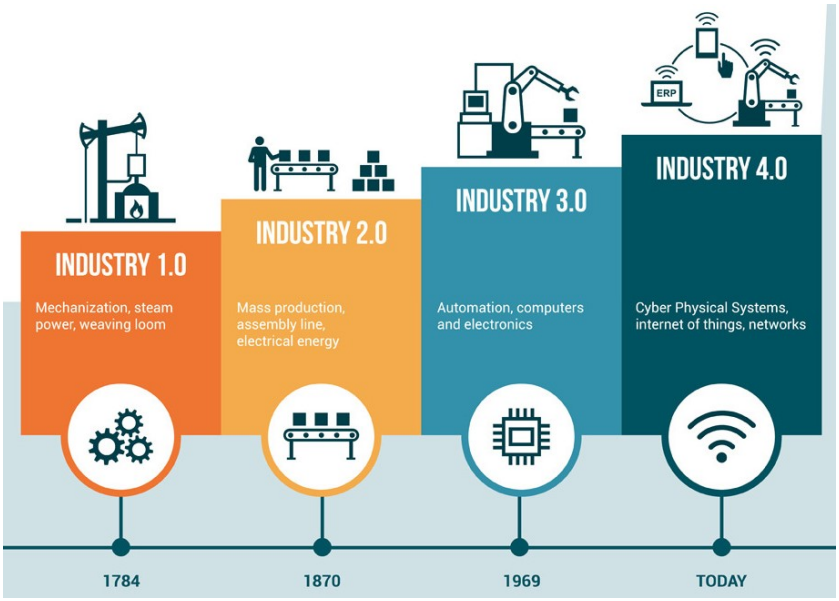

Figure 2.10: The four industrial revolutions (spacenews.com)

and 0s strings. In order to conduct the conversion process and change the original signals, particular infrastructures and specific technical mechanisms are required. It is the algorithms in the digitization process that can decide whether to maintain some signals or get rid of some others and discard them. A good advantage of digitized information is that it can be easily stored (Brennen & Kreiss, 2016). In 1982, compact discs (CD) were invented. After that, the storing process of paper documents, audios, and videos as well as converted cassettes, VHS video, and film reels, became cheaper and easier (Savic, 2019). Digitized information can also give the opportunity to the users to manipulate the information easily and have control over them, while for the analog information this feature was not easily achievable (Brennen & Kreiss, 2016).

2.3.2 Digitalization

Many people use "digitization" and "digitalization" terms interchangeably. Brennen & Kreiss (2016) defined that "*we refer to digitalization as the way in which many domains of social life are restructured around digital communication and media infrastructures*" [p1]. Also according to Gartner Glossary, "*digitalization is*

the use of digital technologies to change a business model and provide new revenue and value-producing opportunities. It is the process of moving to a digital business". However, in many academic books and articles, digitalization is linked to social interactions and the important role of digital media in our world. Automation is an inseparable aspect of digitalization. Muro et al. (2017) believed that peoples' work roles and jobs would be affected or even replaced by technology and digital tools and equipment such as computers, machines, and robots.

Digitalization consists of three different phases. Automation of single processes and operations, like library purchasing, is part of the first phase. The second phase is known as the mid-phase and is related to automating the processes and connecting them. Examples of this phase can be library collection management and supply change management. The last and the most complex phase is about multiple systems integration into enterprise management systems or libraries (Savic, 2019). Indeed, digitalization and digital transformation can help to achieve lower production costs and good business results. They can also contribute to better income and revenue for the businesses and finding new customers (Savic, 2019).

2.3.3 Digital transformation

There is not a lot of valid definitions about 'digital transformation' but Nwankpa & Roumani (2016) defined it as "organizational shift to big data analytic". E-government, e-banking, or e-tourism are some new business areas derived from the digital transformation (Hausberg et al., 2019). It is not usually easy for organizations to undertake digital transformation as a project. It requires strategic and cross-cutting changes in the organizations with the help of digital technologies (Bloomberg, 2018). However, using digitalization in organizations does not guarantee achieving digital transformation. It requires organizational changes in, for example, culture, strategies, management, operations, etc. Digitalization and new technologies strengthen the existing business but can not change the organization's essence (Savic, 2019).

In the Figure 2.11, Savic (2019) illustrates different aspects of 'digitization', 'digitalization', and 'digital transformation'. For each of these terms, there are five

descriptive aspects such as focus, goal, activity, tools, challenges, and examples. As an example, the focus of digitalization is on information processing and the goal is to automate the existing business operations and processes. In order to reach this goal, they should use computer applications and IT systems. However, purchasing technologies can be challenging in terms of the price of tools. A good example of the implementation of digitalization in businesses can be electronic registration processes.

	DIGITIZATION	DIGITILIZATION	DIGITAL TRANSFORMATION
Focus	Data conversion	Information processing	Knowledge leveraging
Goal	Change analog to digital format	Automate existing business operations and processes	Change company's culture, the way it works and thinks
Activity	Convert paper documents, photos, microfilms, LPs, films, and VHS tapes to digital format	Creation of completely digital work processes	Creation of a new digital company or transformation to a digital one
Tools	Computers and conversion/encoding equipment	IT systems and computer applications	Matrix of new (currently disruptive) digital technologies
Challenge	Volume *Material*	Price *Financial*	Resistance to change *Human resource*
Example	Scanning paper-based registration forms 	Completely electronic registration process 	Everything electronic, from registration to content delivery 

Figure 2.11: Digitization, digitalization, and digital transformation (Savic, 2019)

2.3.4 Digital technology categorization

Digital technologies are divided into 3 categories, namely: data collection, data integration, and data analysis. Data collection is about connecting the products and users through the internet. Sensors and RFID are good examples for data collection. Data integration is related to data storage and formatting and data analysis are about developing and producing information (Vaisanen, 2020). Some of the technologies used in each category are presented below:

2.3.4.1 Data collection

Internet of Things (IoT):
Internet of things or IoT is a useful technology in data collection. There are a lot of interconnected objects in this global network that uses unique addresses and communicate with each other through standard protocols (Gubbi et al., 2013). The most important function of IoT is that they help devices to interact with each other without any need for human interaction (Ardolino et al., 2018). In the perspective of circular economy, IoT is an important technological pillar for circular economy (Demestichas & Daskalakis, 2020). It can be useful in environmental monitoring and logistics and enhance the efficiency in logistics in addition to the cost reduction (Zhou et al., 2018). Moreover, the information coming from the sensors can be collected with the IoT technology, and therefore, stakeholders can get connected across the value chains.

Radio-frequency identification (RFID):
Radio-frequency identification (RFID) or smart tags are a technology used for data collection. They are small devices, sensors, or microchips in different shapes and sizes that can be used for tracking objects, material flows, products, and providing product information through the whole life cycle to all stakeholders. RFID has recently been used in the context of circular economy. It is specifically used in circular economy 'R' strategies such as Reuse, Repair, and Remanufacture (Demestichas & Daskalakis, 2020; Pagoropoulos et al., 2017). As another argument Govindan et al. (2015) highlighted the ability of RFID to transition and move towards closed-looped systems in the circular economy context. The data related to the product can be stored in the tags and scanned easily. Sensors can also enable gathering information related to products for example changes in the temperature or changes in the quality of the product and the time when products need to be remanufactured, reused, or recycled (Vaisanen, 2020; Gligoric et al., 2019).

2.3.4.2 Data integration

Blockchain:
Blockchain is a popular technology in data storage and management (Demestichas & Daskalakis, 2020). According to Raikwar et al. (2019) Blockchain is "*a dis-*

tributed ledger maintaining a continuously growing list of data records that are confirmed by all of the participating nodes" [p 148551]. It increases the transparency in the information sharing and smart contracts and enhances the efficiency of works (Khan et al., 2021). Smart contracts are contracts that are like real contracts with the difference that they are in a fully digital form (Demestichas & Daskalakis, 2020). By the use of Blockchain, companies and organizations can generate information, maintain them and also share their databases with each other (Vaisanen, 2020). In the context of circular economy, Blockchain answers the problems related to data sharing and data privacy in peer-to-peer networks and also enables traceability and handling of the wastes especially electronic wastes (Rajala et al., 2018; Dindarian & Chakravarthy, 2020).

2.3.4.3 Data analysis

Big Data analysis:
Very complex, ever-growing, and large volume data that are commonly used and traditional tools and software are unable to analyze or process, is known as Big data (Kristoffersen et al., 2020b). It mainly provides the solutions to gather and analyze large amounts of data and turn them into knowledge and generate value in a fast way (Vaisanen, 2020). In order to process, store, manage, distribute and transform this type of data, advanced tools and technologies are required. Supply chain information, the internet, and machine sensor data are the sources of big data (Kristoffersen et al., 2020b). One of the most popular enablers of circular economy is big data (Demestichas & Daskalakis, 2020). It is a practical approach to use the information in the decision-making process as well as the implementation of strategies (Pagoropoulos et al., 2017). Big data is also capable to monitor the production and consumption process and helps to close the material flow (Moreno & Charnley, 2016).

Artificial Intelligence (AI)
Artificial intelligence (AI) is mainly like data analytic and is connected to data transformation to information. It is "*a collection of technologies and methods that simulate the human cognitive process, including reasoning, learning, and so on*" [p14] (Kristoffersen et al., 2020b). Frankenfield (2021) also highlights that arti-

ficial intelligence is "*the simulation of human intelligence in machines that are programmed to think like humans and mimic their actions*". Machine learning (ML) and Deep learning are two approaches to artificial intelligence. Machine learning is a subset of AI with a lot of computer algorithms and methods that allow machines to carry out and perform different tasks based on previous patterns and without need for instructions or assistant by humans. Deep learning also refers to automatic learning from the different unstructured amount of data like images, text, or video (Kristoffersen et al., 2020b; Frankenfield, 2021). In the case of circular economy, machine learning enables material efficiency, resource consumption optimization, and resource management (Demestichas & Daskalakis, 2020).

Kristoffersen et al. (2020b) also added another dimension to these three categories and mentioned that data sharing is fundamental for circular economy and data or information should be available across all the departments as well as for other external stakeholders. These concepts are sometimes confusing and hard to understand. In the Figure 2.12 he tried to illustrate these concepts and their relationship with each other with a focus on data collection, processing, and analysis.

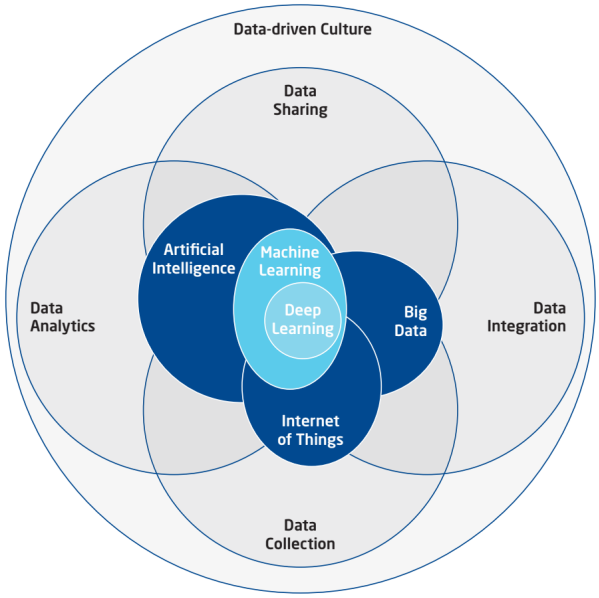

Figure 2.12: Digital technologies categorization (Kristoffersen et al., 2020b)

Chapter 3

Methodology and Research approach

This chapter is about the research methodology. More specifically, the literature review, research design, and methods are going to be further discussed in this chapter. Lastly, the data collection method with remarks on privacy and ethical consideration, validity, reliability, and the limitation of the study will be presented.

3.1 Literature review

Fink (2019) defines literature review as *"a systematic, explicit and reproducible method for identifying, evaluating, and synthesizing the existing body of completed and recorded work produced by researchers, scholars, and practitioners"* [p6]. A literature review is conducted based on different sources and literature to provide relevant information in a writing and structured format to the readers so that readers would be easily able to go through it and understand the main topic (Green et al., 2006).

3.1.1 Different types of literature review

Green et al. (2006) classified the literature review into three different sections: 1- Narrative reviews, 2- Quantitative systematic reviews (meta-analyses), and 3- Qualitative systematic reviews.

3.1.1.1 Narrative reviews

One of the traditional ways of conducting the literature reviews is a narrative review which is categorized into three subsections, namely Unsystematic narrative reviews, Commentaries, and Editorial. The *unsystematic narrative review* is also known as a narrative overview. This type of literature review is usually conducted and written by previous experts and writers who are familiar with the topic and have done research in similar fields before. *Commentaries* are a type of biased review that provokes and encourages the readers to have scholarly dialogue and participatory action research with each other. Lastly, an *Editorial* literature review is usually conducted by guests or the editors of the journal who are invited to express their ideas and write comments about the articles or other events in the journal (Bartunekl, 1993; Green et al., 2006).

3.1.1.2 Quantitative research

Quantitative literature review, also known as Meta-analyses, is about analyzing and evaluating a lot of data by using statistical methods and procedures, testing different variables, and assessing the relation between them. The findings and pooled information can be presented later in a larger size. The most famous quantitative type of research is experimental design and survey research (Creswell, 2014).

3.1.1.3 Qualitative research

Qualitative research, unlike the quantitative one, does not deal with numerical data and is an approach for gathering different literature in order to understand a situation or complexity of a problem. The most famous approaches in qualitative research are case studies and interviews by the use of questions to obtain qualitative data. These data and results can also be illustrated in the tables or graphs so that it would be easier to compare the studies and find out the differences (Green

et al., 2006; Creswell, 2014). Similar topics are usually studied in the qualitative literature review that may result in some overlapping in the research. However, new information and findings can sometimes emerge from the same topics and can be used later as a new area of study for other researchers (Seers, 2014).

3.2 Research design and method

Research design is about the overall structure of research and the plan to obtain the research questions (Rahim & Rahim, 2018). Based on the theoretical review gained in the previous chapter, there is still little understanding about the role of digital technologies in the circular economy especially when it comes to organizational transition. In order to get a better understanding of the thesis topic and answer the research questions, a literature review is conducted. The theoretical information gathered in the previous chapter is aligned with the research questions, performing as a basis for interview questions. Therefore, when the findings of the interviews are compared to the theory, solid results can be obtained which basically covers the gaps of the study and fulfills the aim of the thesis.

The research method is mainly based on the research design and is about the tools and procedures that are used in the research to collect and analyze data (Hasa, 2017). In order to find deep and rich data and information to answer the research questions, a qualitative research is selected. Qualitative researches provide the researchers and writers with different interpretations and insights of a specific topic without any need for numerical data (Mouazan, 2016). There are different approaches in the qualitative method, namely interviews, questionnaires, or case studies. This thesis is conducted based on both literature review and the interview method because it is beneficial to build some knowledge about the topic and collect some base theory to be able to answer the research questions.

3.3 Data collection

As mentioned before, the materials in this thesis are gathered in two ways. Theory or literature part and the interview part. In the following subsections, the strategy

behind these two methods are described.

3.3.1 Literature selection

Useful materials and articles were selected based on their relevance to the thesis topic and the three important concepts of circular economy, digitalization, and organization transaction. According to Tranfield et al. (2003) a good academic literature is not the one relying and written based on only articles published in famous journals, but is the one that uses different sources of materials for example reviews, books, or conferences. This thesis is also written based on different materials found in various sources and databases. Some of these engines were ScienceDirect, ResearchGate, Scopus, Sustainability journal (MDPI), Google Scholar, and most importantly NTNU library (Oria).

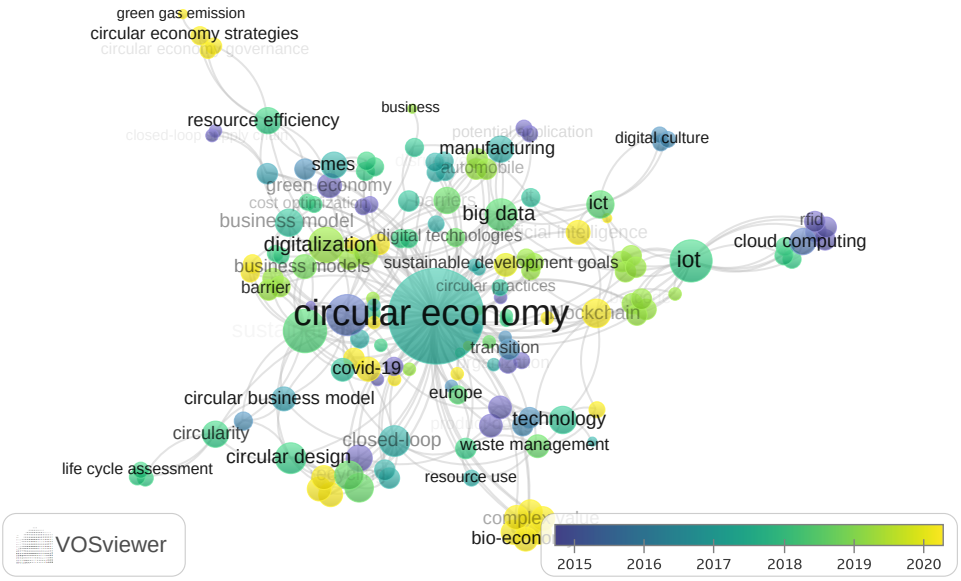

Figure 3.1: Network of key terms from the references created by VOSviewer software (own production)

In order to reflect an overview of the most used keywords among all the references used in this master thesis, the VOSviewer software was used. This is a good tool

for visualizing and building bibliometric networks. A network map was created based on the bibliographic data extracted from the list of references used in this thesis in a RIS format and a threshold of a maximum number of about 160 references. The software reviews the list of keywords in the file and visualizes them as illustrated in the Figure 3.1. The larger and bolder circles show the frequency of each keyword. As it is shown in the figure, circular economy was the most repeated keyword among all the articles used in this thesis, and after that came the words such as IoT, digitalization, sustainability, Big data, etc. The gray nodes also indicate the link between each item in a reference. For example, there could be one article with all the keywords of circular economy, circular business modes, circularity, and life cycle management. The small box on the right side below the figure maps the range of the years when the materials provided in the reference were published. This range was limited to the most recent years from approximately 2015 to 2021 and the color of each circle in the map corresponds to the publication date of the article.

The identified and most focused keywords in this master thesis were 'Circular economy', 'Digitalization', and 'Organization'. The terms 'Circular economy & Digitalization', 'Circular economy & Organization', and 'Digitalization & Organization', were the main search strings used in this thesis. There was an attempt to find the most relevant references based on the research strings. Since there are not enough articles or materials when it comes to digitalizing the circular economy especially in an organization, most of the obtained materials covered whether only the concept of 'Circular economy' or 'Circular economy & Digitalization'. Circular economy has recently received attention, therefore, most of the articles related to circular economy in this thesis are from the last 10 years. The time scope of the found materials and articles was not limited to any specific range of time. However, there was a tendency to use the most recent ones.

In order to conduct this thesis, over 2000 materials were retrieved from research engines mentioned before. Among these references, 21 articles corresponded to the string 'Circular economy & Digitalization', from which 16 articles were selected as the main source in this thesis. Finding articles containing both 'Circular economy & Organization' keywords was challenging because there are not a lot

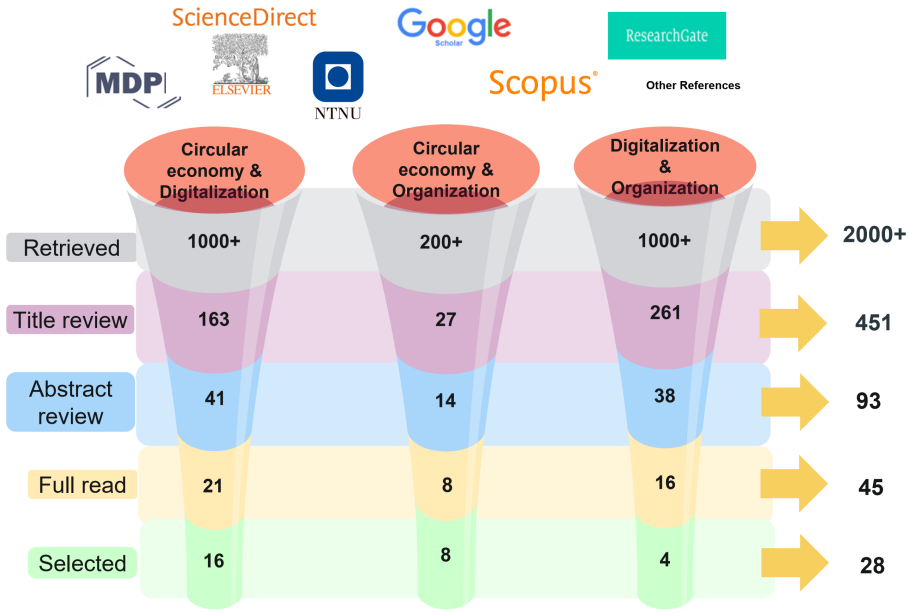

Figure 3.2: Literature selection (own production)

of articles written in this area. Therefore, all the eight fully read articles with the closest research area to circular economy implementation in organizations, were selected for further application in the thesis. There are a lot of articles written about the last research string, 'Digitalization & Organization'. Since the main focus of this master thesis is on the role of digitalization in organizations' transition to circular economy, after reading 16 articles in this area, only four were used to obtain a better understanding of the general digital tools and technologies used in organizations.

As it is illustrated in the Figure 3.2, a total number of 28 articles were finally selected as the main literature source in this thesis. However, a total number of about 140 references are presented in the bibliography list. Other than the 28 used articles, the rest of the manual additions are from reports, books, reviews, conference papers, and websites which contained whether single keywords like circular economy or embraced other relevant information for writing the rest of the chapters.

Table 3.1: Used articles based on the search strings (own production)

No.	Article	Year	Scope
1	Khan, S. A. R. et al	2021	Circular economy & Digitalization
2	Demestichas, K., Daskalakis, E.	2020	Circular economy & Digitalization
3	Kristoffersen, E.	2020b	Circular economy & Digitalization
4	Kristoffersen, E.	2020a	Circular economy & Digitalization
5	Dindarian, A., Chakravarthy, S.	2020	Circular economy & Digitalization
6	Ghisellini, P., Ulgiati, S.	2020	Circular economy & Organization
7	Hoosain, M. S. et al	2020	Circular economy & Digitalization
8	Jose, R. et al	2020	Circular economy & Digitalization
9	Schwanholz, J., Leipold, S.	2020	Circular economy & Digitalization
10	Ellen MacArthur Foundation	2019	Circular economy & Digitalization
11	Agyemang, M. et al	2019	Circular economy & Organization
12	Gligoric, N. et al	2019	Circular economy & Digitalization
13	Hausberg, J. P	2019	Digitalization & Organization
14	Antikainen, M. et al	2018	Circular economy & Digitalization
15	Ardolino, M. et al	2018	Digitalization & Organization
16	Bloomberg, J.	2018	Digitalization & Organization
17	Bressanelli, G. et al	2018	Circular economy & Digitalization
18	Niero, M., Rivera, X. C. S.	2018	Circular economy & Organization
19	Ormazabal, M.,	2018	Circular economy & Organization
20	Rajala, R.,	2018	Circular economy & Digitalization
21	BSI	2017a	Circular economy & Organization
22	BSI	2017b	Circular economy & Organization
23	Pagoropoulos, A.,	2017	Circular economy & Digitalization
24	Bocken, N. M. P. et al	2016	Circular economy & organization
25	Jawahir, I., Bradley, R.	2016	Circular economy & Digitalization
26	Moreno, M., Charnley, F.	2016	Circular economy & Digitalization
27	Rizos, V.,	2016	Circular economy & Organization
28	Li, J., Tao, F. et al	2015	Digitalization & Organization

3.3.2 Interview sampling

More than 30 companies, organizations, and experts were contacted. Some of the emails were never responded and a few of them answered that they were busy and did not have time to conduct the interview. Among them, two people introduced other colleagues instead of themselves that could have time to join the interviews. Eventually, a number of 13 interviews were conducted. These non-random interview objects were chosen based on the purposive interview sampling suggested by Bryman & Bell (2003). It means that all the participants in the interview were chosen in a selective way according to their profession or relevance of job position to the topic of the thesis. The list of the interview object roles and organizations is presented in the table below.

Table 3.2: Interview objects role (own production)

Interview object	Role of interview object
Interview object 1	Sustainability expert
Interview object 2	Sustainability expert
Interview object 3	Circular economy advisor
Interview object 4	Climate advisor
Interview object 5	Sustainability expert
Interview object 6	Sustainability/Circular economy leader
Interview object 7	Professor
Interview object 8	CEO/Co-founder
Interview object 9	Business developer in sustainability/circular economy
Interview object 10	Digitalization expert and sustainability manager
Interview object 11	Professor
Interview object 12	Senior advisor of technology and business modelling
Interview object 13	Digitalization and circular economy expert

Interviewees were selected from both the personnel working in public organizations and some other external companies that were either practicing circular economy strategies in their company/organization or provided digital tools and platforms for circular economy. In addition, in order to obtain a better insight into circular economy, some interviews were conducted with professors, experts, or

advisors in the field of circular economy and digitalization. All the interviewees were invited through NTNU email. Due to the situation of Covid-19, all the interviews were conducted digitally via Microsoft Teams during April 2021. Each interview lasted for approximately one hour and recorded by using the recording function in the Microsoft Teams. The chart below shows the distribution of organizations from which the people were interviewed. As it is illustrated, most of the interview objects were either from the public organizations or private companies.

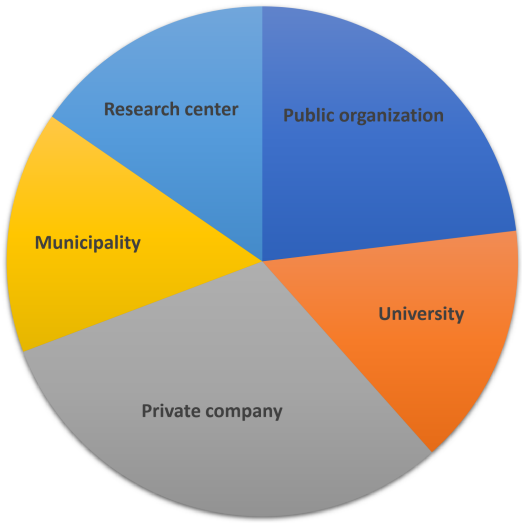

Figure 3.3: Distribution of type of organizations involved in the interviews (own production)

According to Denscombe (2014), interviews can be classified into three different categories: structured interviews, semi-structured interviews, and unstructured interviews. The first category has a fixed and inflexible way of responding. This is a good method for large-scale studies. Unstructured interviews give the respondents a lot of freedom in terms of expressing their ideas and opinions. The interviewer has the task to provide leading questions to get the desired answer in this type of interview. The interview method used in this thesis was a semi-structured interview method. In this kind of interview the participants can respond to the questions freely and in an open-ended way. However, the questions are prepared in advance and the interview objects should be ready to answer them. At the same time, it

gives the interviewer more freedom to ask follow-up questions to get a better understanding of the topic.

After a thorough research process and with the help of my supervisor, a list of 20 questions was prepared. A PDF file containing all the interview questions were sent to the interview objects a minimum of one week in advance so that the person could become familiar with the questions and also prepare for the interview. The questions were classified into four different categories. The first part consisted of a general question to become more familiar with the participants and their role in their organizations. The rest of the questions were divided into two main areas of circular economy and digitalization related questions. The interview ended with another general question which let the participants express their thoughts or add any other relevant information that could be useful in the process of writing the thesis and answering the research questions.

3.3.2.1 Privacy and ethical consideration

There are always some procedures and considerations that need to be fulfilled in the process of conducting an interview. According to the research rules and regulations in Norway, all the researchers that are collecting personal data must fill out the NSD (Norsk Senter for Forskningsdata) form so that the center can assess and approve the accordance of the data collection process in the thesis with the data protection legislation. The information gathered in this form was sent to the participant to become more familiar with the thesis subject, the interview process, and their rights regarding their own personal data. The form was signed by both the project student and the supervisor. The participants were also required to read the form carefully, sign it, and send it back to the thesis writer.

For more data security and safety, all the personal data are stored on the NTNU infrastructure such as OneDrive, SharePoint, and Microsoft Teams. The answers are analyzed and used anonymously in this thesis and the recordings will be deleted after the project is completed. We also make sure that their personal information will not be recognizable in publications and their interview will not affect their relationships or position in their organizations.

3.3.2.2 Validity

Validity or credibility is an important issue in a qualitative research (Denscombe, 2014). According to Kumar (2014), validity is *"the ability of an instrument to measure what it is designed to measure"*[p213]. Checking the validity of a qualitative research is not as easy as doing so in quantitative researches because it is usually unlikely that all the researchers or participants come to the same conclusion. However, there are some ways that researchers can use to check the validity of the information they are provided with. In this way, the readers can also be assured that the data and information used have been checked and are credible. The following methods are usually used to check the validity of interview data: (1) *Triangulation*, is a way of checking the interview data with alternative sources such as documents, observations, and even against other interviews to make sure the consistency of the interview content. (2) *Respondent validation*, which is one of the main methods for checking the validity of the interview data. It is done by sending back the transcription to the participants to make sure if all the ideas and information provided from the interview objects are correctly understood by the interviewer. (3) *Data plausibility*, refers to the position of the participants in the interview and the credibility of the information they provide. Interview with experts or highly experienced people usually ensures the high validity of data. (4) *Looking for themes in the transcript*, was another method used for data validity check in this thesis. This method recommends conducting several interviews and not relying on only one interview so that the researcher can use the data with more confidence (Denscombe, 2014).

3.3.2.3 Reliability

Reliability is the consistency of research tools in presenting the same results, under the same condition, over and over again (Kumar, 2014). Measuring the credibility or accordance of a tool in a qualitative data is as hard as measuring the validity of the data in this kind of research because based on Denscombe (2014), it is quite difficult to recreate the same setting with the same people. However, if a researcher ensures that the result of the conducted research can be relied and used by other researchers over and over during the time, the method can be approved as reliable.

3.4 limitations

The number of organizations that were actually implementing the circular economy approaches were very limited and since the focus of this thesis was more on the public organizations that were only service providers and not manufacturer, it was difficult to find the proper interview objects with expertise in both digitalization and circular economy, also with experience in implementation of circular approaches in organization.

Covid-19 pandemic also created a lot of hindrance in conducting the interviews. Many of the interview invitation emails were not responded and since many of the employees had a home office, visiting the organizations and booking a time in person was not possible. Therefore the late responses as well as the difficulty to find and contact the people resulted in a limited number of interview objects.

Chapter 4

Empirical Results

This chapter presents the findings from the 13 interviews conducted in this master thesis. The interview questions were divided into two main parts. Questions related to "Circular economy" and "Digitalization". Two more questions were also asked at the beginning and at the end of each interview, with the purpose of getting to know the interview objects before starting the interview and one follow-up question to give the interview objects the possibility to add any extra thoughts and ideas about the topics. The following sections will reflect a brief summary of the responses.

4.1 Circular economy

4.1.1 Circular economy definition

The majority of the interview objects referred to the linear economy and the take-make-dispose approach and the new circular consumption model which is based on reducing the waste and using the products for a longer period of time. Only one interview object mentioned that in circular economy the aim is to eliminate the waste and not only to reduce it, while others just used the word "reduce" instead of "eliminate". Interview object 3 described circular economy as the "sustainable

alternative to the linear economy" and interview object 4 summarized it in two words as "recourse efficiency". Some of them referred to the more standard definitions of circular economy provided by famous authors and companies such as Ellen MacArthur.

Interview object 7 preferred not to define circular economy and instead referred to the 114 definitions of circular economy provided in the article written by Kirchherr et al. (2017). However, he/she gave a simple explanation about the product's life cycle where we take out natural resources, produce materials or products, then use them for a limited amount of time and throw them away as waste. He/She mentioned that the difference is that in the circular economy, before going to the waste step, we use the materials for a longer time and get the most out of the resources instead of wasting it. Interview object 9 also had a similar definition for circular economy with using more technical terms such as material loop and some of the 9Rs presented by PBL like remanufacturing, repurposing, and refurbishing.

The table below is a summary of the keywords that interview objects used to define circular economy. Most of them had a similar understanding and perception of circular economy but expressed it in new ways by using different terms.

Table 4.1: Keywords used by the interview objects to define circular economy (own production)

Interview objects	Circular economy keywords
Interview object 1	"reducing the outtake of natural resources"
Interview object 2	"reduce buying new thing" and "recycle more"
Interview object 3	"sustainable alternative to the linear economy"
Interview object 4	"use smarter and for longer" and "resource efficiency"
Interview object 5	"preserve resources", "resource productivity"
Interview object 6	"put resources back into the useful value chain"
Interview object 7	"reuse", "recycle" and "repurpose"
Interview object 8	"reduce", "reuse" and "recycle"
Interview object 9	"material loop", "long lasting products"
Interview object 10	"rethink", "reuse", "recycle"
Interview object 11	"resource efficiency", "value generation", "closing the loop"
Interview object 12	"minimizing resource extraction", " reusing and recycling"
Interview object 13	"decouple value creation from resource consumption"

4.1.2 Transition to circular economy

Most of the interview objects agreed that moving from the linear economy to a circular economy is the solution to organizations' transition to circular economy. However, just a few of them had concrete answers and examples of how organizations can go more circular. Almost all the interview objects had an insight of implementing circular strategies in manufacturing units that produce a product, therefore "if you are a manufacturing company, it is relatively simple to apply circular economy" (interview object 5). However, they did not have enough information on how service provider companies and public organizations can go circular. Interview object 1 believed that circular economy approaches make organizations realize how ineffective their linear model is and how much money and resources can be saved through circular economy.

On the other hand, interview object 6 claimed that during the 8 years of work in the finance sector, he/she had realized that, from a system view, what we have done during all these years are opposite the circular economy. Therefore, all businesses and organizations should take responsibility and shift to a more circular economy (interview objects 2 & 5).

When it comes to organizational levels, it is hard to apply the concept of circular economy (interview object 8). The first thing they can do is to "push organizational development and change their mindsets". Interview object 5 shared the same thoughts and believed that organizations should be "more reflexive, think greener, implement circular mindsets, and interact with other partners". Interaction and collaboration with other green and circular service providers such as Loopfront or Go Good companies in Norway was also one of the solutions given by interview objects 1 and 9.

Some others like interview object 7 and 12 emphasized the importance of material categorization or mapping to get a better overview of the physical elements that the organizations own to make better decisions regarding reusing, recycling, or repurposing their properties. So basically, "they need to look for certain areas where there is more potential and then apply some circular economy indicators and try to distinguish between which of the strategies or specific measures to be taken,

that might give the maximum benefits according to these indicators" (interview object 11).

The transition is more dependent on the type and size of the organization (interview object 13). Some other interview objects like 10 and 11 also motioned the size of the organizations as an important factor that affects the transition process. Some organizations have more executive roles in, for example, construction or building, so that reusing resources and taking into account environmental and social aspects becomes important for them, while some other organizations have more influence on making rules and regulations connected to circular economy and can essentially dictate what the market and businesses can develop by setting requirements.

Among all the interviewees, only interview objects 2, 6, and 7 mentioned the "product as a service" and "sharing platforms" business models in circular economy as a good solution for organizations' transition to circular economy. They gave examples of car-sharing platforms like Nabobil in Norway, food sharing platforms like To Good To Go, and furniture rental platforms that provide leasing furniture services instead of buying the furniture. Philips company and their new strategy of selling lights instead of selling lamps, and Xerox or HP company and selling print services instead of printers, were other examples that the interview objects mentioned as the useful transition approaches for public organizations to go circular.

4.1.3 Benefits of circular economy

Almost all the interview objects emphasized on financial and environmental benefits that circular economy can bring to organizations. However, for organizations that have always followed a linear approach, transition to circular economy may seem a huge and unachievable project (interview objects 6, 9 and 11), and "might be even more expensive in the short term than being profitable" (interview object 6). They also claimed that circular economy is somehow like sustainability and the benefits may show up in long term. Interview object 11 emphasized that it is hard at the beginning but as soon as they start the journey it becomes quite beneficial.

Other interview objects pointed out more positive aspects of the circular economy.

Interview object 9 remarked the Ellen MacArthur Foundation statement that "circular economy contributes to 45% of CO2 cuts and can tackle the climate change". In addition, interview objects 3 and 8 gave more tangible examples of how a circular economy project saved 16 million Norwegian kroner for a public organization in Norway and another circular project that can save 6.5 million trees in the world in long term and at the same time bring competitive advantages and create value for those companies.

The majority of the interview objects believed that if organizations look at the long term, circular economy can increase their economic throughput, improve their environmental and social impacts, increase their corporate reputation, enhance competitiveness in the future, sustain that competitiveness, and also reduce their dependence on resources so that their current products become their future resources and create value for them.

The figure below presents a summary of all the benefits mentioned by interview objects. Some of the same benefits were mentioned by different interview objects by using other terms to describe them, therefore, the figure below is only an abstract of all those points.

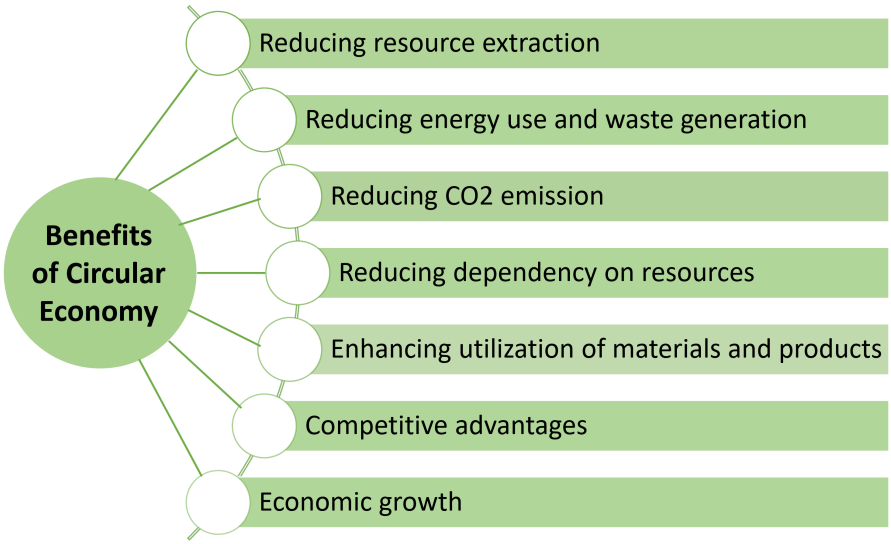

Figure 4.1: Summary of CE benefits based on the responses(own production)

4.1.4 Prerequisites for transition to circular economy

Transition to the circular economy "very often refers to the fact that you cannot implement it unless you have a leadership and good attention and acceptance by the higher-level leaders or managers" (interview object 11). They need to have "system thinking capabilities, holistic view, and stewardship skills" (interview object 13). It is important that they examine the possibilities or the opportunities of what they can do from a systems perspective (interview object 1). That means they cannot only look at what they are doing inside their gates, but they also have to look at the "consequences of different ways of operating upstream and downstream towards their suppliers and towards their customers" (interview object 10).

According to many of the answers, organizations need to get more information on what circular economy is and how beneficial it is for their market. They also need to find "where their most footprint is coming from and calculate how much footprint it is" (interview object 3). According to some others, "changing the mindset", "taking risk", and "thinking differently" are the most important prerequisites for transition to circular economy (interview objects 2,5,9,12, and 13). It is also important for them to have the tendency and willingness to "try, tests, and fail" and understand that they first need to take small steps and expect success in the long term (interview object 9).

However, three of the interview objects mentioned the importance of cooperation and collaboration with other stakeholders and "trust, transparency, and openness" between them (interview objects 4,11, and 13).

> "if you are a huge firm and you own and control your whole value chain, from sourcing and all the way down to recycling, like Coca Cola company, then you can quite easily make changes because you almost own your whole supply and value chain. But if you are a smaller firm that only owns one part of the value chain, you have to collaborate with others and then it is quite important for you to have those capabilities of creating trust and openness between other firms and find overlapping areas to create value" (interview object 13).

4.1.5 Barriers and challenges for transition

The most important barrier is the lack of knowledge (interview objects 1, 5, 6, 7, 9, 10, and 11). Circular economy is getting more and more focused, but it has just been there in the past few years so it is a new concept (interview object 3). There are still a lot of businesses and organizations that do not have that much knowledge and information about the concept of circular economy and do not know in what ways it can be beneficial for their business (interview object 6). "Everybody agrees with good quality but not everybody agrees with circularity, necessarily" (interview object 7) because most of the organizations and businesses think about the short-term gain and consider the price primarily to other developments (interview object 2). However, we always have those people that are really supportive and are advocates, but also there are those that are afraid of change or are risk-averse and do not dare to take risks (interview object 1).

There is also a lack of incentives."People talk about the circular economy and transition but they do not take one of the largest elephants in the room" (interview object 13). The market is immature and there are several incentives in the market that "makes linear business models still more lucrative than circular business models" (interview object 8). We need to change our perceptions because we are so used to doing things as it was (interview object 4). People are used to buying new products and for many of them, buying from a second-hand market is not common because they still doubt the quality of the recycled or reused materials or products (interview object 11).

Rules and regulations are also another challenges in the context of circular economy. There are always policies and requirements that prevent organizations to become circular. For example "in the building industry, there are strict sets of requirements and limitations on the use of secondary materials" that needs to be changed in order to make it easier for organizations and businesses to adapt to the circular strategies (interview object 3 and 10). Hopefully, governments and politicians are now more aware of the importance of the circular economy and nowadays we see more "building materials resource banks" that are used in building road infrastructures (interview object 11).

4.1.6 Effects of Covid-19 on CE

There were different perceptions towards the effect of the pandemic on circular economy. Some believed that Covid-19 has had positive effects on circular economy and some others mentioned the negative effects of that. However, there were some interview objects that were not sure whether the pandemic has had any effect on the circular economy or not (like interview objects 1, 2, and 11). Still, almost all the interview objects believed that depending on the type of the business or organization, the intensity, and type of the impact can vary.

Those interview objects who believed in the positive effects of Covid-19 on circular economy, mentioned that because of the restriction on logistics and importing goods, people and businesses are trying to use more local resources and consume them more critically for an as long period as possible (interview objects 6, 10, and 12) because they know that "if they buy something for example from China, they will not get it on time, so they have started questioning why don't we create them ourselves in a local basis" (interview object 13).

The government is also trying to invest a lot of money and introduce more circular and green solutions and regulations under the pandemic for example "the Covid-19 relief packages introduced by the Norwegian governments which are focusing on green change and green transition towards circular economy" (interview object 9). The researches also show that "companies that have adopted certain common circular economy principles, such as reducing resource dependency and better use of resources, were more resilient and better equipped when the pandemic hit (interview object 6).

However, not everyone had a positive opinion about the Covid-19 effects. Some of them believed that before the pandemic it was possible to meet physically and join free workshops and events about circular economy (interview object 4). Reusing and exchanging products and materials, such as clothes, were also easier, but "due to the pandemic and hygienic problems, it is not as easy as before" (interview object 10). Moreover, "the increased amount of plastic packaging and single-use items for food serving is a totally step back for circular economy" (interview object 8).

4.2 Digitalization

4.2.1 Digitalization and the potentials of it in CE

One of the core impacts of digitalization on circular economy that many of the interview objects mentioned is the ability to connect resource flows with information flow. In the current linear economy, "we have a lot of information in the beginning when we are designing products, but the amount of this information drops when the product is sold and used in the life cycle. Therefore the information we have about the product falls and at some point, we do not know about their location and where they are, we do not know whether it can be used or not, and we do not know the health and condition of the product" (interview object 13). So by using digital tools and technologies the location, availability, and condition of the product can be tracked.

"Circular economy is very data-hungry" (interview object 3) and needs a lot of information and data to "facilitate how we can optimize things at different stages in the life cycle of products" (interview object 12). Digitalization can make it possible for organizations to tap into all the information that already exists in their organizations and get a better view of all the material flows in their organization and help them map their properties to further reuse or recycle them (interview object 3). The importance of digitalization is not limited to only these and as many of the interview objects mentioned, it can help businesses and organization save a lot of time, work more efficiently, better document their processes and bring their stakeholders together and give them an insight into what options are available to better implement the circular economy strategies.

According to interview object 13, digitalization affects the circular economy based on three pillars in organizations, namely "products, processes, and platforms". Digitalization can open up better product-service systems and help different circular business models to regain more value. It can also result in process optimization and better maintenance in manufacturing. Finally, the digital platforms enable co-creation and collaboration between firms. Organizations have of course "different levels of hierarchy and digital maturity", that can affect the implementation of a digital circular economy in different sectors.

However, there were also some interview objects, such as 1, 5, 10, who were certain that digital technologies have a very important role to play in circular economy, but did not exactly know how it could be beneficial, because as they claimed, circular economy is a quite new concept and there have not been so many researches about the effect of digitalization on it.

4.2.2 Most used technologies in CE

Very few of the interview objects had knowledge about specific types of tools and technologies used in circular economy. It was mainly because they were not digitalization experts or had very little information about how digitalization could facilitate circular economy transition. Almost all of them mentioned that digital tools and technologies can play an important role in circular economy transition but they were not sure which technology is the most useful one. However, many of them talked about very simple and accessible tools such as apps or digital platforms as a possible facilitator for circular economy. As interview object 7 mentioned, "for me digitalization is an app which I have on my phone saying that the waste management site is open or when the truck comes by to pick up the paper".

It should not be something very complicated because the concept of circular economy has recently gained so much attention and still needs more investigation and research (interview object 10). Although a lot of people believe that digitalization can make processes faster or more precise, in the case of circular economy buying and using new technologies can add more complexity to circular economy implementation (interview object 8). We also need to think about that "it's not all about new technology because, for example, for repairing your jeans, you don't need new technology. That technology already exists, and actually, you can use a 50-year-old sewing machine to fix your jeans. There is a lot of things that can be solved without new technology but at the same time help to keep the products in the value chain" (interview object 9).

Another application of platforms and apps can be that "they put people together to better implement sustainability and circular economy approaches and also give them information about, for example, repair workshops, and get information about

the time and places" (interview object 4).

Digitalization experts had more concrete examples of the technical tools and technologies that either are being used or can be used in the field of circular economy. "Whenever there is a trade between actor A and B for any kind of material or goods that are based on recycled or recovered material of any value, the blockchain technology holds potential for serving such a market" (interview object 11). AI or machine learning will also have a role to play. "I mean if you think of 10-20 years into the future, if you are developing systems with advanced logistics and processing where many actors are involved, you would like, of course, to optimize these systems, and if you have sensor tagging, and information, parallel to that flow of resources, the system will be potentially improved a lot by optimizing the system performance by the use of machine learning or AI (interview object 12).

A lot of companies, especially in the building material and furniture sectors, use AI to recognize materials from images (interview object 3). We also need "a way of actually getting some data to analyze, and that is where IoT comes in" (interview object 13) and in order to handle a huge amount of data, cloud-based databases are used (interview object 1). In addition, RFID tags, QR codes, and sensor technologies are used to track the products and materials so that the information about their position and condition can be always accessible. The core use of big data is data integration, "so once you have the data and want to transform it into information, big data can actually be used to interpret it by an algorithm and model of predicting" (interview object 12). Using artificial intelligence is also a good solution for optimizing and analyzing the data (interview object 10).

4.2.3 Risks and challenges of digitalization

By using new digital devices and technologies, organizations "add more resources to all the resources they have from before" (interview object 2). New technologies are complex and sometimes expensive to buy (interview object 5). In addition, most of the electronic devices are made out of "rare earth minerals" and rely even more on Big data and AI. Therefore, in order to save and analyze tones of extracted

data we need even more data centers and should use a lot of resources to build them which also means using more energy and water to run them (interview object 4).

Moreover, new concerns have recently raised about the e-waste and heat produced by electronic devices that can "release toxic materials into the air and water affecting both people and animals and having other harmful effects on the environment" (interview object 7). Interview object 6 shared his/her experience of once visiting Ghana and mentioned that a lot of people are working with melting the electronics and selling those materials to other people. Unfortunately, these people have a life span of 25 to 28 years because of breathing and touching so many toxic materials just because people in other countries want new technologies and new phones. So:

> "Other than making sure that circular economy becomes digital, you need to make sure that the digital economy becomes circular and that used devices have the minimum harmful effect on the environment" (interview object 13)

There are also privacy issues and hacking problems connected to digitalization. Several big organizations are being hacked and it can be sometimes very critical, for example, some time ago a German hospital was hacked and some patients died during this period because the hospital personnel did not have control over their data themselves (interview object 3). There is also a risk of individuals and organizations relying too much on the systems and not having proper backups of the data. Most of the information is saved and shared on clouds and if the systems break down, all the information is lost (interview object 2).

Chapter 5

Discussion

The aim of this master thesis was to find out the role of digitalization and digital tools in the organizations' transition to circular economy. Based on the reviewed literature and conducted interviews, the findings are going to be discussed in this chapter. The discussion section is structured into four parts with the aim of answering three sub-research questions and using the beneficial findings to answer the main research question (Main RQ). RQ 1 explores the concepts of circular economy and the main areas of circular economy used in organizations. RQ 2 narrows down the ways and fields that organizations can practice circular strategies and move towards a more circular organization. RQ 3 addresses the barriers and challenges that organizations can face in the transition process, and finally, the main research question will cover how digitalization can facilitate the transition process in organizations.

5.1 Concept of circular economy

Based on the various definitions of circular economy summarized in the Table 2.1 and many keywords used by interview objects illustrated in the Table 4.1, circular economy mainly focuses on using fewer resources, reducing waste production, and closing the material loop (European Commission, 2015; Sauve et al., 2016; Geiss-

doerfer et al., 2017). However, some literature highlights that circular economy does not only seek reduction of waste but the purpose is to eliminate the waste production (Ellen MacArthur Foundation, 2013b; Sverko Grdic et al., 2020). The importance of waste eradication was mentioned by only one of the interview objects. Moreover, most of the literature places their emphasis only on 'recycling' when it comes to circular economy, while it is more than just recycling and has other different aspect as well (PWC, 2018).

Furthermore, as mentioned by the Council for the Environment and Infrastructure (Rli) (2015), nine circular strategies, known as circularity ladder exist. They indicate recycling as only one part of the circular economy strategies and believe that in order to have a better transition, a combination of other strategies (i.e. Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle, and Recover), as shown in the Figure 2.4, are required. Although these strategies are mainly used in the production chain, many of the organizations, especially public organizations in our case, can benefit from most of these 9Rs. As an example, they can consider repairing and reusing their properties such as chairs inside the organization or refuse to use plastic cups and try using recyclable paper cups or even ceramic cups to reduce and eliminate the waste (Poortinga et al., 2019). All the explained information above thoroughly give a response to the RQ1.

5.2 Transition to circular economy

The transition to circular economy is not so easy and may take a lot of time to achieve the circularity strategies and the fruitful results of that (Potting et al., 2020; Cramer, 2020). In accordance with the literature reviewed earlier by Kirchherr et al. (2018) and many other researchers, shifting from a linear economy to a circular economy can bring along several challenges and barriers. To tackle these problems and implement a successful circular model, organizations should apply some principles and prerequisites. As BSI (2017) mentioned in their framework for implementing the principles of the circular economy, organizations should have system thinking capabilities, holistic view, and stewardship skills. Moreover, they should be continually innovative, create value and keep this value at the highest

utility level. It is also important for them to have transparency in their activities and be open to collaborating internally and externally with stakeholders.

In addition to principles and prerequisites discussed in the literature, the interview objects mentioned the importance of leaders and managers' acceptance and their willingness towards the adaptation of circular economy and their tendency to take risks and 'try, test, and fail'. However, Cramer (2020) addressed another aspect of service provider organizations and their important role to make their clients and customers aware of the benefits of circular economy practices and encourage them to make more sustainable decisions. These activities are also in accordance with the European Green Deal to reach a climate-neutral circular economy and make Europe's economy more sustainable by 2050.

In contrary to all the differences between circular economy and sustainability reflected by Geissdoerfer et al. (2017), it can be argued that this research has found more connections and correlations between these two concepts in a way that reducing the resource extractions and eliminating waste production can, directly and indirectly, have an effect on the 17 sustainability development goals introduced by the United Nations (2015).

Furthermore, stated by Taival (2020), based on the size of the organizations and circular maturity level, different strategies and models can be used in the transition from a linear economy to circular economy. Table 5.1 is a summary of the possible areas that organizations can mostly practice circular economy strategies, taken from the reviewed literature and results from the conducted interviews.

According to the findings, public organizations other than being a purchaser and user of products and services inside their organizations, engage in developing policies and have other social responsibilities towards the citizens. As Taival (2020) argued, a lot of people inside or outside the organizations do not have enough information about circular economy. These types of organizations have the responsibility to make the citizens or their customers aware of circular economy. Creating awareness and knowledge requires collaboration and communication with internal and external stakeholders (Het Groene Brein, 2017; Lag-Brotons et al.,

Table 5.1: Internal and external practices in organizations to achieve circular economy (own production)

Internal activities	External services
Product as a service (Leasing)	Providing knowledge/making awareness
Sharing platform	Developing policies and strategies
Resource/energy efficiency models	Collaborating with stakeholders
Waste management/recycling systems	Creating circular solutions

2020). Moreover, policy-maker organizations can have a considerable positive impact on citizens' individual behavior and well-being by developing circular strategies (Klein et al., 2020). Based on Sauve et al. (2016), a lot of these activities also correspond to the social and environmental aspects of sustainability and seeks further objectives than focusing only on the economic aspect and generating profit.

As referred by Goedkoop (2016); Aubertin (2019) and other interview objects, leasing internal properties such as furniture, electronic equipment, lighting system, and any other product that can be rented out instead of buying, are under the category of Product-as-a-service circular business model. In addition, this model can at the same time contribute to environmental sustainability by extracting fewer resources and producing less waste, as well as social sustainability by creating job opportunities for people (Sakao & Webster, 2020). Moreover, sharing services such as car-sharing or sharing platforms for buying and selling the reused product, for example, building materials or even leftovers of the food in organizations' canteen can move organizations towards a more circular economy (Accenture, 2020).

Furthermore, as Sharma et al. (2020) argued, when it comes to the internal processes and activities inside the organizations, implementing good and innovative waste management or resource and energy system becomes very significant. On the other hand, since public organizations are mostly service providers rather than product manufacturers, not all the circular business models are applicable in these

types of organizations. This research has found the *Product as a service* and *Sharing platforms* models, introduced by Accenture (2020), as two most beneficial models for organizations' transition to circular economy. This part and the discussed aspects comprehensively answered the RQ2.

5.3 Barriers and challenges of CE implementation

The last sub-research question in this thesis was about the challenges and barriers regarding circular economy implementation in organizations. To answer this question, different articles and materials were analyzed. Using the earlier literature reviewed in the theory section and the framework illustrated in the table 2.3, the following table (5.2) will summarize the results from the conducted interviews linked to the numerous identified challenges from the literature. As mentioned earlier these barriers and challenges were divided into five categories, namely: Financial and economic, Cultural and behavioral, Organizational, Technological, and Policy and regulatory barriers. Many of these challenges are interrelated and overcoming one challenge can sometimes affect other barriers.

According to the table, among all these challenges, the most important barriers mentioned by interview objects can be grouped as the following:

- Lack of information and knowledge
- Privacy and security problems
- Lack of resources
- Lack of collaboration
- Lack of standardization

Lack of information and knowledge as an organizational barrier and *privacy and security problems* connected to technological barriers turned out as the most important challenges linked to the circular economy implementation and using digitalization in organizations as mentioned by seven interview objects for each item. *lack of resources* and *lack of collaboration* are two other barriers that also belong to the organizational category of challenges. This highlights the importance of organizational changes and preparations before transitioning to circular economy.

Table 5.2: Summary of the interview results linked to the identified barriers from the literature (own production)

Category	Identified barriers	Interview objects												
		1	2	3	4	5	6	7	8	9	10	11	12	13
Financial & economic	Existing economic models			*			*	*						*
	Lack of investment or limited funding	*			*				*	*			*	
	Lack of financial support	*			*	*	*		*					
	Financial Risks		*	*	*							*		
	Lack of willingness to pay	*				*		*	*					
Cultural & behavioural	Lack of incentives			*				*					*	
	Lack of cooperation and trust				*				*	*				
	Lack of willingness to collaborate			*	*	*			*					
	Resistance to change	*	*					*		*	*			
	Environmental culture			*	*				*			*		*
	Conflicts with existing business culture				*			*			*	*		
Organizational	Lack of information and knowledge	*				*	*	*		*	*	*		
	Lack of expertise	*		*	*									
	Lack of resources		*			*				*	*	*		*
	Lack of collaboration		*		*		*		*			*		*
	Existing linear targets			*			*							
	Organizational hierarchy	*												
	Lack of management support			*				*	*		*			
Technological	Privacy and security problems				*		*	*		*	*		*	*
	New and complex technologies	*		*								*		
	Digital infrastructure				*		*		*				*	*
	Lack of proper technology													
	Lack of digital and technical skills				*		*	*					*	*
Policy & regulatory	Legislations		*	*	*				*					*
	Lack of standardization	*		*				*			*	*		*
	Conflicting regulations						*			*		*		
	Lack of supporting policies			*				*	*		*			
	Laws and regulations against CE				*		*						*	
	Lack of government support					*			*	*				
	Complex and overlapping regulations	*		*				*						

However, this result does not necessarily mean that other barriers are not as important as other ones. According to Kirchherr et al. (2018) and Taival (2020), the importance and risks of each challenge can vary according to the size, type and circular economy maturity level of the organizations. For example, for some hierarchical organizations, managerial support can be a major challenge while in another small organization financial risks and constraints can become the main obstacle (Tura et al., 2019; Pheifer, 2017).

Moreover, as it is shown in the table, not all the interview objects covered the whole five categories of challenges. For example, interview objects 2 and 5 did not mention any of the barriers connected to technological challenges. But this does not mean that they are not important. This could happen due to the interview objects' field of expertise or the verbal interaction constraints in the interview to recall all the related answers at that moment.

In addition, the importance of technological barriers, especially in accordance with the topic of this thesis, should not be underestimated. As argued by Kirchherr et al. (2017), technology plays an important role in the transition to circular economy and organizations should overcome the barriers related to technology before implementing circular economy. They should provide good digital infrastructure, obtain good digital and technical knowledge and skills, and consider data security and privacy issue. Both the Table 5.2, and information discussed, give an answer to RQ3 in a concise way.

5.4 Digital circular economy

As mentioned earlier, there are a lot of challenges and barriers regarding the transition to circular economy, and digitalization can help to overcome and addressing many of them. However, we can not expect digitalization as a silver bullet that can tackle all these challenges immediately (Hedberg et al., 2019). According to Antikainen et al. (2018), digitalization supports circular economy implementation by enhancing resource efficiency, narrowing, slowing, or closing the material loops, and improving waste management through using different technologies.

On the other hand, Klein et al. (2020) argued that one of the problems that organizations face is that they do not usually have an overview of their properties or products condition, location, availability, and other necessary data to be able to estimate the time, cost, and resources required for this transition. Digitalization is a key enabler of this process by using new digital technologies such as Sensors, Tags, IoT, Big Data, AI, Blockchain, etc (Ellen MacArthur Foundation, 2019a).

Based on the literature reviewed and the results of the interviews, digital technologies were divided into three architecture groups (data collection, data integration, and data analysis). The blockchain technology and AI can improve transparency and traceability in the product lifecycle and IoT technology can collect the data from smart sensors and allow control and optimization of products throughout their lifecycle. Moreover, accessibility to the real-time data about product location and condition, enables possibility for maintenance, remanufacturing, reusing, or recycling the products (Antikainen et al., 2018; Gligoric et al., 2019).

Furthermore, as mentioned earlier, one of the key approaches in organizations' transition to circular economy is leasing, renting, and sharing products instead of buying them in the first stage and disposing of them afterward. Digital platforms and online marketplaces are a good tool for buying, selling, and exchanging goods and products. Moreover, by the help of digitalization, organizations can build efficient communication and collaboration internally and also externally with their stakeholders. Due to the Covid-19 pandemic and lock downs in different countries, digital tools and technologies have turned to a key channel for communication inside and between organization.

Figure 5.1 illustrates a summary of the identified digital technologies discussed in the literature and interviews, as well as the areas in circular economy that can be affected by these technologies. Finally, the possible circular practices in organizations by the help of digital tools and technologies are presented in the last column of the figure.

Despite the fact that most of the literature reviewed (e.g. Vaisanen (2020); Antikainen et al. (2018); Hedberg et al. (2019); Bressanelli et al. (2018); Kristoffersen

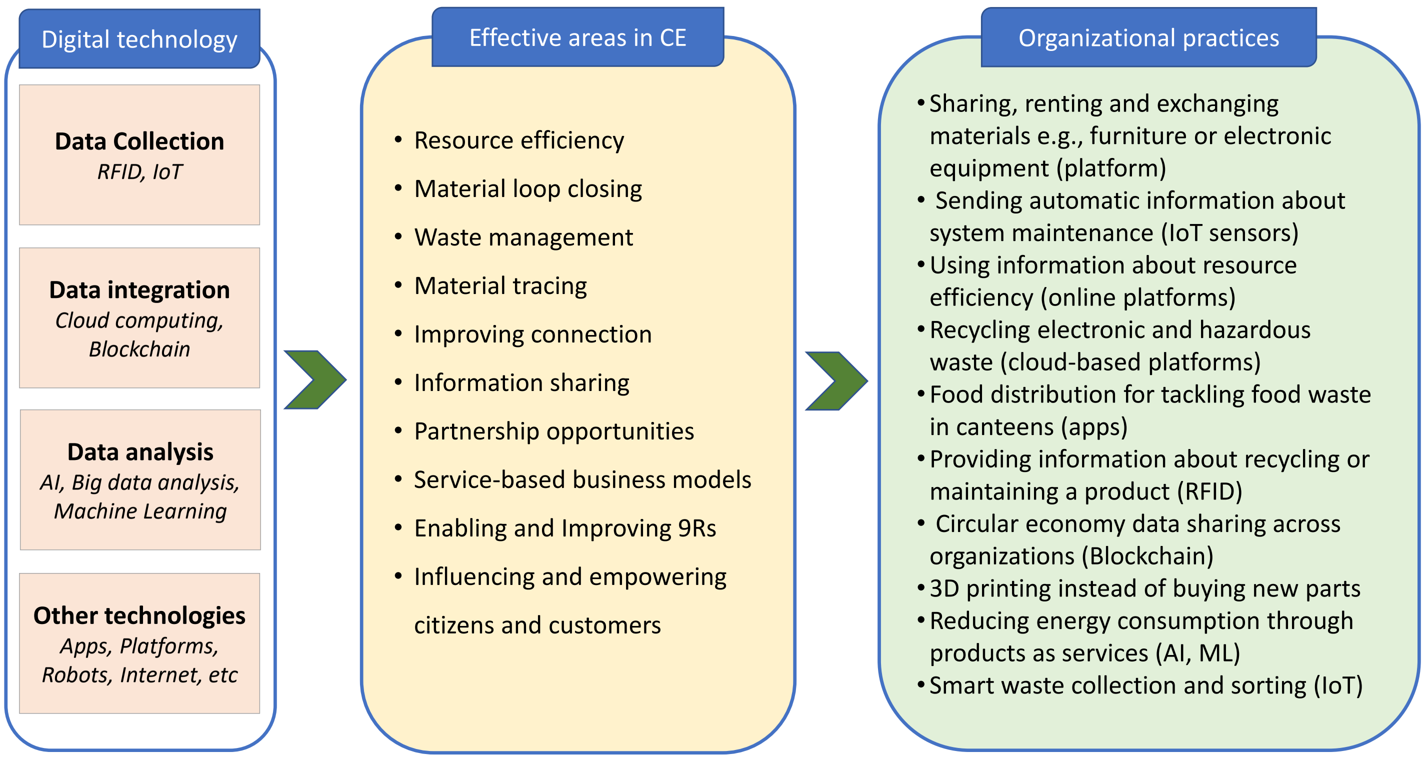

Figure 5.1: How digital technologies can support circular economy in organizations, based on reviewed literature and interview results (own production)

et al. (2020a), consider digitalization or these advanced tools and technologies as a catalyst for circular economy, most of the interview objects did not have enough information about how digitalization can support the transition to circular economy. They all admitted that digitalization can play an important role, but they mostly mentioned the very simple forms of technology, for instance, apps or digital platforms. This also corresponds to the fact mentioned by Okorie et al. (2018); Bressanelli et al. (2018); Pagoropoulos et al. (2017) that digitalization in circular economy is an emerging research field and there has been little understanding and limited researches about this concept.

Last but not least, it is important to mention that digitalization itself can not solve all the challenges related to circular economy implementation in organizations. As mentioned before, there are many other factors that organizations should follow for having a sustainable transition to circular economy. In addition, highlighted by most of the interview objects, since circular economy is still an merging concept in organizations, many of them are skeptical about the financial benefits that it can bring to their organization. Therefore due to the complexity and high cost of the new digital tools and technologies, they find it too risky to invest money in something that has not been practiced much before.

The information provided in this part summed up the required answer for the main research question in this master thesis.

Chapter 6

Conclusion

The concept of circular economy has gained a lot of attention in recent years. Businesses and organizations are trying to embrace circular economy strategies to shift from their linear "take, make, dispose" approach to a more circular one and digitalization is being considered as a potential tool to leverage this transition. However, there has been little attention set on the digitalization and circular economy concepts in organizations. This gap led to the formation of this master thesis with the aim of finding how digitalization can support organizations in their transition to circular economy.

Based on the literature reviewed, circular economy encompasses several strategies, other than just recycling. Among these ten strategies (known as 9Rs), organizations, in our case public organizations, can practice some of them inside the organization and may need to collaborate externally with some other stakeholders to successfully implement all these strategies.

However, transition to circular economy is not an easy process for organizations and they may encounter many challenges. In order to prepare for this transition, organizations can follow the frameworks introduced by British Standard as a prerequisite before implementing circular economy principles. Moreover, from the

literature reviewed and the results form the interview objects since public organizations are mainly service providers and not a manufacturer, there are limited internal and external areas that these organizations can practice circular economy. The most important ones include leasing, renting, and sharing properties and products and using smart resource and waste management models. Nevertheless, the role of some organizations as policy developers and knowledge providers about circular economy should not be underestimated as well.

Despite all the benefits that transition to circular economy can bring to organizations, several financial, cultural, organizational, technological, and policy barriers and challenges have been identified that can directly or indirectly affect this process. As concluded from the conducted interviews, lack of information and knowledge is one of the most important challenges that organizations are facing. This was also an issue highlighted in much of the literature reviewed in this thesis.

Considering all these challenges and barriers, digitalization and digital technologies such as IoT, AI, Blockchain, online platforms, and many other technologies can help organizations to collect, analyses and share data in order to achieve transparency in their processes, develop communication and collaboration, engage in sharing or leasing practices, and better implement resource and waste management system which will ultimately result in closing, slowing, and narrowing down the material loop and reducing or eliminating waste.

Based on this study, and considering the main research question, it can be concluded that digitalization is an ideal enabler for circular economy, however, it mainly supports the end-of-pipe solutions with more focus on recycling after the product use in organizations. On the other hand, digitalization does not always mean buying complex technologies like AI or IoT. Sometimes simple tools such as platforms or apps can support the transition process in the best way. Most of the time the technology is there but the organizations have to learn how to optimize them in the best way. In short, they need to learn how to walk before they can run. Most importantly the organizations need to first change their mindset and accept the circular economy implementation in their organization before utilizing any type of complex digital solutions.

6.1 Future work

It has been indicated from the results that the intersection of digitalization and circular economy is a growing research field that is in an early stage and is still lacking thorough research and factual case studies. Therefore, the efforts initiated in this master thesis can be further investigated to find more possible connections between circular economy and digitalization. Additionally, the main focus of this thesis was on public and service provider organizations, while different types of businesses and industries and the role of digitalization in their transition process would be interesting to study. Lastly, in order to get a better insight and more tangible results of a real transition process to circular economy, it is suggested that a public organization that has either implemented circular economy strategies or is in the process of shifting from linear economy be studied as a case.

References

Accenture. (2020). *Circular advantage: Innovative business models and technologies to create value in a world without limits to growth.* https://www.accenture.com/t20150523T053139__w__/us-en/_acnmedia/Accenture/Conversion-Assets/DotCom/Documents/Global/PDF/Strategy_6/Accenture-Circular-Advantage-Innovative-Business-Models-Technologies-Value-Growth.pdf. (Accessed: 2021-04-11)

Agyemang, M., Kusi-Sarpong, S., Khan, S., Mani, V., Rehman, S. T., & Kusi-Sarpong, H. (2019). Drivers and barriers to circular economy implementation: an explorative study in pakistan's automobile industry. *Management Decision*, *57*, 971-994. Retrieved from https://doi.org/10.1108/MD-11-2018-1178

Antikainen, M., Uusitalo, T., & Kivikyto-Reponen, P. (2018). Digitalisation as an enabler of circular economy. *Procedia CIRP*, *73*, 45-49. Retrieved from https://doi.org/10.1016/j.procir.2018.04.027 (10th CIRP Conference on Industrial Product-Service Systems, IPS2 2018, 29-31 May 2018, Linkoping, Sweden)

Ardolino, M., Rapaccini, M., Saccani, N., Gaiardelli, P., Crespi, G., & Ruggeri, C. (2018). The role of digital technologies for the service transformation of industrial companies. *International Journal of Production Research*, *56*(6), 2116-2132. Retrieved from https://doi.org/10.1080/00207543.2017.1324224

Arnold, R. D., & Wade, J. P. (2015). A definition of systems thinking: A systems approach. *Procedia Computer Science*, *44*, 669-678. Retrieved from https://doi.org/10.1016/j.procs.2015.03.050 (2015 Conference on Systems Engineering Research)

Aubertin, C. (2019). *From product to product-as-a-service.* https://medium.com/swlh/from-product-to-product-as-a-service-37baed471cd6. (Accessed: 2021-04-11)

Bartunekl, J. M. (1993). Scholarly dialogues and participatory action research. *Human Relations*, *46*(10), 1221-1233. Retrieved from https://doi.org/10.1177/001872679304601004

Bloomberg, J. (2018). Digitization, digitalization, and digital transformation: confuse them at your peril. *Forbes*, *28*, 6. Retrieved from https://moniquebabin.com/wp-content/uploads/articulate_uploads/Going-Digital4/story_content/external_files/Digitization%20Digitalization%20and%20Digital%20Transformation%20Confusion.pdf

Bocken, N. M. P., de Pauw, I., Bakker, C., & van der Grinten, B. (2016). Product design and business model strategies for a circular economy. *Journal of Industrial and Production Engineering*, *33*(5), 308-320. Retrieved from https://doi.org/10.1080/21681015.2016.1172124

Boulding, K. E. (1966). *The economics of the coming spaceship earth*.

Brennen, J. S., & Kreiss, D. (2016). Digitalization. In *The international encyclopedia of communication theory and philosophy* (p. 1-11). American Cancer Society. Retrieved from https://doi.org/10.1002/9781118766804.wbiect111

Bressanelli, G., Adrodegari, F., Perona, M., & Saccani, N. (2018). The role of digital technologies to overcome circular economy challenges in pss business models: an exploratory case study. *Procedia CIRP*, *73*, 216-221. Retrieved from https://doi.org/10.1016/j.procir.2018.03.322

Bryman, A., & Bell, E. (2003). *Business research methods*. New York : Oxford University Press.

BSI. (2017). *Bs 8001:2017 framework for implementing the principles of the circular economy in organizations.* https://edisciplinas.usp.br/pluginfile.php/5789671/mod_folder/content/0/BS8001_2017_Framework.pdf?forcedownload=1. (Accessed: 2021-02-24)

Charter, M., & Gray, C. (2008). Remanufacturing and product design. *International Journal of Product Development*, *6*(3-4), 375–392. Retrieved from https://doi.org/10.1504/IJPD.2008.020406

Circle Economy. (2018). *Linear risks: How business as usual is a threat to companies and investors.* https://docs.wbcsd.org/2018/06/linear_risk_report.pdf. (Accessed: 2021-02-22)

Circularity Gap Report. (2020). *Circularity gap report.* https://assets.website-files.com/5e185aa4d27bcf348400ed82/5e26ead616b6d1d157ff4293_20200120%20-%20CGR%20Global%20-%20Report%20web%20single%20page%20-%20210x297mm%20-%20compressed.pdf. (Accessed: 2021-02-22)

Council for the Environment and Infrastructure (Rli). (2015). *Circular economy: from with to practice.* https://en.rli.nl/sites/default/files/advice_rli_circular_economy_interactive_def.pdf. (Accessed: 2021-03-10)

Cramer, J. M. (2020). Implementing the circular economy in the amsterdam metropolitan area: The interplay between market actors mediated by transition brokers. *Business Strategy and the Environment*, *29*(6), 2857-2870. Retrieved from https://doi.org/10.1002/bse.2548

Creswell, J. W. (2014). *Research design: Qualitative, quantitative and mixed methods approaches (4th ed.)*. Thousand Oaks, CA: Sage.

Deloitte. (2020). *Study for a national strategy for circular economy.* https://www.regjeringen.no/contentassets/7ca1a81f57cc4611a193570e80c4dafd/deloitte_study-on-circular-economy_short-summary.pdf. (Accessed: 2021-03-08)

Demestichas, K., & Daskalakis, E. (2020). Information and communication technology solutions for the circular economy. *Sustainability*, *12*(18). Retrieved from https://doi.org/10.3390/su12187272

Denscombe, M. (2014). *The good research guide*. London: McGraw Hill.

Dindarian, A., & Chakravarthy, S. (2020). Chapter 7 traceability of electronic waste using blockchain technology. In *Electronic waste management (2)* (p. 188-212). The Royal Society of Chemistry. Retrieved from https://doi.org/10.1039/9781788018784-00188

EEA. (2014). *Resource-efficient green economy and eu policies.* https://www.eea.europa.eu/publications/resourceefficient-green-economy-and-eu. (Accessed: 2021-03-08)

EEA. (2016). *Circular economy in europe developing the knowledge base.* https://www.eea.europa.eu/publications/circular-economy-in-europe. (Accessed: 2021-03-08)

Eiroa, B. S., Fernandez, E., Martinez, G. M., & Onate, D. S. (2019). Operational principles of circular economy for sustainable development: Linking theory and practice. *Journal of Cleaner Production*, *214*, 952-961. Retrieved from https://doi.org/10.1016/j.jclepro.2018.12.271

Eisenriegler, S. (2020). *The circular economy in the european union: An interim review*. Springer International Publishing.

Ekern, E. M. (2020). *Is the eus new circular economy action plan up to the task?* https://www.jus.uio.no/english/research/areas/companies/blog/sustainable-market-actors-for-responsible-trade/eus-new-circular-economy-action-plan.html. (Accessed: 2021-03-01)

Ellen MacArthur Foundation. (2013a). *Towards the circular economy economic and business rationale for an accelerated transition.* https://www.ellenmacarthurfoundation.org/assets/downloads/publications/Ellen-MacArthur-Foundation-Towards-the-Circular-Economy-vol.1.pdf. (Accessed: 2021-02-24)

Ellen MacArthur Foundation. (2013b). *Towards the circular economy vol 2: opportunities for the consumer goods sector.* https://www.ellenmacarthurfoundation.org/assets/downloads/publications/TCE_Report-2013.pdf. (Accessed: 2021-03-08)

Ellen MacArthur Foundation. (2019a). *Artificial intelligence and the circular economy.* https://www.ellenmacarthurfoundation.org/assets/downloads/Artificial-intelligence-and-the-circular-economy.pdf. (Accessed: 2021-03-09)

Ellen MacArthur Foundation. (2019b). *Completing the picture: how the circular economy tackles climate change.* https://www.ellenmacarthurfoundation.org/assets/downloads/Completing_The_Picture_How_The_Circular_Economy_Tackles_Climate_Change_V3_26_September.pdf. (Accessed: 2021-03-31)

Ellen MacArthur Foundation. (2020). *The eu's circular economy action plan.* https://www.ellenmacarthurfoundation.org/assets/downloads/EU-Case-Study-june2020-EN.pdf. (Accessed: 2021-02-23)

European Commission. (2015). *Communication from the commission to the european parliament, the council, the european economic and social committee and the committee of the regions. closing the loop – an eu action plan for the circular economy.* https://ec.europa.eu/transparency/regdoc/rep/1/2015/EN/1-2015-614-EN-F1-1.PDF. (Accessed: 2021-02-26)

European Commission. (2016). *Ecodesign working plan 2016-2019.* https://ec.europa.eu/energy/sites/ener/files/documents/com_2016_773.en_.pdf. (Accessed: 2021-03-01)

European Commission. (2017). *European circular economy stakeholder platform.* https://www.eesc.europa.eu/sites/default/files/files/qe-04-18-972-en-n.pdf. (Accessed: 2021-02-26)

European Commission. (2018). *Measuring progress towards circular economy in the european union – key indicators for a monitoring framework.* https://ec.europa.eu/environment/circular-economy/pdf/monitoring-framework_staff-working-document.pdf. (Accessed: 2021-03-01)

European Commission. (2019). *The european green deal.* https://ec.europa.eu/info/sites/info/files/european-green-deal-communication_en.pdf. (Accessed: 2021-03-01)

European Commission. (2020). *The new circular economy action plan for a cleaner and more competitive europe.* https://eur-lex.europa.eu/resource.html?uri=cellar:9903b325-6388-11ea-b735-01aa75ed71a1.0017.02/DOC_1&format=PDF. (Accessed: 2021-03-01)

FAO. (2020). *Impacts of covid-19 on food security and nutrition: developing effective policy responses to address the hunger and malnutrition pandemic.* http://www.fao.org/3/cb1000en/cb1000en.pdf. (Accessed: 2021-03-31)

Ferguson, E. L. (2010). Precise sound source localisation of dolphin biosonar pulse transmissions. In *Oceans'10 ieee sydney* (p. 1-8). Retrieved from https://doi.org/10.1109/OCEANSSYD.2010.5603893

Fink, A. (2019). *Conducting research literature reviews: From the internet to paper*. SAGE Publications. Retrieved from https://books.google.no/books?id=0z1_DwAAQBAJ

Frankenfield, J. (2021). *Artificial intelligence (ai).* https://www.investopedia.com/terms/a/artificial-intelligence-ai.asp#:~:text=Artificial%20intelligence%20(AI)%20refers%20to,as%20learning%20and%20problem%2Dsolving. (Accessed: 2021-03-29)

Gates, B. (2020). *Covid-19 is awful. climate change could be worse.* https://www.gatesnotes.com/Energy/Climate-and-COVID-19. (Accessed: 2021-03-31)

Geissdoerfer, M., Savaget, P., Bocken, N. M., & Hultink, E. J. (2017). The circular economy–a new sustainability paradigm? *Journal of Cleaner Production*, *143*, 757-768. Retrieved from https://doi.org/10.1016/j.jclepro.2016.12.048

GGKP. (2020). *Ggkp webinar - sustainability after covid-19: the medical waste response.* https://www.greengrowthknowledge.org/webinar/ggkp-webinar-sustainability-after-covid-19-medical-waste-response. (Accessed: 2021-03-31)

Ghisellini, P., & Ulgiati, S. (2020). Circular economy transition in italy. achievements, perspectives and constraints. *Journal of Cleaner Production*, *243*, 118360. Retrieved from https://doi.org/10.1016/j.jclepro.2019.118360

Gligoric, N., Krco, S., Hakola, L., Vehmas, K., De, S., Moessner, K., ... Kranenburg, R. (2019). Smarttags: Iot product passport for circular economy based on printed sensors and unique item-level identifiers. *Sensors*, *19*, 27. Retrieved from https://doi.org/10.3390/s19030586

Goedkoop, M. (2016). *Five ways to circular economy: Product as a service.* https://simapro.com/2016/five-ways-to-circular-economy-and-lca

-product-as-a-service/#:~:text=Introducing%20a%20product%2Das%2Da,have%20an%20environmental%20benefit%2C%20though. (Accessed: 2021-04-11)

Govindan, K., Soleimani, H., & Kannan, D. (2015). Reverse logistics and closed-loop supply chain: A comprehensive review to explore the future. *European Journal of Operational Research*, *240*, 603–626. Retrieved from https://doi.org/10.1016/j.ejor.2014.07.012

Green, B. N., Johnson, C. D., & Adams, A. (2006). Writing narrative literature reviews for peer-reviewed journals: secrets of the trade. *Journal of Chiropractic Medicine*, *5*(3), 101 - 117. Retrieved from https://doi.org/10.1016/S0899-3467(07)60142-6

Gubbi, J., Buyya, R., Marusic, S., & Palaniswami, M. (2013). Internet of things (iot): A vision, architectural elements, and future directions. *Future Generation Computer Systems*, *29*(7), 1645-1660. Retrieved from https://doi.org/10.1016/j.future.2013.01.010 (Including Special sections: Cyber-enabled Distributed Computing for Ubiquitous Cloud and Network Services & Cloud Computing and Scientific Applications — Big Data, Scalable Analytics, and Beyond)

Hasa. (2017). *Difference between research methods and research design.* https://pediaa.com/difference-between-research-methods-and-research-design/. (Accessed: 2021-04-12)

Hausberg, J. P., Liere-Netheler, K., Packmohr, S., Pakura, S., & Vogelsang, K. (2019). Research streams on digital transformation from a holistic business perspective: a systematic literature review and citation network analysis. *Journal of Business Economics*, *89*(8), 931-963. Retrieved from https://doi.org/10.1007/s11573-019-00956-z

Haywood, L., Wright, C., Godfrey, L., Armiento, G., Inglesi-Lotz, R., Lyne, K., & Schwerdtle, P. (2019). Circular economy and environmental health in low- and middle-income countries. *Globalization and Health*, *15*. Retrieved from https://doi.org/10.1186/s12992-019-0501-y

Hedberg, A., Sipka, S., & Bjerkem, J. (2019). *Creating a digital roadmap for a circular economy.* https://www.climate-kic.org/wp-content/uploads/2019/07/DRCE.pdf. (Accessed: 2021-04-01)

Het Groene Brein. (2017). *What is collaboration in the value chain?* https://kenniskaarten.hetgroenebrein.nl/en/knowledge-map-circular-economy/ce-collaboration-value-chain/. (Accessed: 2021-04-04)

Homrich, A. S., Galvao, G., Abadia, L. G., & Carvalho, M. M. (2018). The circular economy umbrella: Trends and gaps on integrating pathways. *Journal of Cleaner Production*, *175*, 525-543. Retrieved from https://doi.org/10.1016/j.jclepro.2017.11.064

Hoosain, M. S., Paul, B. S., & Ramakrishna, S. (2020). The impact of 4ir digital technologies and circular thinking on the united nations sustainable development goals. *Sustainability*, *12*(23). Retrieved from https://doi.org/10.3390/su122310143

Ibn-Mohammed, T., Mustapha, K., Godsell, J., Adamu, Z., Babatunde, K., Akintade, D., ... Koh, S. (2021). A critical analysis of the impacts of covid-19 on the global economy and ecosystems and opportunities for circular economy strategies. *Resources, Conservation and Recycling*, *164*, 105-169. Retrieved from https://doi.org/10.1016/j.resconrec.2020.105169

Jahren, S., Norstebo, V. S., Simas, M. S., & Wiebe, K. S. (2020). *Study of the potential for reduced greenhouse gas emissions and the transition to a low-emission society through circular economy strategies.* www.sintef.no. (Accessed: 2021-02-23)

Jawahir, I., & Bradley, R. (2016). Technological elements of circular economy and the principles of 6r-based closed-loop material flow in sustainable manufacturing. *Procedia CIRP*, *40*, 103-108. Retrieved from https://doi.org/10.1016/j.procir.2016.01.067 (13th Global Conference on Sustainable Manufacturing – Decoupling Growth from Resource Use)

Jensen, J. (2018). *Narrowing, slowing and closing the resource loops: circular economy in the wind industry* (Unpublished doctoral dissertation). (PhD supervisor: Professor Arne Remmen, Aalborg University Assistant PhD supervisor: Professor Han Brezet, Aalborg University)

Jose, R., Panigrahi, S., Patil, R., Fernando, Y., & Ramakrishna, S. (2020). Artificial intelligence-driven circular economy as a key enabler for sustainable energy management. *Materials Circular Economy*, *2*, 8. Retrieved from https://doi.org/10.1007/s42824-020-00009-9

Jovanovic, M., Dlacic, J., & Okanovic, M. (2018). Digitalization and society's sustainable development - measures and implications. *Zbornik Radova Ekonomskog Fakulteta u Rijeci / Proceedings of Rijeka School of Economics*, *36*, 905-928. Retrieved from https://doi.org/10.18045/zbefri.2018.2.905

Keeble, B. R. (1988). The brundtland report: Our common future. *Medicine and War*, *4*(1), 17-25. Retrieved from https://doi.org/10.1080/07488008808408783

Khan, S. A. R., Yu, Z., Sarwat, S., Godil, D. I., Amin, S., & Shujaat, S. (2021). The role of block chain technology in circular economy practices to improve organisational performance. *International Journal of Logistics Research and Applications*, *0*(0), 1-18. Retrieved from https://doi.org/10.1080/13675567.2021.1872512

Kirchherr, J., Piscicelli, L., Bour, R., Kostense-Smit, E., Muller, J., Huibrechtse-Truijens, A., & Hekkert, M. (2018). Barriers to the circular economy: Evidence from the european union (eu). *Ecological Economics*, *150*, 264-272. Retrieved from https://doi.org/10.1016/j.ecolecon.2018.04.028

Kirchherr, J., Reike, D., & Hekkert, M. (2017). Conceptualizing the circular economy: An analysis of 114 definitions. *Resources, Conservation and Recycling*, *127*, 221-232. Retrieved from https://doi.org/10.1016/j.resconrec.2017.09.005

Klein, N., Ramos, T., & Deutz, P. (2020). Circular economy practices and strategies in public sector organizations: An integrative review. *Sustainability*, *12*, 4181. Retrieved from https://doi.org/10.3390/su12104181

Korhonen, J., Nuur, C., Feldmann, A., & Birkie, S. E. (2018). Circular economy as an essentially contested concept. *Journal of Cleaner Production*, *175*, 544-552. Retrieved from https://doi.org/10.1016/j.jclepro.2017.12.111

Kovacic, Z., Strand, R., & Volker, T. (2019). *The circular economy in europe: Critical perspectives on policies and imaginaries*. Routledge. Retrieved from https://doi.org/10.4324/9780429061028

Kristoffersen, E., Blomsma, F., Mikalef, P., & Li, J. (2020a). The smart circular economy: A digital-enabled circular strategies framework for manufacturing companies. *Journal of Business Research*, *120*, 241-261. Retrieved from https://doi.org/10.1016/j.jbusres.2020.07.044

Kristoffersen, E., Li, Z., Li, J., Jensen, T., Pigosso, D., & McAloone, T. (2020b). *Smart circular economy: Circit workbook 4*. Technical University of Denmark. Retrieved from https://backend.orbit.dtu.dk/ws/portalfiles/portal/210455530/WB4_CIRCit_double.pdf

Kumar, R. (2014). *Research methodology: A step-by-step guide for beginners*. SAGE Publications Ltd., London.

Lag-Brotons, A. J., Velenturf, A. P. M., Crane, R., Head, I. M., Purnell, P., & Semple, K. T. (2020). Editorial: Resource recovery from waste. *Frontiers in Environmental Science*, *8*, 35. Retrieved from https://doi.org/10.3389/fenvs.2020.00035

Lee, G. (2019). *Extending product life to build a circular economy.* https://www.greenbiz.com/article/extending-product-life-build-circular-economy#:~:text=%22Product%20life%20extension%22%20is%20a,%22utilization%22%20rate%20and%20duration. (Accessed: 2021-04-11)

li, J., Tao, F., Cheng, Y., & Zhao, L. (2015). Big data in product lifecycle management. *The International Journal of Advanced Manufacturing Technology*, *81*. Retrieved from https://doi.org/10.1007/s00170-015-7151-x

Matova, H., kaputa, V., & Triznova, M. (2019). Responsible consumer in the context of circular economy. *12th International Scientific Conference WoodEMA Varna, Bulgaria*, 69-74. Retrieved from http://www.woodema.org/conferences/2019_Varna_presentations/205_Kaputa.pdf

Moreno, M., & Charnley, F. (2016). Can re-distributed manufacturing and digital intelligence enable a regenerative economy? an integrative literature review..

Morseletto, P. (2020). Targets for a circular economy. *Resources, Conservation and Recycling*, *153*, 104553. Retrieved from https://doi.org/10.1016/j.resconrec.2019.104553

Mouazan, E. (2016). *Understanding circular business models drivers, obstacles and conditions towards a successful transition* (Unpublished master's thesis).

Mulvey, R. (1976). *closed-loop economy*.

Muro, M., Liu, S., Whiton, J., & Kulkarni, S. (2017). *Digitalization and the american workforce.* https://www.brookings.edu/research/digitalization-and-the-american-workforce/. (Accessed: 2020-10-24)

Murray, A., Skene, K., & Haynes, K. (2017). The Circular Economy: An Interdisciplinary Exploration of the Concept and Application in a Global Context. *Journal of Business Ethics*, *140*(3), 369-380. Retrieved from https://doi.org/10.1007/s10551-015-2693-2

Naidoo, R., & Fisher, B. (2020). *Reset sustainable development goals for a pandemic world.* https://www.nature.com/articles/d41586-020-01999-x. Nature Publishing Group. (Accessed: 2021-03-31)

Niero, M., & Rivera, X. C. S. (2018). The role of life cycle sustainability assessment in the implementation of circular economy principles in organizations. *Procedia CIRP*, *69*, 793-798. Retrieved from https://doi.org/10.1016/j.procir.2017.11.022

Nwankpa, J., & Roumani, Y. (2016). It capability and digital transformation: A firm performance perspective. In *Proceedings of the thirty seventh international conference on information systems, dublin.*

OECD. (2020). *Covid-19 and the low-carbon transition: Impacts and possible policy responses.* http://www.oecd.org/coronavirus/policy-responses/covid-19-and-the-low-carbon-transition-impacts-and-possible-policy-responses-749738fc/. (Accessed: 2021-03-31)

Okorie, O., Salonitis, K., Charnley, F., Turner, C., Moreno, M., & Tiwari, A. (2018). Digitisation and the circular economy: A review of current research and future trends. *Energies*, *11*, 3009. doi: 10.3390/en11113009

Ormazabal, M., Prieto-Sandoval, V., Puga-Leal, R., & Jaca, C. (2018). Circular economy in spanish smes: Challenges and opportunities. *Journal of Cleaner Production*, *185*, 157-167. Retrieved from https://doi.org/10.1016/j.jclepro.2018.03.031

Pagoropoulos, A., Pigosso, D. C., & McAloone, T. C. (2017). The emergent role of digital technologies in the circular economy: A review. *Procedia CIRP*, *64*, 19-24. Retrieved from https://doi.org/10.1016/j.procir.2017.02.047 (9th CIRP IPSS Conference: Circular Perspectives on PSS)

Pheifer, A. (2017). *Barriers and enablers to circular business models.* https://www.circulairondernemen.nl/uploads/4f4995c266e00bee8fdb8fb34fbc5c15.pdf. (Accessed: 2021-04-01)

Poortinga, W., Nash, N., & Hoeijmakers, L. (2019). Rapid review of charging for disposable coffee cups and other waste minimisation measure..

Potting, J., Hanemaaijer, A., Delahaye, R., Hoekstra, R., Ganzevles, J., & Lijzen, J. (2020). *Circular economy: what we want to know and can measure.* https://www.pbl.nl/sites/default/files/downloads/pbl-2018-circular-economy-what-we-want-to-know-and-can-measure-3217.pdf. (Accessed: 2021-02-23)

Potting, J., Hekkert, M., Worrell, E., & Hanemaaijer, A. (2017). *Circular economy: measuring innovation in the product chain* (No. 2544). PBL Publishers.

Preston, F. (2012). *A global redesign? shaping the circular economy.* https://www.chathamhouse.org/sites/default/files/public/Research/Energy%2C%20Environment%20and%20Development/bp0312_preston.pdf. (Accessed: 2021-03-08)

Purcell, W. (2019). *The importance of innovation in business.* https://www.northeastern.edu/graduate/blog/importance-of-innovation/#:~:text=Innovation%2C%20as%20a%20concept%2C%20refers,that%20a%20company%20might%20pursue. (Accessed: 2021-04-04)

PWC. (2018). *Closing the loop – the circular economy, what it means and what it can do for you.* https://www.pwc.com/hu/en/kiadvanyok/assets/pdf/Closing-the-loop-the-circular-economy.pdf. (Accessed: 2021-03-31)

Rahim, F. N. K., & Rahim, K. K. (2018). *Shift towards circular economy in technical industries with the help of the product information system & standardization* (Unpublished master's thesis).

Raikwar, M., Gligoroski, D., & Kralevska, K. (2019). Sok of used cryptography in blockchain. *IEEE Access*, *7*, 148550-148575. Retrieved from https://doi.org/10.1109/ACCESS.2019.2946983

Rajala, R., Hakanen, E., Mattila, J., Seppala, T., & Westerlund, M. (2018). How do intelligent goods shape closed-loop systems? *California Management Review*, *60*(3), 20-44. Retrieved from https://doi.org/10.1177/0008125618759685

Ritzen, S., & Sandstrom, G. O. (2017). Barriers to the circular economy – integration of perspectives and domains. *Procedia CIRP*, *64*, 7-12. Retrieved from https://doi.org/10.1016/j.procir.2017.03.005 (9th CIRP IPSS Conference: Circular Perspectives on PSS)

Rizos, V., Behrens, A., Kafyeke, T., Hirschnitz-Garbers, M., & Ioannou, A. (2015). The circular economy: Barriers and opportunities for smes. , 26.

Rizos, V., Behrens, A., Van der Gaast, W., Hofman, E., Ioannou, A., Kafyeke, T., ... Topi, C. (2016). Implementation of circular economy business models by small and medium-sized enterprises (smes): Barriers and enablers. *Sustainability*, *8*(11). Retrieved from https://doi.org/10.3390/su8111212

Rizos, V., Tuokko, K., & Behrens, A. (2017). The circular economy: A review of definitions, processes and impacts. , 44.

Sakao, T., & Webster, K. (2020). *In a circular economy, product-as-a-service has social and environmental benefits.* https://www.greenbiz.com/article/circular-economy-product-service-has-social-and-environmental-benefits. (Accessed: 2021-04-11)

Sauve, S., Bernard, S., & Sloan, P. (2016). Environmental sciences, sustainable development and circular economy: Alternative concepts for trans-disciplinary research. *Environmental Development*, *17*, 48-56. Retrieved from https://doi.org/10.1016/j.envdev.2015.09.002

Savic, D. (2019). From digitization, through digitalization, to digital transformation. , *43/2019*, 36-39.

Schwab, K. (2017). *The fourth industrial revolution*. Crown. Retrieved from https://books.google.no/books?id=ST_FDAAAQBAJ

Schwanholz, J., & Leipold, S. (2020). Sharing for a circular economy? an analysis of digital sharing platforms principles and business models. *Journal of Cleaner Production*, *269*, 122327. Retrieved from https://doi.org/10.1016/j.jclepro.2020.122327

Seers, K. (2014). Qualitative systematic reviews: Their importance for our understanding of research relevant to pain. *British Journal of Pain*, *9*, 36-40. Retrieved from https://doi.org/10.1177/2049463714549777

Sharma, N. K., Govindan, K., Lai, K. K., Chen, W. K., & Kumar, V. (2020). The transition from linear economy to circular economy for sustainability among smes: A study on prospects, impediments, and prerequisites. *Business Strategy and the Environment*, *30*(4), 1803-1822. Retrieved from https://doi.org/10.1002/bse.2717

Sverko Grdic, Z., Krstinic Nizic, M., & Rudan, E. (2020). Circular economy concept in the context of economic development in eu countries. *Sustainability*, *12*(7). Retrieved from https://doi.org/10.3390/su12073060

Taival. (2020). *The circular maturity model.* https://uploads-ssl.webflow.com/5d146fbac4ad4282d99311c1/5fcdc94f2336959a1cb76989_Circular%20Maturity%20Model.pdf. (Accessed: 2021-04-07)

Tan, S. L. (2018). *Circular economy needs trust, transparency and traceability.* https://chemsec.org/circular-economy-needs-trust-transparency-and-traceability/#:~:text=When%20using%20end%2Dof%2Duse,the%20circular%20model%20economically%20viable. (Accessed: 2021-04-04)

Tranfield, D., Denyer, D., & Smart, P. (2003). Towards a methodology for developing evidence-informed management knowledge by means of systematic review. *British Journal of Management*, *14*(3), 207-222. Retrieved from https://doi.org/10.1111/1467-8551.00375

Tura, N., Hanski, J., Ahola, T., Stahle, M., Piiparinen, S., & Valkokari, P. (2019). Unlocking circular business: A framework of barriers and drivers. *Journal of Cleaner Production*, *212*, 90-98. Retrieved from https://doi.org/10.1016/j.jclepro.2018.11.202

United Nations. (2015). *Transforming our world: The 2030 agenda for sustainable development.* https://sustainabledevelopment.un.org/content/documents/21252030%20Agenda%20for%20Sustainable%20Development%20web.pdf. (Accessed: 2021-03-12)

United Nations. (2019). *World population prospects 2019.* https://population.un.org/wpp/Publications/Files/WPP2019_10KeyFindings.pdf. (Accessed: 2020-09-10)

Upadhayay, S., & Alqassimi, O. (2019). Transition from linear to circular economy. , *2*, 62-74. Retrieved from https://doi.org/10.47670/wuwijar201822OASU

Vaisanen, J.-M. (2020). *Enabling circular economy with digital solutions multiple-case study in finland* (Unpublished master's thesis).

van Eijk, F., & Acceleratio, M. D. (2016). *Barriers & drivers towards a circular economy.* https://www.circulairondernemen.nl/uploads/e00e8643951aef8adde612123e824493.pdf. (Accessed: 2021-04-02)

van Kruchten, S., & Eijk, F. V. (2020). *Circular economy & sdgs: How circular economy practices help to achieve the sustainable development goals.* https://circulareconomy.europa.eu/platform/sites/default/files/3228

_brochure_sdg_-_hch_cmyk_a4_portrait_-_0520-012.pdf. (Accessed: 2021-03-12)

Veolia. (2020). *Join the circular economy.* https://info.veolianorthamerica.com/join-the-circular-economy-ebook. (Accessed: 2021-04-11)

WBCSDa. (2017). *8 business cases for the circular economy.* https://docs.wbcsd.org/2017/07/8business_case_studies.pdf. (Accessed: 2021-02-22)

WBCSDb. (2019). *Circular economy indicators:proposed metrics for business, by business.* https://docs.wbcsd.org/2019/07/WBCSD_Circular_Transition_Indicators_Proposed_metrics_for_business_by_business.pdf. (Accessed: 2021-02-22)

WCED, U., et al. (1987). *Our common future.* Oxford University Press Oxford. Retrieved from https://sustainabledevelopment.un.org/content/documents/5987our-common-future.pdf

Winans, K., Kendall, A., & Deng, H. (2017). The history and current applications of the circular economy concept. *Renewable and Sustainable Energy Reviews*, *68*, 825-833. Retrieved from https://doi.org/10.1016/j.rser.2016.09.123

World Economic Forum. (2014). *Towards the circular economy: Accelerating the scale-up across global supply chains.* http://www3.weforum.org/docs/WEF_ENV_TowardsCircularEconomy_Report_2014.pdf. (Accessed: 2021-02-22)

World Economic Forum. (2016). *The new plastic economy: Rethinking the value of plastics.* http://www3.weforum.org/docs/WEF_The_New_Plastics_Economy.pdf. (Accessed: 2021-02-22)

WRAP. (n.d). *What is a circular economy?* https://wrap.org.uk/about-us/our-vision/wrap-and-circular-economy#:~:text=A%20circular%20economy%20is%20an,end%20of%20each%20service%20life. (Accessed: 2021-03-08)

Wuyts, W., Marin, J., Brusselaers, J., & Vrancken, K. (2020). Circular economy as a covid-19 cure? *Resources, Conservation and Recycling*, *162*, 105016. Retrieved from https://doi.org/10.1016/j.resconrec.2020.105016

Zhang, A., Venkatesh, V., Liu, Y., Wan, M., Qu, T., & Huisingh, D. (2019). Barriers to smart waste management for a circular economy in china. *Journal of Cleaner Production*, *240*, 118198. Retrieved from https://doi.org/10.1016/j.jclepro.2019.118198

Zhou, Z., Cai, Y., Xiao, Y., Chen, X., & Zeng, H. (2018). The optimization of reverse logistics cost based on value flow analysis – a case study on automobile recycling company in china. *Journal*

of Intelligent & Fuzzy Systems, *34*, 807-818. Retrieved from https://doi.org/10.3233/JIFS-169374

Zink, T., & Geyer, R. (2017). Circular economy rebound. *Journal of Industrial Ecology*, *21*(3), 593-602. Retrieved from https://doi.org/10.1111/jiec.12545