Aalto University
School of Engineering

Lauri Ruokonen

# Circular Economy and Property Development – Potential for Construction Client

Master's Thesis
Department of Built Environment
School of Engineering
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Supervisors: Professor Seppo Junnila
Advisors: M. Sc. (Tech) Ari-Pekka Lassila, D. Sc (Fil) Suvi Nenonen

**Aalto University**
**School of Engineering**

Aalto University, P.O. BOX 11000, 00076
AALTO
www.aalto.fi

**Abstract of master's thesis**

**Author** Lauri Ruokonen

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**Abstract**

Circular economy has been seen as a way to maintain the value of resources by keeping them in a circulation. The concept of circular economy comprises multiple schools of thoughts and it has been defined in various ways. Due to significant environmental impact caused by construction and real estate industry, the role of construction clients is undisputable in a transition towards circular economy.

This master's thesis aims to increase the understanding on the construction clients' possibilities to adapt circular economy practices in the property development, especially in campus facilities. Currently, the research regarding circular economy from construction client's perspective is scarce.

The research questions are answered by conducting the literature review and expert interviews for different stakeholders of the property development process. Literature review aims to provide a background for the research in order to understand how the principles of circular economy can be applied in the built environment and property development processes. The gained knowledge in the literature review will be deepened through seven thematic interviews with professionals of real estate and construction sector

The major challenges for the construction client in order to act more circular are the financial feasibility of development processes, uncertainties related to new materials and contractual issues. To tackle these challenges construction client should; (1) have an adequate knowledge on circular economy; (2) set a measurable criterion to assess the level of circularity; (3) facilitate collaboration between different stakeholders; (4) and finally, supervise the construction and demand detailed building information documentation.

Furthermore, this thesis recognized several needs for a further research. For example, the opportunities of digitalization in more detailed building information management should be researched. Moreover, the need for circular economy framework in the built environment was recognized.

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**Keywords** circular economy, property development, construction client

**Aalto-yliopisto**
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**Aalto-yliopisto, PL 11000, 00076 AALTO**
**www.aalto.fi**

**Diplomityön tiivistelmä**

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**Tiivistelmä**

Kiertotalous on nähty keinona säilyttää resurssien arvo pitämällä ne suljetuissa kierroissa. Kiertotalous käsittää useita erilaisia koulukuntia ja sitä on pyritty myös selittämään eri tavoin. Rakennus- ja kiinteistöalan merkittävä vaikutus ympäristöömme on tunnistettu jo kansainvälisellä tasolla. Rakennushankkeiden tilaajien rooli tulee olemaan kiistaton alan siirtyessä kohti kiertotaloudellisempia toimintamalleja.

Tämä diplomityö pyrkii kasvattamaan tietoisuutta tilaajan mahdollisuuksista soveltaa kiertotalouden periaatteita etenkin kampuskiinteistöjä koskevissa kiinteistökehityshankkeissa. Tällä hetkellä aihetta käsittelevää tutkimusta on hyvin niukasti saatavissa.

Tutkimuskysymyksiin vastataan kirjallisuuskatsauksen ja asiantuntijahaastatteluiden avulla. Kirjallisuuskatsauksen tavoitteena on tarjota teoreettinen tausta tutkimukselle, sekä selittää kuinka kiertotalouden periaatteita voidaan soveltaa rakennetussa ympäristössä ja kiinteistökehityshankkeissa. Kirjallisuuskatsauksessa kerättyä teoriapohjaa syvennetään suorittamalla seitsemän teemahaastattelua rakennus- ja kiinteistöalan ammattilaisten kanssa.

Suurimpia haasteita kiertotaloudellisemman toiminnan kannalta tilaajalle aiheuttaa kehityshankkeiden kannattavuus, uusiin materiaaleihin liittyvät epävarmuustekijät sekä sopimukselliset asiat sidosryhmien kanssa. Selättääkseen nämä haasteet rakennushankkeen tilaajan; (1) tulisi omata riittävä tietous kiertotaloudesta; (2) asettaa kiertotalouden toteutumista mittaava kriteeristö; (3) edesauttaa yhteistyötä eri sidosryhmien välillä; (4) ja viimeiseksi valvoa rakentamisen toteutumista suunnitelulla tavalla sekä vaatia yksityiskohtaista rakennustiedon dokumentointia.

Tämä diplomityö tunnisti useita tarpeita jatkotutkimukselle. Esimerkiksi digitalisaation tarjoamia mahdollisuuksia yksityiskohtaisemman rakennusinformaation hallinnassa tulisi tutkia. Lisäksi työssä tunnistettiin tarve kiertotalouden viitekehykselle rakennetussa ympäristössä.

Diplomityö on Suomen Yliopisto Kiinteistöt Oy:n (myöhemmin SYK) rahoittama sekä osa Sitran koordinoimaa kiertotalousprojektia.

**Avainsanat** kiertotalous, kiinteistökehittäminen, rakennushankkeen tilaaja

# Forewords

This master's thesis was written for SYK in a collaboration with Sitra. The first steps for this thesis were taken during the winter 2019 when I started to form the research questions together with Ari-Pekka and Suvi from SYK. Thereafter, the time spent with the thesis has been extremely rewarding. I have had a unique opportunity to meet and interview many experienced professionals from the Finnish construction and real estate sectors.

Firstly, I would like to thank my advisors M. Sc. (Tech) Ari-Pekka Lassila and D. Sc (Fil) Suvi Nenonen for valuable advices and support. Furthermore, my special thanks belong to thesis supervisor, professor Seppo Junnila, for valuable guidance. I would also like to thank Elizabeth and Delphine for useful meetings and interesting conversations about circular economy. Additionally, I am very thankful to all interviewees who participated in the research and shared their wide knowledge with me.

Besides the thesis, I have been working as a part-time employee, and therefore, I would like to thank my colleagues at Catella for flexibility and understanding. Additionally, I am sincerely grateful for my friends. With these guys, I have had a unique opportunity to do sports, play PS4 and of course drink couple of beers, when needed.

Furthermore, I thank my mother and deceased father for the great support, that they have offered me during the academic path which I have chosen.

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Espoo, 8 December 2019

Lauri Ruokonen

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# 1 Introduction

## 1.1 Background

The role of built environment is undisputable in Finnish society due to various reasons. Buildings form 45% of our national wealth by meaning approximately EUR 500 billion. Moreover, real estate and construction sector composes 15% of Finnish GDP and employs 500 000 people, by meaning approximately 20% of employed people. Simultaneously, urbanization is one of the most significant current mega trends. In Finland, over 80% of the population lives in cities, whereas in a global level the equivalent share is 54%. (ROTI 2019)

Despite the positive effects, the Finnish built environment has faced some major challenges as well. Urbanization is dividing Finland into growing and degrowing regions. Whereas growing regions are struggling with a low supply of apartments, degrowing regions have their own challenges with increasing apartment vacancy rates. (ROTI 2019) Moreover, it seems that there will be no change in this trend since MDI (2019) estimated that Finland will have only three growing city regions in 2040. Additionally, vacancy rates of non-modern and weakly located offices are relatively high even in the Helsinki Metropolitan Area when compared to Stockholm and Copenhagen (Catella 2019). However, for example slow zoning processes hinders the conversion of these vacant properties for other uses. Furthermore, the high maintenance backlog especially in degrowing regions is a major challenge. (ROTI 2019)

Moreover, significant environmental impacts caused by the built environment have been recognised both in global and national levels. In 2017, construction sector was responsible of 36% global final energy use and almost 40% of energy related $CO_2$ emissions (IEA 2018). Furthermore, building sector consumes 25% of water and 40% of raw materials in global level (GBC Finland & Sitra 2018). In Finland, according to ROTI (2019), buildings consume 32% of the total energy consumption and account for 30% of Finland’s $CO_2$ emissions. In addition to a significant energy consumption, the construction sector was the second largest waste producer after mining sector in Finland in 2017 (Statistics Finland 2019).

Demographic changes together with overconsumption and negative environmental impacts has showed that the current linear economy does not offer a solution for a sustainable future. In 2012, Ellen MacArthur Foundation (EMF) and McKinsey Company published together a report in World Economic Forum in Davos. (Wautelet 2018) This report indicated that transition to circular economy would create cost savings of USD 630 billion a year for only a subset of the EU manufacturing sector. In addition, EMF presented remarkable both social and environmental benefits, which circular economy would create. In contrary to traditional linear economy, circular economy keeps materials in closed cycles and by this way targets to upkeep their value. (EMF 2012) Circular economy as a concept has motivated many governments, organizations and companies to implement the principles of circular economy (Wautelet 2018). For example, China’s Circular Economy Promotion Law came in force in January 2009 and European Commission launched the EU Action Plan for the Circular Economy in 2015 (World Bank Group 2019; EMF 2018).

In Finland, Sitra in a cooperation with ministries and wide group of different stakeholders published “Road map to a circular economy 2016-2025”, which provides information on the implementation of circular economy in practise. Moreover, this road map is supplemented with a publication called "Action Plan for a Circular Economy". (Ministry of Environment 2019) Thereafter, various Finnish companies from several sectors have started to examine the potential of circular economy for their businesses. Examples vary from small start-up companies to publicly listed companies such as Fiskars, Konecranes and Neste. (Sitra 2019)

In Finnish construction and real estate sector, Green Building Council Finland (GBC Finland) can be regarded as one of the most significant actors, which has worked with the concept of circular economy from the sector's perspective. Gradually, some construction and real estate investment companies has started to interest about circular economy. One of these companies is the thesis' case company, SYK, which is the owner of Finnish university properties located outside of the Helsinki Metropolitan Area.

The academic literature has identified three key trends that will influence management of universities and campuses: (1) knowledge economy and the crucial role of universities, (2) the network university – universities as nodes in a network and (3) the green campus – sustainable development and reducing the carbon footprint (Den Heijer 2011). Inter alia, these trends are leading Finnish universities to develop their properties constantly. Consequently, University Properties of Finland Ltd is willing to investigate their potential to facilitate the realization of circular economy as a significant Finnish property owner and construction client.

## 1.2 Research Aim and Research Questions

As it was indicated already in the background, the circular economy is a concept which popularity in construction and real estate sector is rapidly increasing. Especially the largest property owners, such as the case company SYK are playing a significant role as construction clients in a shift towards circular economy. In the end, construction clients have a major effect on environmental impacts of development projects, since they can set requirements for each project, which they order.

Consequently, the main purpose of the thesis is to research construction clients' potential to facilitate the realization of circular economy. This is executed by analysing relationships between construction clients and different stakeholders by recognising the key characteristics of construction clients. Moreover, this thesis aims to recognise the most relevant indicators which measure the realization of circular economy.

In order to attain the goal of the thesis, this thesis aims to answer on following research questions:

1. How can the construction client contribute the realization of the circular economy when ordering construction projects?
2. How can the realization of circular economy be measured in the built environment?

The aim of the first research question is to recognise construction client's main opportunities to facilitate the realization of circular economy. The second research question aims to recognise the most relevant indicators that could be used to measure the level of circularity in the built environment.

Obviously, the results of this study will be the most beneficial for the case company, since the results will strive to perceive the key characteristics of the case company. Moreover, other campus real estate owners, such as Aalto University Properties Ltd and Helsinki University Properties Ltd, could utilise these results. In addition to campus real estate owners, also other long-term property owners, such as pension funds, which act also as construction clients may benefit from the results.

## 1.3 Scope of the Research

The main scope of the thesis is on property development. Thus, this thesis studies the opportunities in the early phases of buildings' life cycle. Even though this thesis recognises the significance of use and demolition phases when discussing circular economy, it does not offer detailed recommendations on how to operate in those phases. Furthermore, the thesis has the scope of construction client and thus, it does not deepen in any specific field of engineering, such as in structural or energy engineering. Rather the scope is on the setting the most suitable goals for projects and on the management and supervision issues related to projects.

Moreover, the thesis is written from the case company's perspective. Even though the results can be applied also on other types of actors under certain circumstances, the thesis has the scope of the university property developer, who remains long time periods as the owner of properties after the development. This becomes particularly in a question, when the client is considering long-term savings (such as more durable materials etc.) regarding the asset. The client, who is not responsible for owning the property after the construction is not necessarily that much interested of long-term savings than the client who remains as the property owner. Long-term savings are usually more difficult to justify for the investors, and thus, such solutions might be excluded from projects.

Additionally, the scope is set on the construction material cycles instead of other resource cycles such as energy and water. As it will be discussed further in the thesis, energy efficiency issues are starting to be self-evidences for investors and users. However, the same has not happened with materials yet, and thus, it offers an interesting research gap. Another justification for setting the scope on materials is, that many principles of circular economy are actually more or less focused on materials and waste production.

Moreover, geographical focus of the thesis is on Finland. Even though many circular economy innovations can be applied in other countries as well, this thesis considers the Finnish circumstances regarding development processes from legislative perspective. Traditionally, real estate sector is rather restricted by different authorities, and thus, the geographical focus needs to be set.

## 1.4 Research Methods

Literature review is based partly on academic literature and professional literature (e.g. by Ellen MacArthur Foundation and Finnish Green Building Council). The aim of the literature review is to provide a strong theoretical background for two relatively complex concepts; circular economy and property development. Moreover, the literature review aims to support the conduction of interviews by recognising the most important issues to focus on. Additionally, literature review improves the reliability of interviews.

The empirical part of the thesis utilises semi-structured thematic interviews. This research method is chosen, since open-ended questions of this methods enable relatively free conversation around agreed themes (Hirsjärvi & Hurme 2011, p. 48.). Since the concept of circular economy is rather new and research regarding circular economy in the built environment is rather scarce, this method is the most suitable for the purpose. The method is further presented more detailed in section 6.1.1. The aim of the interviews is to enable professionals to provide practical insights on construction clients' possibilities to facilitate the realization of circular economy.

## 1.5 Structure of the Thesis

This thesis comprises in total seven sections, which are divided into theoretical and empirical sections. The detailed structure of the thesis is in Table of Contents. Sections 2, 3 and 4 form the theoretical background of the research. Moreover, sections 5 and 6 form the empirical part of the research. The main findings from the literature review and empirical part are presented and compared in section 7.

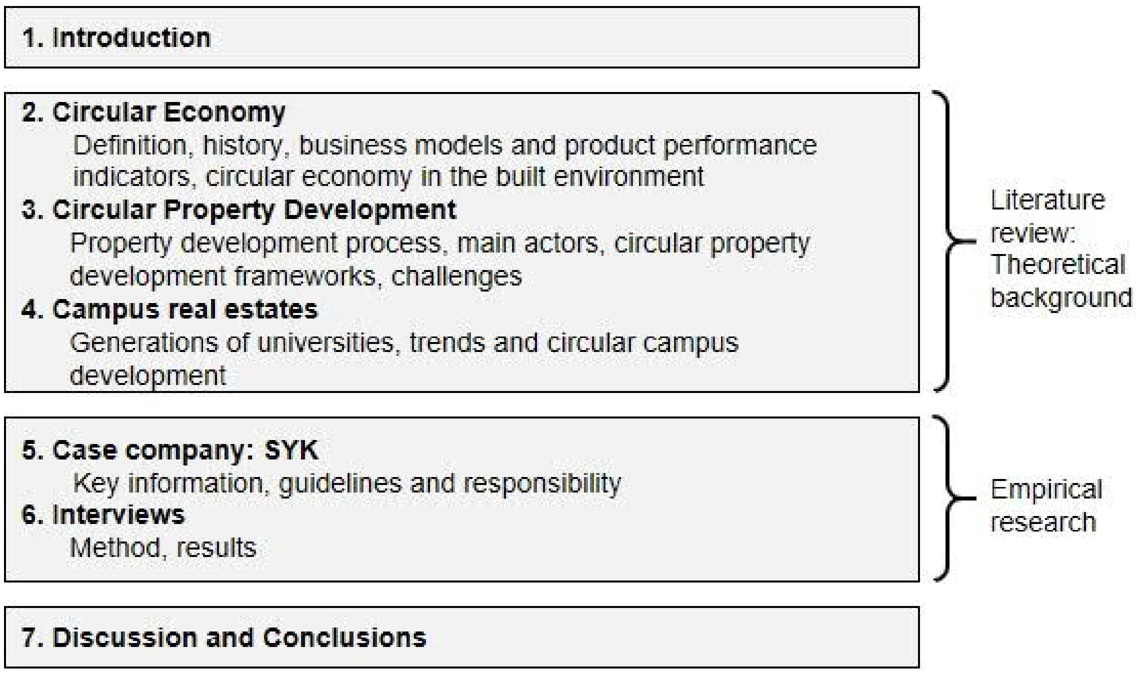


*Figure 1: Structure of the research*

The first section, introduction, offers the background for the research. Furthermore, it presents research questions, methods, the scope and the structure of research. Section 2 is focused on the concept of circular economy and presents its definition and history, circular business models and some basic product performance indicators to measure the level of circularity. Furthermore, the concept of circular economy in the built environment is explained. The third section provides a theoretical background for the concept of property development. Moreover, this section presents some frameworks regarding the adaption of circular economy principles in the property development process. Section 4 is focused on the characteristics of campus real estates and helps reader to conceive better the scope of the research.

As discussed earlier, sections 5 and 6 form the empirical part of the research. Section 5 presents the key information on case company and its property development processes. Moreover, section 5 evaluates briefly how responsibility and circularity issues are already visible in their current operations. The fifth section is based on public information that is available on the case company's website. Section 6 presents the key findings of the interviews and a description of the used method. The aim of section 7 is to conclude and summarize the findings of theoretical and empirical parts. Moreover, section 7 will provide recommendations for the case company.

# 2 Circular Economy

This chapter will define the concept of circular economy and describe its development. After the definition and the history, this chapter will introduce circular business models and thereafter aims to describe how can the principles of a circular economy be applied in the built environment and how can the realization of the concept be measured.

## 2.1 Circular Economy in General

### 2.1.1 Definition for Circular Economy

In the course of time, there has been numerous attempts by many authors to define the concept of "circular economy" (Rizos et al. 2017). The roots of the concept are in industrial ecology and industrial metabolism, which were developed in 1970's and 1980's due to reanalysing of the industrial processes (Frosch & Gallopoulus 1989). Basically, this concept was popularized in 90's and it suggest that the life cycles of products should be redesigned to require minimal material input and to minimize the amount of waste. Therefore, it can be regarded as the inverse of the traditional linear economy. (Murray et al. 2015; EMF, 2012). The concept of circular economy and its principles have been extensively developed by practitioners, such as policy makers and business associations, whereas the effort of scientific research on the development of the concept has been tangential (Korhonen et al. 2018). According to Preston (2012) the term has been used quite inconsistently by companies and governments and additionally the understanding of the concept is relatively low.

Ghisellini et al. (2016) noticed that 3R's principles: reduction, reuse and recycle are usually linked with circular economy in literature. For example, according to The Chinese CE promotion Laws circular economy is "a generic term for the reducing, reusing and recycling activities conducted in the process of production, circulation and consumption" (CCIED 2008). In addition, Murray et al. (2015) emphasized the use of the word "restorative" in many definitions and expressed that a circular economy is not only aiming to prevent, since it additionally focus on to repair the damage that has been made before by designing better systems. Therefore, for example Hu et al. (2011) adopted the 4R approach: reduce, reuse, recycle and recover. However, many authors (e.g. Geng & Doberstein 2008; Yuan et al. 2008; Bocken et al. 2016 etc.) have used a same core idea: a system which is based on circular energy and materials flows. Table 1 introduces some popular and widely cited definitions for circular economy.

| Source | Definition |
|---|---|
| **EMF (2012)** | "A 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 aims for the elimination of waste through the superior design of materials, products, systems, and, within this, business models." |
| **Kirchherr et al. (2017)** | "A circular economy describes an economic system that is based on business models which replace the 'end-of-life' concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes, thus operating at the micro level (products, companies, consumers), meso level (eco- |

| | |
|---|---|
| | industrial parks) and macro level (city, region, nation and beyond), with the aim to accomplish sustainable development, which implies creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations.” |
| **Geissdoerfer et al. (2017)** | “a regenerative system in which resource input and waste, emission, and energy leakage are minimised by slowing, closing and narrowing material and energy loops. This can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing and recycling. ” |
| **Murray et al. (2015)** | “The Circular Economy is an economic model wherein planning, resourcing, procurement, production and reprocessing are designed and managed as both process and output, to maximise ecosystem functioning and human well-being” |

*Table 1: Assorted definitions of a circular economy*

According to various authors, the definition framed by EMF is regarded as the most well-known (e.g. Geissdoerfer et al. 2017; Millios 2017; Murray et al. 2015 etc.) It, in turn, emphasizes the importance of restorative and regenerative intention and design and additionally highlights the use of renewables and avoidance of the use of toxic substances. According to EMF (2015b) the concept of circular economy is eclectic and lacks a scientific definition, even though it has been figured in political, economic and business dialogues in recent years. EMF (2015b) states that circular economy is an economy, which “provides multiple value-creation mechanisms which are decoupled from the consumption of finite resources.” This definition is described in Figure 2 and it is based on three principles:

“Preserve and enhance natural capital by controlling finite stocks and balancing renewable resource flow – for example, replacing fossil fuels with renewable energy or returning nutrients to ecosystems

Optimise resource yields by circulating products, components, and materials in use at the highest utility at all times in both technical and biological cycles – for example, sharing, or looping products and extending product lifetimes

Foster system effectiveness by revealing and designing out negative externalities, such as water, air, soil, and noise pollution; climate change; toxins; congestion; and negative health effects related to resource use.”

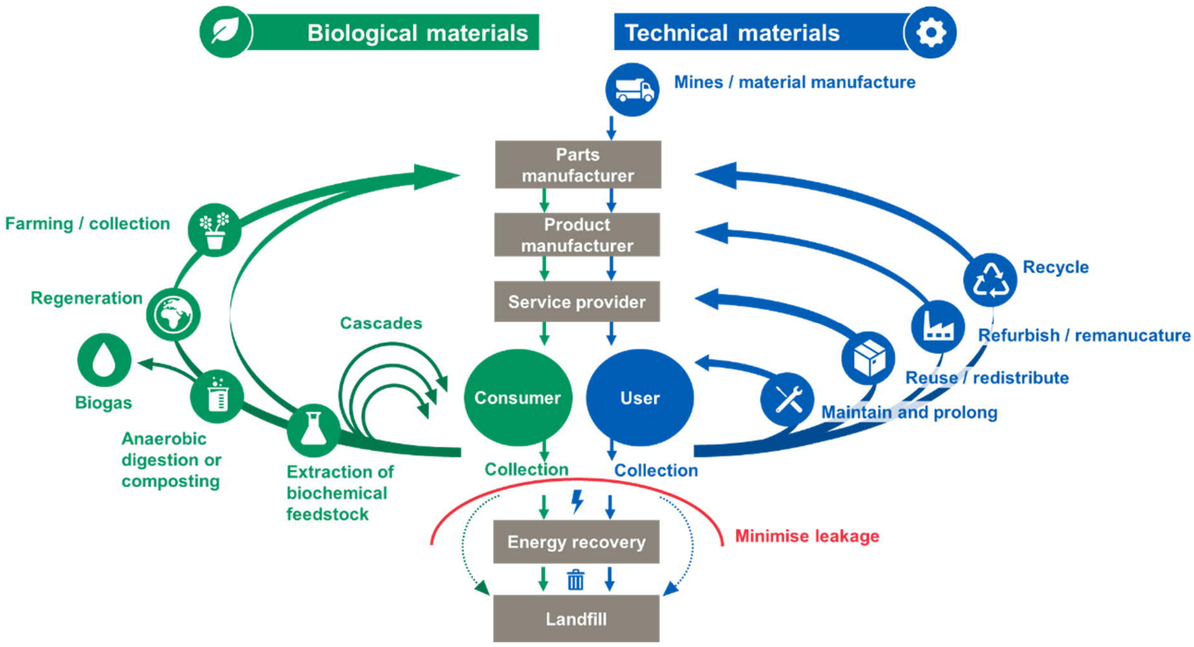


*Figure 2: Model of a circular economy (EMF 2012)*

EMF's circular economy model divides materials to biological and materials, as presented in the Figure 2, since their material flows and measures to keep them economic system as long as possible differs from each other's. Technical materials are manufactured especially of non-renewable materials, but also of renewable materials by people. The idea of this circular economy model is, that material losses will be minimised the most efficiently, when the material flows of the user and consumer are kept enough close to them. This means, that when we are moving from the inner cycles towards outer ones in  Figure 2, the priority of the cycles decreases in both, biological and technical, cycles. For instance, recycling is the least wanted measure in the technical cycle and sharing the most wanted, since recycling requires more energy than sharing. (EMF 2012)

To understand the concept of a circular economy, it is crucial to understand its relationship with sustainable development. This relationship has not been made explicit in literature, which currently constraints their use both in research and practice. Circular economy aims to reach closed loop system in which resource inputs and leakages are eliminated, whereas sustainable development more open-ended concepts with multiple goals depending on a situation. Therefore, improved use of resources and changing waste leakage are regarded as the main motivation for the circular economy whereas for sustainable development this is more diffused and diverse. One significant difference between these two concepts are also the actors, who are responsible for implementing these concepts. Basically, a circular economy is more driven by companies, governments, whereas in sustainable development responsibilities are not clearly defined. The circular economy is also more focused on environmental benefits than social benefits, while in the sustainable development these three dimensions are equal and balanced. (Geissdoerfer et al. 2017) Despite the dissimilarities between these two concepts, it has been also suggested that the circular economy is one method to reach sustainable development (Kirchherr et al. 2017). Also, Murray et al. (2015) suggest that "the circular economy is an important and significant new school of thought in sustainable development".

### 2.1.2 Brief History of the Circular Economy

The concept of a circular economy originates in 1970s and therefore, various schools of thoughts have developed among its principles (Wautelet 2018). According to Prieto-Sandoval et al. (2017) the conceptual evolution of the circular economy can be divided in three stages; linear economy, industrial ecology and circular economy. During these three stages the concept has influenced by various disciplines such as engineering, business, ecology, design and economy. Thus, it can be regarded as a multidisciplinary concept. (Prieto-Sandoval et al. 2017)

The linear economy has its roots in the industrial revolution. This led to an overconsumption of resources (Prieto-Sandoval et. al 2017). However, in the 1960's, the awareness of environmental problems raised because of released publications such as "Silent Spring" by Carson et. al. (1962). This book highlighted that humans had damaged the planet by overconsuming resources and using toxic substances. In 1960's, many other economists recognized also the demand for rethinking the relation between the environment and current economic system. One of these economists was Kenneth E Boulding (1966) who presented an idea of a "spaceman economy", which was an opposite to so called "cowboy economy", in which natural environment is perceived as limitless, since there did not exist limit on the capacity of the energy and material flows. Boulding stated, that cowboy economy has negative environmental and social impacts, such as pollution and violent behaviour. Therefore, Boulding presented the concept of spaceman economy in which the Earth was considered as a closed system. In spaceman economy, the environment and the economy are in a circular relationship, in which every article have an impact on everything else.

The second stage is called industrial ecology, which lasted from the beginning of 1970's until 1990's (Prieto-Sandoval et. al 2017). This stage was based on Ayres (1969; 1989), who discussed about industrial activities working as a metabolism, in which wastes, and resources of different actors would circulate continuously through the resource inventory of the system. Industrial metabolism led to the concept of industrial ecology (IE), which tries to explain how energy and material flows effect on the biosphere and how they can be regulated. Industrial ecology has resulted into creation of different methods, such as life cycle assessment, which can be used in measuring of environmental impacts of industrial production or human consumption. However, its practical implementation has been seen as challenging due to inadequate current technology. Circular economy has much common with industrial economy. Consequently, industrial economy aims to analyse and optimise the industrial systems at a micro-level. Thereafter, it aims to have an impact on whole economic systems, which processes and products are redesigned, in order to maximise the value of resources. (Wautelet 2018)

The research made by Pearce and Turner (1989) began the third stage in the 1990's (Prieto-Sandoval et. al 2017, p. 609). Many scholars claim, that circular economy as a concept was firstly introduced by environmental economist Pearce and Turner (1989), whose research was based on previous studies of ecological economist Kenneth Boulding (1966) (Andersen 2007; Ghisellini et al 2016; Greyson 2007; Heshmati 2015; Murray et al. 2015; Su et al. 2013). Additionally, more recent theories such as Performance Economy (Stahel 2010), Cradle to Cradle (McDonough & Braungart 2010), Biomimicry (Benyus 2002) and Blue Economy (Pauli 2010) have also influenced on the concept of the circular economy by refining it further (EMF 2012).

Currently, many governments and companies have recognized the circular economy as a potential concept, since the environmental pressure has been increasing and resource prices are volatile (EMF 2012; 2013). Therefore, circular economy has attracted significant attention both in China and Europe during the last decade. China enacted a circular economy specific law (i.e. Circular Economy Promotion Law in 2009) as the first nation in the world. Its aim was to promote circular economy nationwide. (Wautelet 2018) Since circular economy was adapted nationwide so early in China, there has been published more circular economy literature than in Europe (Ghisellini et al. 2016).

Whereas in China the circular economy is adapted in early stages in their national political strategy (top down approach), in Europe the shift towards circular economy has occurred mainly due to organizations and NGOs (bottom up approach) (Ghisellini et al. 2016). The main measures in order to implement circular economy in Europe are waste policies, such as Waste Disposal Act in Germany in early 1976 and EU Waste Directive 2008/98/EC, which has focused mainly on promotion of recycling principle of a circular economy. However, NGOs (e.g. EMF, Circle Economy and Institut de l'économie circulaire) have had the main focus on closed loop flows of materials at different stages of the supply chain instead of only on recycling of waste. As a result, in 2015, the European Commission published a new Circular Economy Package, which presented actions to close the loop of products by recycling, re-using and repairing (European Commission 2015). (Wautelet 2018)

Approaches on circular economy differs between China and EU. In China, the importance of cleaner production and consumption and the "3Rs" principles are highlighted, and they can be regarded as the central principles of circular economy policy (Preston 2012). As a result, "Chinese CE's concept in many ways resonates with the concept of industrial ecology which emphasizes the benefits of utilizing residual waste materials, including energy, water, different by-products as well as information" (Su et al. 2013). Alternatively, European approach is inspired more by Cradle to Cradle methodology and closed loop economic model focusing on system design. (Wautelet 2018)

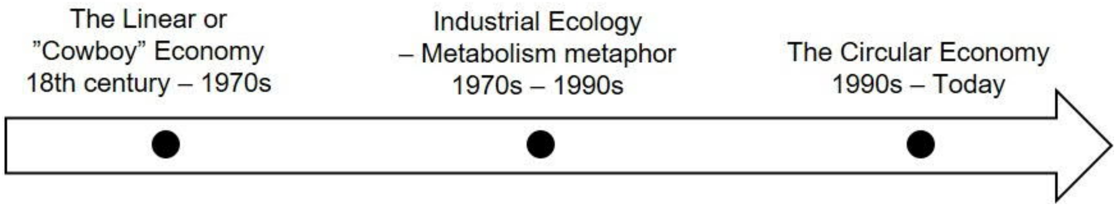


*Figure 3: Conceptual development of circular economy (Prieto-Sandoval et al 2017)*

### 2.1.3 Circular Economy Business Models

Business models are regarded as structured management tools, which aims to introduce organisation's structure and value creation processes (Margareta 2002; Richardson 2008; Wirtz et al. 2016). Teece (2010) describes business models as a financial and organisational architecture which aims to define how resources and capabilities are transformed into economic value. Osterwalder and Pigneur (2010) explain business model as "a core logic how a company creates, delivers and captures value". Consequently, business models aim to answer to following questions; "what value is provided and to whom, how is value provided and how does the company make profit and capture other forms of value?"

The framework for Osterwalder's and Pigneur's (2010) explanation of the business model is known as "business model canvas", which comprises following nine business model elements: "key resources, key partners, customer segments, customer relationships, channels, value propositions, revenue streams, cost structure, key activities". This business model conceptualisation is presented in Figure 4.

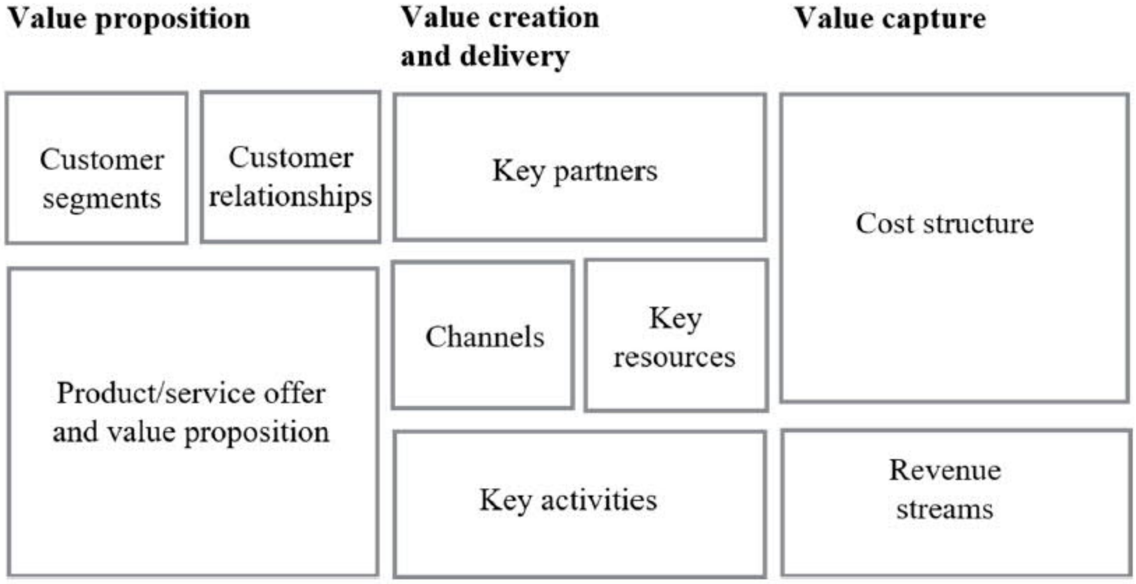


*Figure 4: Business model canvas (Osterwalder & Pigneur 2010)*

According to Geissdoerfer et al. (2018) the interest of the academic and practitioners on sustainable business models has grown significantly. Geissdoerfer et al. (2018) defines sustainable business model as "business model that incorporate pro-active multi-stakeholder management, the creation of monetary and non-monetary value for a broad range of stakeholders and hold a long-term perspective." Most definitions in literature regard sustainable business models as modifications of conventional business models with certain added features and aims. Sustainable business models either include "concepts, principles or goals which aim at sustainability" or "integrate sustainability into their value proposition, value creations and delivery activities and/or value capture mechanisms". Sustainable business models have different subcategories, archetypes and generic strategies with own characteristics like base of the pyramid, product services and circular business models (Bocken et al. 2014). Circular business models employ "pro-active multi-stakeholder management and have a long perspective aims to close, slow, intensify, dematerialise and narrow resource loops" as well. (Geissdoerfer et al. 2018)

Most business models are designed to be used in a linear economy, in which harms caused to the environment do not increase resource prices. According to Nußholz (2017), the most significant dissimilarity between circular and linear business models is the "embeddedness of a circular strategy in the offer". When circular strategies are implemented in business models, the value creation logic needs to be rethought to ensure the economic benefits. This can be made through rethinking three value dimensions presented in Figure 4; value creation, proposition and delivery and value capture. It has to be considered that what value will be provided and to whom. In a circular business model, the service or product should deliberately use circular strategy to create value, for example, by increasing resource efficiency or using closed-loop resource flows. (Nußholz 2017) The product which design uses a circular strategy can be designed for example for long-life, repair or remanufacturing (Bakker et al. 2014). Another example is a product which is based on leasing instead of owning, that is discussed widely as a solution, which facilitates collecting products and applying circular principles (Mont & Tukker 2006; Mont 2008; Tukker 2015; Diener et al. 2015).

According to Nußholz (2017) value creation and delivery elements explain the potential value of offers and their nested circular strategy and considerations in this part are related to how to create the potential value and deliver it effectively. It can be for example considered whether the resource recovery will be performed inhouse or outsourced (Karvonen et. al 2015), or how will be the reverse logistics performed. Channels can be also designed so that they motivate the returning of goods (Nußholz 2017). Also, finding appropriate key partners is an important part, since closing the materials flows requires a larger value chain network (Wells & Seitz 2005).

Value capturing can be made through extra revenue sources, cost reductions or non-monetary benefits which are related to circular strategies (Nußholz 2017). Additional revenue streams can be acquired by redistributing, repairing and reselling of post-consumer products (Bakker et al. 2014). Revenue streams can gain profit from higher price due to enhanced durability, leasing or from maintenance services of products as well (Mont et al. 2006; Moreno et al. 2016). Cost reductions can be performed either by avoiding costs related to end-of-life elimination or by using lower-priced secondary production instead of primary production (Linder & Williander 2015). According to Schenkel et al. (2015) closed-loop chains create other indirect benefits as well such as customer, informational and environmental values which can be captured.

According to literature review by Nußholz (2017), three attempts (Bakker et al. 2014; Bocken et al. 2016; Moreno et al. 2016) have been made to categorise circular business models in academic literature. Each of these typologies includes 5-6 business models which “create, deliver and capture value from embedding circular strategies in their offer”. The understanding on circular business models remains rather heterogeneous between these three authors. However, authors agree that “circular business models lend themselves to:

- substituting primary material input with secondary production;
- extending the useful lifetime of products through design for longer average lifespans and enabling second life (e.g. repair or remanufacturing); and
- material recycling.”

Sometimes, these three strategies have been considered as synonyms for resource efficiency gains (Nußholz 2017). Nevertheless, implementing these circular strategies does not automatically facilitate higher resource efficiency. Consequently, when implementing circular strategies targets regarding resource efficiency should be set (Bakker et al. 2014; Cooper et al. 2017). Nußholz (2017) names three main contingencies encumber resource efficiency gains from circular strategies:

- Replacement versus Reuse
- Limits to Material Recycling

- Rebound Effects

Although reuse of products is regarded as an effective strategy to achieve resource efficiency gains, this is not always true. Resource efficiency gains are dependent for instance on processes that are needed to modify a product to suitable condition on the impacts during the use-phase of the second-life phase (Cooper et al. 2017). Additionally, it is discussed, that there are limits to benefits which can be acquired by recycling, since each stage of recycling process includes inefficiencies and therefore recycling efficiency is always under 100 % (Nußholz 2017). Finally, rebound effects should be considered as well. This means, that using secondary production does not reduce primary production. According to Zink & Greyer (2017), two mechanisms can lead to such situation. Firstly, it is possible, that secondary phase products are not compatible in comparison to primary products. Secondly, prices of secondary products might be low leading to the increased consumption.

### 2.1.4 Product Performance Indicators in a Context of Circular Economy

There have been proposed several tools for measuring product performance from the circular economy perspective. Yet, no consensus exists on how circularity should be measured. However, both academics and NGOs suggested several tools for measuring it. This section describes three tools for this purpose. Tools are available online or on demand for free. The summary of these tools is presented in Table 2.

Material Circularity Indicator (MCI) developed by EMF (2015a) is one example of a tool which can be used for measuring how restorative material or companies are. MCI is basically developed for product design. However, it can be utilized for several purposes such as for internal reporting or evaluation of companies. MCI is based on Excel sheet and can be accessed for free online. MCI has four inputs; “input in the production process, utility during use phase, destination after use and efficiency of recycling”, for which MCI provides value between 0 to 1 where higher value indicate an increased level of circular economy. In the first phase, MCI determines the input of virgin, recycled and reused material. In the second phase, the intensity of use is evaluated in comparison to average products of similar type. This phase accounts the durability of products and business models such as repair shared consumption. The third phase aims for modelling the amount of material which goes into landfill in the end-of-life and how much or material is recycled and reused. The final phase assesses the efficiency of recycling processes. (EMF 2015a)

The Circular Economy Toolkit (CET), as MCI, is also available online for free. The aim of CET is to detect the potential for improvement in products circularity. CET is based on the dynamic web page instead of Excel sheet. In contrast to MCI, which is based solely on percentages, CET is based on 33 trinary format (yes/partly/no and high/medium/low) questions. These questions are related different product’s life cycle phases such as, design, usage and end-of-life. (Evans & Bocken 2019)

Griffiths & Cayzer (2016) developed a measurement tool called The Circular Economy Indicator Prototype (CEIP) to assess the product’s circular economy performance. As MCI, also CEIP is based on Excel sheet. In contrary to MCI and CET, CEIP is available on demand instead of online. However, also CEIP can be used for free. CEIP is based on fifteen weighted questions, which have been weighted and split up into five phases of lifecycle; “design or redesign; manufacturing; commercialisation; usage; and end-of-life". As on output, the tool provides The CEIP score (%) and radar diagram which shows the individual score for each lifecycle stage. (Griffiths & Cayzer 2016)

| Characteristics | Material Circular Indicator (MCI) | Circular Economy Toolkit (CET) | Circular Economy Indicator Prototype (CEIP) |
|---|---|---|---|
| **Description** | Measures transition towards a circular economy | Detects potential improvement in products circularity | Evaluates the product performance from the aspect of circular economy |
| **Platform** | Excel sheet | Web page | Excel sheet |
| **Inputs** | Percentages (reused or recycled) regarding the origin and destination of materials | 33 trinary format questions with 7 sub categories which are related to different phases of lifecycle | 15 weighted questions divided into 5 lifecycle stages. |
| **Outputs** | Quantitative: The MCI, single score, gives a value between 0 and 1 where higher values indicate a higher circularity. | Qualitative: Improvement potential at 3 level (high, medium, low) for every of the 7 sub-categories. | Quantitative: The CEIP score (%) and a radar diagram showing aggregated score for each lifecycle stage. |

*Table 2: Product performance indicators (Saidini et al. 2017)*

## 2.2 Circular Economy in the Built Environment

It has been noticed, that there is a lack in the research related to circular economy and built environment (e.g. Adams et al. 2017; Pomponi & Moncaster 2017). On the building level, research have focused more on post-occupancy evaluation and on life cycle assessment. Thus, the research has been less multidisciplinary in comparison to research made on macro and micro levels. (Pomponi & Moncaster 2017) The concept of the circular building is defined by Pomponi & Moncaster (2017) as "a building that is designed, planned, built, operated, maintained, and deconstructed in a manner consistent with CE principles". A slightly more detailed definition is provided by Leising et al. (2018), who defines CE approach for circular buildings as "A lifecycle approach that optimises the buildings' useful lifetime, integrating the end-of-life phase in the design and uses new ownership models where materials are only temporarily stored in the building that acts as a material bank".

### 2.2.1 Four Building Blocks of Circularity in the Built Environment

This section presents various solutions that facilitate the realization of circular economy in the built environment and divides them into four categories by using four building blocks by EMF (2019) as follows: (1) circular economy design, (2) circular business models, (3) reverse cycles and (4) enablers and favourable system conditions.

#### 2.2.1.1 Circular Economy Design

Circular design plays a significant role in a transition towards circular economy (GBC Finland 2018). The goal of circular design is to ease reuse, recycling and cascading. New working methods and information of new materials are required for circular design. Circular economy design in the built environment includes various divisions such as varying from reuse of existing buildings to circular material selection. (ARUP & EMF 2018; EMF 2019) Bocken et al. (2016) divides circular design strategies for those that slow resource loops and for others that close resource loops. Adapting these strategies into building design means designing buildings with long life cycle, buildings which life-span can be extended and buildings that can be reconstructed in the end-of-life phase.

Reducing the amount of new construction is regarded as a starting point to implement principles of circular design in the built environment. (Geldermans 2016; GBC Finland 2018). Demolition audit should be implemented as a part of designing, which secures the condition of existing structures. (GBC Finland 2018). Additionally, the role of more efficient space use is important in the circular built environment, which can also replace the need for building something new. (EMF 2015b; Geldermans 2016; GBC Finland 2018)

When new construction is required, the building should be designed for long-life and building-life extension (Bocken et al. 2016). In practise, this means choosing durable materials and designing buildings for repair, flexibility and adaptability (Adams et al. 2017; GBC Finland 2018). According to GBC Finland (2018), buildings should be designed so that minimal alteration work during use phase is required. This means both design of systems in the buildings and the space design. For example, pipes should be designed so that they are easy to access and to change when required. Additionally, during relatively long lifecycles of buildings, requirements for space design changes for example due to new ways of working or housing. Therefore, spaces should be designed, so that they can be adapted for various uses. Premises, that do not have continuous use, should be designed so that they can support many uses. (GBC Finland 2018)

In order to maximise the useful material and minimise the waste amount in the end-of-life the building should be designed for deconstruction (EMF 2015b, Adams et al. 2017). Deconstructed materials can be further be utilised either in a technological cycle or in a biological cycle (Bocken et al. 2016). Design for deconstruction means that demolition phase should be considered already in the design and construction phase (GBC Finland 2018). The goal of design for deconstruction is to increase both economic and resource efficiency and simultaneously to decrease the amount of waste generated during renovation or demolition. Furthermore, the purpose is that buildings could be utilised as primary source of materials instead of natural environment. (Guy et al. 2006).

Material choices are important part of circular design strategies. Material choices can be either used to slow resource loops by choosing durable materials or reusing old materials, when their lifespan will be extended. Additionally, they are also crucial part of closing the resource loops as a part of design for deconstruction. As earlier discussed, they should be fit either into technical or biological cycles in the end-of-life. In addition to material choices, the building should be designed, so that the amount of materials is minimised. (Adams et al. 2017; GBC Finland 2018) Examples of circular materials are those, which are in line with EN 15804 standard or C2C™-certification. (ARUP & EMF 2018; GBC Finland 2018)

### 2.2.1.2 Circular Business Models

The shift to a circular economy from a linear economy demands new innovative circular business models, which either replace old ones or create new opportunities. Large and significant companies have a significant opportunity to drive new circular business models into mainstream. (ARUP & EMF 2018; EMF 2019)

A Design Build Operate Maintain (DBOM) contract is an integrated procurement model where the responsibility of designing, constructing, operating and maintaining a facility is held by a single entity. DBOM contracts help to facilitate a life cycle driven approach to design, procurement and operation in the built environment, realising maximum value from resources. For example, designers are incentivised to deliver designs that respond to commercial objectives accounting for the whole asset life cycle. When the responsibility of designing, constructing and maintaining is wanted to hold for a single entity, a Design Build Operate Maintain (DBOM) contract should be considered. The benefits of DBOM contracts is that they support life cycle driven approach for different phases of the life cycle of a building. For example, these contract incentives designers to design buildings so that the design fulfils the objectives regarding the whole life cycle. Additionally, more circular project can be executed through public private partnerships (PPP), in which the private sector takes the responsibility of project with public benefit on design, construction and finance. In Finland, this is called life cycle model (in Finnish elinkaarimalli). (ARUP & EMF 2018)

New ownership models need to be considered to reach more circular built environment (GBC Finland 2018). One example of a circular business model is called products-as-service, which is also known as performance-based contracts. Instead of offering a product, this business model offers a service, in which the service provider has the ownership of the product. The revenue stream for the service provider generates from payments for performance delivered. This business model can be applied especially for technical services and fitout. Theoretically, applying it to all parts of the building is possible as well. (ARUP & BAM 2017) By using this business model, the lessor of the product is incentivised to return products back to repair or reused instead of disposing them. One example of such product-as-service business model is Phillips' "pay per lux", in which Phillips is responsible for the performance of the lighting based on the contract (ARUP 2016). A well-known product-as-a-service business model in Finland is the carpet service by Lindström.

Open and shared information is recognized also as a one precondition for circular economy to emerge in the built environment (GBC Finland 2018). Therefore, the role of sharing platforms will be undisputable in the future. The aim of sharing platforms is to increase the utilisation rate of products, systems or buildings by offering a shared use or access for users. (ARUP & BAM 2017) An example of such platform is Airbnb, which enables to share own apartment for other software users, who are needing a place where to stay. Additionally, for example companies such as The Collective, WeLive and Common are offering Co-living solutions. (ARUP 2016)

Additionally, other digital solutions play a major role in a shift towards more circular built environment. For example, Building Information Modelling (BIM) has already made it easier to manage building related information among different stakeholders. Furthermore, digital market places for surplus materials from construction and demolition sites facilitates the supply and demand for recycled construction materials. (ARUP & BAM 2017) Digitalization effects also on the working culture. Solutions based more or less on digitalisation, such as flexible seating, desk-sharing, office hoteling and remote working will reduce the need for office space in the future. (EMF 2015b)

#### 2.2.1.3 Reverse Cycles

Returning materials back to the earth or into the industrial production system a crucial part of circular economy. Creating reverse cycles demand for example adequate chain logistics, warehousing and even molecular biology and chemistry. Furthermore, the role of digitalization will be undisputable in this case as well. The material leakage can be decreased with effective decomposition of products at end-of-life phase and treatment systems. (ARUP & EMF 2018)

Reverse cycles utilise repairing, reusing, remanufacturing, refurbishment or recycling to return materials back into the cycle after the point of consumption. Incentivised return policies play a key role when returning materials and products back to the owner. For example, Catepillar has a deposit-return system that facilitate returning of used engine cores. After returning, the engines are remanufactured and resold. Additionally, DHL has developed a reverse logistics system to recover, track and redistribute both waste and used materials. (ARUP 2016)

In the built environment, material passports have crucial role when creating reverse cycles (ARUP & EMF 2018). Material passports enables having a traceability on materials and products and retains the electronic information of materials and products. This information can be further used when assessing the residual value of the material or product in the end-of-life phase. (ARUP & BAM 2017) The material passport allows using the building as “material bank”, when it will be deconstructed (GBC Finland 2018).

Development of enhanced extraction techniques of materials and design for deconstruction are preconditions for reverse cycles. Extracting materials and products from the building needs to be possible with minimal alteration work, so that the value of them remains and returning them is feasible. For example, currently glue connections etc. other chemical connections between components creates challenges for material recovery. (ARUP & EMF 2018; Hart et al. 2019)

#### 2.2.1.4 Enablers and Favourable System Conditions

In order to reuse of products and materials would become more common, market mechanism for them needs to be developed. However, stakeholders such as, universities, politicians and public authorities play also a key role. The shift into circular economy needs a significant change in the practices of all stakeholders in the built environment. (ARUP & EMF 2018)

Planning in regional, building and structural levels will be important part of the realization of circular economy. Planning could set for example more exact requirements for material choices or circular economy related terms plot disposal contracts, which would drive developers to choose solutions that are more circular. (GBC Finland 2018) The role of municipalities is emphasized in this transition, since they are the responsible actors for zoning.

In corporate level, People should unlearn current practices, which requires shift in people's attitudes. This affects both on the professionals of the built environment and on the end-users. Simultaneously, Innovations will change old earning logics and create space for new actors in the market. Furthermore, the transition towards circular economy understanding of the concept and educations. Professionals of the built environment should consider circular economy in their own work and decisions. Good material and life cycle knowledge are crucial for designers and contractors. (GBC Finland 2018)

Collaboration with open and shared information are additionally crucial parts of the transition. The data regarding new projects should be shared and transparent. Both failures and good practises should be transparently communicated. (GBC Finland & Sitra 2018) The shift requires designers and investors to take a longer-term view for assets in comparison to the current practices (ARUP & BAM 2017). Life cycle knowledge is core concepts of circular economy, which should be a precondition for decision making (GBC Finland & Sitra 2018).

### 2.2.2 Overview of Circular Solutions in Different Building Layers

Previous sections (2.2.1.1-2.2.1.4) divided solution that facilitate the realization of circular economy in the built environment into four categories. Solutions vary from the circular material choices to circular business models and new practices in the corporate level. Figure 5 concludes the findings by using the four building block by EMF (2019).

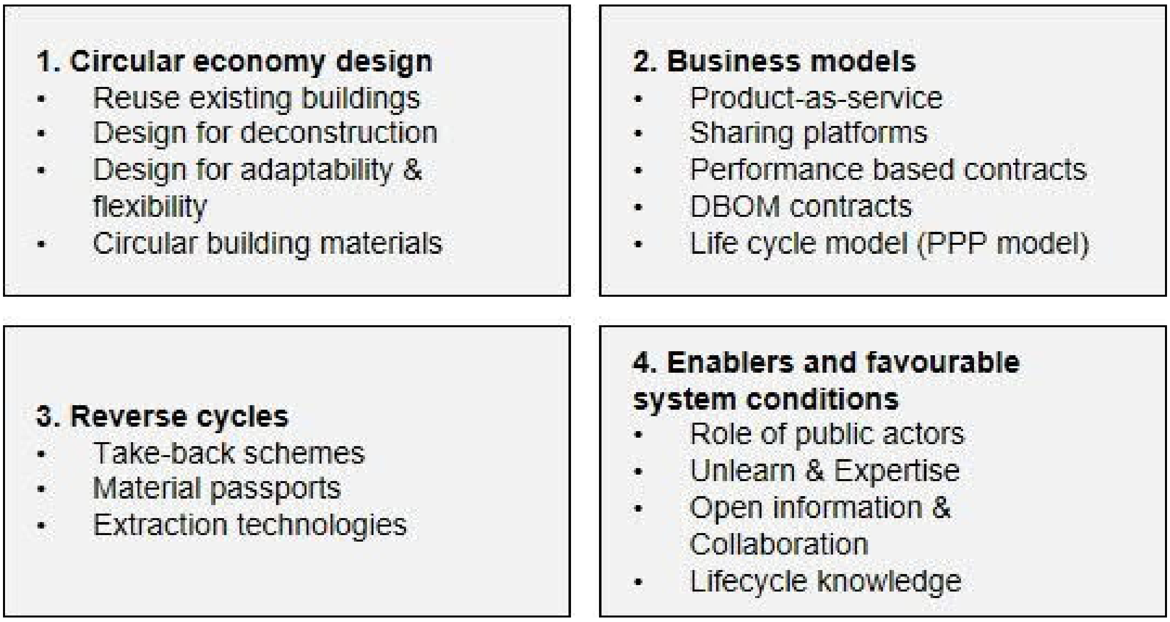


*Figure 5: Examples of solutions that facilitate the transition towards CE in the built environment ("Four building blocks" adapted from EMF)*

These solutions can be adapted in various ways in the built environment. It is important to notice that some solutions can be adapted in various building components. For example, design for durability is important for the whole building, especially for structures of the building, which are assumed to last long. However, components which life cycle are shorter than the whole built asset's, should be designed also for disassembly, flexibility and adaptability in order to reflect on external changes that might effect on building. Examples of such changes are shifting planning policy or changes in market demand. If the building is unable to fulfil new requirements, it may have shorter life cycle than expected. (UKGBC 2019)

UKGBC (2019) has determined overall strategies for different building components. These components are divided into two categories based on their lifespan; short life components and long life components. Short life components are further divided into two categories; the ones which life span varies between 0-5 year (e.g. internal finishes and furniture) and the others that varies between 5-10 years (e.g. partitions, ceilings, floors and local services). Moreover, long life components are divided into elements with a lifespan of 20-30 years (e.g. building services) and with a lifespan of 30-300 years (e.g. sub-structure, structure, floors and fabric).

According to UKGBC (2019), the overall strategy for short life components is to prefer flexible and adaptable solutions, which enable to fit into altered circumstances. The components with the shortest lifespan (0-5 years) should be designed for disassembly and utilize business models which enable to return components back to manufacturer in the end-of-life phase. Components with the lifespan of 5-10 years should be designed for reconfiguration and utilize modular systems. In turn, overall strategies for long life components emphasizes solutions that enables the maximum lifespan for them. Building services should be designed for maintenance, replaceability and remanufacture whereas structures should favour long-life design and adaptable design for different uses. Additionally, temporary buildings should be designed so that they can be relocated.

According to UKGBC (2019), it is crucial to consider inconsistent lifespan of different components in the building. For instance, designing short life components for long life does not necessarily lead in to the most optimal outcome, Therefore, it should be considered that which solutions are the most optimal ones for each building component. Figure 6 addresses some optimal circular economy solutions for different building layers. Figure 6 does not include all possible measures to reach circularity in the built environment. For example, material choices are important in all building layers.

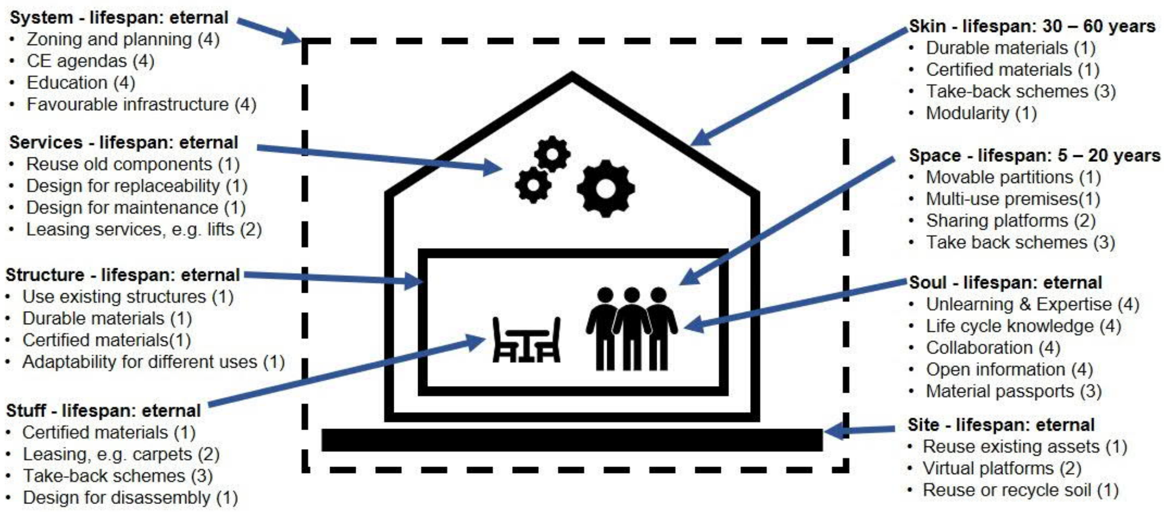


*Figure 6: Circular economy in the built environment based on Shearing layers by Brand (1994). Important solutions are discussed under every building layer. Number in the end of each solutions relates it to one of the four building blocks presented in Figure 5.*

### 2.2.3 Indicators for Measuring Circular Economy in the Built Environment

Open information and indicators for circular economy in the built environment are seen as an important feature in shifting towards circular economy especially by designers, contractor and manufacturers. Therefore, common circularity indicators through buildings' life cycle needs to be developed so that different stakeholders can understand the key opportunities. (Adams et al. 2017) This section discusses some indicators and metric tools to assess the realization circular economy in the built environment. These tools have different perspectives to assess the realization of circularity varying from the building component level until the corporate level.

One example of circular economy metric system is proposed by Constructing Excellence in Wales (CEW) in their report "Circular economy, Opportunity for the Welsh built environment" in 2017. This proposal includes various material flow indicators for different project phases. Basically, these indicators are percentages related to reuse and recycle of waste in different phases of the construction project. These indicators are presented in Table 3, the report does not provide any methods how to implement the measurement of these indicators in practice.

| Phase | Indicator |
|---|---|
| **Concept/design** | Waste prevented<br>Percentage recycled/secondary/by-product content<br>Percentage reuse content |
| **Construction** | Percentage waste to landfill – 0%<br>Percentage waste incineration/energy recovery 0%<br>Percentage waste reused/recycled |
| **Occupancy** | Percentage waste to landfill – 0%<br>Percentage waste incineration/energy recovery 0%<br>Reuse/repair/Refurbish/Adaptability<br>Utilisation rate |
| **Demolition** | Percentage waste to landfill – 0%<br>Percentage waste reused/recycled |

*Table 3: CE indicators in the construction project (CEW 2017)*

Additionally, it has been suggested to incorporate circular indicator in the building certification system BREEAM in the report called "A framework for circular buildings" by Circle economy, Metabolic, Dutch Green Building Council, SGS Search and Redevco Foundation (2018). Based on gap-analysis and expert consultation six essential sub-strategies for designing and constructing circular buildings were determined as follows; accountability and substantiation of building volume, design for reassembly, maximise amount of reused materials, maximise amount of renewable materials, availability of information (element, component, material) and building design embodies no or minimal toxicity. Thereafter, a set of metrics for each sub-strategy was determined. Some examples of these metrics are presented in Table 4. The inclusive list of all sub-strategies and metrics is presented in Appendix 1. The BREEAM indicator proposal is focused on the different components of the building, whereas the metric system by CEW introduced indicators to evaluate the circularity of different phases of buildings' lifecycle. Therefore, some measurements are on very detailed level such as, the share of remountable connections of total connections or the share of reused materials of total materials used in the building. (Circle economy et al. 2018) Using these measurements to assess the circularity of each building demands extensive and detailed data of buildings.

| Sub-strategy | Metrics |
|---|---|
| **Design for reassembly** | Share of remountable connections (%) |
| | Share of accessible connections (%) |
| **Maximise amount of reused materials** | Share of reused materials (%) |
| **Maximise amount of renewable materials** | Share of technologically reusable materials (%) |
| | Share of bio-based materials (%) |

*Table 4: Examples of circularity metrics by Circle economy et al. (2018)*

Even though two previous indicator systems are based the professional literature, measuring circular economy in the built environment has been discussed also in the academic literature. For instance, Nuñez-Cacho et al. (2018) proposed the circular economy scale for the building industry. This scale comprises seven weighted dimensions of which four are related to resource management (“3Rs, efficient management of energy, water and materials”), two to environmental impact (generated emissions and waste) and one to evaluate the shift towards circular economy. The scale is based on the questionnaire composing 44 questions and claims, which the respondent should evaluate on the 7-staged scale from “Fully disagree” to “Fully agree”. Consequently, since the answers are based on each respondents’ perception, this scale can produce biased information. Additionally, the questionnaire does not discuss the occurance under study in depth and therefore the results can be unreliable. Due to characteristics of the scale, it can be used to evaluate the realization of circular economy from the companies’ employees’ perspective. However, it does not produce an objective outlook for the realization of circular economy.

Whereas the previous indicators have been focusing on circularity in different phases of the construction, in the building or the corporate level, Fregonara et al. (2017) created a set of economic-environmental indicators to support investments decisions conforming the principles of life cycle thinking and circular economy. The focus of this methodology is on the end-of-life stage. The methodology composes three phases; “(1) environmental indicators calculation according to LCA and LCT; (2) economic indicators calculation according to LCC; (3) economic-environmental indicator calculation according to Global Cost calculation method.” The last phase considers residual value, disposal and dismantling costs and environmental impacts, embodied energy and embodied carbon, in monetary terms based on energy prices and carbon tax.

The supply of circular economy indicators for the built environment is diverse and therefore assessing the circularity of the built environment can be challenging. As earlier discussed, various indicators exist with different perspectives and focuses. Some metrics are focused on the measurements the circularity in the component level, whereas the others are focused on the waste generation on different phases of the construction level. However, the focus on the material cycles unites these metrics. This enables the measurement of the realization of circular economy in several situations. Concepts circular economy and built environment are both multidimensional. Therefore, coupling these two concepts requires multidimensional indicators to assess the circularity in the best possible manner.

# 3 Circular Economy and Property Development

This section describes first the traditional property development process and its main actors. Thereafter, some examples of implementing the principles of circular economy in the property development process is presented. Finally, this section summarizes the key principles for circular property development process and discusses challenges related to it.

## 3.1 Property Development in General

### 3.1.1 Property Development Process

Property development process is defined as "a change of land use and/or a new or altered building in a process which combines land, labour, materials and finance" (Cadman and Topping 1995, p. 2). Additionally, it has been addressed that property development aims to meet "the society´s needs" (Miles et al. 2007, p.3). According to Rakli (2012, p. 12), the aim of property development is to "increase the value of an individual property, or the value of a certain area with property, by investments". The object of the property development can vary from a "land or water area that forms the raw land for the real estate" to "a building or its part within a plot". The focus can be on real estate which is under planning or on existing real estates. (Rakli 2012, p. 12) Some of the most well-known definitions for property development are presented in Table 5.

| Source | Definition |
|---|---|
| **Cadman & Topping 1995** | "A change of land use and/or a new or altered building in a process which combines land, labour, materials and finance." |
| **Miles et al. 2007** | " Property development is the continual reconfiguration of the built environment to meet the society´s needs" |
| **Rakli 2012** | "Operation whose purpose is to increase the value of an individual property, or the value of a certain area with property, by investments" |

*Table 5:Definitions for property development*

Property development can be compared to any other industrial process, which aim is to create a product or output by utilizing various inputs. However, usually property development process is more complex and has a rather long timeframe. Another significant difference between property development and many other industrial processes is that the in property development the end product is unique by physical characteristics or / and its location. Usually, property development is not a completely subsequent activity and thus various process phases can repeat and overlap. (Wilkinson et al. 2008, p.2-3) According to Wilkinson et al. (2008, p.3), there are eight different phases in a property development process, which are described below:

**Initiation**
When some site is seen to be acceptable for different and/or more intensive used or there would a better use for an existing property, can the development process initiate. Basically, any actor or stakeholder of the development process (these actors will be described in section

3.2) can start the process. The initiator conducts a market research so that the planning for change of land use can begin. (Wilkinson et al. 2008, p.3)

**Evaluation**

This phase is regarded one of the most significant phases of the whole development process. Evaluation includes a market research and a financial valuation of the proposal. The aim of this phase is to determine the development cost, which has to be both reasonable and viable. If the development process is implemented by private sector, the focus will be on a potential for profit in relation to the risks incurred, whereas the public sector and non-profit organizations aim to ensure the recover of the costs. At this phase, the developer usually receives advices from the professional teams and decides whether to proceed the process or not. (Wilkinson et al. 2008, p.4)

**Acquisition**

Property development requires a land area, which has to be either bought or leased. Before the acquisition of the land, some investigations related to legal issues, ground quality and finance must be conducted. Legal issues related to the site which should be assessed before the acquisition are for example zoning, ownership and any other rights or restrictions related to the site. Ground investigations as for are focused for example on site's bearing capacity, access and drainage. Additionally, existing structures (electricity, water, gas and telephone) needs to be surveyed and cost for their possible expansion to be determined. Ground investigations aims also to detect underground problems, such as contamination and storage tanks. In addition to legal and ground investigations, also financial issues of the development process should to be considered. If the developer does not use internal resources, appropriate finance for acquisition has to be decided. Normally there are two different types of finance, which are considered. The first one is called short-term finance, which covers the costs during the development process. The second one is long-term finance (aka funding) which is used for covering the costs of the holding the completed development as an investment or to secure a buyer for the completed project. (Wilkinson et al. 2008, p.4-5)

**Design and costing**

The design and costing phase is a constant process during the development process and it gets more comprehensive when the development proposal increases in certainty. Before the developer commits himself to the scheme, design costs will be kept low. However, the plans should be enough detailed, so that the quantity surveyor can conduct the cost estimation. This means usually layout plans which present proposed building(s) on the plot, floor plans and drawings, plans of the main elevations and building material choices. (Wilkinson et al. 2008, p.5-6)

**Permissions**

The development processes basically require always various permissions from different the local authorities or from the state. Examples of these permissions are building and demolition permissions. Permissions may demand a long time to be approved by the authorities, which needs to be considered already at the evaluation phase. Sometimes permission processes can be very complex and demand rather much knowledge about local legislation and policies. (Wilkinson et al. 2008, p.6-7)

**Commitment**
Before any substantial commitment is made by the developer, the preliminary work has to be completed. This means that all issues related to land, finance, labor, materials and permissions have to be at least satisfactorily negotiated. After the preliminary work is completed, it has to be evaluated one more time, thus the timeframe of the project is so long, that the economic circumstances might have changed during it. The developer has to be completely satisfied that, the evaluation has "based on the best possible information and the scheme is still viable". Before the land is acquired, the costs have to be still kept low. (Wilkinson et al. 2008, p.8)

**Implementation**
When the all needed raw materials are in a place, the implementation phase can begin. This phase, as previous ones, is not any more flexible**,** since most of the most important decisions have been made. The inflexibility of the implementation phase highlights the "the importance of careful evaluation and of maintaining flexibility". The goal of the implementation phase is to implement the development within the certain timeframe and budget. This goal is usually relatively difficult to reach and therefore, depending on the complexity of the project and the experience of the developer, the employing of the project manager should be considered at this phase. Project managers' task is to co-ordinate the design and building process. (Wilkinson et al. 2008, p 8-9)

**Let/manage/dispose**
The last step of the development process is that the developer either lets the property and to manages it or disposes it to investors. This has to be decided in the early phases of the project whether to sell or let the property. The decisions are dependent on the developer and the market. Occupiers of the property must be involved in the process as a part of the design phase, if possible, since then the developer can learn more about occupier's requirements and thus, implement the project more successfully. (Wilkinson et al. 2008, p.9-10)

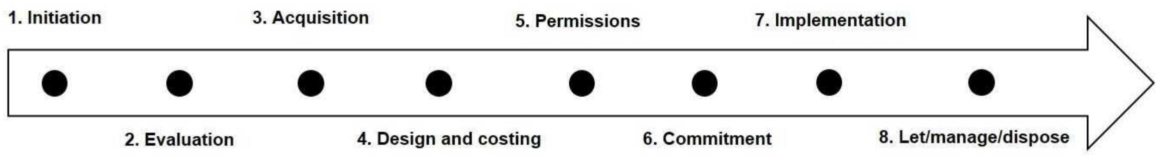


*Figure 7: Property development process, author's own version (Wilkinson et al. 2008)*

## 3.1.2 Main Actors and Stakeholders in the Property Development Process

**Landowners**
Landowners are regarded either as active or passive in the terms of property development. Active landowners act as initiators, who are willing to divest or increase the value of their land, whereas passive landowners can complicate developments, if they don't want to sell their land or to participate in process. In some cases, land owners can also act as developers simultaneously. Landowners can be divided into three different categories; traditional landowners, industrial landowners and financial landowners. Traditional land owners include government, municipalities and other public actors, which one key characteristic is

that they are not entirely motivated by economic benefits. Their operations are rather driven by social, political and ideological factors. The second group is called, industrial landowners, who own land for their own purposes and they can be for example manufacturers, farmers and retailers. The motives of this group are more complex in comparison to motives of traditional land owners, since the motives are determined by their own product. The ownership for the third group, financial landowners, is as an investment and thus they are assumed to involve in development if it is financially optimal for them. Due to financial motives, financial land owners are usually the most informed group of land owners regarding development process and land values. (Wilkinson et al. 2008, p.11-12)

**Developers**
The size of private development company can vary from one-man band up to large internationals. The purpose of these companies is often to gain a direct financial profit from development process. Usually, developers work as investors or traders. Especially, the smaller companies must operate as traders, since they do not have financial resources to maintain their completed development projects. Some developers are focused only on certain types of properties, such as offices or residential, or on certain geographical locations, whereas other developers are willing to spread their risk across different property types and locations. (Wilkinson et al. 2008, p.12-13)

**Public sector and government agencies**
The role of authorities is to supervise and guide the planning and construction by different rules, regulations and decrees. Thus, authorities act as supervisors, which can either contribute or restrain the implementation of the development. In addition to supervision, to achieve for example economic or environmental development of there are, public sector can support development by supplying land and buildings for developers as well. Additionally, they can assist developers by financial grants, which are usually granted to support construction for the public good. (Wilkinson et al. 2008, p.12-13; Kiiras & Tammilehto 2014, p.25)

**Planners**
Planners are responsible for “encouraging development” and for preventing “undesirable development”, through different zonings plans, which are categorized into three types in Finland. These plans are regional, master and detailed plan. However, these plans include gaps often and therefore, planning consultants are often employed by the developer to support negotiations with planners. Planning authorities in different areas have usually different characteristics. For example, planners in areas of low economic activity usually support development activity with less restrictions. Conversely, planners in areas of high economic activity set more restrictions for development to maintain the high standards of built environment. Consequently, this can lead to conflicts between developers and planners. (Wilkinson et al. 2008, p.14-15)

**Financial institutions**
Development is usually a project, which demands a significant amount of capital. Therefore, unless the developers or that of partners has enough their own capital, the role of financial institutions is crucial in the development process as providers of finance. Additionally, financial institutions can act as financier, developer or investor. Examples of financial institutions are banks, pensions funds, insurance companies, building societies and additionally some government agencies. (Wilkinson et al. 2008, p.15-17) Especially pension

funds have had an important role in capital markets in Finland (Kiiras & Tammilehto 2014, p.26). As mentioned earlier, financial institutions can provide either short-term money (i.e. development finance), which covers the costs during the development or long-term money (i.e. funding), which is used to cover the cost of holding the completed development. Public sector developers have similar sources to obtain finances as private developers. However, obtaining can be more difficult due to regulations regarding public sector borrowing. (Wilkinson et al. 2008, p.16-17) Depending of the structure of the finance and the amount of leverage, financial institutions may set some requirements or limitations to developments through the terms of development and lease contracts (Kiiras & Tammilehto 2014, p.25).

**Building contractors**

To construct the development scheme, developer employs a building contractor. Building contractors' aim to the "direct financial gain". However, there are wide range of various contractual systems for obtaining a completed building. (Wilkinson et al. 2008, p.17-18) For example, the contract can be executed as a turn-key contract, in which the contractor is also responsible for planning (Kiiras & Tammilehto 2014, p.25). Larger building contractors may also take the role of management contractor, which is responsible for managing all sub-contractors for the developer's fee. Resulting from the significant role of the building contractor in the development process, developer must ensure the capability and capacity of the contractor, so that the development scheme can be completed in a desired quality. Therefore, the developer must find the balance between the lowest tender and quality of execution. (Wilkinson et al. 2008, p.17-18)

**Agents**

Agents can initiate developments or bring the main actors together in the process. They can also form a link between the developer and occupier. Agents have comprehensive knowledge of the real estate market (e.g. demand and rents) and therefore, they are crucial players in the process. They have aim to make a direct financial profit, that is usually based on the fees charged to their client. The amount of the fee is usually dependent on the value of the transaction. Agents can act both on the developer's and occupier's side. For example, they can search sites for a certain use for developers, but also search suitable premises for occupiers. (Wilkinson et al. 2008, p.19-20)

**Professional team**

Resulting from the complex and multidisciplinary nature of the development process, developers, depending on their needs, employ a professional team to support the process (Wilkinson et al. 2008, p.21; Kiiras & Tammilehto 2014, p.28). The most important members of the professional team are described below:

- **Planning consultants:** Usually, zoning issues demand relatively much negotiations with local planning authorities. Developer can employ a planning consultant for these negotiations. Planning consultants can also work for landowners, which site are about to be developed and evaluate whether the development results in the "highest and best use of the land" or not. (Wilkinson et al. 2008, p.21)

- **Property economics consultants/valuation surveyors:** In the evaluation phase, there are usually employed property economic consultants or valuation surveyors to perform analysis of current market in terms of demand and supply (Wilkinson et al. 2008, p.22). This is essential, when the developer is considering raising funding or debt for the development (Kiiras & Tammilehto 2014, p.27). When financiers are considering a development funding proposal, they usually insist on these analyses and additionally they have usually some in-house researchers as well. (Wilkinson et al. 2008, p.22)

- **Architects:** The developer employs the architect to design the appearance and the construction of new buildings the refurbishment of old buildings. (Wilkinson et al. 2008, p.22) Usually architects participate in proposal, general and production planning phases. In addition to designing of the building, architects maintain relations to local authorities and may support bidding or negotiation processes. Architects' work contribution is essential in relative to building's functional planning, esthetics, physical safety and to risks related to politics and markets. (Kiiras & Tammilehto 2014, p.27) Employing architect in the early phase of the development is crucial to achieve the best possible outcome. It is important for the developer, that employed architect can produce good architecture, which is simultaneously cost-effective and functional for the occupier. Problems can arise when there is a lack of discussion between architect and client. (Wilkinson et al. 2008, p.22)

- **Construction economists or quantity surveyors:** The main task of construction economists or quantity surveyors is to advise the developer with costs related to the building contract and its associated costs. Additionally, they can for example calculate costs for plans provided by the architect and advise in choosing the most appropriate form of the building contract. Fluent cooperation between the architect and the quantity surveyor is crucial and in addition the quantity surveyor should present cost effective alternative solutions for the developer to those of provided by the architect. (Wilkinson et al. 2008, p.23)

- **Engineers:** The development demands various engineers from different fields, such structural, HVAC, civil and electrical engineers. The need for different engineers is development differs based on the complexity of the project. Engineers' fee is usually percentage based on the value of their element of the building contract. (Wilkinson et al. 2008, p.23)

- **Project managers:** If the scheme is large and complicated, the developer can employee the project manager to manage the professional team in the development. Usually, their educational background is construction or architectural studies. The project manager should be employed before any other members will be hired in the professional team to secure "the best professional team for the project". (Wilkinson et al. 2008, p.23)

- **Solicitors:** The developer needs solicitors in various phases of development from the acquisition of the site until the competition of leases and contracts of sale. (Wilkinson et al. 2008, p.24)

- **Accountants:** For example, in the case of complex tax regulations, developer should consider employing an accountant in the professional team. (Wilkinson et al. 2008, p.24)

**Objectors**

Potential objectors against development process can be divided in two categories. The first group is formed for example of "amateurs" and self- interested neighbors, who want to prevent the implementation of the proposed development. (Wilkinson et al. 2008, p.24-25)

**Occupiers**
If the occupier is known in the early phase of the development process, it can be regarded as one of the main actors of the process, which sets the requirements for design and construction. In some cases, the developer should convince the occupier to compromise with their requirements to produce a more standard and flexible type of building, which would fulfil the requirements of markets after the event of disposal as well. In the past, developers produced buildings, which fulfilled the requirements of financial institutions instead of those of occupiers. However, practices have been changing and currently developers have put more effort to recognize the requirements of occupiers. Additionally, occupiers are becoming more aware of the role of property within their business in comparison to the past. (Wilkinson et al. 2008, p.25-26)

## 3.2 Property Development in Circular Economy

Currently, there is relatively little research on how to adapt principles of circular economy in the property development process. This section introduces three frameworks for implementation of circular economy in design and property development. Thereafter, possible challenges related to implementation of circular economy in property development are discussed. Finally, the most crucial measures for different phases of the property development are summarized in a theoretical framework for circular property development.

### 3.2.1 Frameworks for Circular Property Development

#### 3.2.1.1 Circular Economy Criteria for Projects in the Built Environment

In 2018, Green Building Council Finland (2018) published "Circular economy criterion for projects in the built environment". Report presents various measurements which can be considered in the different phases of the property development process to facilitate the realization of circular economy. The list of measurements is not all-inclusive; however, it provides a clear basis for implementation of the principles of circular economy in the built environment. The most important measures for each phase are introduced below as follows:

**Zoning and regional planning**
Zoning creates boundaries for the implementation of circular economy in a certain region. Adequate areas for the intermediate storing of materials needs to be reserved and regions' developers must be committed to recycle. Regional planning should consider the synergies between different areas regarding the energy production and utilization of waste heat.

**Plot disposition**
Circular economy requirements for the development project can be determined during the plot disposition. One concrete example is a circular economy plan, which introduces how the development project contributes the realization of circular economy. This can be demanded from the developer during the plot disposition.

**Ordering and bidding**

The role of ordering and bidding is significant in the realization of circular economy. The client should have a clear vision of goals to implement circular economy. The project should be ordered from the professional of circular economy and thus, circular economy references should have a significant influence in the selection of suitable partners. Additionally, the client should demand a list of used products and materials in the building in order to produce the material passport. The client can also set requirements for designing during ordering and bidding. For example, the amount of preserved existing structures or the amount of recycled material/product under EN 15804 standard can be used as a basis for bidding.

**Infrastructure, planning and construction**
The efficient utilization of landmass and the use of recycled soil in the projects are in key roles when implementing circular economy in infrastructure construction. Produced additional soil in the project should be utilized in some other project.

**Designing**
Good designing has an essential role in the implementation of circular economy. The starting point for designing is to design a high-quality, long-lived, energy efficient and cost-efficient building. The key principles for designing are the minimised use of virgin materials, the use of recycled material when something new needs to be built, design for disassembly, the versatility and the flexibility of the building.

**Construction**
In this phase, it should be confirmed that the requirements set for designing will be achieved, and the project is implemented under circular economy principles. The starting point for the construction is that any non-recoverable waste should not be produced. Consequently, all produced waste material during the construction should be sorted and utilised by obeying the waste hierarchy; (1) reuse, (2) recycle and (3) energy utilisation.

**Demolition**
The schedule of demolition work should be arranged so there is enough time for careful recycling. The demolition work should begin with a demolition survey, in which utilisation potential of materials will be analysed. Especially, when the component is disassembled as unbroken, recognizing the next purpose of use or the place for intermediate storing is crucial.

**Use-phase**
The use of the building should be maximised around the clock as efficiently as possible. This reduces the needed overall number of premises in the region and consequently preserves resources. The need for alteration work should be minimised and when the building has to be altered, the starting point for the work should be the use of recycled and recyclable materials.

| Phase | Criterion |
|---|---|
| **Zoning and regional planning** | Defining the circular economy areas<br>Regional recycling and storing of heat energy |
| **Plot disposition** | Circular economy plan<br>Requirements the realization of circular economy in the projects |

| | |
|---|---|
| **Ordering and bidding** | Circular economy knowledge<br>Material passport<br>Use of recycling materials<br>Requirements for designing and construction |
| **Infrastructure, planning and construction** | Use of recycled materials<br>Mass balance within the area |
| **Designing** | Retaining existing structures<br>Need for construction materials<br>Use of recycled materials<br>Reuse plan<br>Designing for repair<br>Flexibility<br>Shared spaces |
| **Construction** | Recycling of construction waste<br>Recycled materials and products<br>Collecting the material passport |
| **Demolition** | Demolition survey<br>Sorting and utilization of demolition waste |
| **Use-phase** | Use of shared premises<br>Minimisation of alteration work<br>Use of recycled materials |

*Table 6: Circular economy criterion for a construction project (GBC Finland 2018)*

#### 3.2.1.2 Collaboration Tool for Circular Economy in the Building Sector

Leising et al. (2018) proposed a collaboration tool for practitioners and professionals in the building sector to promote the realization of circular economy. This tool (see Figure 8) comprises five phases starting from vision development to re-use of materials. The purpose of the model is to support new pilot projects and assist actors in the building sector to explore more circular methods to work. The tool is made from the perspective of the initiator, which can also act as an end user, and consist of five phases as follows:

**Phase 1: Preparation & Vision Development**
In the first phase of the collaboration tool, the initiator starts to create vision based on ambitions for both the collective process and the product (i.e. building) instead of setting requirements for the project. This phase requires leadership from the initiator and support from the own organisation. The circular vision for the project is the output of this phase.

**Phase 2: Involve Market & Supply Chain**
The multidisciplinary team, which designs, builds and maintains the building is selected in the second phase. In this phase, required disciplines for the projects needs to be recognized. Based on these chosen disciplines, collaboration partners will be chosen instead of specific firms. This facilitates collaboration between companies, which otherwise would not necessarily have collaborated and facilitates innovation. In this case, companies are focused on creating value for the project instead of just completing their conventional operations without looking at the entire building life cycle.

**Phase 3: Process Design & Collaboration**
In this phase, the collaboration between partners will be formalized by using non-traditional contracts, which aim to collective benefits instead of strict specifications regarding parties' responsibilities. The trust between parties is crucial during the third phase, since in these types of contracts stakeholders has to be sure of their involvement in the next phase. This phase involves also the implementation of the Building Integrated Modelling (BIM) software, which enables to reveal all the material flows in the building in one data set.

**Phase 4: Business Model & Implementation**
In the fourth phase, the construction starts and simultaneously developing new business models begins. These business models should contain an inducement for the common aim of constructing a circular building. The building should be constructed for disassembly and reuse. Additionally, material passport of used materials will be gathered during the construction to facilitate the end-of-life use.

**Phase 5: Usage & Prepare for next use**
The final phase guarantees the maintenance of material value via repair, reuse or recycling of construction materials. Materials can be divided in two categories; those with short lifecycles, such as furniture, spaces and services, and the others with long lifecycles, such as site, structures and facades. Suppliers should take a responsibility of short-lived materials. Additionally, a "material market place" for long-lived materials could be established.

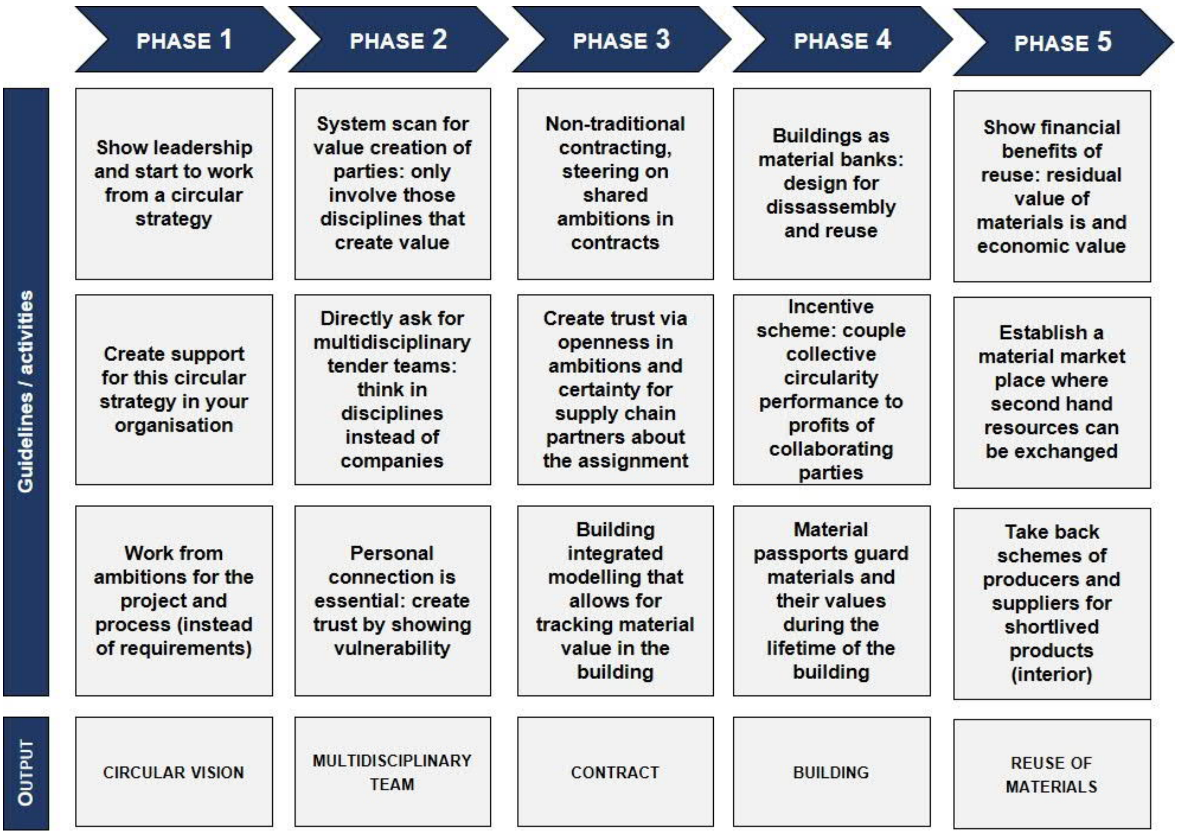


*Figure 8: Collaboration tool for CE in the building sector (Leising et al. 2018)*

### 3.2.1.3 Stepwise approach Circular Building

The stepwise approach Circular Building by Geldermans (2016) utilises The New Stepped Strategy, which has introduced at first time by Dobbelsteen (2008). This approach is based on three steps: "1. Reduce resource demand (passive, smart & bioclimatic design), 2. Reuse resources (waste heat, waste water, waste materials), and 3. Apply regenerative – circular – solutions with regard to the remaining resource demand". Gelderman's stepwise approach is explained below step by step.

**Step 1**
Firstly, the added value of the new building should be considered and evaluated carefully. For example, it should be considered whether the construction of the new office building could be replaced by new ways of working with an increased space use or remote working.

**Step 2**
If the need for extra space exists, exploring for new premises should be started from the current available and usable vacant buildings.

**Step 3**
The third step is to apply "change" as a starting point for a design. Products, which lifespan is long, should be distinguished from the products with shorter lifespan. Connections and dimensions of materials are in a key role in adaptable design. For example, cut outs can be integrated in load bearing walls for future operations. If the leading design principle is local sourcing, then straight preceding from step 3 to step 5 is possible.

**Step 4**
The fourth step should integrate "intelligent dimensioning". This means that planned function, performance and lifespan should be considered when determining measures and capabilities for materials and components.

**Step 5**
The supply of reusable materials nearby should be assessed in this phase. The feasible material collection distance should be determined. Example of a useful tool for this is a "harvest map", that shows the planned construction activities. In some cases, this step may lead into the design, i.e. step 3.

**Step 6**
As in the step 3, also in the design of materials and products, the design principle should be "change". Material should be designed for assembly and flexibility and additionally they should maintain or increase their value.

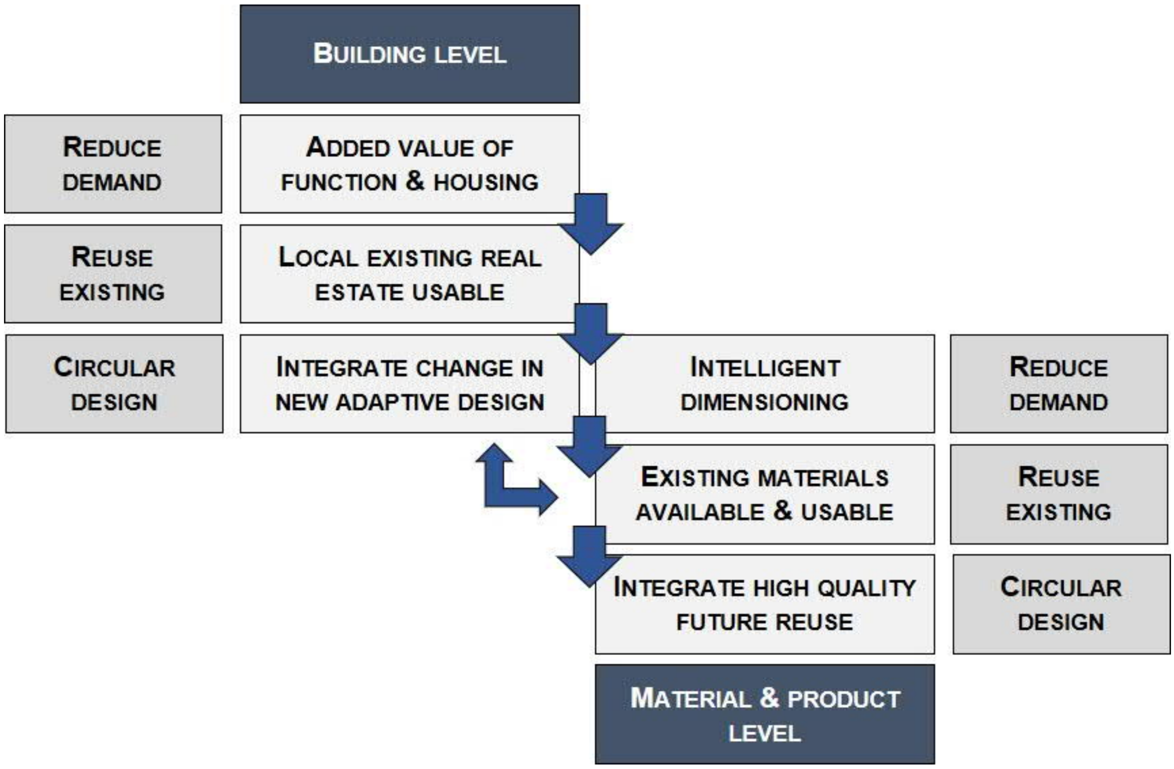


*Figure 9: Stepwise approach Circular Building by Geldermans (2016)*

### 3.2.2 Challenges Related to Circular Property Development

Academic literature has categorized the enablers and barriers to more circular economy in different phases. For example De Jesus & Mendonca (2018) divides enablers and barriers into soft (institutional and social) and hard (technical and economic) categories, whereas Adams et al. (2017) categorizes them into seven categories: "legislation and policy, awareness and understanding, manufacture of construction products (design for end-of-life), designing and operating buildings (design for disassembly, adaptability etc.), recovery of materials and products (market mechanisms), business (circular business models) and economic (the financial case for circular economy)."

The transition towards a circular economy requires a change in social, behavioral and managerial contexts. One major cultural challenge for implementing circular economy in the construction sector has been seen to be the lack of interest, knowledge/skills and engagement throughout the value chain including stakeholders such as suppliers, customers and client etc. (Adams et al. 2017; Hart et al. 2019) Additionally, some authors have emphasized the current linear practices as a challenge for delivering circular economy, since it is difficult to implement circular business models, when adequate infrastructure for them does not exist (Despeisse et al. 2017; Kirchherr et al. 2018). In addition to previous challenges, also the lack of collaboration between stakeholders has been often seen as a challenge especially in the construction sector. This can be divided into two categories; lack of collaboration between businesses and the lack of collaboration between business functions. The first one is often argued by competitive instincts and the latter one by inability between different functions such as, finance and corporate responsibility, to work transparently with a common goal. (Hart et al. 2019) Even though the property owner would be willing to contribute the realization of circular economy, other actors may not have same vision. For instance, new material choices may create challenges to architects by limiting his/her artistic visions or to constructors when their treatment on site differs in comparison to conventional ones.

Additionally, the lack of consistent CE related regulatory framework has been seen as a challenge (Adams et al. 2017; Hart et al. 2019). For instance, even though the circular economy is supported already on EU-level, there is an absence of Finnish legislation regarding circular economy. In some cases, it is possible that existing laws and regulation can obstruct the implementation of principles of circular economy. For instance, zoning regulations can prevent the conversion of old office premises into apartments, even though there would be more demand for apartments than for offices. In addition to zoning, also conservation legislation can prevent to make changes to old buildings, even though the solution would be more sensible from the circular economy perspective. Moreover, the academic literature has discussed the lack of incentives for circular economy as a challenge (Hart et al. 2019).

Furthermore, relatively short investment periods, which prioritize capital expenditures over operational expenditures have been seen as a challenge as well. This promotes transactional relationships with shorter financial paybacks instead of long-period collaboration with wider social and environmental objectives. (ARUP & BAM 2017; Hart et al. 2019) Moreover, infrastructure supporting for circular economy, R&D and certification processes has relatively high upfront costs, which can cause challenges, since the construction costs can be already relatively high in urban regions (Hart 2019 et al.). Several authors have emphasized the low virgin material prices as a major challenges and even lower end-of-life values (Adams et al 2017; Kirchherr et al. 2018). This can make reprocessing and take-back schemes at end-of-life phase uneconomical (Adams et al. 2017). Additionally, the business case of circular economy is said to be poor or poorly articulated as well as the case studies related to it. Furthermore, the funding needed for circular economy projects has been seen as limited. (Hart et al. 2019)

Traditionally, buildings are characterized as assets with rather long life cycles, when compared to many other products. This creates uncertainties related to future ownership, adaptability and end-of-life phase and furthermore, generates challenges in building a feasible financial case for circular economy in the property sector. (Hart et al. 2019) In addition to long lifecycles, buildings are complex systems with fragmented supply chains and actors with conflicting interests (ARUP 2016; Adams et al. 2017). This complicates creating common goals especially those with longer financial payback periods. Moreover, the construction sector is regarded as “conservative, uncollaborative and adversial”, that prefers risk-averse solutions instead of new innovations. Furthermore, it has been noticed that there is as an absence of coherent circular economy for the construction industry, lack of standardization for recycled materials and insufficient development use or development of circular economy focused tools and metrics. (Hart et al. 2019) Basically these challenges refers to the fact, that the construction industry has difficulties to recognize the characteristics of circular economy for the built environment and concepts relationships to other frameworks such as sustainable development. Finally, material recovery causes technical challenges for instance when trying to separate brick bonded with OPC or to recycle or reuse industrialized natural products, which are not belonging solely to biological or technical loops. (Hart et al. 2019)

Most of the previously mentioned challenges can represent in the various phases during property development process. Many challenges are actually consequences of sectoral characteristics related to property markets. In addition to complexity and multidisciplinary of the markets, stakeholders' interests might differs from others'. As it was discussed in section 3.1.1, the highest opportunity for flexibility in the process is before the construction phase. Therefore, early phases are the most crucial, since then the challenges can either realize or to be tackled.

### 3.2.3 Theoretical Framework for Circular Property Development

Theoretical framework below summarizes how the principles of circular economy could be adapted in a property development process. The framework aims for a simple interpretation and is based on phases 1, 2, 4, 7 and 8 of the property development model presented by Wilkinson (2008). These phases include the best possibilities for the developer, to contribute the realization of circular economy. Additionally, the realization of circular economy can be contributed in the phase 3 (acquisition) by circular plot disposal terms (GBC Finland 2018) and in the phase 5 (permissions) as well. However, public authorities, such as municipalities, have higher possibilities to influence on it than the developer. Thus, the realization of circular economy in these phases is highly connected to regional characteristics.

**Initiation**

According to Wilkinson et al. (2008, p.8), the phase 7, implementation phase (aka construction phase), in the property development process is not anymore that flexible than the previous phases. Therefore, phases before implementation should be emphasized, when discussing about circular property development. Before making decision on constructing a new building, developer should consider whether the construction could be by new ways of working, such as virtual solutions, or by using old premises more intense (ARUP 2016; Geldermans 2016). However, if the decision on constructing something new is made, the plan for implementing circularity, e.g. circular vision proposed by Leising et al. (2018), in the project should be created. According to Leising et al. (2018), the vision should be based on ambitions for the collective work and building itself, instead of strict requirements. In creating the vision, the role of leadership is important. The collaboration between multidisciplinary team is also crucial already in the beginning and this might facilitate cooperation between companies which would necessarily cooperate otherwise. Partners should be chosen based on disciplines instead of specific firms (Leising et al. 2018). Additionally, circular economy references should be emphasized when choosing the collaboration partners (GBC Finland 2018).

**Evaluation**

According to Wilkinson et al. (2008, p.4), the evaluation is the most important phase in the property development process. Thus, it cannot be ignored in circular property development process neither. Private sector developers aim for the maximal profit of projects, whereas the public sectors aim for covering the costs. In the both cases, the amount of investment has to be reasonable and costs needs to be covered to reach the desired outcome for the project. For example, low virgin material prices and limited funding has been seen as a barrier for the implementation of circular economy (Hart et al 2019). However, whole life costing (WLC) and new valuation techniques, which would incorporate example environmental and social elements, should be emphasized due to increased focus on the value of materials. (Hart et al. 2019) Example of such technique is presented by Fregonara et al. (2017), which was earlier discussed in the section 2.2.3 Additionally, circular solutions, which can save money, such as using reclaimed materials in some cases, should be highly considered. (Hart et al. 2019)

**Design**

The design phase has a crucial part in the circular property development process, since it determines the material choices for the project. Circular design principles for circular buildings include for example reusing existing structures and buildings, design for reconstruction, design for adaptability, using durable recycled and recyclable materials instead of virgin materials as already discussed in section 2.2.1.1 (e.g. EMF 2015b; Adams et al. 2017; GBC Finland 2018). To facilitate the reuse of existing materials in proximity, "harvest map" can be considered during this phase (Geldermans 2016). Additionally, the supply of construction material surplus markets can be investigated as a basis for design. "Change" should be applied in a new adaptable design, where the focus will be already in the end-of-life phase (Geldermans 2016). Related to this, reuse plan for the building should be implemented already in the design phase which requires collaboration between designers and demolition contractors (GBC Finland 2018).

**Construction**

(aka "Implementation" in Wilkinson's model). The amount of waste should be minimised during the construction phase. The produced waste and surplus materials should be delivered further, if possible. One possible solution to decrease the amount of waste during the construction, is to utilise modular off-site production. Metrics regarding the waste generation provided by CEW (2017) can be utilized in this phase. Material passport should be gathered by the contractor, since it is an important part when considering the future's refurbishments and reuse. (GBC Finland 2018; Leising et al. 2018) Additionally, collaboration between other construction and demolition sites in proximity should be applied to maximise the use of construction waste (Geldermans 2016).

**Use phase**

("Let/manage/dispose" in Wilkinson's model). During the use phase, the use of premises should be intense through sharing and multifunctionality. (GBC Finland 2018). Additionally, the utilization of commercial premises in different purposes of use outside normal working hours can be investigated when it is possible. Amount of alteration work should also be minimized during the use phase (GBC Finland 2018). However, if the building is design by using circular design strategies, such as design for flexibility and design for disassembly, changes in use do not demand significant refurbishment work.

# 4 Campus real estates

The aim of this section is to describe briefly the characteristics of campus real estates as an asset class. Additionally, the current trends of campus trends will be discussed and adoption of circular economy in the campus development is analyzed.

## 4.1 Three Generations of Universities

Traditionally, three different generations of universities are recognised in academic literature as follows: (1) Medieval university, (2) the Humboldt University, (3) A network university. In the course of time, changes in primary processes of research and education has shaped needs regarding buildings and locations of university in urban context. These changes have influenced in variables such as types of space, suitable location and required floor area. (Den Heijer 2011)

Western Europe Medieval universities were born in 13th – 15th centuries during the aegis of Catholic Church. Medieval universities were orientated mainly in education as the main goal of these universities was “enlightenment and encouraging obedience to God”. The research was not that significant part of universities as it is currently. The lingua franca in Medieval universities was Latin, which made the communication between members of different institutions easy. Often, universities were located in central locations, since they were regarded as status symbols for their cities. (Den Heijer 2011)

The second generation, known as the Humboldt University, was during 16th – 20th centuries. Whereas medieval universities were focused solely on religion and education, the Humboldt University started to integrate research in university operations as well. Universities started also to use local languages instead of Latin, which improved the quality of research, however created challenges in communication between other universities. During the second generation, the enrolment of students increased significantly, which lead to increased space demand. Due to this, universities started to more towards the periphery of cities. (Den Heijer 2011)

The third generation, known as network university, started in 20th century and is regarded as continuing at present is highly shaped by the technological development, English as lingua franca and the shift into a knowledge economy. These developments have shifted current goals of universities, and currently, many universities are considering how to challenge these shifts. Network universities are regarded as valorisation oriented based on both physical and virtual spaces and on the collaboration with various partners. One important characteristic of current universities is the extensive amount of available knowledge, which may demand more face-to-face contact to discuss and focus. (Den Heijer 2011)

It is obvious, that the past trends in campus development have had effect on today’s campuses. This has both advantages and disadvantages. Central locations and cultural heritage buildings can be regarded as advantages. On the other hand, these cultural heritage buildings have often relatively high maintenance disadvantage. (Den Heijer 2011)

## 4.2 Key Trends of Campus Development

Den Heijer (2011) has identified three key trends that will influence management of universities and campuses: (1) knowledge economy and the crucial role of universities, (2) the network university – universities as nodes in a network and (3) the green campus – sustainable development and reducing the carbon footprint.

Economy in many countries has shifted or is shifting from agriculture and industry to services and knowledge (Den Heijer 2011). Whereas the agrarian and industrial economies are restricted to particular areas, knowledge economy is less restricted and thus can be regarded as a network economy (Castells & Himanen 2002). The whole world as a potential labour market for knowledge workers tightens the competition between workers and demands specialisation, which is one of the key characteristics for a knowledge economy. The presence of universities strengthens the knowledge base of the certain area. Additionally, the student population and highly educated workforce generated by universities add value to the economic base, quality of life and urban diversity. Universities have a significant role as an employer in areas they are located in, which is underestimated often. In addition to offering knowledge jobs, universities offer other supporting jobs. (Den Heijer 2011)

"The current network universities comprise education, research and knowledge transfer towards related businesses and society." These networks can be identified within different universities and between universities and other actors as well. Current practices have encouraged cross-disciplinary research, whereas some faculties have been traditionally quite autonomous. Trends such as technological change and globalization have facilitated the mobility of students and stuff, which can either effect increased competition or collaboration. Sharing premises with other actors is regarded as a part of network universities, which can stimulate collaboration and additionally reduce faculty costs. (Den Heijer 2011)

While themes such as sustainability increases its popularity in global scale and climate issues are getting more attention, universities have started to adopt environmental issues in their campus strategies. Campus strategies are not only limited on energy issues, they rather adopt all three dimensions of sustainability. Moreover, universities have paid more attention on low occupancy rates in some premises such as laboratories after financial crises, which has facilitated the amount of shared and multifunctional premises. Due to economic and environmental context, convincing these premises is easier than what it was before. Green campuses have seen to have many benefits. In addition to supporting environmental goals, they can create more environmentally-conscious users of the campus. However, this requires to have visible sustainable solutions in the campus or alternatively have solutions that are known by the users. Moreover, green campus ideology supports different facilities to share premises in order to reduce the ecological footprint of the university. (Den Heijer 2011)

## 4.3 Campus Development in a Context of Circular Economy

The gap in literature considering circular economy in campus development has been noticed. Current literature has focused only on certain scale levels in campus development, such as energy or food and waste flows. However, the literature considering various scales of campus development from the perspective of circular economy is relatively scarce. Furthermore, only few projects have been implemented in which circularity have been a determining factor for campus or area development. Thus, there is not any systematic overview how to combine the concepts of circular economy and campus development. (Hopff et al. 2019)

Generally, circular economy is an organisational issue, which main focus is on technological questions. The challenge in the implementation of circularity objectives in campus development is to set them concrete requirements at the tactical and operational levels. Concept of circular economy is perceived as complex by organisations. (Hopff et al. 2019) Thus, "wicked problems" or unstructured problems are regarded as repeating challenges (Nijhuis et al. 2017). Three levels to implement circular objectives in campus development are recognised: (1) ambition, (2) integral strategy and (3) making specific (Hopff et al. 2019).

Campus development can be understood to comprise four dimensions: (1) organisation, (2) use & function, (3) spatial scale levels and (4) flows & materials. These dimensions have effect on the whole system and further on the application of circular principles. Thus, the logical starting point is the system thinking. More integrated policies between different departments and faculties are necessary. Moreover, understanding various spatial scales and the influence of intangible factors and processes (e.g. procurements and design choices) has a major significance when applying circular principles. The shift towards more circular policies requires a change in the culture, which will not be reached just by setting goals from the management. (Hopff et al. 2019)

The integral circular economy policy between each department in order to avoid a situation where departments form policies that are not consistent with the others'. The coherence or the circular economy strategy must be safeguarded. The role of external actors is almost as important as the role of internal actors. The client can stimulate the implementation of new solutions by asking clear questions without prescribing them. The general atmosphere has to be positive to various ways for work and to new contracting models, which already exist. However, they should be linked to circularity objectives. (Hopff et al. 2019)

In order to realize circular objectives, priorities and clear objectives needs to be set for operational and tactical levels. The abstract ambition needs to be translated into concrete content in these levels, which makes the concept of circular economy more understandable and accessible. Concrete criteria must be done, which aims to make relevant flows circular. After defining the desired scope and working within it, the complexity reduces and the subject will be clearer. (Hopff et al. 2019)

# 5 Case Company: SYK

This section describes the case company, SYK, and its role in a property development process. Furthermore, this section introduces company's goals and guidelines regarding property development processes and evaluates company's current status from circular perspective. Finally, opportunities and challenges to facilitate the realization of circular economy in the future is analyzed.

## 5.1 Brief Description of Case Company

SYK is founded in 2009 and has leased and developed premises mainly for Finnish universities outside the Helsinki Metropolitan Area since 2010 (SYK 2018d). The company is owned by universities (2/3 share) and the State of Finland (1/3) and therefore, SYK is not regarded as a public procurement unit (SYK 2011a).

Currently, the company owns in total 247 properties (SYK 2019a) which equivalents approximately to leasable area of 1.1 million square meters. In 2018, SYK's revenue was EUR 159.5 million. (SYK 2019b) The estimated market value of the properties in 2018 was approximately 1.4 billion euros (Newsec 2018). The company is owned by 9 universities operating outside the Helsinki Metropolitan Area (University of Eastern Finland, University of Jyväskylä, University of Lapland, Lappeenranta University of Technology, University of Oulu, Tampere University, University of Turku, University of Vaasa and Åbo Akademi University) and by the State of Finland. (SYK 2018d)

The company aims to offer premises with a reasonable price for universities and develop its properties also for other actors. The goal of the company is to create attractive and sustainable learning and innovation environments which support the success of universities on the international level as well. SYK invests significantly on research and development and by this way aims to secure the competiveness of its tenants through functional space solutions. (SYK 2018d)

SYK has produced Campus strategies for each campus. The aim of these strategies is to create a basis for future's land use and functional development. According to SYK, campus strategies have produced positive outcomes and launched zoning work almost in every city. Shared use campus buildings have been set up in Tampere and Oulu. Additionally, more shared use buildings will be implemented in Turku and Lappeenranta. SYK is aiming for similar development in other cities as well in further years. (SYK 2018d)

Universities act as main users of properties owned by SYK. Each university has their own departments of disciplines, strategic plans and both education and research programs. Furthermore, department in these universities have their own strategic plans. Universities (user) act as SYK's tenants, who sublease premises for different departments (end user). (SYK 2011a)

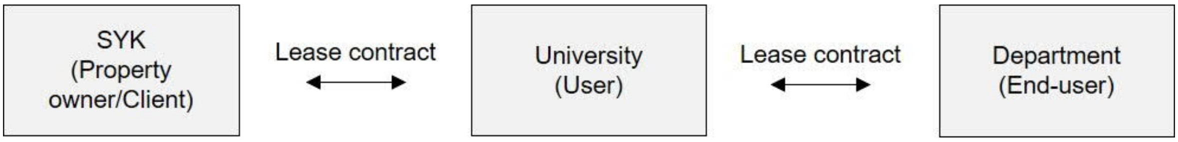


*Figure 10: Users' strategic plan (SYK 2011)*

## 5.2 Case Company's Role and Guidelines in the Property Development

SYK as a client invites property developer consultants to tender and chooses the consultant for each development project. The tasks of consultant are determined in the invitation for bid and in SYK's property development guidelines. After the selection of the consultant, the mandate will be confirmed either by a contract (consultant compiles) or by an order (SYK compiles). Thereafter, the consultant is responsible for the progress of the development project based on the delegation of SYK. (SYK 2011a)

The consultant is responsible for all duties which are denoted for clients in Land Use and Building Act (132/1999). The consultant is responsible for obtaining decisions from SYK to all required issues and for reporting about the competition of tasks and the progress of the project monthly. The consultant is responsible for determining project goals together with SYK and for supervising and reporting about the realization of these goals. (SYK 2011a)

The responsible party for projects on SYK's behalf is the property development department. SYK's regional campus managers act as contact persons and local representatives of SYK. Campus managers participate in local meetings and are responsible for practical tasks related to projects. Campus managers are also responsible for tasks in the commissioning phase including maintenance manual, the guidance of use and education related to commissioning. However, the principle responsibility is on SYK's property development department. (SYK 2011a)

While the consultant is responsible for the management of the project comprising issues such as scheduling and preparing, distributing and saving the minutes, SYK makes required decisions based on consultant's proposals. SYK makes decisions on issues such as the selection of stakeholders (e.g. designers and contractors), approval of plans, approval of costs, investment decisions, approval of possible additional or alteration work. In addition to approvals, SYK is responsible for drafting of investment and preparation decision, pre-lease agreement, lease agreement and examination of lease agreement. Additionally, SYK is responsible for raising funding. (SYK 2011a)

## 5.3 Responsibility and Circular Economy in Current Practices

This section evaluates how circular economy has been already perceived in SYK in corporate level and in property development process. Distinction between these levels has been made, since implementation of circular economy requires measures in both levels as discussed already in section 2.2.1.4. This section starts first by analyzing responsibility in these two levels and thereafter recognizes the circular economy elements in both levels.

### 5.3.1 Responsibility Vision

SYK has recognized three main themes for the responsibility which are; (1) responsibility for own operations, (2) responsibility to the customer and (3) responsibility for the property portfolio managed by the company. In the long term, SYK aims that its properties are sustainable from environmental, economic and social perspectives. SYK compiled a responsibility vision in 2017, which aim is to have the most responsible campuses in Europe until year 2030. This vision is categorized in three dimensions of sustainable development as follows; (1) environmental responsibility, (2) financial responsibility, and (3) social responsibility. Additionally, SYK report on responsibility in accordance with the GRI principles. (SYK 2018e)

According to SYK, property development is significant part of environmental responsibility, since this life cycle phase of the building is favorable in making strides. SYK states that environmental impacts during the construction phase have even higher weight currently than before. Therefore, it should be focused on consumed energy during the construction and on environmental impacts of production and delivery of construction materials. Energy and construction materials should not be wasted. Additionally, organizing efficient logistics choosing construction site location rationally are important issues. (SYK 2018g)

As a part of the second dimension, financial responsibility SYK aims to apply principles of sharing economy and resource knowledge in its operations (SYK 2018e). Moreover, long-term real estate management, which aims to spatial efficiency, is an important part of sustainable economy from SYK's perspective. The aim is to build shared and multifunctional premises that are not only meant for one user group or for one use. The space utilization is intensified for example by moving from separate work rooms and extensive meeting rooms into activity-based offices. Additionally, refurbishments are always prioritized over new construction. The cultural heritage is considered as an important issue and therefore existing buildings will be remained when possible. Furthermore, campuses are seen as a part of surrounding urban environments. Thus, vacant premises can be leased also for other users than universities. (SYK 2018c)

According to SYK "social responsibility means looking after people and the surrounding society, including buildings". The development of each is made in a cooperation with their customers. SYK has developed a joint development process which facilitates the customer-driven approach in the planning and design of premises. Additionally, when properties are sold, the seller should have same values and willing to develop properties as a part of urban environment. Other important social aspects in SYK's vision are research projects and supporting different local communities. (SYK 2018b)

SYK's stakeholders comprises for example Finnish universities, higher education institutes, businesses and public corporations. Responsibility in stakeholder interaction means that premises are maintained properly, and they are able to serve stakeholders' changing needs. Additionally, there is active communication with partners and policy makers. (SYK 2018a)

### 5.3.2 Project and Planning Goals

SYK's property development process is described in property development guideline. Moreover, SYK has presented more detailed goals for projects in additional guidelines in order to implement corporate level responsibility goals.

Most of the SYK's goals for development processes are discussed in the guideline called "Planning and Project Goals" (available only in Finnish: Suunnittelu ja hanketavoitteita). SYK together with the consultant determine goals for each project based on this guideline. Project goals are reviewed in each project during project planning and planning phase. (SYK 2011a) The guideline divides goals in five categories; (1) functional premises, (2) technical aims, (3) ecology, (4) maintenance and (5) goals for the development project and for the property development consultant. Goals discussed in this guideline are related to themes such as efficient and adaptable space design, indoor air and energy efficiency issues. Since SYK is a long-lived owner of properties and is responsible for maintaining them, goals regarding the maintenance of systems in reasonable price and their durability are significant for SYK. Detailed goals are presented in Figure 11. (SYK 2011b)

**Functional premises**
- Considering users needs
- High space utilization & Efficiency
- Functionality & Convenience
- Modern activity-based premises that support new working methods
- Adaptability
- Dividing premises into different sector based on differen uses

**Technical aims**
- Terve talo – principles
- Cleanliness classification P1
- M1 materials and the compatibility of products
- Inner air classification S2 (partly S1)
- Minimum acoustic classification C
- Technically high-level building
- Energy classification requirements
- Service life goals
- System related goals

**Property maintenance**
- Low operating costs
- Easy and reasonable priced winter maintenance conditions

**Ecology**
- Energy efficiency, energy manager monitors
- Passive energy saving, considering waste heat etc.
- High space utilisation rate
- Free and renewable energy forms
- Functionality of automation
- Flexible HVAC-technic for different space solutions
- Energy monitoring

**Aims for project and consultant**
- Obeying SYK's investment process and informs the client
- Active planning monitoring based on client's goals
- Up-to-dateness and accuracy of project's cost monitoring and estimates
- Keeping on schedule
- Systematic acceptance phase

*Figure 11: Planning and project goals (SYK 2011b)*

In addition to "Planning and Project Goals" -guideline, SYK has set some goals in guideline called "Environment and Energy Goals in Construction" in 2018, which is focused more on the energy issues. This guideline guides new construction and significant renovation projects. Reaching all goals within reasonable price is considered not to be necessarily possible always. This guideline sets four goals for use phase regarding energy use, which consider both new construction and renovation projects as follows; (1) desirable energy class: A, (2) amount of delivered energy: under 150 kWh/brm2a, (3) share of renewable energy: over 75%, (4) amount of emissions: under 25 kg$CO_2$/brm2a. Goals (1) and (2) are prioritized over goals (3) and (4). Additionally, this guideline sets grade "Excellent" in BREEAM as a goal for new construction. Significant refurbishment projects aim to reach grade "Very Good". (SYK 2018f)

The majority of these property development goals presented in guidelines are in line with corporate level responsibility. As it was discussed in section 5.3.1, corporate level aims are based on three dimensions of sustainable development. The same categorization would be possible also for these more detailed goals. Kirchherr et al. (2017) has suggested that circular economy is one way to reach sustainability. Furthermore, the next section will analyze, which of these goals are related to circular economy.

### 5.3.3 Circular Economy in Current Practices

Three dimensions of sustainable development and stakeholder interaction are strongly expressed to be a part of corporate responsibility in SYK. As a part of environmental responsibility, SYK mentions circular economy (SYK 2018e). A further examination of dimension specific descriptions reveals, that responsibility vision incorporates some elements of circular economy in financial responsibility in addition to environmental responsibility.

According to SYK, an important part of environmental responsibility is the efficient use of construction materials, which is seen as a circular economy design strategy (e.g. GBC Finland 2018; Adams et al. 2017). Additionally, organising efficient logistics and choosing construction site locations rationally can contribute the realization of circular economy when it aims to close, slow, narrow or intensify material flows, as it was discussed by Geldermans (2016). Some authors, such as EMF (2012), consider also renewable energy as a part of circular economy. Therefore, it can been seen, that SYK contributes the realization of circular economy by favouring renewable energy in their corporate strategies.

Financial responsibility emphasizes the importance of solutions such as more efficient space use, activity-based office premises and prioritizing refurbishments over new construction. These are discussed to be an essential part of circular economy design in section 2.2.1.1. Moreover, SYK is aiming to maximal space utilisation by leasing vacated premises also for other operators than universities. The role of high occupancy rate in circular economy is emphasized for instance by GBC Finland (2018). Additionally, sharing economy is mentioned to be one theme related to financial responsibility. Solutions, such as sharing platforms which were discussed in section 2.2.1.2, are regarded as to be in accordance with circular economy.

Whereas environmental and financial responsibility incorporate some circular elements, social responsibility does not discuss such issues. The lack of social aspects in circular economy have been discussed e.g. by Geissdoerfer et al. (2017) and Murray et al. (2015), which explains partly the exclusion of circular elements in this dimension. Figure 12 concludes the incorporation of circular elements in SYK’s responsibility vision, which are clustered under environmental and financial dimensions.

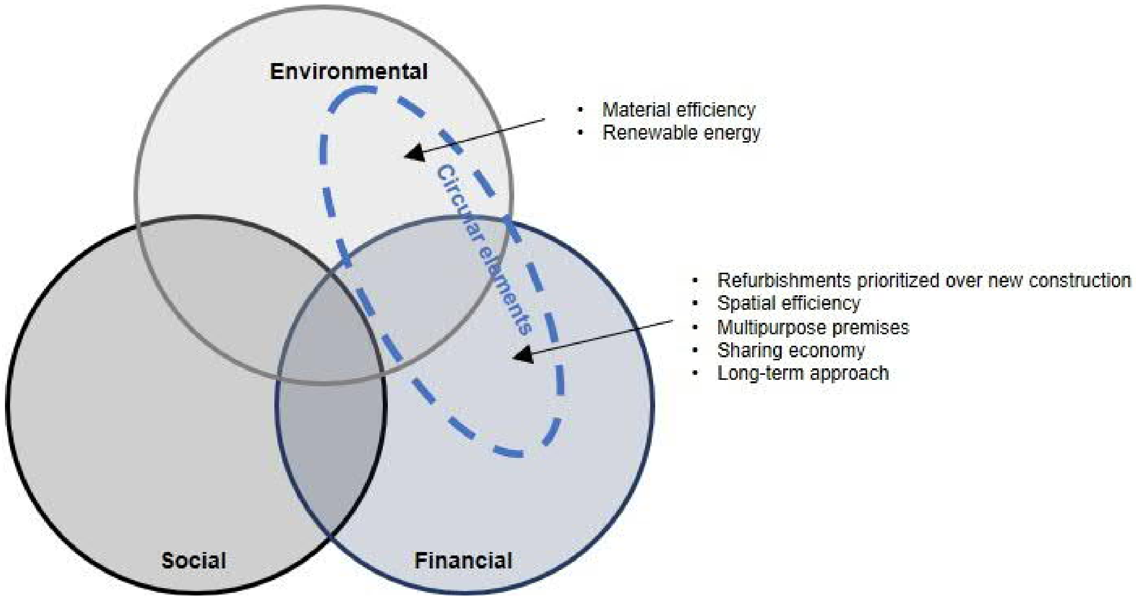


*Figure 12: Elements of circularity in responsibility vision (SYK 2018c; 2018e; 2018g)*

As it was discussed in section 5.3.2, SYK's more detailed goals for property development project are discussed in guidelines "Planning and Project Goals" and "Environmental and Energy Goals in Construction". These guidelines offer a clear indication on what SYK demands for property development and construction. Basically, the goals presented in these process level guidelines are in line with corporate level vision. However, they offer a bit more detailed picture on how the corporate level visions should be implemented.

"Planning and Project Goals" -guideline offers some elements which are discussed to be in accordance with circular economy as high space utilization rate, activity-based premises and adaptability. These goals are discussed under "Functional premises" category and are highly regarded as solutions that facilitates circular economy (e.g. GBC Finland, Adams et al. 2017). Additionally, both "Planning and Project Goals" and "Environmental and Energy Goals in Construction" emphasizes significantly the importance renewable energy, as it was discussed also in the responsibility vision. Each project should set also the service life goals. It does not automatically lead to circular economy, however if it aims e.g. to close or slow material flows it can be regarded to be in accordance with circular economy.

All things considering, SYK's goals, both corporate and project level, incorporate already circular economy elements. Furthermore, implementing some goals might contribute the realization of circular economy as a side effect, even though its primary goal would be achieving cost savings in the long run. For instance, constructing "technically high-level buildings" as discussed in Figure 11, might realize the principles of circular economy through services which utilizes renewable energy and waste heat, or by incorporating durable construction materials. Additionally, service life goals which are aiming to lengthened service life for systems and materials, facilitate the shift towards circular economy. However, the most goals were related either on more efficient use of spaces or on energy solutions. This is obvious, since these solutions generates direct cost savings for universities. Furthermore, SYK could explore the potential of material choices and circular design strategies (e.g. design for deconstruction) that would aim for more circular end-of-life performance. As the long-term property owner, SYK has an opportunity to analyse their feasibility from their own perspective.

# 6 Interviews

## 6.1 Methodology

### 6.1.1 Thematic Interviews

Interview is a flexible research method, that can be used for many purposes. Even though interviews are relatively popular method to gather information, they include some risks and problems. Interviews are always affected both by the context and situation. Results require always analyzing. Building statements based on interviews should be considered carefully. (Hirsjärvi & Hurme 2011, p 11-12.)

Interviews can be divided into different categories based on how structured they are; structured interviews, semi-structured interviews and unstructured interviews. The most structured interviews are based on standardized questionnaires, whereas unstructured interviews remind more conventional conversations. Standardized questionnaires fit best for quantitative research, whereas semi-structures and unstructured for qualitative research. (Hirsjärvi & Hurme 2011, p. 44-47.)

Semi-structured interviews were used to acquire data in this thesis. In this type of interview the questions are open ended and they are built around certain topics. Such interview is also known as a thematic interview. Themes are same for every interviewee. However, the exact wording of questions and their order might differ in thematic interviews. In this sense, thematic interviews differ from other semi-structured interviews. Nevertheless, the order and wording of questions is not completely open as in unstructured interviews. (Hirsjärvi & Hurme 2011, p. 48.)

Thematic interviews offered flexibility to conduct interviews with several different stakeholder, since the exact wording of questions could differ between interviews. Asking exactly same questions from every stakeholder would not have resulted a desired outcome, since every stakeholder has an own scope for the subject. Moreover, due to novelty of the subject and a bit vague concepts such as circular economy, less structured interview was expected to provide better answers. There was no assurance on that every interviewee understood the concept the same way. Therefore, it was crucial to have a more open conversation, which offered a possibility for more detailed questions when needed.

In the beginning of each interview, interviewees presented themselves and told important things regarding their background such as education and work experience. After the short introduction, interviews included four parts; (1) circular economy as concept, (2) construction client's opportunities, (3) challenges for construction client and (4) examples of projects that included principles of circular economy.

In the first part, interviewee was asked to define the concept of circular economy and to specify which issues he/she included under the concept of circular economy. Additionally, some specifying questions were asked depending on the interviewee and his/her opinions such as "Do you see renewable energy solutions as a part of circular economy?". Moreover, interviewees were asked that how the circular economy realizes in construction and real estate sector.

The second part of the interview aimed to evaluate construction clients' potential to contribute the realization of circular economy. Thus, interviewees were asked how the construction client can effect on the realization of circular economy. Additionally, depending on the interviewees role in the development process specifying questions were asked to facilitate the conversation. For example, it was asked, in which phase of the development process the client has the highest potential to facilitate circularity. Moreover, it was discussed whether there exist some financial incentives for the client regarding the circular economy. Due to different backgrounds and roles of interviewees, every interview had a bit different perspective for this part of interview. Thus, the relationship of interviewee (if he/she was not client) and the client was discussed and how this collaboration could facilitate circularity. Furthermore, interviewees were asked to tell if some stakeholder's role in construction and development projects is particularly crucial regarding circularity issues. Additionally, interviewees were asked to state why the role of this certain stakeholder was crucial.

The third part of the interviewee aimed to recognize the barriers and challenges in order to facilitate circularity in development processes. Interviewees were asked to define the barriers for the implementation of circular economy in construction and real estate sector, i.e. why do not the circular economy already realize in the sectors. Furthermore, depending on the role of interviewee, it was asked if there are some specific legal, technical or financial challenges which complicates the realization of circular economy. For example, the discussion with engineers and architects was more focused on the technical details whereas with clients more on the financial feasibility. Moreover, problematic issues in the relationships between interviewees and clients was discussed with each interviewee when the interviewee was not the client. Thus, in the same way as the second part, also the third part aimed to focus on the relationship between different stakeholders. However, this part focused on the challenges, whereas the previous on the opportunities.

In the final part, interviewees were asked to tell examples about the circular economy successes in the construction and real estate sector. However, in some cases, these successes were already discussed in the previous interview phases and thus, they were not re-discussed. Additionally, interviewees were allowed to send possible materials of these projects afterwards.

### 6.1.2 Interview Sample

Interview sample comprises in total seven interviews, which were conducted during 14.6.2019-16.8.2019. The empirical part was executed by conducting interviews with different stakeholders in the property development process based on the actors discussed in section 3.1.2. The aim was to analyze different actors' possibilities to facilitate circular economy in the development process and their relations with the construction client.

The interview sample is presented in Table 7. Interviews were conducted anonymously, which enabled to provide better picture on conflicts between different stakeholders. Thus, results of interviews use pseudonyms to present different stakeholders' opinions. These pseudonyms are presented in Name column in Table 7. Even though the sample includes two developers, it is crucial to notice, that first developer do not act as property owner after the development, whereas the second one continues owning the developed properties. Moreover, two engineers were focused on different disciplines; the first one into energy and the second one on the structural engineering.

The interview guide was sent to interviewees before the interview, so that they had time to familiarize with the themes. This guide is presented in Appendix 2. The interview guide was relatively general with main questions. However, depending on the stakeholder, suitable specifying questions were asked as described in the section 6.1.1 to facilitate the conversation. Interviews were audio-recorded, and notes were written based on the recordings after the interviews. The most important discussed issues were written in the notes and thus, notes were not written word for word.

| Name | Stakeholder category | Description |
|---|---|---|
| **D. Developer** | Developer | Developer in a Nordic development company |
| **Energy Engineer** | Engineer | Energy consultant in a Finnish engineering office |
| **Structural Engineer** | Engineer | Head of Unit in a global consulting engineering group |
| **Architect** | Architect | Partner in a Finnish architect company |
| **O. Developer** | Property owner & Developer | Construction manager in a Finnish pension fund company |
| **Public Officer** | Public sector | Employee in Ministry of Environment |
| **Material Supplier** | Material supplier | Sustainability Manager in a construction material company |

*Table 7: The list of interviewees*

After conducting all interviews, notes were analyzed by identifying repeating topics from different interviews. Thereafter, notes were merged and reordered by using these repeating topics under four themes, which were discussed in section 6.1.1. Topics, which were not related to themes, were excluded from the notes. The most repeated topics were assumed to be the most reliable, and topics which were discussed in fewer interviews, less reliable. In following sections, it will be mentioned, whether several interviewees discussed the topic or if it was only an opinion of one interviewee.

## 6.2 Result from the Interviews

### 6.2.1 Circular Economy in the Built Environment

As it has been discussed in the literature review, circular economy is a rather new concept. The concept has various definitions and basically many academic articles that discuss circular economy, include an own definition for it. Due to the obscurity of the concept, interviewees were asked to define the concept in their own words. Additionally, some specifying questions were asked in order to gain wider perception on interviewees understanding regarding circular economy. The concept was relatively new for many interviewees, and they were familiarized with the concept as a part of their work or circular economy related educational event. Additionally, the increasing popularity of the concept in a public conversation was noticed with many interviewees. Even though circular economy is regarded more or less as a buzzword, it was not seen as a problem by interviewees. It was also mentioned, that circular economy is one of the most important tools to cut down $CO_2$ emissions among renewable energy solutions.

Despite the novelty of the concept, many interviewees were able to offer a definition for circular economy. Public Officer mentioned definitions by EMF and European Commission to be examples of good definitions. According to several interviewees, circular economy is an umbrella term for resource efficiency and for saving materials and energy. Moreover, Public Officer mentioned, that people lived in circular economy before industrialization, and thus, principles of circular economy have a long history. D. Developer thought that circular economy is related to how all resources in cities could be utilized as efficient as possible, since for example a building is regarded as a cost instead of value generating asset, when it is not in use. The minimal waste and energy production and the minimal use of raw materials were mentioned as themes of circular economy. Additionally, maintaining the value of materials and the minimizing the environmental impacts were mentioned to be part of circular economy several times. Moreover, one interviewee mentioned that the difference between recycling economy and circular economy should be set. Circular economy is based on business models which aim to upkeep the value of materials, whereas recycling economy aims only for recycling them without the value perspective.

Additionally, some themes regarding circular economy in the built environment were recognized during interviews, since all interviewees were working either in the real estate or construction sectors. Using real estate as long as possible and sharing resources were mentioned to be part of circular economy in the built environment. Moreover, themes such as, diversity and adaptability were recognized to be important as well as spaces that support each other's. Altogether, aspects which were related to more efficient use of buildings and multi-use potential were thought to be crucial. However, it was seen that circular economy in real estate and construction sector is focused relatively much on waste issues. Thus, the opportunities during the entire life cycle of the building are not emphasized that much yet.

Many interviewees recognized material choices to be an important aspect. Themes such, as reuse, design out waste and the durability, were regarded to be crucial. For example, one interviewee mentioned, that Isover's wools are using relatively much recycled materials, and consequently they can be regarded as circular. Using durable and recycled construction materials was thought to be important aspect when implementing circular economy principles in repair planning. However, the necessity for repairing should be evaluated, which was recognized to be important perspective as well. Moreover, the service life goals for new materials should be in line with goals, that are set for other materials in repair project. Therefore, circular economy should be strongly connected to service life goals.

To gain a better understanding on whether the energy solutions are related to circular economy or not, interviewees were asked their opinions. A complete consensus on this issue did not exist between the interviewees. For example, it was mentioned, that it has been suggested to include own circular economy metrics in BREEAM due to current absence. Therefore, it could be understood, that circular economy is an independent concept. However, renewable energy resources, such as solar energy and geothermal energy, were seen as a part of circular economy. According to one interviewee, circular economy is an incomplete concept, if it does not include energy aspect due to environmental significance of circular economy.

Couple of interviewees mentioned digitalization as key enabler for more circular built environment. Especially, the role of open information is significant in the realization of circular economy in the built environment. For example, the information regarding vacant premises, locations of construction and demolition site should be open in order to utilize material flows efficiently by meaning higher occupancy and construction waste utilization rates. Furthermore, the role of material passports was emphasized by one interviewee. For example, possible changes in material choices during the construction phase should be registered in the material passport. This would ease the demolition phase, since then the demolition contractor would know the materials that are included in the building.

### 6.2.2 Challenges for the Construction Client

The interviewees identified various challenges, which the construction client might face when trying to order more circular economy construction projects. Some major challenges were discussed in all interviews and they were identified by different stakeholders. One of these challenges was the financial feasibility of circular construction solutions. The major problem is, that there is no adequate knowledge on costs, which are related to reach more circular buildings. According to Energy Engineer, this might stand as a challenge for clients. Even though circular construction projects have been already implemented for example in Netherlands, according to D. Developer the case studies of these project are regarded as defective, since the discussion on financial feasibility have been mostly excluded. D. Developer mentioned, that in order to get clients interested on circular solutions, they should be as cheap as conventional ones or even cheaper. Additionally, there is a belief, that neither investors nor users are willing to pay more on buildings that incorporate circularity. The feasibility of solution related to materials and structures is more difficult to justify than for example increased energy efficiency that results in direct savings.

Another major challenge, that was identified by D. Developer and Architect, is the uncertainty related to new materials. This challenge, to a certain extent, is very similar and even the part of previous challenge, financial feasibility. According to D. Developer, chosen materials should last relatively long time which is one of the reasons, that leads to avoid new materials. If there is no experience on new materials in use, the risk for increased operating and capital costs is higher in comparison to conventional materials. In this sense, uncertainty related to new materials can be regarded as part of question of financial feasibility. Alternatively, Architect and Structural Engineer pointed out the possible indoor problems, that might be caused by new materials, which have not been investigated as much as conventional ones. Currently, the sanctions for designers on indoor problem issues are significant, which results to risk-averse behavior and simultaneously decreases the desire to experiment new materials. In order to facilitate the use of new materials, authorities should be more open to experiments. The need for a “show-case”, which would enable experimenting new materials, was mentioned by D. Developer.

Interviews indicate that the unwillingness to experiment new materials is basically justified by avoiding risks. O. Developer criticized designers on being too conservative and using same planning catalogues from year to year. O. Developer continued that the market for circular materials is not extensive, which would demand designers to be more creative. However, on the other hand, Structural Engineer mentioned that, clients determine actually most of materials in their method of construction briefing and they have the vision on materials. According to Structural Engineer, making changes into these briefings is not that simple, since the changes may have influence on various details, which needs to be considered further. It can be noticed that interviews indicate a bit conflicting results regarding the responsibilities on material choices. Moreover, experimenting new materials requires more time on planning phase. However, traditional contract models do not often support creative planning. According to Structural Engineer, the problem is that traditionally the winner of the bidding is the one, who offers the lowest price. Additionally, these contracts have timeframes, when designers can use only a certain time for a certain project. Testing new solutions would require a longer timeframe to be implemented, which demand different contracting. Additionally, Architect mentioned, that contractors can make alteration works during the projects without discussing them with architects. This might cause frustration related to material choices among architects.

The fourth major challenge that was identified in interviews was too strict regulations regarding land use and zoning. Interviews indicate that authorities should be more flexible for new material experiments. O. Developer mentioned, that experimenting new materials should be incentivized. Both, O. Developer and Material Supplier discussed that for example in Netherlands, it is possible to get mitigations for regulations, when circular solutions are incorporated in construction. However, in Finland, for example some glass walls might not fulfill requirements of authorities and thus they cannot be used, even though they would cause smaller environmental impacts. Material Supplier mentioned that some of the current standards are a bit problematic. For example, they can enforce one to use cement as binder, even though there would more environmentally friendly materials with better strength characteristics available. O. Developer wished authorities to be more flexible to allow conversions of buildings that are vacant in their current use. For example, finding tenants for old office buildings in poor locations is very challenging.

According to D. Developer and Material Supplier, one of the current challenges is that, no clear picture exists on where different construction and demolition site are located in order to enable the utilize material flows efficiently. Moreover, there are not that much market places, where one could buy or sell surplus materials. Even though for example rakennusoutlet.com website was mentioned during the interview, it was noticed that such market places are not yet very common. However, O. Developer mentioned that increasing demand for surplus materials would probably increase demand for new market places and applications. Furthermore, Structural Engineer remarked that supply of materials for professional construction, that would have been branded as environmentally friendly is relatively small. Professional contractors prefer materials that have been used before and ordered by using on annual contracts.

In addition to earlier mentioned issues, some other challenges where discussed as well, which did not however come up in various interviews. For example, managing the extensive building data was assumed to cause challenges, since reaching circularity in buildings requires relatively detailed data on materials and different components in the building. Moreover, technical challenges related to conversion projects were discussed in addition to strict zoning regulations. According to Structural Engineer, structures of old buildings do not often fulfill today’s requirements for example due to wrong floor height or building’s shape. Furthermore, conservativeness of construction sector was mentioned as one challenge. Finally, O. Developer and Material Supplier cited the lack of knowledge as one challenge, since many people are so busy, that they do not have time to focus on to learn new things.

Figure 13 summarizes the major challenges, which construction client might face when trying to contribute the realization of circular economy in construction project. Strict regulations and lack of market place are regarded as external challenges which are related to the business environment. Construction client does not have that significant potential to solve these challenges. Challenges related to financial feasibility, new materials and planning and contracting are process related issues and are partly overlapping. For example, the belief that circular construction materials might pay a higher price than conventional ones connect challenges of financial feasibility and uncertainty related to new materials. Moreover, designers are not necessarily willing to suggest new circular materials since they are not sure about their properties. The construction client's potential to solve these process related challenges is higher in comparison to external challenges. This will be discussed more on section 6.2.3.

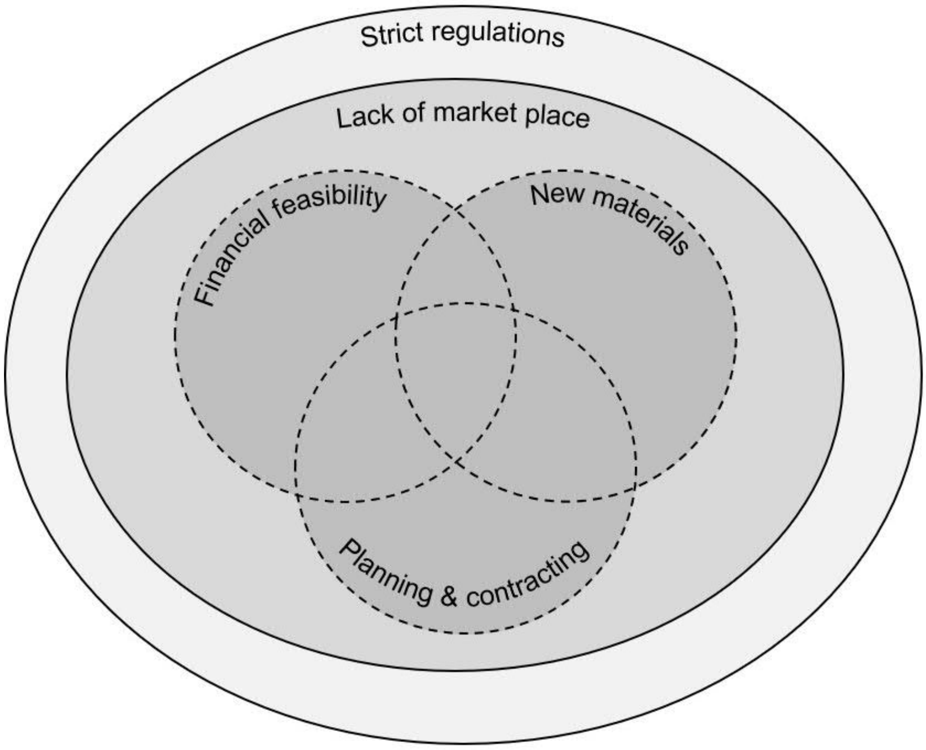


*Figure 13: The main challenges for construction client according to the interviewees*

### 6.2.3 Opportunities for the Construction Client

Overall, all interviews indicated, that the construction client has an extensive potential to effect on the output of the project. Reasons for this are obvious; clients have the equity, ideas and possibility to set criteria for tendering. For example, D. Developer said that "Basically, the client can do whatever he wants, when tenants or investors are willing to pay for it." Furthermore, the role of designers and authorities were emphasized, and it was discussed, that they should indicate willing to act more circular. However, if the client does not order project that would facilitate circular economy, then nothing will happen. Therefore, the role of the client as the leader of the project is crucial, which demands clients to have adequate knowledge on circular economy. Corporate level strategies and process level goals of large companies were discussed to be important tools in order to reach more circular development. According to D. Developer, ordering more circular projects demands client to be "courage, visionary and open" and to show a great development contribution. Furthermore, Material Supplier added that clients have possibility to market their projects and by this way communicate good examples for other stakeholders as well.

Both developers (D. Developer & O. Developer) emphasized the importance of early phases in the project, if the client is willing to incorporate circular features in the development. The use of renewable energy, material flows, maintenance and easiness of repair should be discussed in the early steps of the project. Making some changes into materials was discussed to be possible in further phases as well, however the mindset for circular economy should be involved from the very beginning. According to O. Developer, the absolute last phase for making major decisions is construction phase, since making changes during the use phase is challenging and expensive. Moreover, the strategic alignment of circular development project with investors should be agreed in the beginning of the project according to D. Developer. Early adaption of circular principles was discussed to demand leadership from the client, since there is a risk, that project will lead into a wrong direction easily. Furthermore, many users are quite aware on environmental issues currently, due to branding value or certifications, which basically facilitates incorporation of several sustainable features in buildings.

The importance of collaboration was agreed in several interviews (D. Developer, O. Developer, Architect, Structural Engineer and Material Supplier) as well. Especially the collaboration with users, material suppliers, engineers and architects was discussed to be crucial. As discussed in section 6.2.2, user have become more demanding on environmental issues, which pressurizes clients to change. Nowadays, for example energy efficiency is self-evident truth for many users, even though it could be used as a selling point before. Some users are even not willing to become as tenants, if the building is not certified. Consequently, the role of demanding users is significant and the collaboration with them might lead into more circular outcome.

According to Material Supplier the collaboration between them and construction clients is on low level due to many actors between them, such as contractors, sub-contractors and consultants. Consequently, Material Supplier emphasized that there should be more collaboration between them and clients, since finally, material suppliers have the best knowledge on the current supply and properties of circular construction materials. According to D. Developer, new materials might cause confusion in the construction site. Therefore, material suppliers should consult clients about new materials, so that client is able to communicate to contractor about them.

Especially, the collaboration between clients and designers (including both architects and engineers) provoked discussion with several interviewees and was regarded as a relatively important issue. Planning guidelines which include suggestive instructions for architects were agreed to be decent both by Architect and O. Developer, since they do not restrict too much architect's work. However, O. Developer and Material Supplier wished, that designers would have knowledge on circular economy, and they could suggest new and more circular solutions. However, as discussed in section 6.2.2, competitive biddings, in which the one with the lowest price wins, do not motivate designers to think circularity issues. Contracting models, such as alliance model, which reserve an adequate time for designing and planning in the beginning of the project were seen as important tools to facilitate collaboration. According to Structural Engineer, it would be important to have a development phase, that would enable the discussion on challenges and goals without pressure. During this phase, material choices would be agreed, and billing would begin after this phase. These so called "big room" practices have been applied already in infrastructure projects for some time, however the first applications in the building sector have been made during the last two years. These demand long time periods and therefore, they have been applied only in larger projects, such as in construction of hospitals. Moreover, the planning costs in these projects are relatively high obviously.

Even though the financial feasibility of many circular features was questioned in section 6.2.2, interviewees were able to offer some solutions to tackle this challenge. Firstly, when evaluating the feasibility of the development, life cycle costs should be considered in addition to the initial investment. This is especially relatively efficient way to justify higher initial investment, when the client remains as the owner of the property after the development. Furthermore, the higher price of circular solutions challenged. For example, even though geothermal energy has a higher initial investment, it has relatively short payback period due to significant cost savings. Moreover, surplus materials from other construction sites are cheaper in comparison to new ones. Even though it would not be possible to buy all of the materials as from other construction sites, buying a share of them as recycled will decrease the initial investment. Additionally, easy repair and maintenance were mentioned as important aspect that generates cost savings and do not necessarily increase the initial investment. In addition to design for easy maintenance, flexible space design is another significant solution, to decrease the costs during the use phase, even though the investment might be higher. Design for flexibility demands to consider many aspects in order to minimize future's alteration works, such as design of HVAC-channels and the use of movable partition wall etc.

Moreover, According to Public Officer, some financial institutions supports environmentally friendly construction projects, which can facilitate the realization of circular economy as well. For example, Kuntarahoitus appropriates loan with a lower margin rate for projects that fulfill their criteria. Other examples of such financial solutions are green bonds issued by SYK and Northern Investment Bank. Public Officer mentioned that taxonomies for low carbon investments are being researched on the EU-level at the moment. According to Public Officer, global investors' increasing interest towards more responsible investing could offer an opportunity for Finnish construction clients who are seeking for funding. Overall, even though interviews recognized the financial feasibility as a major challenge, they were able to offer solutions to tackle this challenge. These solutions included both technical solutions that are actually less expensive and direct financial incentives.

Whereas the earlier mentioned possibilities are focused on the early phases of the development, contribution of circular principles is still possible during the construction phase. For example, NCC have established the concept of "responsible construction site", in which it commits to reach certain goals. These goals vary from issues such as equality between genders to recycling rates and sorting construction waste. Consequently, the client can demand contractors to fulfill such goals when ordering projects and by this way to facilitate the circularity. Moreover, clients can demand contractors to sell surplus materials into further use. According to O. Developer, many contractors are willing to do this nowadays due to image reasons.

Overall, clients have wide possibilities to effect on the circularity of certain construction projects, since they can set requirements and goals for their project and by this way effect on the outcome. Results of interviews indicated that there are four main tools, which the client needs to use in order to reach more circular outcomes from the property development. These tools are presented in Figure 14. The tools can be divided into two categories; those which have to be used before property development (knowledge and criteria) and others which have to be used during property development (collaboration and supervision). The first tool (knowledge) means that finding the best ways to operate requires more knowledge on material properties, circular design strategies, feasibility and contracting models. The second tool (criteria) means that the construction client should determine adequate criteria for tendering, which facilitates the realization of circular economy after reaching the understanding on the concept. Thereafter, the third tool (collaboration) will be used by realistic scheduling and contracting, which facilitates collaboration between many different stakeholders. The fourth tool (supervision) means, that the client should be aware on the possible changes to design during the construction. After the competition of construction, the client should know what materials are included in the building. The reutilization of materials during the end-of-life phase becomes more difficult, when there is no information regarding materials included in the building.


*Figure 14: Opportunities for Construction Client*

### 6.2.4 Examples of Circular Economy in Construction and Real Estate

In addition to previous themes, interviewees were asked to tell examples of projects that had contributed the realization of circular economy. However, this request seemed to be relatively challenging for many interviewees. During the interviews it was recognized that some infrastructure projects in Finland have adapted principles of circular economy relatively well. However, there is a still need for examples of circular construction projects. Nevertheless, further conversation about examples resulted some interviewees to recognize circular features of projects in which they have been involved in. Consequently, interviews indicate that some interviewees have been already operated in a ways that can be regarded partly as circular without knowing it. It seems that different dimensions of circular economy are still challenging to recognize for many practitioners.

Due to further conversation, different material choices in current project were recognized to be circular. For example, surplus materials, recycled glass and recycled soil in infrastructure projects were discussed to be circular material choices. In addition, one example was discussing recycling of windows of the old office building. However, this project is currently unfinished due to the conflict with local conservation regulations. Nevertheless, there are not materials, that would have been branded as circular in Finland currently according to Material Supplier.

As it was discussed in section 6.2.2, it is still uncertain for many professional whether circular construction projects can be feasible or not. One example from the Norway was discussing how to tackle this challenge. In this example, the developer wanted to construct a wooden office building. In order to reach lower initial investment, the site for the building was found from cheaper area. In the beginning, finding tenants in the building with poor location was difficult. However, after the completion of the building was fully let due to extensive R&D activities.

ABM Amro's conference center was mentioned as an interesting circular economy example both by Material Supplier, Public Officer and D. Developer. This conference center was utilizing significant amounts of recycled materials. Examples of these solutions are the floor which is made of waste wood and chairs which are made of old CDs.

Due to small number of examples, interviewees were allowed to send information on possible circular economy examples after interviews, which resulted one interviewee to send few links considering circular economy in construction and real estate sector. These examples were considering the certification of buildings, market places for surplus material and construction waste and responsible construction sites.

The first example was discussing residential building in Vantaa, which had received Joutsenmerkki-certification. Joutsenmerkki-certification aims to ensure the environmental-friendliness of building during their whole life cycle. The building resulted to have 17% smaller carbon foot print in comparison to conventional. In addition to enhanced energy solutions, smaller carbon footprint was reached by considering material efficiency during the planning and construction. For example, the recycle/reuse –rate of the construction site was 73%. (Joutsenmerkki 2019)

In addition to Joutsenmerkki-certification, information about start-up company called Netlet Oy was received from the interviewee via email. The aim of Netlet is to sell surplus materials from construction sites further with lower price in their online shop. Currently, the company has 20 storages in Finland, that are used to store materials, which are collected from construction sites. (Kauppalehti 2019) Moreover, Loops Rocks –platform developed by NCC utilizes quite similar idea as Netlet, however it is focused on recycling of soil material instead of construction materials (Projektiuutiset 2017).

Overall, all examples were considering either applications or some partial solutions, which include some features of circularity. However, according to interviews, it seems that there does not exist buildings in Finland, which would have been branded as "circular". Consequently, some sort of circularity exists in the Finnish construction and real estate industry due to increased popularity of sustainability issues, however circular elements just have not been yet recognized. It is good to remember, that sustainability and circularity are not excluding each other's'. On the contrary, circularity is one method to reach sustainability.

# 7 Discussion and Conclusions

## 7.1 Key Findings of the Research

The main goal of this thesis was to explore the potential of the construction client to contribute the realization of circular economy. Additionally, the case company's current practices were evaluated from a perspective of circular economy. Moreover, relevant indicators for measuring circular economy in the built environment were recognized through a literature review. Furthermore, these indicators were identified to be a crucial part of construction client's potential.

### 7.1.1 The Potential for Construction Client

The potential of construction client to contribute the realization of circular economy is significant. In order to increase the circular output of construction project, four main tools for construction clients were recognized in interviews as follows; (1) circular economy knowledge, (2) circular economy criteria in procurements, (3) collaboration during projects and (4) supervision and data management. These four tools will be discussed in next chapters, which aim to provide answers on what these tools are, why they should be used and how they can be used.

The first tool for construction client is circular economy knowledge, which basically means that the client should be familiar with the principles of circular economy. During interviews it was discussed that the major opportunity for a construction client is to order a construction project with circular outcomes. However, the concept of circular economy is relatively disorganized (Preston 2012; Korhonen et al. 2018) and thus, its feasibility is questioned as discussed in interviews. Therefore, the clients should have more knowledge on the circular economy and understand the financial feasibility of different circular solutions. It is obvious, that solutions which financial feasibility is uncertain will not be implemented. According to GBC Finland (2018), the shift towards circular economy requires people to unlearn old practises and expertise, which can be simply reached by education. In practise, the construction client should have knowledge on circular design strategies (e.g. design for long-life, adaptability and repair) and circular business models (e.g. product as a service, leasing and sharing platforms), which was emphasized both in literature review (e.g. EMF 2015b; ARUP 2016; Adams et al. 2017; GBC Finland 2018) and in interviews.

The next tool for the client is to set a circular economy criterion, which means that the client should be able to communicate concrete requirements for construction by using circularity indicators. This is an important step, since the most important task for the client is to order a project and set goals regarding its outcomes. Basically, this criterion can be built on self-determined circularity indicators or on certifications. However, currently the challenge with certifications is the fact, that no certification exists, which would assess the level of circularity. Section 2.2.3 recognized some indicators, which measure the realization of circular economy in the built environment. Some of the indicators were focused on the waste production and prevention during the construction phase (CEW 2017). The other ones were focused on the characteristics of the building (Circle economy et al. 2018). As a result, the construction client could create a set of indicators, which could be utilized as a criterion for each project. The construction client could set requirements for construction phase considering the waste production; the minimum amount of waste that should be reused or recycled (%) or the maximum amount of waste could end up into landfill (%). Furthermore, requirements for building materials and connections could be set. Examples of such indicators include share of reused materials (%), share of bio-based materials (%), share of remountable connections (%) and share of accessible connections (Circle economy et al. 2018). The inclusive list of these indicators is presented in Appendix 1.

The third tool for the client is the collaboration, which means that the client should enable the collaboration between various stakeholders. Its importance was highly remarked both in literature review (Leising et al. 2018; GBC Finland & Sitra 2018) and in interviews, since many challenges can be tackled by sufficient collaboration between different stakeholders from different backgrounds. The results of interviews indicate that clients should collaborate more especially with material suppliers and designers (including architects and engineers) in order to reach higher levels of circularity. The collaboration between these stakeholders would especially decrease the uncertainty related to new materials and design strategies and improve problem solving. Additionally, collaboration might tackle possible delusions related to financial feasibility. For example, the cost savings when using surplus materials instead of new materials or long-term savings due to circular design strategies should be estimated. According to interviews, contracting models, such as alliance model, which reserve a sufficient time for designing and planning in the beginning of the project are important tools in order to facilitate the collaboration.

According to interviews, it is relatively usual, that contractors make alterations to plans during the construction phase. This requires supervision from client's side in order to be up-to-date on made changes, since the client should ensure that the desired level of circularity will be reached. Collaboration and continuous communication with contractors, designers and material suppliers are required, so that client could receive information of changes and discuss their effect on the circularity with other experts. In the end, the client should have a flawless knowledge on the characteristics of the completed building. The importance of the flawless building information is emphasized in circular economy, where buildings are considered as material banks. When there is no complete information regarding materials included in the buildings, reutilization of old materials becomes more challenging in the end-of-life phase. According to the literature review (ARUP & BAM 2017; Leising et al. 2018), BIM-models are one solution for enhanced building data management. As discussed earlier, many indicators are based on detailed information regarding the construction components and materials such as whether the material is bio-based or reused or if the components are accessible or not. Currently, conventional property owners do not necessarily have that detailed information on buildings. However, enhanced building information management is required in order to reach higher levels of circularity in construction and real estate sector.

Finally, Figure 15 summarizes construction client's four tools in order to reach higher level of circularity based on the results of literature review and interviews. In line with results of interviews, these tools are divided into those which should be used before development and the others' that should be used during development. To summarize results presented in this section, "What?"-row provides a short definition for each tool, "Why?"-row motivates why the client should utilize this tool and "How?"-row provides a summarized answer on how to use these tools.

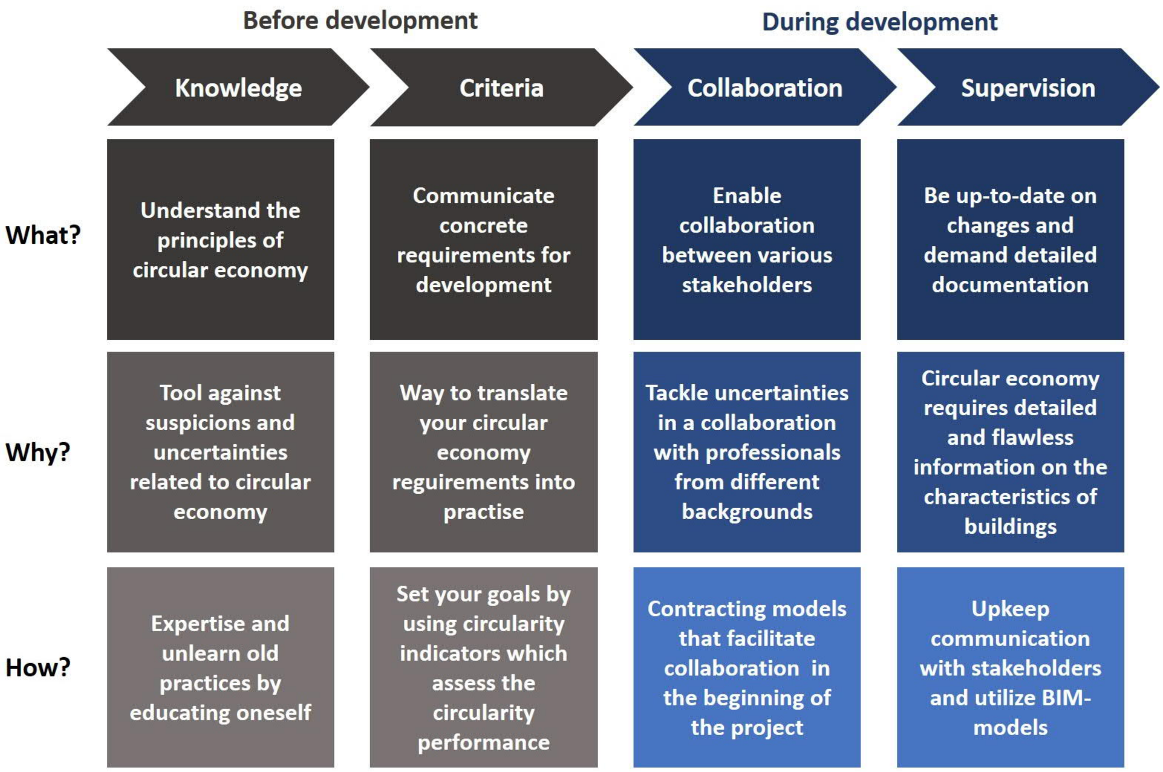


*Figure 15: Construction client's potential to contribute the realization of circular economy in property development*

## 7.1.2 Recommendations for the Case Company

Especially, the role of SYK as a facilitator of circular economy in Finland is significant due to couple of reasons. Firstly, the property stock of SYK is relatively large and the company has a strong local presence in several Finnish regional cities. Thus, when SYK will act more circular, it will have effect on relatively large amount of properties. Interviews suggested that public actors such as municipalities should take a bigger role as forerunners of circular economy for example through "show-cases". As SYK is a relatively significant actor in a Finnish society, it could have an opportunity to participate in such project and facilitate circular economy in a societal level.

As it was discussed in section 5.3.3, SYK is already implementing the principles of circular economy in their property development processes in some levels. Moreover, circular economy is mentioned to be part of their responsibility vision (SYK 2018e). However, it is not communicated, how the case company understands the circular economy. Even though the circular economy has been mentioned in the responsibility vision, no clear principles have not been stated in order to implement it.

In line with results presented in Figure 15, the case company should define the concept of circular economy and recognise its opportunities and challenges. As it has been discussed, circular economy is mainly focused on end-of-life phase of buildings, which should be emphazized in future. Currently, the case company's guidelines are focused more on energy goals than those that are related to construction materials and end-of-life phase. In order to be more circular, the role of materials should be emphasized. There are three important material characteristics in which the focus should be set in the future; (1) origin, (2) durability and (3) end-of-life potential. In addition to material choices, there should be stronger focus on material flows in the demolition phase, i.e. how they could be minimised and closed. Consequently, design for deconstruction potential should be investigated in further projects.

The case company expresses quite clearly the goals for property development in separate documents. For example, desirable energy class for new buildings communicated to be “A” and the amount of delivered energy should be under 150 kWh/brm$^2$a (SYK 2018f). Similarly, requirements could be created to contribute the realization of circular economy. For example, minimum requirements for materials could be set based on their characteristics. Examples of such requirements would be a minimum required share of bio-based materials (%) or reused materials (%). Moreover, potential of certification systems, such as Joutsenmerkki, could be further studied in order to lead more circular construction.

When the decision will be made to initiate a circular property development, the importance of collaboration is high. As the client, the case company has an opportunity to facilitate the collaboration in early phases of the project by choosing suitable contracting models. However, as it was discussed in section 6.2.3, contracting models such as alliance model demands are relatively expensive and therefore using them in smaller projects is not financial feasibility. Nevertheless, the discussion with designers and material suppliers could be opened in order to create a mind-set for upcoming projects. New materials and design strategies could be investigated in a collaboration before any actual development case.

Finally, probably the major challenge for the case company will be the management of the building related information in the future. At first, the case company must be up-to-date on the possible changes that are made to plans during the construction. Those changes might decrease the circular performance of the building and cause harm to the material flows in the end-of-life phase. Secondly, the case company should have relatively detailed data considering the characteristics of the building. Characteristics of all construction materials and components included in the building should be registered.

## 7.2 Research Quality

A majority of academic literature which discusses circular economy is either focused on defining the concept or on different circular business models. In addition, many academic papers are focused on products instead of real estates and buildings. This causes problems, since real estates are unique, whereas many other products are identical copies of each other’s. Real estates have always at least different location, and thus, making generic conclusions on good practices is more difficult. Most of the literature that discusses circular economy in construction and real estate sectors is published by companies and organization leaving the share of academic literature very little. Using this so-called professional literature as a reference is problematic, since their results are not usually justified or analyzed in depth. Moreover, research methods are usually described insufficiently. This demanded researcher to analyze existing literature carefully in order to avoid stating false or vague claims.

As a conclusion for literature review can be commented, that in general existing literature on circular economy is rather vague by many respects. Principles of circular economy in the built environment are not defined unequivocal in the literature. Therefore, the literature review focused relatively much on defining the concept of circular economy in the built environment. Carefully carried theoretical part helped researcher in conducting interviews and further analyzing them.

In the empirical part, different stakeholders of real estate development were interviewed. Moreover, the case company was explored by utilizing open data provided in the company's website. The findings of interviews were mainly in line with the findings of literature review. However, the number of interviewees was relatively little (7 interviews) and thus, no generalization cannot be made based on the results. Moreover, some significant stakeholders, such as contractors and zoning authorities, were not interviewed, even though they were criticized relatively much by other stakeholders. Additionally, the blurriness of the circular economy concept caused challenges, since it was not always clear for interviewees what kind of issues the concept includes in the context of construction and real estate sector.

Analyzing the case company from the circular economy perspective remained relatively vague since open data on their website did not offer in-depth insight on their operations. Giving more detailed recommendations for the case company would require interviewing company's employees and more detailed data on how the case company operates. For example, the current situation regarding the documentation of building related information remained unclear, which is a crucial issue in circular economy.

## 7.3 Proposed Further Research

The scope of the research was quite broad, and thus, many issues in this thesis was discussed quite cursory. The current research focused on circular economy in the built environment is still in its infancy. As a result, many interesting opportunities for further in-depth research were identified.

Firstly, the concept of circular economy in the built environment should be researched more in order to strengthen the theoretical background. The demand for a framework to concretise the principles of circular economy in the built environment exists. Conducting more detailed research would require us to understand better, what does circular economy in the built environment mean. Having consensus on it would enable research to focus more on desired issues instead of trying to define circular economy in the built environment. Currently, it remains vague whether the resource efficiency and energy issues should be studied under the concept of circular economy or not. For example, some studies suggest that resource efficiency is not related to circular economy since it can be applied also in linear economy.

As mentioned earlier, this research had the scope of property owner as client. Four key tools for the client were identified, however further analysis on them remained quite cursory. Thus, possible opportunities for further investigations would be e.g. to investigate how the client could facilitate the collaboration between stakeholders in property development or what would be the most relevant and executable circularity indicators in order to set up a procurement criterion. Moreover, one interesting subject for further research would be to research, what kind of new requirements does circular economy set for the management of building related information.

Finally, the literature regarding the financial feasibility of circular solutions in the built environment is extremely scarce. Shift towards circular economy in construction and real estate sectors requires research that would analyse carefully financial feasibility of different solutions, such as design strategies and new materials. Moreover, circular economy offers interesting opportunities to research in the context of property valuation. For example, how does the concept of buildings as material banks effect on the property valuation in the future?

## 7.4 Conclusions

The main goal of this research was to research construction client's potential to facilitate the realization of circular economy. In addition, the most relevant circularity indicators for construction and real estate were recognised and the case company's current circular economy performance and potential was briefly analysed.

In overall, the construction client has a significant potential to effect on the outcome of the property development, and consequently, to a realization of circular economy. This potential is mainly explained by clients' broad participatory powers in the property development process; the client can e.g. define the desired outcome of the project and tender out and choose the stakeholders. However, in order to reach the circular outcome in property development, four tools for the client were recognised.

Firstly, the client should gain knowledge on principles of circular economy, and further, understand how to apply those principles into construction and real estate. Secondly, these principles should be formed into an organizational level ambition. This ambition should be translated into more detailed circularity indicators, which could be used to assess the level of circularity in construction. Thirdly, the collaboration between different stakeholders is crucial and it should start in the early phases of the development. The collaboration can be facilitated e.g. by choosing contracting models, which enable enough time for planning and collaboration before the construction phase. The final step for the client is to supervise the construction so that the desired outcome will be reached and require detailed documentation of the building related information.

In addition to recognising client's potential to facilitate circular economy, relevant indicators to assess the level of circularity in construction and real estates were identified. The current supply of circular economy indicators was perceived to be rather diverse. Some of these metrics are meant to assess the circularity on the component level, whereas others' were focused on the waste production during construction. However, the focus on resource cycles and end-of-life phase performance unites these different indicators. In the very end, the main goal in measuring the circular economy is to assess the utilization level of reused and recycled resources, and simultaneously, the amount chosen resources which can be reused and recycled after the end-of-life.

Furthermore, the case company has a significant role as the owner of campus real estates, when discussing circular economy in construction and real estate. Campus real estates are constantly evolving and nation widely a large asset class by its total floor area, which produces and consumes significantly resource cycles. Thus, incorporating the principles of circular economy in their day-to-day operations would be remarkably crucial. Moreover, the universities have plausible role in our society as the centres of science, which offers a unique opportunity to apply new principles through pilot projects in construction and real estate, and further, to communicate successes for the whole industry. It was remarked, that the case company already implements the principles of circular economy in certain levels in construction. However, it is not communicated outwards clearly.

Finally, as this master's thesis had the geographical scope on Finland, it is good to discuss, what it means in practise. Traditionally, Finnish construction and real estate industry is characterised by strict regulations. This complicates for example conversion projects of real estates which are not in use in their current purposes. Moreover, these regulations might determine, which materials can be used, and which not as discussed in interviews. This might prevent the use of more circular materials. In Finland, there does not exist similar "experiment culture" as for example in Netherlands. Furthermore, Finnish construction and real estate industry is currently adjusted to choose new virgin materials instead of used materials, which drawbacks the realization of circular economy. However, growing popularity of the concept and increasing knowledge among the professionals can facilitate the shift towards circular economy in the future. In overall, change in prevailing mindset needs to realize.

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# List of Appendices

## Appendix 2. CE indicators in the built environment (Circle economy et al. 2018)

| Sub-strategy | Indicator | | Examples of measures |
|---|---|---|---|
| **Accountability and substantiation of building volume** | The necessity need for new construction | Feasibility study on the possibilities of building refurbishment, possibly excluding the option of new development | Qualitative |
| | Minimise the building volume | Feasibility study on the possibilities of minimising the square meters of development (both new construction and renovation) within specified metrics | Net gross floor area ratio (%) |
| | Reduction of material use within minimum required m2 GFA | Feasibility study on the possibilities of minimising the total material mass used within the specified requirements and square meter surface of development | Quantity of solid material per element ($m^3$) |
| **Design for reassembly** | Remountable connections between product and environment | De-/remountable connections are used when placing /installing the product in its direct surrounding, of which the preservation of similar quality can be guaranteed. | Share or remountable connections (%) |
| | Remountable connections at product level | The product is assembled through de-/remountable connections, of which the preservation of similar quality can be guaranteed. | Share or remountable connections (%) |
| | Accessible connections | The connections used for placing/installing the product in its (direct) environment are accessible. | Share or accessible connections (%) |
| **Maximise amount of re-used materials** | Material Circularity Indicators | 1 The score calculated by the tool MCI (Material Circularity Indicator) is equal or higher than X. | Share of reused materials (%) |
| | Locally reused material are applied | When determining the materialisation, search for local supply of reusable/secondhand materials | A weighted cumulative distance of material transportation from the source (km) |
| **Maximise amount of re-newable materials** | Application of technical reusable and/or recyclable materials | Recyclable materials are used in the technical cycle | Share of technologically reusable materials (%). Calculated separately for each category such as metals and plastics |
| | Application of biological renewable materials | Biobased materials are used in the biological cycle | Share of bio-based materials (%) |
| | Circular procurement | An environmental costs calculation (MPG) needs to be presented along with the design | Environmental costs calculated in €/sq.m. (GFA)/year. Needs to be done by an expert. |
| **Availability of information (element, component, material)** | Material passport | A building material passport is composed and maintained during the use cycle of the building regarding material cycles | Not measurable (yes/no) |
| | Availability of the material passport | The building material passport is available for every building stakeholder. | Not measurable (yes/no) |
| | Disassembly guidelines (demolition specifications) | Upon completion, the building is deliverd with demolition specifications / disassembly guidelines | Not measurable (yes/no) |
| **Building design embodies no or minimal toxicity** | Banned list | No materials from the C2C Banned List of Chemical Materials are used | Share of materials used mentioned on the Banned List of C2C |
| | VOC emissions | Building products have no or minimal VOC emissions | Measured as $\mu g/m^3$ |

## Appendix 1 Interview Guide

**Tausta**
- Haastateltavan tausta (koulutus ja työtehtävät)

**Kiertotalous käsitteenä**
- Kuinka ymmärrät kiertotalouden käsitteenä?
- Miten kiertotalous toteutuu rakennus ja kiinteistöalalla?

**Rakennushankkeen tilaajan vaikuttamismahdollisuudet kiertotalouden toteutumiseen kiinteistöalalla näkökulmastasi?**
- Miten rakennushankkeen tilaaja voi osaltaan vaikuttaa kiertotalouden toteutumiseen?
- Onko jonkin toimijan rooli rakennus/kehityshankkeissa erityisen tärkeä?

**Tilaajien kohtaamat haasteet kiertotaloudellisten ratkaisujen toteuttamisessa näkökulmastasi**
- Mitkä asiat rajoittavat kiertotalouden toteuttamista?

**Esimerkkejä kiertotalouden onnistumisista rakennus- ja kiinteistöalalla**
- Mitkä ovat mielestäsi hyviä esimerkkejä onnistumisista?

**Background**
- Interviewee’s background (education and tasks)

**Circular economy as concept**
- How do you understand the concept of circular economy?
- How does circular economy realize in construction and real estate sector?

**Construction client’s potential to contribute on the realization of circular economy in construction and real estate sector from your perspective?**
- How can the construction client effect on the realization of circular economy?
- Do you think that some stakeholder’s role in construction and development projects in particularly crucial?

**Challenges for construction clients in the implementation of circular solutions from your perspective**
- What issues constrains the realization of circular economy?

**Examples regarding the successes of circular economy in the construction and real estate sectors**
- What are good examples of successes in your opinion