THE CIRCULAR ECONOMY TRANSITION IN EXISTING PUBLIC REAL ESTATE

An overview of the facts and barriers of the central government public real estate

Ç.N. Aslan
2020/2021

Frontpage: Own Illustration, edited photo of the CGREA's office in the Hague (2021).

“The problems that exist in the world today cannot be solved by the level of thinking that created them.”

- A. Einstein

The Circular Economy transition in existing Public Real Estate

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MSc Thesis

Graduation Laboratory [AR4R010]

MSc Management in the Built Environment

Architecture, Urbanism and Building Sciences

Delft University of Technology

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2020/2021

TU Delft

Rijksvastgoedbedrijf

Ministerie van Binnenlandse Zaken en Koninkrijksrelaties

Colophon

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REPORT DETAILS

Version:	P5
Words/Pages:	39.047/119
Subject:	Circular Economy in Existing Public Real Estate

UNIVERSITY

Institution:	Delft University of Technology
Faculty:	Architecture & the Built Environment
Master:	Architecture, Urbanism & Building Sciences
Track:	Management in the Built Environment (MBE)

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Preface

Dear reader,

In front of you lies the master thesis about the Circular Economy in Existing Public Real Estate which is made for the MSc track Management in the Built Environment at the Delft University of Technology.

Since my childhood, I always loved playing games that involved buildings and constructions. Playing these games made me aware that you are always limited on resources, be it building blocks, workers or money, there were always barriers that you had to deal with. This made these games entertaining. The reason was that it challenges your creative thought on how to deal with the given barriers. This of course resulted in creative solutions in which you could find joy. In today's world, we have similar challenges at hand. We have always produced and consumed everything in a linear way. Yet, we see that more limitations, such as scarcity of resources, arise from our current linear economy. Hence, the rising demand for a more circular economy began.

After my internship at a contractor firm and graduation on my Bachelor of Architecture, Urbanism and Building Sciences, my interest in Sustainability and Circular Economy had grown. And during my masters, I followed the course named Urban Development Game, where students had to take roles of different actors that were crucial in a development project. I choose to be part of the municipality's Land Department. I liked the responsibility that I had, safeguarding and realising public interests in development projects. And since then my interest in the public sector also started.

In order to dive into more depth around these subjects, I choose to do my master thesis on Circular Economy and Public Real Estate Management. And since I followed an internship at the Central Government Real Estate Agencies this thesis has data of their public real estate portfolio.

I would like to thank the following people for their guidance and support, without whose help this study would never have been possible. First, I want to thank my supervisors from TU Delft, Alexandra den Heijer and Paul Chan. I want to thank Alexandra who kept me on the right track and helped me using the PREM framework. And I want to thank Paul for giving me the critical feedback that I needed to dive deeper in my research. Thanks are also due to Ad Heeman, Rob van Roon, Thomas Metz, and all my colleagues from the CGREA who gave me the possibility to do the internship and helped me with my research.

I hope the findings of my research will contribute to your work and hope you will enjoy reading this thesis.

Çağrıhan N. Aslan
2020/2021

Abstract

Problem statement - The global community is facing scarcity of finite materials and environmental pollution. In response to these mounting issues, the government of the Netherlands plans to transition to a circular economy (CE) by 2050. The shift towards a CE affects the built environment. Currently, the global building industry is responsible for 40% of material consumption and one-third of energy consumption. In essence, there are CE developments happening in the Public Real Estate (PRE) and barriers are known in the existing building stocks. However, insufficient research has been conducted on what the barriers could be for the existing PRE in regards to the CE transition. Barriers can hinder further CE development and the CE transition in existing PRE. What these barriers exactly are, has yet to be mapped out for the existing PRE. Therefore, sufficient research is needed to fill this gap. Hence, the following research question is then formulated for this research: *"What are the current barriers to the circular economy transition for existing public real estate?"*. Sub questions have been formulated in order to answer the main research question: 1. *"How is the CE ambition integrated into CGREA's existing PRE projects?" 2. "How are CE strategies implemented in existing PRE?" 3. "What challenges arise when implementing CE strategies in existing PRE?". 4. "How are these challenges currently managed in order to realise the CE goal?".* This study explores three cases of the Central Government Real Estate Agencies (CGREA) existing PRE. The results will be used to identify and assess the current barriers for the existing PRE regarding the transition to a CE.

Objectives - The aim of this study is to provide an overview of the current barriers to transitioning to a CE for the CGREA's existing PRE. Moreover, the current CE activities around existing PRE will be analysed, and the facts and barriers for the CGREA will be established.

Research method - The methodology of this study is divided into theoretical research, empirical research and synthesis. The research methods of this study consists of a review of previous scientific literature studies on the subject of CE in existing PRE, three case studies and interviews regarding the three cases, and an expert panel to assess, validate and improve the results.

Discussion - In essence, this study contributes a more nuanced view on the subject of CE transition in the built environment focused on the existing PRE. The theoretical research indicated that the CE transition in existing PRE was neglected. Yet, empirical research indicated that the CE transition in existing PRE projects is being realised. Moreover, this study has found that, even if the CE ambition is integrated into the later stages of a project, it is still difficult to realise this ambition with the current economy we live in. The analysed cases have indicated the challenges that are an obstruction for further transition to the CE. These challenges are identified and validated as barriers.

Conclusion - In this study twelve barriers were identified and assessed that are currently a barrier for further CE transitioning in existing PRE. These barriers are: that there is (1) No CE ambition in the project scope, (2) unknown resource availability, (3)No assessment framework, (4) Inexperience of the contractor with the CE, (5) Cost and time driven projects,

(6) No separate budget for CE strategies, (7) Finding CE installations, (8) Unknown quality of building materials, (9) current regulations, (10) No CE award criteria, (11) Users satisfaction, and (12) Definitive design without CE strategies.

Keywords - *Circular Economy, Public Real Estate Management, Central Government Real Estate Agency, Circularity barriers*

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Acronyms

CE	Circular Economy
CGREA	Central Government Real Estate Agency
CREM	Corporate Real Estate Management
PRE	Public Real Estate
PREM	Public Real Estate Management

1. Introduction

In this chapter, the subject of this research will be introduced, and the foundation for this thesis will be established. A knowledge gap and an explanation of why this gap needs to be filled will be introduced. Finally, the structure of this study will be described.

1.1 Problem statement

The global community is facing scarcity of finite materials and environmental pollution (OECD, 2018; PBL, 2019; Rijksvastgoedbedrijf, 2016; van den Wildenberg, 2018). In response to these mounting issues, the government of the Netherlands plans to transition to a circular economy (CE) by 2050 (Rijksoverheid, 2016). Yet, the shift towards a CE is not an easy task because the Dutch economy was, and currently is, locked into a system that favours the linear model of production and consumption (Geldermans & Rosen-Jacobson, 2015; Ellen MacArthur Foundation, 2013).

The shift towards a CE affects the built environment. Currently, the global building industry is responsible for 40% of material consumption and one-third of energy consumption (Ecorys, 2014; OECD, 2018; Pomponi & Moncaster, 2016; WEF, 2016). In the scientific literature regarding the CE transition, great emphasis is placed on building components and urban areas, and less on individual buildings (Anastasiades et al., 2020; Kyro, 2020; Pomponi & Moncaster, 2016). The meso scale mainly focuses on buildings and construction projects as individual objects.

Furthermore, most of the scientific literature is focused on new construction. The existing building stock may have difficulties, as it was not built with a CE in mind. It is also assumed that 75 - 90% of the existing building stock will still be standing by 2050 (Pomponi & Moncaster, 2016). On top of that, only 1% of the existing building stock is demountable (Kanters, 2018). Focussing only on new construction is not enough to achieve circularity in buildings (Kyro, 2020). Therefore, the transition to a CE presents challenges to the existing building industry.

The CE transition is also occurring in public real estate (PRE). Yet, as most of the real estate case studies in the literature are non-public, studies about PRE seem to have been neglected. In addition, while CE aims and goals have been identified in the construction industry, there is not enough evidence to prove that all the actions needed to promote the CE transition are being implemented. (Vergara d'Alençon et al., 2019).

In conclusion, CE strategies are becoming more nuanced as more research is being conducted around this trending subject. However, insufficient research has been conducted to identify the current barriers in existing PRE with regard to the CE transition. Therefore, further research is needed.

1.2 Demarcation of the study

In this study, the Central Government Real Estate Agencies (CGREA) existing PRE will be analysed, to identify the current barriers for the existing PRE regarding the transition to a CE. The CGREA is a governmental organisation with the largest PRE portfolio in the Netherlands. The CGREA is planning to apply CE strategies to its PRE portfolio. As mentioned, transitioning to a CE is not an easy task. This is also a difficult task for the CGREA because of their various real estate portfolios (Rijksoverheid, 2019; Ririassa, 2019). The CGREA wants to become an example for society by transforming their real estate portfolio to align with a CE. They have developed tools to measure which CE strategies should be implemented in their PRE portfolio (Circulair Bouweconomie, 2020). In Figure 1, an illustration is given of the demarcation of the study.

Figure 1: Demarcation of the study (Source: Author).

1.2.1 Target Audience

The target audience for this thesis is the public sector, mainly the CGREA. The results of this research will give the CGREA and the academic community a scientific overview of the current barriers regarding the transition to a CE for their existing PRE. Without an overview of the current activities, it is difficult to provide effective recommendations for transitioning to a CE (Behrens et al., 2017; Ririassa, 2019).

1.2.2 Aim of the Study

The aim of this study is to provide an overview of the current barriers to transitioning to a CE for the CGREA's existing PRE. Moreover, the current CE activities around PRE will be described, and the facts and barriers for the CGREA will be established. The CGREA is working on transitioning its PRE portfolio from the current economy to a CE and aims to fully transition by 2030. The results of this research could aid the CGREA by informing them where they stand regarding the CE transition. This research can be a starting point in dealing with the current barriers that hinder further CE development in existing PRE. Hence, it can help the organisation in managing future projects and improve the CE transition of their PRE portfolio. This knowledge can be used by other organisations as well.

1.3 Study Relevance

1.3.1 Social Relevance

Recent research done by the Ellen Macarthur Foundation (2020a), showed that the COVID-19 pandemic has revealed the vulnerability and shortcomings of the current linear economy. The actions that governments take today, will shape the post-COVID-19 world for future generations. The need for this global economic transition has been identified by several academic sources as necessary for a more resilient future (Ellen Macarthur Foundation, 2020b). The need for a shift towards a CE is described by Geldermans and Rosen-Jacobson (2015), as a desire for a better symbiotic relationship between people and nature. In addition, a CE will promote the wellbeing of the growing world population (van den Wildenberg, 2018).

The urgency around shifting towards a CE also caught the attention of the European Commission, they made an action plan to achieve this transition. In response to the Paris climate agreement, the Netherlands aims to fully transition to a CE by 2050 (Rijksoverheid, 2016; Ririassa 2019). The construction industry is one of the five industries, in which the Dutch Government has taken special action (Rijksoverheid, 2016). Without an overview of the current activities taking place in the construction industry, it is difficult to provide effective recommendations regarding the CE transition (Behrens et al., 2017; Ririassa, 2019).

1.3.2 Scientific Relevance

In the scientific literature, great emphasis is placed on the building components and urban areas regarding the CE transition, and less on individual buildings regarding the CE transition. This is called the meso scale, which is mainly focused on buildings and construction projects as individual objects. Pomponi and Moncaster (2016), argue that there is a lack of interdisciplinary research conducted on the meso scale, which is critical for understanding and applying CE strategies to public buildings. This concept is also supported by Geldermans and Rosen-Jacobson (2015). Furthermore, most of the scientific literature is focused on new constructions (Anastasiades et al., 2020; Kyro, 2020). Hence, the transition to a CE presents challenges to the existing building industry. The CE transition is also occurring in PRE. Yet, as most of the real estate case studies in the literature are non-public, studies about PRE seem to have been neglected (Vergara D'Alencon et. al, 2019).

In conclusion, there are CE developments happening in the PRE and barriers are known in the existing building stocks. However, insufficient research has been conducted on what the barriers could be for the existing PRE in regards to the CE transition. Barriers can hinder further CE development and the transition of the existing PRE to a CE. What these barriers exactly are, has yet to be mapped out for the existing PRE. Therefore, sufficient research is needed to fill this gap. Hence, this study will focus on what the current barriers are for the CE transition in the existing PRE. Barriers are an obstruction in realising CE transition in existing PRE. Hence, its relevance is of high importance.

1.4 Research Questions

Based on a review of the scientific literature, the importance of the CE transition in the built environment is clear. The literature mostly focuses on CE strategies for new constructions and building components. CE transition strategies for existing PRE are not made explicit. Furthermore, case studies have shown that there is not enough evidence to prove that all the actions needed to promote the CE transition in the construction industry are being implemented. Therefore, the barriers that are obstructing the CE transition in existing PRE, need to be characterized.

In this study, these barriers will be defined and the current situation will be presented. In addition, the existing PRE of the CGREA will be researched. The CGREA is working on transitioning its existing PRE portfolio from the current economy to the CE and aims to fully transition by 2030. The CGREa wants to set an example for society. This study will explain their current standing in the CE transition.

Based on a review of the scientific literature regarding the CE in the built environment, the main question of this thesis has been determined:

"What are the current barriers to the circular economy transition for existing public real estate?"

Sub questions have been formulated in order to answer the main research question:

1. *"How is the CE ambition integrated into CGREA's existing PRE projects?"*
2. *"How are CE strategies implemented in existing PRE?"*

The answers to these sub-questions will offer insights into the facts of the current situation of CGREA's existing PRE. Implementing CE strategies in existing buildings will surely bring barriers with them, as mentioned in the literature. Hence, the following sub-questions have been formulated:

3. *"What challenges arise when implementing CE strategies in existing PRE?"*
4. *"How are these challenges currently managed in order to realise the CE goal?"*

Discovering the challenges that arise from implementing CE strategies will provide insight on what is possible and what is not. This will aid in identifying the barriers that hinder the CE transition in existing PRE. The answers to these sub-questions will impact the answer to the main research question.

1.5 Research Structure

The structure of this thesis is shown in Figure 2. In this chapter the study of the thesis was introduced. In the second chapter, a review of scientific literature about CE's in the built environment will be conducted. The scientific literature review will be used to develop the theoretical framework for this research, which can be found in chapter three. In the fourth chapter, the methods by which this research will be conducted will be defined. In chapter five

the field practice knowledge will be reported and assessed. In chapter six, the chosen cases will be analysed. The results of this research can be found in chapter seven: Synthesis. The results will then be validated and improved in chapter eight: Expert Panel. Finally, a discussion, conclusion and reflection will be provided. The first four chapters can be seen as desk research, while the chapters six to nine can be seen as field research.

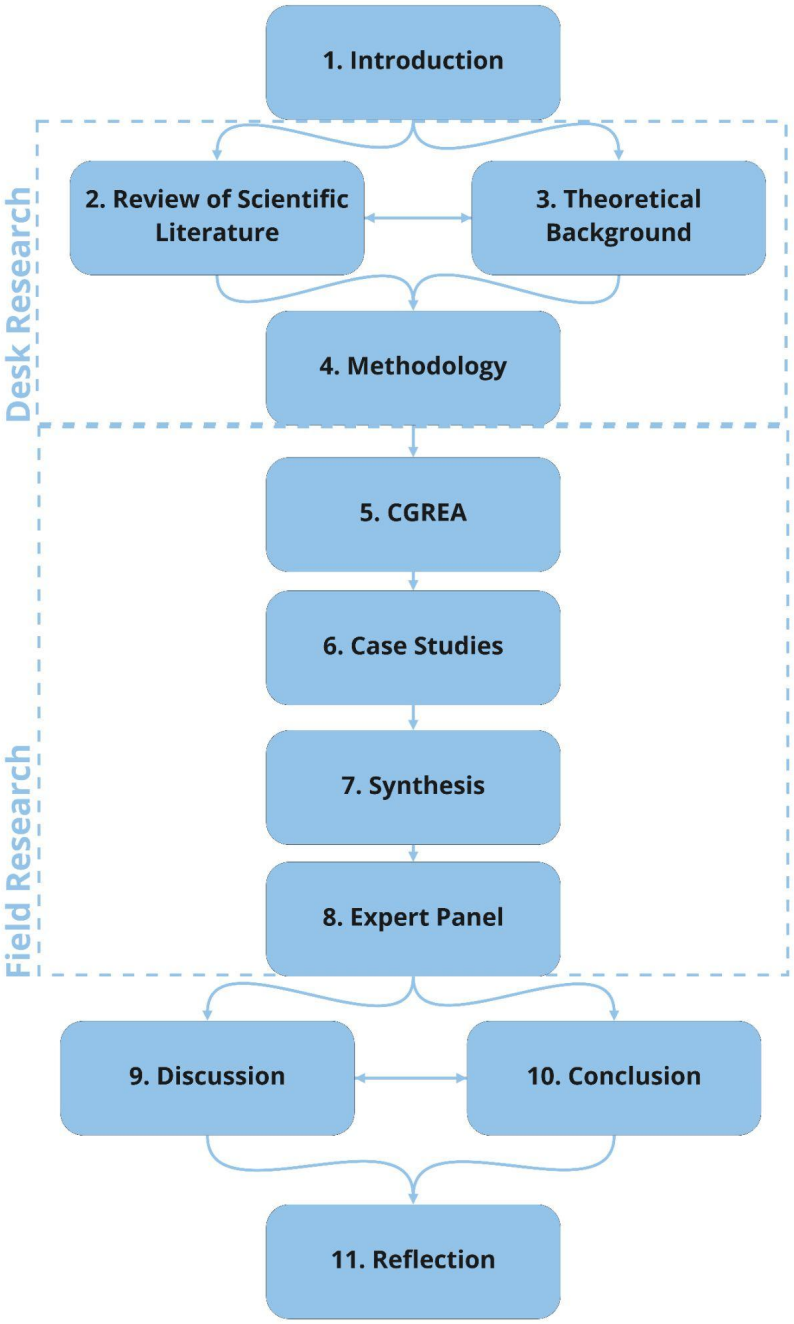


Figure 2: The structure of the study (source: author).

2. Review of Scientific Literature

This chapter presents the review of previous scientific literature studies. The chapter is organized and focussed on the subject of CE in the Built Environment. This review of previous studies will give insights and knowledge of the mentioned subjects. Additionally, this review will be used in finding the scientific gap and arguing the research questions.

2.1 Circular Economy

This section will focus on the CE from the Built Environment perspective. The section covers the necessity of CE, the definitions of CE, the different scales CE is positioned in literature and different strategies that are being used.

2.1.1 The urge of Circular Economy

Over the last century, the demand for raw materials has only kept increasing (PBL, 2019). While in 2009, the consumption of raw materials was a total of 58 gigatons. In 2017, this number has risen to 90 gigaton of raw materials consumption (OECD, 2018; Rijksvastgoedbedrijf, 2016; van den Wildenberg, 2018). In Figure 3, it is shown that resource consumption of raw materials is highly dominant in the construction industry and by 2060 it is estimated that the consumption of raw materials will hit 167 gigaton. This number will only increase if urgent actions to counter the rising raw materials consumption is not dealt with. Eventually, the increase is expected to worsen environmental pollution, which will contribute to climate change (OECD, 2018). In addition, these raw materials are finitive and thus in danger of becoming scarce due to the growing population and increasing world prosperity (PBL, 2019; Rood & Hanemaaijer, 2017).

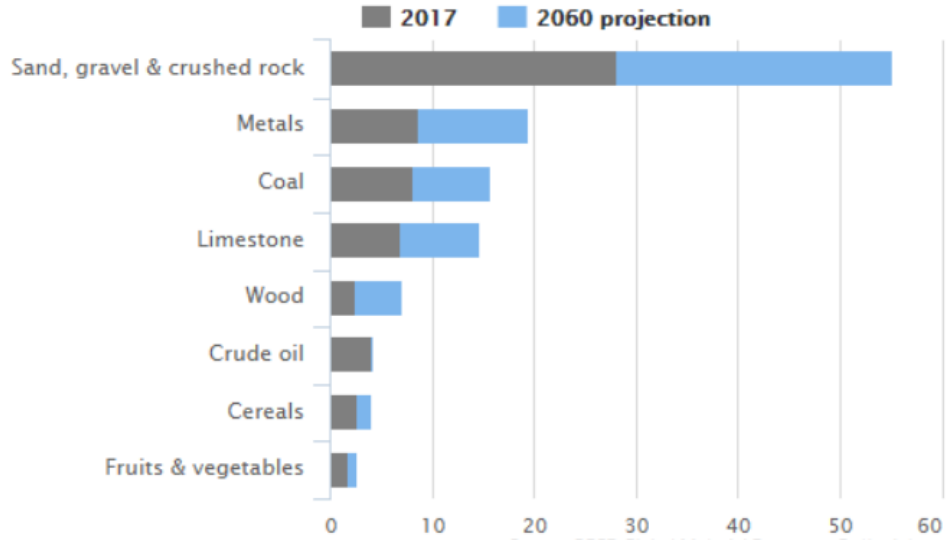


Figure 3: Consumption of raw materials (OECD, 2017).

The current economy of the world is mostly relying on a linear approach to production and consumption (Sariatli, 2017; van Bakel, 2020). In a linear economy the materials are extracted, products are processed and ultimately disposed of as shown in Figure 4. Linear

economy, also known as the “build-use-demolish paradigm” in the building industry, leads eventually to increasing pressure on raw materials, environmental pollution, carbon emissions and waste generation (Geldermans, et al., 2016; Ellen MacArthur Foundation, 2013; Sariatli, 2017).

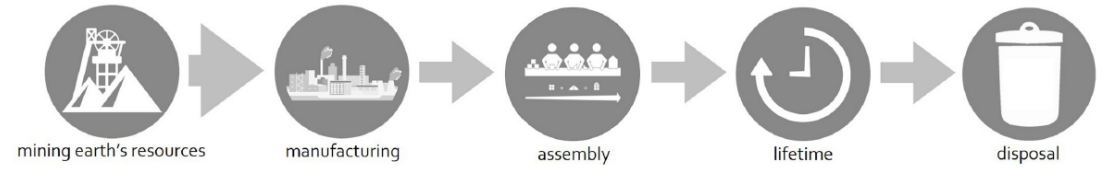


Figure 4: Production and consumption in a linear economy (Anastasiades et al., 2020).

The Ellen MacArthur Foundation (2013) states that the current economy is locked into a system where everything is in favour of the linear approach of production and consumption. Stijn & Gruis (2019) argue that CE is a more resource-effective solution for growing material consumption. Geldermans et al. (2016) and Sariatli (2017) go further and emphasise that in order to continue to have access to raw materials, a paradigm shift towards a circular economy is unavoidable. Ultimately, Gerldermans et al (2016), Ellen MacArthur Foundation (2013), Rijksoverheid (2016) and Sariatli (2017) all affirm that in order to shift from a linear economy towards a more circular economy, to preserve current finite materials, urgent changes are required. However, Geldermans & Rosen-Jacobson (2015) and (Behrens et al, 2017) both state that this is not an easy task for the complex accumulation of products, services and materials, such as a building. Pomponi & Moncaster, 2016 even state that 75-90% of the existing building stock will still be standing by 2050. On top of that only 1% of the existing building stock is demountable (Kanters, 2018).

Moreover, the building industry is responsible for 40% of material consumption and production, 35% of waste generation and 33% of energy consumption globally (Ecorys, 2014, OECD, 2018; Pomponi & Moncaster, 2016; WEF, 2016). The focus in the construction industry is mostly on dealing with waste, or recycling (Stijn & Gruis, 2019). This is also evident in the Dutch construction sector, where 95% of the waste is being recycled (Anastasiades et al., 2020). Ghisellini et al. (2016) stress that due to physical constraints of recycling the value of resources can decrease. Charlotte Malabi Eberhardt et al. (2019), mentions this as downcycling of materials that occur during renovation and transformation of projects. In this case, downcycling is referred to as a cascade of new applications of the used material in a way that it decreases its value (Geldermans & Rosen-Jacobson, 2015). The Ellen MacArthur Foundation (2013), argues that recycling is part of the “outer technological cycle” in the technical cycle. In addition, a main principle of the CE is to first make optimal use of the “inner technological cycles” such as maintenance, reuse and remanufacture, instead of recycling (Stijn & Gruis, 2019). Hence, CE focuses first on the optimal use and reuse of raw materials in the various links of the production chain from the extraction of raw materials to consumption (Ellen MacArthur Foundation, 2013). Instead of downcycling materials, upcycling is introduced in the CE. This method is also called Cradle to Cradle in which the value of raw materials is not lost when recycling.

2.1.2 Defining the Circular Economy

In the last decade, CE became increasingly popular, which resulted in the emergence of various definitions (Lieder & Rashid, 2016). The definition of the CE is based on different theories and schools of thought that confront the current linear economy (Behrens et al., 2017). Hence, CE is a terminology that is interpreted differently by a large number of authors. However, most authors have accepted and frequently cited the Ellen Macarthur Foundation's (2015) definition of CE (Geldermans & Jacobson, 2015; Pomponi & Moncaster, 2016; Stijn & Gruis, 2019; van Bakel, 2020), which state that the CE is "*an industrial system that is restorative or regenerative by intention and design. It replaces the 'end-of-life' concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse, and aims for the elimination of waste through the superior design of materials, products, systems, and, within this, business models*" (Ellen Macarthur Foundation, 2013, p.2).

For the Ellen MacArthur Foundation's (2013) definition of CE, there is a distinction made between a biological and a technical cycle. These cycles are illustrated in the "Butterfly model", which is shown in Figure 5. The biological cycle holds the flows of renewable materials (renewable flow management). In the technical cycle, stock management is mostly involved. For example, stocks of finite materials. Here the use of materials replaces consumption. The technical cycle mostly holds the raw materials that are produced and consumed in the built environment (Ellen Macarthur Foundation, 2015, Ploeger et al., 2018).

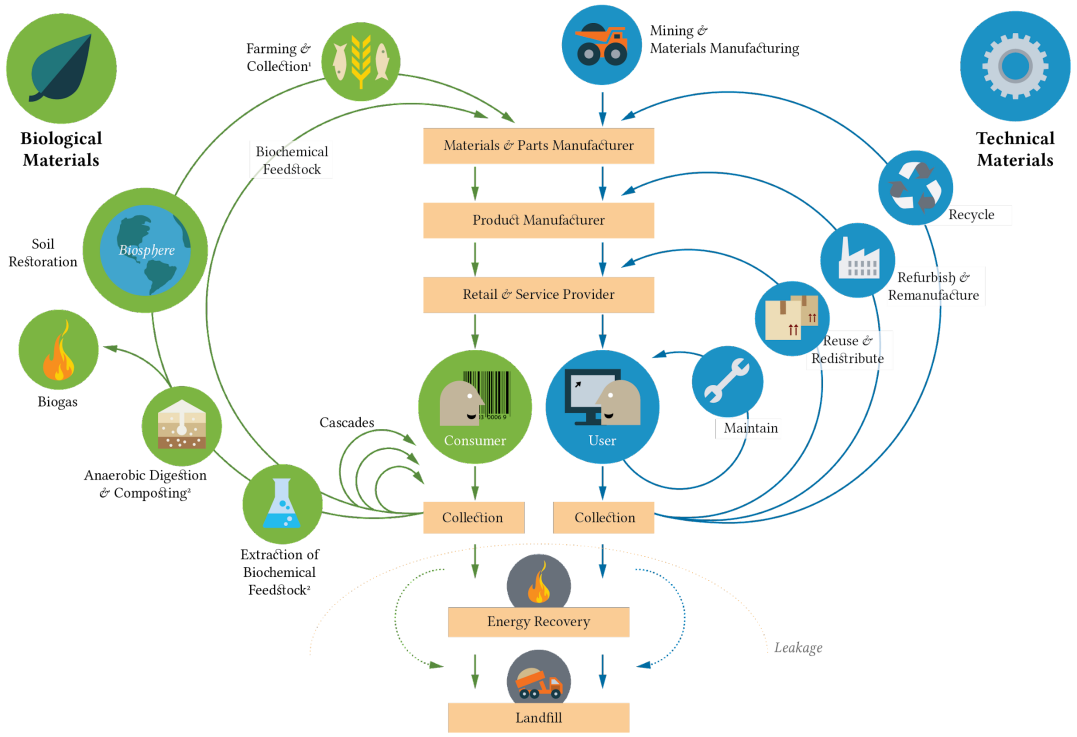


Figure 5: The biological and technical cycles of CE (Ellen MacArthur Foundation, 2015, p. 4)

2.1.3 The goal of Circular Economy

In essence, the main goal of CE is to decouple economic growth from the consumption and production of finite materials to a closed-loop growth (Anastasiades et al., 2020; Ellen MacArthur Foundation, 2013; Ghisellini et al., 2016; Rood & Hanemaaijer, 2017). The need for such a shift towards CE is described by Geldermans & Rosen-Jacobson (2015), as a desire for a symbiotic relation between people and nature. Another reason is of course to keep up with the growing well being of the world population. Adapting circularity principles to the current economy can lead towards this goal (Ellen MacArthur Foundation, 2013).

Another goal that has to be defined is sustainability. Sustainability and CE are being used together interchangeably by policymakers in similar contexts, which creates confusion (Charlotte Malabi Eberhardt et al., 2019). For instance, Geissdoerfer et al. (2017, p. 1) argue that this is "blurring their conceptual contours and constraints the efficacy of using the approaches in research and practice". Hence, the authors have identified the relationship between the two terms in their study. According to Geissdoerfer et al (2017), the goals for sustainability are open-ended, with various goals depending on the client's interest. While the goal for CE is to have a closed economic loop, eliminating all the newly added resources and leakage out of the system. Furthermore, the study concludes that CE can be viewed in three ways. Firstly, as a condition for a sustainable system. Secondly, as a beneficial relationship. And last as a trade-off (Geissdoerfer et al., 2017). In addition, Charlotte Malabi Eberhardt et al. (2019) states that sustainability is mainly focused on eliminating or reducing the environmental pollution created by humans, while CE focuses on maintaining productivity, value and quality of materials with an end goal to have a net positive environmental impact. A more recent study conducted by Anastasiades et al. (2020, p.1), concluded that "sustainability is the goal, while the CE is a means to achieve a more sustainable economy".

2.1.4 Circular Economy Strategies

CE strategies are being used in order to realise the CE ambition. Kirchherr et al. (2017) has gathered 114 CE definitions and concluded that most circularity strategies were based on recycle, reuse and reduction. In addition, Potting et al. (2017) has formulated six other R strategies which altogether form the R-framework. The R's in the framework are different principles that are set in a hierarchy from one to nine. The lowest number (R0: Refuse) is ranked as the highest circularity strategy, while the highest number (R9: Recover) is seen as the lowest. The nine R's principles are divided into three parts: (1) smarter product usage, (2) extending the lifespan and (3) finding a useful application (Potting et al., 2017). Nonetheless, The Ellen MacArthur Foundation (2017) has adapted the R-framework and changed the position of the seventh R: Repurpose. Repurpose is now put "finding a useful application" instead of "extending the lifespan" as shown in Figure 6.

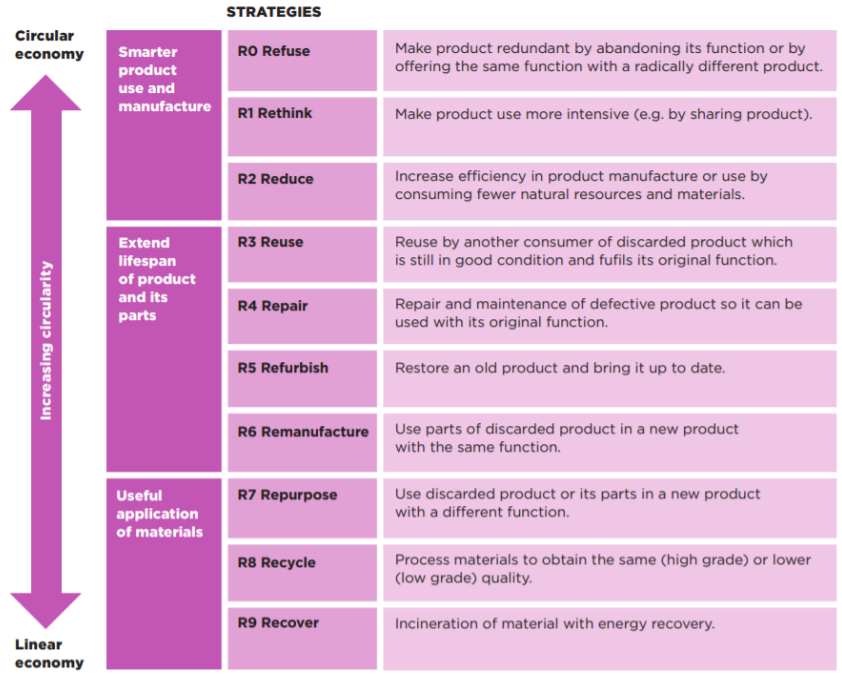


Figure 6: The ten strategies of the Circular Economy. (Ellen MacArthur Foundation, 2017).

The Dutch Environmental Assessment Agency (PBL) conducted research in finding which form of R-framework is used the most in the Netherlands. It became evident that recycling is the most used form of circular principle in the Netherlands (PBL, 2019). Potting et al. (2017) concluded that closing the loop of production and consumption, which is called ultimate circularity, is not feasible in practice. Similarly, Charlotte Malabi Eberhardt et al. (2019) states that it can be questioned whether the circularity strategies can succeed in transforming the current linear economy, which has been in place for many years, into the CE. However, PBL (2019) and Potting et al. (2017) both agree that ultimate circularity is an ideal situation, and circularity strategies can offer support towards a more CE.

2.2 The Built Environment

The subjects of this study are around CE in the built environment. Hence this part of the chapter will present knowledge on which scales CE is being realised, circular buildings, CE developments in PRE, existing buildings, and the challenges.

2.2.1 Different scales

CE In the built environment is known on different scales. According to Ghisellini et al. (2015) the CE can also be divided in three different scales: (1) mirco-, (2) meso- and (3) macro-scale. In the built environment the micro scale can be seen as the building component, the meso as individual buildings where all the components are assembled and the macro scale as cities as shown in Figure 7. Pomponi & Moncaster (2016) argues that regarding the CE discourse, micro-scale and macro-scale gained the most emphasis. This is backed by Anastasiades et al. (2020), which highlights that possibilities for building components and materials in the micro-scale have been researched the most. Furthermore, most of the material flows on the macro-scale have been mapped for a built environment, while research on the meso-scale is inadequate.

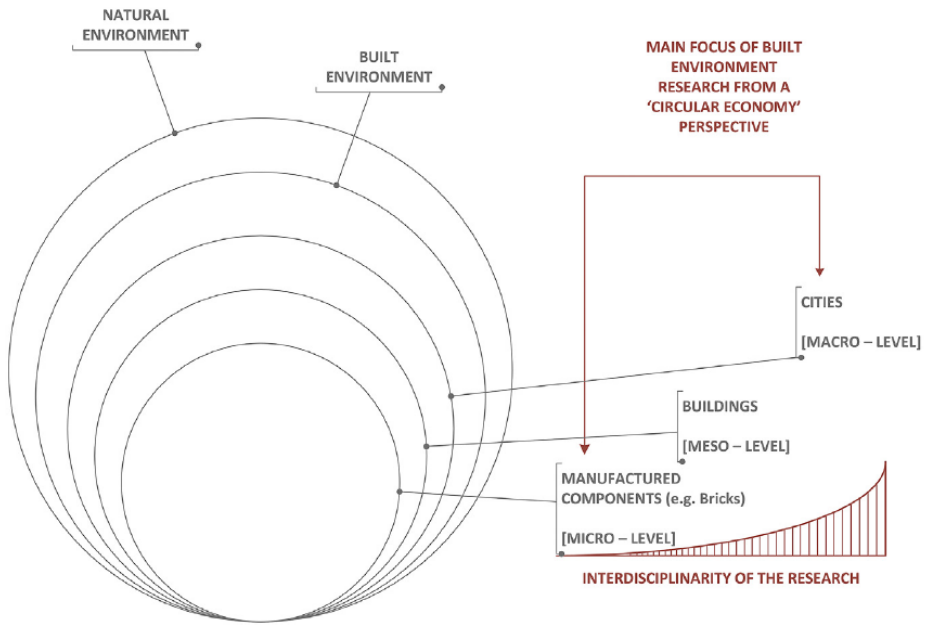


Figure 7: The three scales of the built environment (Pomponi & Moncaster, 2016).

2.2.2 Circular Buildings

Circular building is defined as a building that is designed, planned, built, operated, maintained and deconstructed in a manner consistent with the CE (Pomponi & Moncaster, 2016). In addition, the Transitieagenda Circulaire Bouweconomie (2018, p.10) states also that a circular building is built without unnecessarily depleting natural resources, polluting the environment and damaging the ecosystem.

As mentioned earlier in section 2.1.1, buildings are complex products making it part of the CE is not an easy task. However, Charlotte Malabi Eberhardt et al. (2019) indicates that buildings that become part of the CE have the highest positive environmental and economic impact, and thus worth developing. However, Brand (1994) made it clear that if components of a building were integrated indistinctly then that building is not designed for change, and so not ready for becoming a circular building. Hence, Brand (1994) states that each building consists of components with their own lifespan as shown in Figure 8.

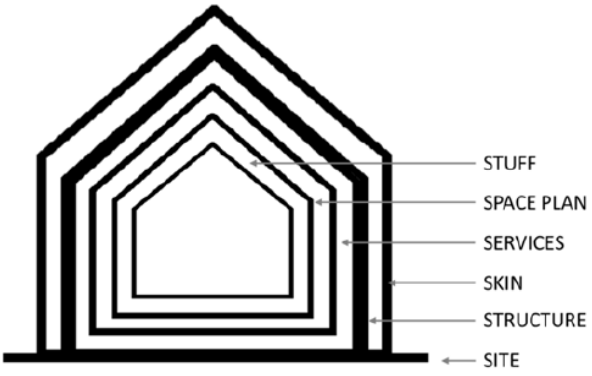


Figure 8: The six layers of a building (Brand, 1994).

These components are divided in six building layers; First, the site which has an infinite lifespan.Second, the structure has an estimated lifespan between 30 to 300 years. Third, the skin has an estimated lifespan of 20 years. According to Brand (1994), the focus on reducing energy costs has led to re-engineering exterior surfaces. Fourth, the services have an estimated lifespan of 7 to 15 years. The services of a building are the systems, installations, and all the other technical aspects. Fifth, the space plan has an estimated lifespan between 3 to 30 years. In the space plan, the interior layout of a space goes. so the walls, ceilings. Last, the stuff layer has an estimated lifespan of 1 year. In this layer all the things that can be moved daily to monthly in a building (E.g. furniture).

The rate of replacing the building component varies on the lifespan. According to Charlotte Malabi Eberhardt et al. (2019), a circular building is all about making smart use of these six layers so that they can be replaced and reused.

In a CE paradigm, products and materials are being owned by their suppliers. The clients or users pay for the services only of these commodities (Ellen MacArthur Foundation, 2013). Contractors that implement CE strategies to a project could face challenges, as implemented commodities can be seen as fixtures. According to Dutch property law, fixtures

are part of the property and thus in ownership of the owner. This is called the rule of accesio. This leaves legal uncertainties for the contractor, since the commodities can not be part of a multi-cyclic behaviour, as they can not circulate in the CE. Therefore, CE initiatives within the construction sector should focus on alternatives for suppliers to stay in ownership. Reuse and recycling models and buy-back and take back contracts do seem to be possible without hindrance of property law (Ploeger et al., 2018). This could eventually lead to a “circular” building that will have several stakeholders as owners. This will lead to a more complex project and also make it financially difficult for the owners to retain ownership (Van den Brink et al., 2017).

2.2.3 Public Real Estate

Tjeerdsma & Veuger (2015) states that PRE is all the properties that physically facilitate public functions. In addition, Hakenberg (2019) defines PRE as real estate that is owned by the government. Over the years PRE has increased in value. In 2007 the value of PRE was estimated to be around 30-50 Billion euros (Teuben & Waldmann, 2007). In 2011, an estimated amount of PRE square meters was indicated to be 83.5 million, of which 70% had an education or health function. (Bouwstenen voor sociaal, 2011). In 2015 new research was done and the square meters for PRE had risen to 85.5 Million (m2). The value of the PRE has more than tripled, and was estimated to be 157 Billion euros (Tjeerdsma & Veuger, 2015). In Figure 9 it can be seen that the whole PRE is far larger than all the offices, retail and industrial real estate in the Netherlands combined.

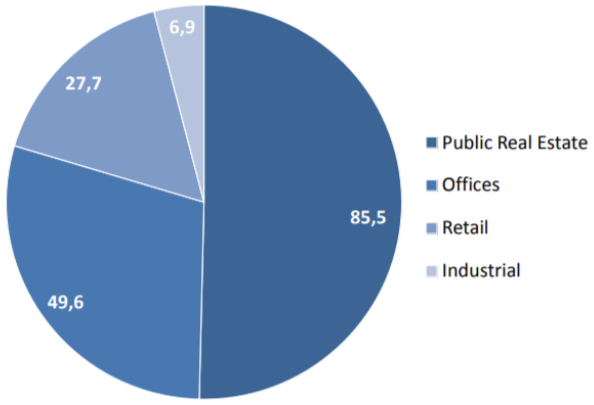


Figure 9: Dutch Real Estate in m2 x 10^6 (Tjeerdsma & Veuger, 2015).

The PRE and CRE have a lot of differences, the biggest difference is that PRE is owned by the public sector. In addition, corporate leaders are driven by making profit on their investment. While the drivers for public leaders are mainly getting re-elected. Furthermore, the financial focus on PRE is mostly on the services that the public sector provides. Therefore, most buildings that are owned by the public sector are not seen as investment but as a building to provide these public services. Another difference is that PRE managers have to deal with more stakeholders than their CRE colleagues. Having to deal with more stakeholders eventually leads to difficulties in managing and operating PRE (Van der Schaaf, 2002).

Becoming fully part of the CE is the goal of the Dutch Government. There are already policies being made to meet that end. The public sector sets an example to society and has a responsibility to apply these public policies (den Heijer, 2020). For example, the CGREA has already plans for their own real estate portfolio in realising circular buildings (Rijksoverheid, 2016). In order to implement the CE ambitions of the government, good real estate management is needed. However, the public sector faces difficulties in developing a PRE portfolio that matches their current and future needs (Van der Schaaf, 2002). In addition, Hakenberg (2019) states that the public sector is not fully aware of the current situations of all the real estate that they own, but they are working on getting more insight into their real estate portfolio.

2.2.4 Public CE ambition

Recent research done by the Ellen Macarthur Foundation (2020a), showed that the covid-19 pandemic has revealed the vulnerability and shortcomings of the current linear economy. The actions that the governments take today will shape the post-Covid-19 world for future generations. Hence, policies and investments will also determine the direction to a more resilient economy. In response to the economic impact of the Covid-19 pandemic, governments around the world are being mobilised by policymakers to achieve a resilient economy with the CE. To achieve such economic recovery, CE strategies are being used, meaning that a new way of thinking is needed in redesigning our current linear economy into a CE (Ellen Macarthur Foundation, 2020a).

In recent years the European Commission launched the "CE Package", which is an action plan for shifting towards the CE. This transition is seen as "an essential contribution to the EU's efforts to develop a sustainable, low carbon, resource efficient and competitive economy" (European Commission, 2015, p.2). In response to the Paris climate agreement, the Netherlands also aims to become fully part of the CE by 2050 (Rijksoverheid, 2016; Ririassa 2019). The construction industry is one of the five industries where the Dutch Government takes special action (Rijksoverheid, 2016). Without an overview of the current activities, it is difficult to give an effective direction to the CE transition (Behrens et al., 2017; Ririassa, 2019). An overview on the CE activities on the PRE can support the government in considering what works and what doesn't. Hence, PBL (2019) delivered an overview concerning the CE activities in the Netherlands. The emphasis on this report is mostly on the product chain (E.g. recycling of plastic).

According to Rijksdienst voor Ondernemend Nederland (2019), when applying for an environmental permit, new government buildings and all other types of buildings in the Netherlands are required to be almost energy neutral (BENG). However, shifting the existing building stock towards energy neutrality will be a challenge for the Public sector as it is not their main priority (Hakenberg, 2019). In Figure 10 the timeline of planned legislation for the Netherlands can be seen (Twynstra Gudde, 2019).

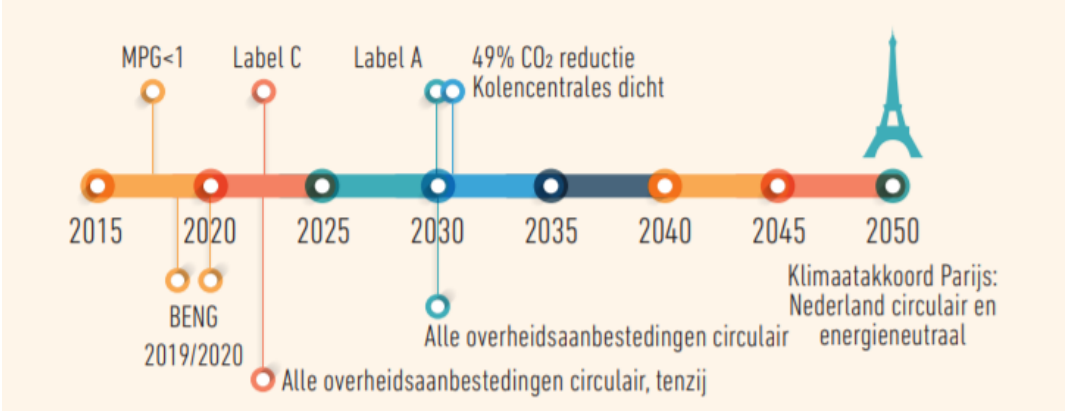


Figure 10: Timeline of sustainability law and regulations 2015-2050, (Twynstra Gudde, 2019).

2.2.5 CE development in PRE

As described in the previous section, real estate is necessary for the public sector in order to perform their public functions. Real estate management of public property can be challenging due to its user needs, differences in desired public requirements, and various real estate plans (Zavadskas et al., 2021).

In a research conducted by Vergara D'Alencon et. al (2019), 29 case studies of the construction sector were analysed. The cases had various circular strategies, circular ambitions, and different levels of circular implementations. Three of these cases were related to the public sector.

The first case is about the circular demolition of an old tax office in Winterswijk conducted by Gremmen (2018). This PRE was owned by the CGREA. The materials in the building were first identified by the CGREA (client). After the identification, a demolition company extracts the materials and components of the building. Afterwards, an internal company of the demolition company transports, stores and sells the "mined" resources. The whole process of this circular demolition can be seen in Figure 11. Yet, this is only the case for the high quality reusable materials and components of the building. It is not clear from the case study what happened to the not so high quality resources.

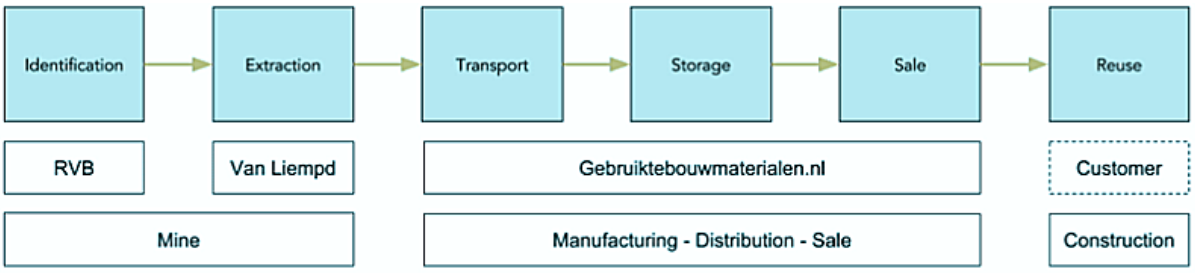


Figure 11: Circular Demolition (adapted from Gremmen, 2018).

In another case study conducted by Gemmen (2018), Erasmus MC campus was analysed. In this case study the campus was demolished and waste of the demolition was minimised by reusing extracted materials and components. Even though the main objective of the Erasmus MC is to offer health care, a future-proof hospital is still of vital importance for the user. Hence, the planned demolition was done in a circular way. This plan was initiated by the real estate team, which was approved by the board who wanted to contribute to society (Gremmen, 2018). The case study was conducted during the initiative phase, therefore the results of the case study were not shared.

According to Vergara D'Alencon et. al (2019), the analysed cases showed that not all the defined CE strategies were implemented. The circular activities, ambitions, and goals that are implemented in the construction industry can be identified. Yet, from the research it has become clear that there isn't adequate evidence, that all the actions taken to realise CE transition in the construction industry, are being correctly realised.

2.2.6 Key investment for the built environment

In a recent study done by the Ellen Macarthur Foundation (2020b), two CE opportunities are seen as attractive to invest in for existing buildings. Firstly, renovating and upgrading existing buildings with the CE strategies can lead to more comfortable, low-carbon, and adaptable buildings. In a study done by the BPIE (2020), it became clear that the public sector is aware of the need for renovating public properties. Yet, when looking at the current situation of public properties in the EU alone, half of the member states do not have sufficient strategies to improve their existing building stock. In comparison with new constructions and demolition, lower emissions, cost-effectiveness and less use of raw materials can be achieved for improving the existing buildings by using CE strategies in renovation projects (Ecorys, 2014). However, when making investments to renovate and upgrade existing buildings, CE strategies have to be in alignment in this process. Only this way the public sector can make sure that renovating and upgrading brings the desired environmental and economic benefits (Ellen Macarthur Foundation, 2020b). Secondly, reusing and creating recycling infrastructure of building materials can increase the availability of raw materials. From the Circular Economy section, it has become clear that the construction industry is the largest consumer of raw materials and resources globally. In addition to the use of the resources, waste also comes to play as the construction industry is the highest producer of waste (Kanters, 2018). It is estimated that the construction sector will generate 2.2 billion tonnes of waste by 2022 (OECD, 2018). Hence, reusing the materials could stop construction waste and keep materials in the CE. The Ellen Macarthur Foundation (2020b) claims that these two key investments can aid a more resilient future for the built environment.

2.2.7 Existing building

According to Pomponi & Moncaster (2016) 75%-90% of the existing building stock will still be standing by 2050. These existing buildings are 80% built prior to 1990, which all have a lifespan of an estimated 60 to 90 years. In addition, only 1% of the existing building stock is demountable. This means that it is a huge task in order to realise CE transition in the existing building stock, since many of the materials are difficult to be extracted as they are not built to be demountable (Kanters, 2018). Kyro (2020), states that the current focus on transitioning to the CE in the built environment is mostly on designing new construction and on materials. The latter, the focus on materials (micro-scale), is also supported by Pomponi & Moncaster (2017). The emphasis only on new constructions is in contradiction with the concept of CE as well as the waste hierarchy. The focus on existing buildings is often neglected. Therefore, focusing only on the new construction would not be enough to achieve circularity in buildings (Kyro, 2020).

2.2.8 CE Strategies in existing buildings

CE strategies are being implemented to existing real estate objects by different stakeholders. The focus of the strategic perspective is to add value to the institutional ambitions (Den Heijer, 2011, p.108). As De Jongh et al. (2009) states, there is not just one way for strategy design, there are various ways to achieve this. The same goes for the stakeholders that use the CE strategies to implement on their real estate to realise the CE ambitions for 2050. Kyro (2020) states that there is a need for structured approaches to the transition toward the CE in the built environment.

CE strategies can be taken from the R-Framework, which was discussed in section 2.1.4. However, the R-framework is not focussed only on the construction industry, specially not only on existing buildings, it is meant for use to the whole industrial economy (Ellen Macarthur Foundation, 2017). A recent review of the literature on the context of existing buildings, Kyro (2020) identified that Share, Preserve, Adapt, and Rethink approaches are relevant for existing buildings (see Figure 12).

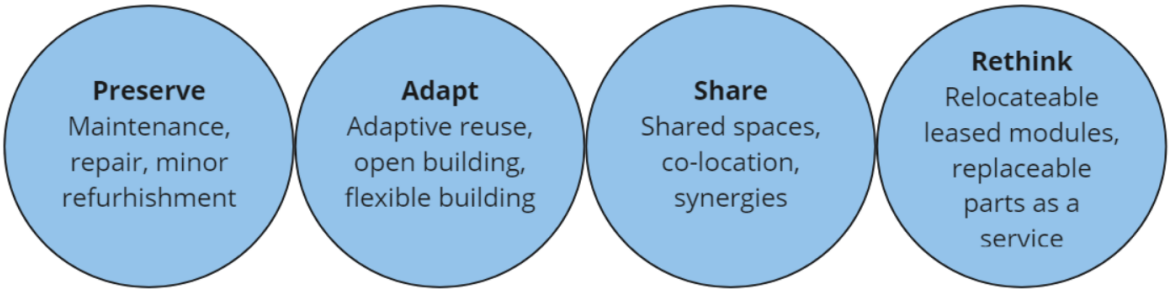


Figure 12: The four CE approaches in existing buildings (Own illustration, adapted from Kyro, 2020).

The Share approach refers to sharing assets such as spaces of a building. There is not just one owner, but multiple owners through a sharing economy. Meanwhile, adapt and preserve are two approaches to emphasize the significance of optimising the lifespan of existing buildings. The first approach is to preserve functionality and optimise use, through adaptive reuse of the existing building, while the second one is to preserve the building through ongoing maintenance. Finally, the rethink approach challenges the existing new production and ownership paradigm. These four approaches can be linked to the R-Framework. For instance, the preserve approach has the repair and refurbishment as CE strategies in it. These approaches give a good overview of which CE strategies from the R-Framework can be expected to be used in the existing buildings.

2.3 Conclusion

In the conclusion section, the key findings of the review of scientific literature are summarised and their significance is emphasized.

2.3.1 Summary

Circular Economy

Consumption of raw materials kept increasing, due to the growing population and increasing world prosperity (PBL, 2019; Rood & Hanemaaijer, 2017). This results in scarcity of finite materials and worsens environmental pollution (OECD, 2018). The current linear economy will only keep pressuring finite materials, environmental pollution, carbon emission, and waste generation (Geldermans, et al., 2016; Ellen MacArthur Foundation, 2013; Sariatli, 2017). Hence, CE is seen as a more resource-effective solution for material consumption and the way to achieve a sustainable economy (Ellen Macarthur Foundation, 2013; Stijn & Gruis, 2019).

Furthermore, the building industry is responsible for 40% of material consumption globally. Regarding the CE strategies, the focus on the construction industry is mostly on recycling (PBL, 2017). Notably, this can be seen as the least effective CE strategy as seen from the R framework (Ellen MacArthur Foundation, 2013; Anastasiades et al., 2020; Stijn & Gruis, 2019). Therefore, smarter production and consumption is needed and better CE strategies should be implemented (PBL, 2019; Potting et al., 2017).

The CE is a trending topic, a lot of literature is written on this topic. This makes the CE more nuanced than a decade ago. However, various definitions have emerged with different interpretations (Geldermans & Jacobson, 2015; Lieder & Rashid, 2016; Pomponi & Moncaster, 2016; Stijn & Gruis, 2019; van Bakel, 2020). In essence, the main goal of CE is to decouple economic growth from the consumption and production of finite materials to a closed-loop growth (Anastasiades et al., 2020; Ellen MacArthur Foundation, 2013; Ghisellini et al., 2016; Rood & Hanemaaijer, 2017).

Built Environment

Furthermore, the previous review of scientific literature studies suggest that the emphasis, regarding CE scales, is more on the macro and micro scales and less on the meso scale (individual buildings) (Anastasiades et al., 2020; Pomponi & Moncaster, 2016; Kyro, 2020). This makes the CE research on the meso scale of the built environment inadequate.

A circular building is a construction, which is in alignment with the CE (Pomponi & Moncaster, 2016; Transitieagenda Circulaire Bouweconomie, 2018). According to Charlotte Malabi Eberhardt et al. (2019), a circular building is all about making smart use of Brand's (1994) six layers of a building. This way CE strategies can be implemented to each layer, and realising the CE transition in building is made possible. Yet, in circular buildings when products and materials are implemented can be seen as fixtures, which are in ownership of the owner. This makes it difficult for the commodities to circulate in the CE (Ploeger et al., 2018). Even though there are some possible ways to overcome these challenges, circular buildings can lead to financial difficulties for the owners (Brink et al., 2017).

In the Netherlands, the public sector owns the largest real estate per square meter (Tjeerdsma & Veuger, 2015). The public sector's primary function is to provide public services and has to deal with many stakeholders. This leads to difficulties in managing and operating their PRE portfolio (Hakenberg, 2019; Van der Schaaf, 2002, Zavadskas et al., 2021). It is evident that real estate can add value to an organisation if it is managed correctly.

The urgency of shifting towards the CE also caught the European Commission's attention, and they made an action plan to achieve this. In response to the Paris climate agreement, the Netherlands also aims to become fully part of the CE by 2050 (Rijksoverheid, 2016; Ririassa 2019). The construction industry is one of the five industries where the Dutch Government takes special action (Rijksoverheid, 2016). Without an overview of the current activities, in the context of the construction industry regarding the CE, it is difficult to give effective direction to the CE transition (Behrens et al., 2017; Ririassa, 2019)

In a research conducted by Vergara D'Alencon et. al (2019), only three analysed case studies from the 29 cases were related to the PRE. In essence, it became clear that from this research circular activities, ambitions, and goals that are implemented in the construction industry can be identified. Yet, from the research it has become clear that there isn't adequate evidence, that all the actions taken to realise CE transition in the construction industry, are being correctly realised.

The Ellen Macarthur Foundation (2020b), states that renovating and upgrading existing buildings with the CE strategies and reusing and creating recycling infrastructures of building materials are key investments, which can lead towards a more resilient future for the built environment.

Estimated 75 to 90 percent of the existing building stock will be standing by 2050. Additionally, only 1% of the existing building stock is demountable (Kanter, 2018). The focus

on existing buildings is often neglected. Therefore, focusing only on the new construction would not be enough to achieve circularity in buildings (Kyro, 2020).

Furthermore, four main approaches are being used for CE transition in the existing buildings. These are Preserve, Adapt, Share, and Rethink. These approaches give a good overview of which CE strategies from the R-Framework can be expected to be used in the existing buildings (Kyro, 2020).

Literature Conclusion

All things considered it has become evident that the CE has become more nuanced as more research is being conducted around this trending subject. In the literature review, the importance of the transition to the CE became truly clear. The scarcity of finite materials and environmental pollution is a global issue and has to be dealt with. This transition is happening in the built environment as well, which is currently responsible for 40% of material consumption globally.

In the scientific literature there is a significant emphasis on the building components and urban areas regarding the CE transition, but less on individual buildings. In the literature this is called the meso scale, which is mainly focussed on buildings and construction as an individual object. Furthermore, most of the scientific literature is focused on new constructions. This makes it evident that more data needs to be gathered around the transition to the CE in the existing building industry. In addition, CE transition is also occurring in the PRE. Yet, from previous literature studies, focus on the PRE seems neglected as well, as most of the real estate cases are generally non-public.

In essence, there are CE developments happening in the PRE and barriers are known in the existing building stocks. However, insufficient research has been conducted on what the barriers could be for the existing PRE in regards to the CE transition. Barriers can hinder further CE development and the transition of the existing PRE to the CE. What these barriers exactly are, has yet to be mapped out for the existing PRE. Therefore, sufficient research is needed to fill this gap. Hence, this study will focus on what the current barriers are for the CE transition in the existing PRE.

For this study an assessment is needed to map out the current situation of the existing PRE regarding the transition to the CE. In the next chapter theory will be introduced, which can aid in conducting such an assessment. This assessment will give an overview of the current barriers of CE transition in the existing PRE.

3. Theoretical Background

In this chapter, the theoretical background for the thesis will be described. The theory in the theoretical background will be used in order to help answer the research questions, which were formulated from the review of scientific literature. In addition, the current barriers of the CE transition in the existing PRE will be mapped out with the aid of the theoretical framework.

3.1 Public Real Estate Management

Van Montfort et al. (2017) states that PREM is the whole of activities that are aimed at realising financial and social ambitions with the use of real estate. PREM can also be defined as management of a government's real estate portfolio by aligning the portfolio and services to user satisfaction, financial policies and political ambitions that the government wants to achieve (Van der Schaaf, 2002). Hence, Hakenberg (2019), defines PREM as management to obtain the maximum added value for the Public sector in terms of user satisfaction, financial policies and political goals.

Van der Schaaf (2002), states that CREM is closely related to PREM. The CREM can be formulated as real estate management, which is necessary for an organization to conduct its business (Arkestijn, 2019). The real estate in CREM supports the business function (CoreNet Global, 2015). The four perspectives of C/PREM are adapted into four different domains. In Figure 13 the four domains are shown, which are: general management, asset management, project management and facility management. De Jonge et al. (2009) states that these domains share the goal of adding value to an organisation and indirectly create revenue.

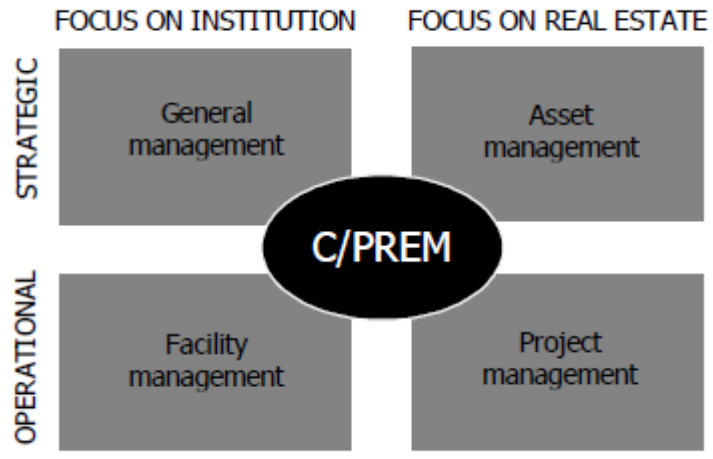


Figure 13: The four domains of C/PREM (De Jonge et al., 2009)

According to Becker et al. (1993) there are five stages where CREM's changing role is displayed. The first stage is the taskmaster, in this stage REM is used in order to supply the technical needs of a corporation (e.g. physical space). Secondly the controller, in this stage the focus is mainly on cost minimisation and transparency of real estate. It has a more

analytical approach on CREM. The third stage is the dealmaker, where the CRE is used to solve real estate related issues, which leads to financial value for the corporation. Fourthly the intrapreneurs, which is a stage where CREM is used in matching the CRE with the corporation's business plan. The last stage is the business strategist, in this stage the CRE is used to anticipate business trends. The focus here is mainly of the corporation's goals rather than on its real estate. In short, the five stages of Becker et al. (1993) shows that the taskmaster sees CRE as a technical problem that can be solved. And a strategist, in the final stage, sees CRE as a strategic business asset that can be added to the business process of a corporation. In CREM, placing an organisation on the five stages of Corporate Real Estate Development (see Figure 14) can give an indication on which stage it operates (Becker et al., 1993). Knowing in which stage an organization, such as the Public sector, operates can give an indication on how it manages its current real estate portfolio (Hakenberg, 2019).

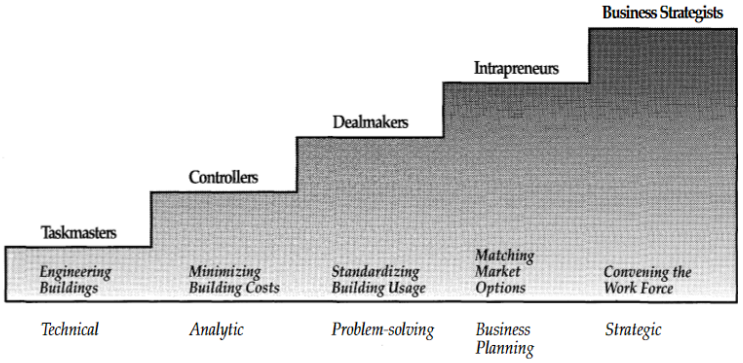


Figure 14: Five stages of Corporate Real Estate Development (Becker et al., 1993, p. 27)

According to De Jonge et al. (2009) similarities can be drawn with the perspectives on real estate observation. They concluded that the four methods of approach regarding REM don't differ much with the five stages of CRE-development as shown in Table 1. One clear difference is that De Jonge et al. (2009) have integrated the "entrepreneur" stage within the first three stages.

Development Stages	**Stakeholders**	**Adding Value**
Task Manager	Technical Manager	Productivity
Controller	Controller	Profitability
Dealmaker	User	Profitability & productivity
Business Strategist	Policymaker	Distinctiveness

Table 1: Combination of the stages with the stakeholders (adapted from De Jonge et al., 2009).

The four stakeholders each add value on the different development stages of CREM. Each of them are important in the decision making process of real estate. Hence, Den Heijer (2011) has integrated the four stakeholders with the four domains of CREM (see Figure 15). Each stakeholder is now part of a CREM domain. The policy makers have the responsibility to make strategies that are important for an organization. The controllers are focussed on the

financial side of an organisation's real estate. The technical managers are focussed on the physical aspects of an organisation's real estate. For the users the functionality of the organisation is important.

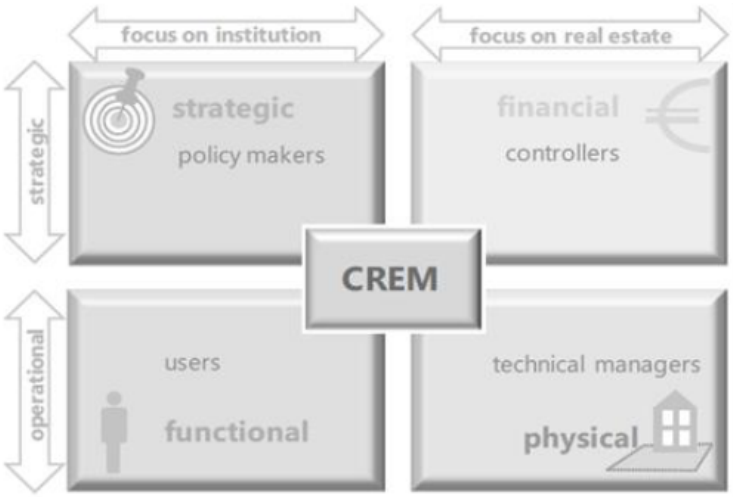


Figure 15: The four stakeholders integrated with the four domains.

3.2 The DAS Framework

De Jonge et al., (2009) have developed the DAS Framework for CREM (see Figure 16). The name stands for Designing an Accommodation Strategy Framework. This framework is used as a tool for creating a strategy to match the current supply and demand with the future demand and supply. It gives an organisation the essential knowledge to design an accommodation strategy. The DAS Framework has four main tasks to manage real estate. The first task is assessing what the current situation is, finding the mismatch between the current demand and current supply. Afterwards, the mismatch between the future demand and current supply is determined. Next to that, an analysis is made for weighing and selecting alternatives for the mismatches. In this step, evaluation, designing and solutions are created between future demand and future supply. And as last, a step by step plan is determined to re-design the current supply into the favourable future supply.

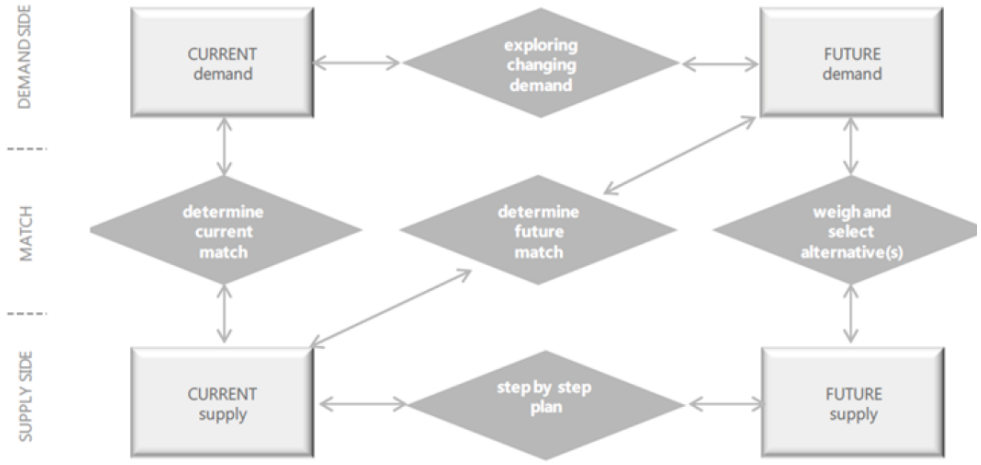


Figure 16: The DAS Framework (de jonge et al., 2009)

The DAS Framework is a broadly applicable framework and it can give organisations a good overview of the current situation of their real estate portfolio. The DAS Framework can be used in designing a first real estate strategy for an organisation. Nevertheless, Arkestijn (2019) argues that In the DAS Framework most attention goes to the analysis of what needs to be taken into account rather than the synthesis i.e. how different stakeholders' interests are actually integrated.

Den Heijer (2011) has extended the DAS Framework in her dissertation; the framework is now further developed as shown in Figure 17. Changes include: defining tasks instead of steering events, exploring changing demand, focus on the university campus and the CREM perspectives. All together, the ways on how CRE can add value to the organization are included in the DAS framework (Arkestijn, 2019; Den Heijer, 2011). In essence, the framework is a good commencement for developing a real estate strategy. It also gives a good overview of the current situation and future developments for an organization. On the other hand, it is difficult to determine what the future demand will be. Hence, anticipating will be a difficult task for a real estate manager. An example could be given by looking at the covid-19 pandemic from 2020. During this time many people worked from home and did not use all the spaces of their company. This led to a mismatch between the demand and supply side since fewer square meters were needed than prior.

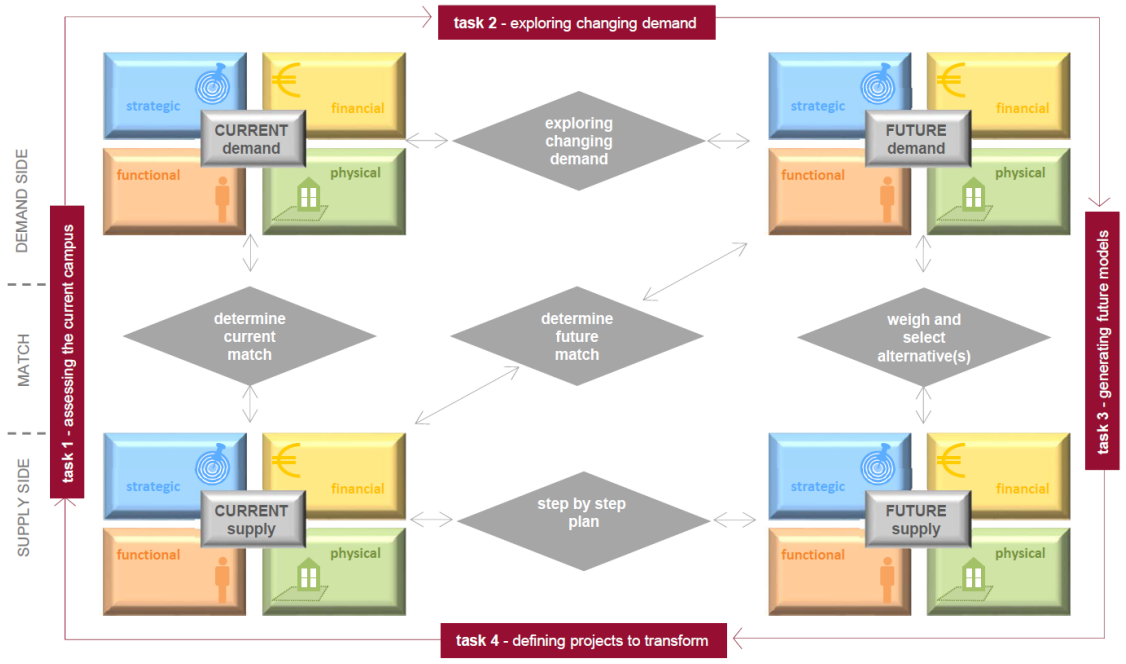


Figure 17: The four different stakeholders and their ways to add value integrated in the DAS framework (Den Heijer, 2011, p.115)

3.3 Theory Conclusion

Since the research is around the field of PRE and the management of the PRE, the DAS framework will be used. The DAS framework came forth from the PREM/CREM theory. There are different CREM stages that an organization can be placed on (Becker et al., 1993). In essence, the five stages of CREM shows that the taskmaster sees CRE as a technical problem that can be solved. And a strategist, in the final stage, sees CRE as a strategic business asset that can be added to the business process of a corporation. In addition, De

Jonge et al. (2009) integrated the four stakeholders of CREM (technical manager, controller, user, and policymaker) into the five stages.

De Jonge et al., (2009) have developed the DAS Framework for CREM. This framework is used as a tool for creating a strategy to match the current supply and demand with future demand and supply. In addition, Den Heijer (2011) further developed the DAS framework by integrating the four stakeholders with their respective four domains of CREM and used it on PRE. The DAS Framework is a broadly applicable framework and it can give organisations a good overview of the current situation of their real estate portfolio.

3.4 Theoretical Framework

Since the CE in the built environment is a trending subject, in which the focus mostly isn't on the existing PRE, finding one single framework that could be used as a tool was difficult. Hence, for this research, one unique theoretical framework is created as shown visually in Figure 18. The framework is composed of the key concepts that came from the scientific literature review and PREM theory.

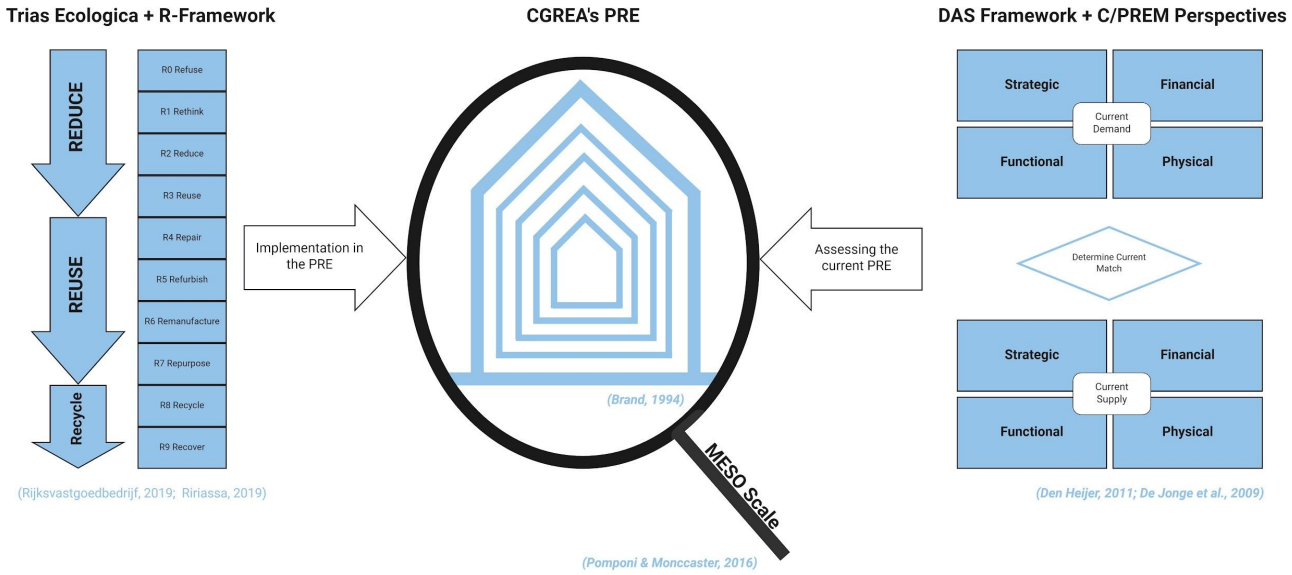


Figure 18: The theoretical framework (Source: Author).

In order to conduct the research and answer the research questions this theoretical framework will be used. The theoretical framework will define the key concepts of this research and will propose the relation between them. Subsequently, it will give this research direction into explaining, generalising, and interpreting the findings.

From the scientific literature review, it has become clear that the CE strategies are being implemented in buildings. To achieve CE transition of these buildings, CE strategies are implemented in different layers of a building. Hence, brands (1994) six layers of a building will be used to find out in which CE strategy is being implemented in which layer of an existing PRE. Thus, the existing PRE will not be researched as a whole, but in every six layers

of one PRE. Furthermore, to make an assessment possible of what the current barriers are in transitioning CE in the existing PRE, PREM theory is used. From this theory, the DAS framework together with the PREM perspectives came forth. The DAS framework will be used in order to make an assessment and map out the current barriers in existing PRE. The focus on the DAS framework will be mainly on the first task, which is assessing the current situation.

With the help of the theoretical framework and the theory that is integrated into it, answers to the research questions will be researched. In the next chapter 4 Methodology, information is given on how to collect field data and answer the research questions.

4. METHODOLOGY

This chapter will elaborate on the methodology that has been applied to the research. The research aims to find out where the Dutch government's existing real estate portfolio is standing regarding the transition to the CE.

4.1 Research Design

A clear overview of what is already there in both academics and in the field of research is needed to answer the research questions. Qualitative research will enable the study to gather in-depth insights on the subjects around CE, PREM, and CGREA. Therefore, this research will have a qualitative approach. Since these subjects are trending, new ideas and irrelevant aspects can be found along with the study. Qualitative research helps in including and excluding aspects that in later phases can not be considered to be relevant (Kumar, 2014).

In this study, both theoretical and empirical research is conducted. The results will be compared and verified in the synthesis section of this study. From theoretical research, insights and information are gained on the subjects of CE in the built environment. Furthermore, research questions have been formulated that still need to be answered in this study. Hence, empirical research is then conducted in order to find answers. However, to know what to expect from the empirical data, scientific and field knowledge are sought through the literature review first. Afterwards, case studies and interviews will be conducted to gain empirical data. As of last the findings will then be analysed and verified in order to conclude this study. The whole research design can be seen in Figure 19. In the next section, a more detailed explanation will be given for the chosen research methods.

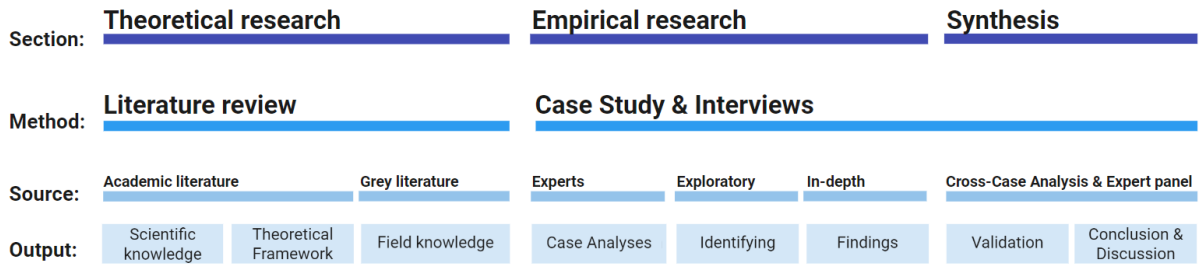


Figure 19: The research design (Own illustration).

4.1 Literature Review

The objective of the literature review is to gain information on the main subjects of this study. These subjects are CE, PREM, and CGREA. The literature review is divided into two, academic and grey literature. Along with the academic literature, previous studies are reviewed. This review of previous studies will give insights and knowledge of the mentioned subjects. Additionally, this review will be used in writing the theoretical framework. In addition, the grey literature is conducted to get familiar with the field that the study is placed

in. The field in this case is the CGREA's perspective on the CE transition of their existing PRE. The findings of the literature review will be set as a basis for empirical research.

4.3 Empirical Research

In the Empirical research, expert meetings, case studies, exploratory interviews, and in-depth interviews will be conducted to collect data. Through the use of these methods, insights and information from the field are gained, which are hardly touched by academic literature. The aim of this research is to find reliable field data that can be used to answer the research questions.

4.3.2 Case Selection

The criteria for selecting the cases can be seen in Table 2. The case studies will contain a detailed and profound analysis of the selected PRE of the CGREA.

Selection Criteria Case Studies	
Similarities	**Differences**
Owned by CGREA	The building is in a renovation and/or maintenance phase
Existing building stock	Different CE strategies are being implemented
CE strategies are being implemented to the building stock	Ongoing or Finished
It's a recent project (max. 3 y. old)	
Implementation of CE strategies can be succeeded, failed, or are on hold	
The PRE have offices as function	

Table 2: Selection criteria case studies

In this study, the focus is on CGREA since they are a public party who are implementing their CE strategies to their PRE portfolio. Therefore, both cases should be owned by CGREA. Another similarity that the cases should have is that they are both existing building stock. From the literature, it has become evident that more challenges arise from the transitioning of the existing building stock to the CE. There should also be existing plans to make the chosen cases part of the CE. In addition, the cases should be projects that are still being worked on. To make this study more relevant when mapping out the current situation. The chosen cases can be projects that are either succeeded, failed or are paused.

The differences between the cases are that they can be either in renovation or maintenance project phases. As mentioned in the Theoretical framework chapter, from the literature it has become evident that CGREA is implementing their CE strategies at these "natural stages" of their PRE. When the research is being conducted for the CGREA's PRE, it is already known

that these CE strategies are being implemented in different phases of the PRE. From the literature, it has become clear that these are: new built, rent, maintenance, renovation, and demolition PRE. In the criteria for the case studies, it should be mentioned that the focus should be on maintenance or a renovation PRE of the CGREA. There are several reasons to focus on these two phases of the project. For a new building, this would not be interesting to research, since it became evident from the literature that newly built buildings are already being built to be future proof (Rijksoverheid, 2019). Furthermore, rented buildings are not in the ownership of the CGREA. Even so, it is stated that CGREA will negotiate with the owners of the rented properties to realize the CE ambitions. However, this is another field that the focus of this research will not look into. As of last, properties that are in the phase of being demolished or even sold are also not interesting for this research, as demolished properties' materials are planned to be recycled, and sold properties will have new owners. It can be stated that demolished properties can still be owned by CGREA. However, even then a new building will be placed, which as mentioned earlier, will be future proof.

This research will assess the current situation of CGREA's PRE, which also exists in the near future. Hence, the focus of this research will be on the properties that are in the maintenance and or renovation phases. In addition, since there are different CE strategies, different implementations of these strategies can be expected to be used for different cases. In Appendix D the selected four cases can be found.

4.3.1 Case Study

The objective of the case study is to gain more data on the current situation of the existing PRE. Subsequently, with the knowledge gained from the case studies research questions could be answered. For this study, the three selected cases will be researched. Firstly, data on the background information of the specific PRE project has been collected. Secondly, the theoretical framework has set the structure in the needed data for the cases. The theoretical framework has shown that with the DAS framework the PRE can be assessed. This assessment will be done focussing on the first task of the DAS framework, which is focussing on the current supply and demand. In other words, what do we have and what is needed regarding the CE transition in PRE. The DAS framework is being used as the four PREM stakeholders perspectives (Strategic, Financial, Functional, and Physical). Thirdly, data on CE strategy implementation on the six layers of Brand’s model has been collected. Furthermore, during the case studies interviews will be conducted to get more detailed data from the chosen cases.

4.3.2 Explorative Expert Meeting

Experts from CGREA are being interviewed in order to gain data about which projects are currently being developed to make the transition towards the CE possible (Table 3).

Code	Function	Experience at CGREA	Date
Expert 1	sustainability advisor & expert in circular, nature inclusive and climate-adaptive	2 years	03/03/21
Expert 2	Real Estate advisor & Architect	2 years	15/03/21

Table 3: Conducted expert meetings (2021)

4.3.2 Exploratory interview

As seen in both Figures 17 and 18 exploratory interviews (see Appendix A) will be conducted prior to the in-depth interview. This is done in order to identify who the right stakeholders are to conduct an in-depth interview. For the PREM perspectives, interviewees will be sought. For example, a stakeholder will be chosen that can give data about the strategic aspects of the chosen case. More information on this is in the section In-Depth Interview.

For each case an exploratory interview will be conducted, resulting in a total of four exploratory interviews. The interviewees for the exploratory interview will be chosen based on the cases. The main criteria are that the interviewees must have knowledge of the CE developments of the CGREA's PRE. In addition, the interviewee must also have knowledge on who the decision-makers are, regarding the four PREM perspectives, in realising the CE strategies to CGREA's PRE. The interviewees' knowledge of the cases is important since it will be used as input for the in-depth interview. In Table 4 the conducted exploratory interviews are shown.

	Code	Function	Experience at CGREA	Date
Case 1	SustainabilityConsultant_1A	Sustainability consultant & Technical Manager	6 years	16/03/21
Case 2	Projectleader_2A	Projectleader	5 years	23/03/21
Case 3	SustainabilityAdvisor_3A	Sustainability advisor & Technical Manager	3 years	22/03/21
Case 4	SustainabilityCoordinator_4A	Sustainability coordinator	4 years	18/03/21

Table 4: Conducted exploratory interviews (2021).

4.3.4 In-Depth Interview

An in-depth interview will be used in order to do further research on the chosen cases. The interview will be more conversation-like rather than a question-answer interview. The purpose of an interview according to Moerman (2016) is to obtain as much and specific useful information. To ensure that this is obtained, an interview protocol is developed (see Appendix B). This protocol is based on deductive codes that will be formulated from the insights of conducted case studies and literature reviews. The interview protocol will begin with a short introduction and ask for background information on the case. This creates rapport and builds a relationship that ensures good qualitative research (Moerman, 2016).

The selection of the interviewees for the in-depth interview depends highly on the outcome of the exploratory interviews. For each case, the minimum number of interviews are two (see Table 5). The interviewees must have the following requirements to conduct this interview:
- Have worked on the case and have good insights into the critical stages of the project.
- Knows the CE strategies that are being applied to the case.
- And has to say something on either two of the four PREM perspectives.

	Interviewee	**Function**	**Experience**	**Date**
Case 1	TechnicalManager_ 1B	Technical Manager	15 years (CGREA)	12/04/21
Case 2	Architect_2B	Architect	23 years (Superuse)	14/04/21
	Projectleader_2C	Projectleader	4 years (CGREA)	19/04/21
Case 3	HTAD_3B	Head of the Technical advice department	20 years (CGREA)	06/04/21
Case 4	TechnicalManager_ 4B	Technical Manager	3 years (CGREA)	09/04/21

Table 5: Conducted In depth interviews (2021).

4.4 Synthesis

In the synthesis research section of this study, the collected data will be combined and compared to find relations. The cross-case analysis will combine the four cases, from the empirical research. This will be done with the subjects of the theoretical framework. Afterwards, the findings of the cases will be compared with the findings of the literature. The results of this study come from assessing the CGREA's existing PRE current situation regarding the transition to the CE.

4.4.1 Internship

In addition to the case studies and the interviews, additional data from the practice will be obtained by following an internship at the CGREA. The internship will assure that this study can get information from the practice that normally can not be found in the literature due to confidential information. Since most of the literature is confidential for CGREA only.

Furthermore, the internship will also aid in making the right connections with stakeholders that can be used for the interviews.

4.4.2 Dataplan

At the end of the research, the collected data will be integrated into the MSc thesis. In the Appendix, the formats of the Interview protocols and interview results will be found. However, sensitive and confidential data (i.e. names of interviewees, their responses, opinions, etc.) will not be shared with third parties and will be blurred out. In addition, before the data is even collected, concessions will be asked from the participants of the interviews by sending a letter of consent (Appendix C). This is done to ensure that the data that is collected and analysed also can be published.

After each interview data will be collected offline. For the exploratory interviews, notes of the conducted interview will be sent to the interviewee to get feedback. This is done to ensure that the collected data is correct and exclude corrupted data. For the In-depth interviews, transcriptions will be made to analyse them. Transcriptions will be sent to the interviewees as well.

All the results and collected data will be sent to the interviewees for confirmation. This is done to assure that the data is correctly written down to the report. Moreover, this aids in minimising misunderstanding and reporting false data. Prior to the discussion and conclusion of the study, an expert panel will be held. The results will be discussed with the experts, to open discussion and validate the results. In addition, the knowledge gained from the expert panel will be used to improve the results.

All saved data (i.e. interview recordings, transcriptions) will be stored locally. The data will be purely used for academic purposes and when not needed it will be discarded. After P5, the study will be published, without confidential data, to the education repository of TU Delft

5. The CGREA

As stated in the introduction of this thesis, the focus of the research will be on the PRE of the CGREA. As a governmental organisation, CGREA's existing PRE is also being developed towards the CE. In this chapter, more information about the CGREA will be given.

5.1 Portfolio of CGREA

The Government of the Netherlands has their own real estate agency, the Central Government Real Estate Agency (CGREA). The CGREA is responsible for managing and maintaining the largest and most diverse real estate portfolio in the Netherlands. The CGEA owns 12 million (m2) of real estate of the 85,5 million (m2) national PRE. The CGREA's real estate portfolio includes prisons, defence sites, tax offices, court buildings, museums, ministerial offices, airports, historical monuments, military barracks and palaces (Rijksvastgoedbedrijf, 2017). The expert staff of the CGREA have several tasks, these are: (1) developing and redeveloping properties, (2) transformation and renovating, (3) constructing, (4) purchasing and selling, (5) managing and maintaining and (6) developing strategies and policies for their real estate portfolio (Rijksvastgoedbedrijf, 2017).

The CGREA's portfolio can be divided into two: (1) offices and (2) specialties. Currently there are 2.4 million m2 GFA of CGREA offices (225 buildings), 49% of which are rented and 9% are regarded as monumental buildings. It is estimated that 56% of these buildings were built prior to the 90's. In recent years many renovations took place and currently 20% of the buildings have an energy label A. The rented properties are not in the ownership of the CGREA. Therefore, they are not directly responsible for the management of these portfolios. However, it should be noted that these properties also have to realise the CE goals and legal requirements by 2050 (Rijksvastgoedbedrijf, 2019).

The CGREA has their own PRE measures for making their portfolio sustainable and circular as shown in Table 6.

Phases of PRE		**Sustainability measurers**	**CE measures**
Owned:	Maintenance	- Limit nuisance - Optimising it till renovation - Limited to non (freeze period) till next maintenance.	- Components are reused, applied as reuse or are saved for future reuse - Measures are demountable - Applied materials have low environmental impact and can be reused
	Renovation	- Scanning for energy label - High nuisance - Minimal Energy label A+ - Challenge the market for more	- Same as New Building, with focus is on high-quality material reuse

	Monument	- Same as renovation, however, custom approach is applicable	x
	New Build	- Scanning for energy label - Minimal BENG - Challenge the market for more	- Designed for next user - A building that is adaptable, that can be well maintained and managed.
Rent		- In accordance with minimum legislation - Striving for 2050 ambition	- Asking the owner to reduce material usage to reduce environmental impact
Rent (till 2023)		- No measures/strategy - Only if necessary by legislation	x
Sale/demolition		- No measures/strategy - Only if necessary by legislation	- components with value will be reused - in the tender process, reuse and low environmental impact is demanded

Table 6: Sustainability and CE measurements of the CGREA (own table adapted from Rijksvastgoedbedrijf, 2019; Ririassa, 2019).

2.3.2 Goals and Vision

The CGREA anticipates to the "Netherlands 100% circular by 2050" goal and wants to manage and procure their real estate portfolio in a circular manner. Regarding the CE goals of the CGREA, Table 7 gives a clear overview of what is planned in the upcoming years.

Year	**Goal**
2020	- Material passports statement - 25% CO2 reduction
2023	- Everyone of the CGREA is aware and knows about the CE - Knowing exactly how to upscale CE into the PRE
2030	- Managing and procuring CGREA offices circularly - 50% reduction of finite resources
2040	- 50% CO2 reduction
2050	- CGREA's PRE is 100% part of the CE - 100% sustainable energy supply - 100% CO2 Neutral

Table 7: Overview CGREA's CE Goals (own table adapted from Albers, 2019; Ririassa 2019).

The CGREA has formulated their own vision on the meaning of "building circularly". It was found necessary as there are various other definitions of CE and building circularly. This vision entails that building in the CE is using and reusing buildings, areas and infrastructure without unnecessarily depleting natural resources. This is done without depleting natural resources, polluting the environment and the ecosystem. To a certain extent that is economically and ecologically justified and contributes to human and animal welfare, for now and in the future (Ririassa, 2019; Transitieagenda Circulaire Bouweconomie, 2018). In addition, the Trias Ecologica is also part of CGREA's vision in building and managing their PRE. Trias Ecologica is based on three main aspects, which are: (1) limiting the use of materials, (2) using infinite and sustainable resources/materials, (3) usage of finitive materials in an efficient manner only when necessary (Ririassa, 2019).

The circular principles, from the nine R's framework, Brand's six layers, and Trias Ecologica, are implemented in the PRE. The CGREA does not implement the circular principles directly to each of their real estate portfolios. Therefore, Brand's (1994) six layers of a building are used in order to do this. Here the circular principles are implemented in the six layers of a PRE. This is mainly done in the different phases that the PRE is located in: new construction, rent, maintenance, renovation, and demolition.

2.3.3 The BLOEI instrument

For the CGREA, REM means mostly demolishing, maintaining, buying- and selling, renovating and building new buildings of real estate (Circulaire Bouweconomie, 2020; Rijksvastgoedbedrijf, 2019). These are also categorized as the current phases that the PRE is located in. Due to its unique and various real estate portfolio developing one single circular strategy would not suffice. Hence, CGREA has developed the BLOEI instrument, which aims to aid in deciding which set of circular principles best suits a project to be implemented. This instrument has arised from twenty different circular principles, including Brand's building layers, the R-Framework and the Trias Ecologica. BLOEI is an acronym where each letter stands for a theme: beheren of oogsten (management or harvesting), laagste grondstoffen-en milieu-impact (low environmental impact), Ontwerpstrategie (design strategy), economische & samenwerking modellen (economic & corporation models) and informatie vastleggen (capturing information) (Circulaire Bouweconomie, 2020).

Currently, CGREA is implementing and testing the BLOEI instrument on 14 different projects. From the interview with Expert 2 it became clear that most of these cases are new construction projects (Expert2, Interview, March 15, 2021). To be precise, BLOEI is used in existing buildings as well. Yet, in these projects usage of the BLOEI instrument is only meant for building parts and therefore not used on the whole existing building. Main reason for this is because only the parts of the building are renovated in which the BLOEI instrument could be applicable to.

2.3.4 The Seven Action Plan

The transition from a linear economy towards a CE is also for the CGREA a complex task. That is why an adaptable approach is needed. An adaptable approach offers the possibility to tackle this complex task with an open mind (Ririassa, 2020, p. 10). This approach is translated into the slogan: “learning by doing”.

In addition, the CGREA has developed a seven action plan to achieve their ambitions towards the CE.

1. carry out learning projects
2. Implement Learning Lessons
3. Circular management program
4. Passports, marketplace and knowledge development
5. Circular purchasing
6. Circular RVB professional
7. KPI’s

6.3.4 Conclusion

The CGREA manages the real estate portfolio of the Dutch Government. It has the largest and most diverse portfolio in the Netherlands with 12 million square meters of GFA. For the CGREA, REM means mostly demolishing, maintaining, buying- and selling, renovating, and building new buildings of real estate (Circulaire Bouweconomie, 2020; Rijksvastgoedbedrijf, 2019). These are also categorized as the current phases that their PRE is located in. Different sustainability and CE measurements are already set up for their PRE portfolio (see Table 2). The CGREA anticipates to the, Dutch Government’s ambition regarding becoming fully part of the CE by 2050. Hence, they want to manage and procure their real estate portfolio in a manner that is aligned with the CE by 2030. The CE strategies, from the R framework, Brand’s six layers, and Trias Ecologica, are used tools and instruments in their PRE.

The CGREA does not implement the circular principles directly to each of their real estate portfolios. Therefore, Brand's (1994) six layers of a building are used in order to do this. Here the circular principles are implemented in one of the six layers of their PRE. This is mainly done in the different phases that the PRE is located in; this can be new build, rent, maintenance, renovation, and demolition. From the CE principles, the CGREA has developed the BLOEI instrument, which is currently being tested on 14 different projects.

In essence, The transition from a linear economy towards a CE is also for the CGREA a complex task. That is why an adaptable approach is needed. An adaptable approach offers the possibility to tackle this complex task with an open mind (Ririassa, 2020, p. 10). This approach is translated into the slogan: “learning by doing”. The CGREA wants to become an example for society by transforming its real estate portfolio into the CE.

6. Case Studies

This chapter entails the three conducted case studies. First, is the Temporary Accommodation case, then the Warehouse Transformation case and lastly the Building Complex Case.

6.1 Case 1: Temporary Accommodation

The project for case 1 started with the need to renovate the previous building of the users of case 1. The users of this building had to be moved somewhere else during this renovation period. This renovation period is estimated to be 5 years. Hence, the users had to be temporarily accommodated elsewhere for 5 years. This is where case 1 takes place, in which the existing PRE will be used to accommodate the users. The existing PRE of case 1 needs to be renovated as well to fit the demands of the users. The CE strategies are implemented and the building is almost ready for usage.

CASE 1	Old	New
Function	Offices	Offices
Year		2017- 2021
m2	94.000 GFA	68.500 GFA
Development Budget	-	161.000.000,- ex. VAT
Users	Civil servants	Civil servants + New users

6.1.1 Strategic Perspective

Organisation's culture

According to the technical manager of Case 1, there is an ambience in the organisation, meaning that CE is gaining momentum in the organisation's culture.

"CE is high on the organisation's agenda and you can notice that attention is given through, for example, workshops during advice days. And the demand for CE development can also be seen in projects." - Technical manager_1B, Interview, April 12, 2021.

This became evident since CGREA gives a lot of attention to the CE transition through various activities, such as organising advice days, workshops, and new tools that are created regarding the CE. With the latter, the BLOEI-tool is meant, which is mostly used to implement CE strategies to the new building stock.

"Sustainability advisors take their role seriously and bring the CE ideas to the projects. The culture of CE is not only known for the sustainability advisors but also for other colleagues at CGREA." - Sustainability consultant, Interview, March 16, 2021.

Technical managers are even familiar with the trias ecologica terminology. In essence, CE is getting attention in the organisation, which is even known to colleagues who do not necessarily work with sustainability themes such as CE.

"Even though I, as a technical manager, am aware of the CE ambition and know the trias ecologica, this shows how deep-rooted it is in the organisation." - Technical manager_1B, Interview, April 12, 2021.

Project phases

In the initiation phase of case 1, the question arises, where to accommodate the users, where to find the quality in square meters, and the facilities that are currently available for usage. The Head Portfolio Strategy allocates users to a new suitable building. According to the technical manager:

"The building of case 1 looked in terms of surface area and location as an excellent option for accommodation." - Technical manager, Interview, April 12, 2021.

Furthermore, the sustainability consultant stated:

"The building of case 1 was previously a large office building and it fits the needs of the users. For this reason, it was a practical decision to accommodate the users of this building." Sustainability consultant, Interview, March 16, 2021.

The sustainability consultant together with the building physicist assesses the current situation of the building. Then make a plan of requirements that are best suited to tender out to find a market party to make a design. During this assessment, it became evident that the climate installations, electrotechnical installations, security, and fire security were still being able to be used.

"There were a lot of existing commodities that could be reused, which was seen as an opportunity to implement CE strategies." - Sustainability consultant, Interview, March 16, 2021.

In the definition phase, external parties were hired to assess the quality of the existing commodities. From these assessments, a spatial plan of requirements has been made for case 1, in which the users' demand was integrated. Additionally, a technical plan of requirements was made. In the latter, the climate technical, electrotechnical, security, architectural, and transport technical requirements were integrated into the plan of requirements.

Opportunity sessions

The main objective of case 1, was to accommodate the users quickly in a new building. With the advice from the sustainability consultant, CE opportunities, in which CE strategies could be implemented in case 1, were discussed with the design team of case 1.

"I have organised a sustainability session, an opportunity session, and we had discussed what we could do to develop it with CE ambition in mind." - Sustainability consultant, Interview, March 16, 2021.

The results from this meeting were used to implement CE strategies to the existing building of case 1. From the session, four methods to implement CE strategies came forth (see Figure 19).

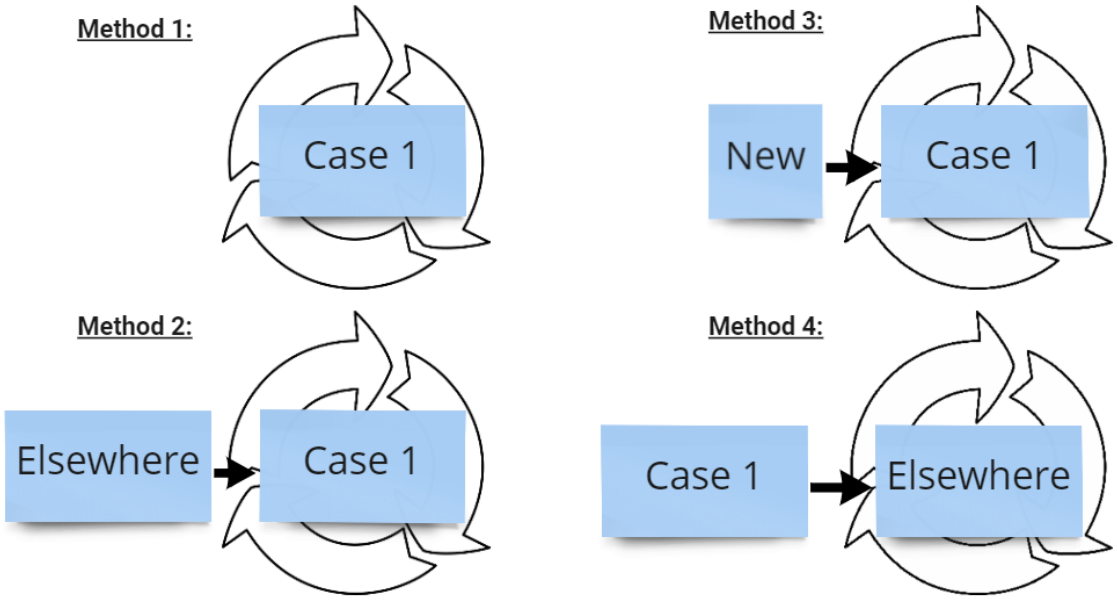


Figure 19: Methods used to implement CE strategies (Own illustration, based on sustainability consultant).

The first method was to reuse the existing materials in case 1. Second, reusable materials are searched and selected from other projects. Third, new circular materials are added. These are materials that are in alignment with the CE ambition, i.e. biodegradable and demountable. Fourth , reusable materials from case 1 are reused elsewhere. In the next sections, the exact CE strategies that were implemented in the building layers are described. A detailed version of the conducted methods can be found in Appendix E.

6.1.2 Financial Perspective

There was no separate budget made to realise the CE transition for case 1. Since the CE ambitions came from a bottom-up approach, the budget was already divided into other parts of the project. From the opportunity session, ideas were discussed to implement CE strategies in case 1. However, most of these ideas that were not realised, was due to the fact that there were no reusable materials available. Additionally, time and cost outweighed the search, assessing the quality and refurbishing of the reusable materials. An example of a CE strategy that was thought of but not realised was the six existing kitchens in the previous building.

"In the previous building, six existing kitchens were available for reuse. The same types of kitchens were desired for case 1. The idea was to reuse the kitchens from a demolished project to case 1. However, this was not realised. Due to the sensitivity, confidentiality and due to delays of demolition projects. So you could not reuse elements as fast as you want for another project for this reason." - Sustainability consultant, Interview, March 16, 2021.

6.1.3 Physical Perspective

Services

In the existing situation of case 1, climate installations and electrotonic facilities were mostly in a good state. These services were being reused in the offices of case 1. New installations were also needed in order to comply with building regulations. Therefore, existing installations together with the new installations are being used in case 1. Yet, connecting the existing with the new installations was not an easy task. Difficulties arose when the contractor would not take the responsibility to maintain the existing installations in the building. The contractor is only willing to maintain the new systems that are being integrated into the building. Hence, the CGREA took the responsibility for maintaining the existing systems.

Together with the management and maintenance board of the CGREA, the decision was made to reuse most of the existing installations and architectural facilities in the building. However, there were several challenges to this choice in case 1. Reusing the existing services means that the older they get the more they will become susceptible to disruptions. Moreover, there is no guarantee that services and maintenance will be provided in the future. Meaning that together with the scarcity of materials, the availability of these services will not be self-evident. Therefore, additional maintenance plans had to be made to deal with services that are old and are able to break in the future. The CGREA solved this issue by overhauling and stocking commodities that were needed for the services to function in the future. For example, this was done with the motors of the sunblinds in the building. The sunblinds were a specific system, which was 30 years old. In case 1 not everywhere in the building sunblinds were needed for the users. Therefore, in spaces where there was no need for the sunblinds, it was overhauled and stocked. If something breaks or needs to be repaired, stocked materials can be used to repair it. The real estate advisor stated that the CGREA does not have special warehouses to restore materials that can be used as a CE strategy in other projects (Expert 2, Interview, March 15, 2021).

Hence, the materials in case 1 that were needed for services are stored locally in the building. This was done by either leaving the material in place or storing it locally in a stockroom. Nonetheless, this can still be seen as a temporary solution. Eventually, the stocked commodities will still run out. Then the existing services still need to be maintained, but when there isn't a contractor or supplier to maintain these services anymore, then a new barrier will be evident that could be an obstruction for further CE transition. Thus, the ideal would be to have a contractor that could maintain these existing services for years to come, in which the commodities could circulate in the CE.

Quality of services

Indicating the quality of existing architectural facilities was an important demand for case 1. This is also the situation for fire and security safety. According to the technical manager, these two services were reused successfully in the building of case 1. Both services passed the testing phases successfully; this was the main indication for the quality assurance of the reused services. If the tests had failed, then these services would have been removed for new ones. Hence, indicating the reused services made it possible that CE strategies could be implemented.

"The services also simply had to meet certain strict requirements. One of the barriers is, when you talk about existing services, that it is not always easy to demonstrate the quality of it." - Technical manager, Interview, April 12, 2021.

From the opportunity sessions with the design team, an idea came forth to use the safety systems of other buildings that were planned to be demolished. Yet, in practice, this idea seemed difficult to realise. The main reason that it was not realised was due to the fact that there was no information about the current availability of resources elsewhere. In addition, there was no guarantee of what the quality of the existing system would be when found. As mentioned before, time and costs then overweigh the search for reusable materials. According to the sustainability consultant, another commodity that was planned to be reused were the kitchens of the previous building. The previous building had multiple big kitchens that could be reused in the building of case 1 (Sustainability consultant, Interview, March 16, 2021). Yet, in practice, this seemed impossible. Due to the fact that the moving time of the users from the previous building to the temporary accommodated building was too short (2 weeks). This meant that it was difficult to extract the kitchens, refurbish them, and then reuse them in the building of case 1 in such a short amount of time.

"You have to build and design integrally, and this was not done that way. A project on such a large scale was difficult to reuse the existing kitchens. It is possible, you transfer it quickly, move, plug and play. That can work, but time is a barrier, which makes it difficult." - Technical Manager, Interview, April 12, 2021.

6.1.4 Functional Perspective

Space plan

Refusing to change the existing situation of the spaces is the highest form of CE strategy that could be implemented. Since most of the existing facilities in the building were of good quality, most of them could be used by the new users as well.

"During the renovation of the spaces in case 1, the plan was that if space did not need to change, then the existing space was kept intact." - Sustainability consultant, Interview, March 16, 2021.

However, barriers also exist in the space layer of case 1. The CGREA PRE is built mostly for civil servants. For case 1, the main users were not civil servants.

"In itself, imposing them and demanding them to move to another building was not an easy task. We could not set some rules that would apply to them." - Sustainability consultant, Interview, March 16, 2021.

The users of case 1 had a certain functional need in the building which had to be realised. Specific spaces with special functions were not available in the existing building of case 1. Therefore, these rooms had been made new with a certain route in them. In addition, new security, fire safety and climate installations had to be installed in these new spaces. This meant that new commodities were added which is not in alignment with the CE. According to the technical manager, this meant that existing facilities could not be reused for these newly added spaces.

"The users of our buildings are the most important stakeholders. They can have expectations of a building they are going to use. If they want everything new, and also everything according to the latest requirements and standards. Then it can be a barrier for CE development." - Technical manager, Interview, April 12, 2021.

Stuff

In the Stuff building layer of case 1, mostly adding new commodities in the offices were refused as a main CE strategy. The stuff in this layer was reused, and if needed refurbished. Yet, in the newly added spaces, most of the stuff was not reused. Only two existing stuff were reused. Firstly the wooden elements of the interior walls from the previous building. And secondly, the chairs of the previous building. The reused commodities that were in bad shape were either repaired or refurbished to make it possible for reuse in case 1.

According to the Technical Manager, the users wanted specific spaces in the building with special functions to have a certain appearance. This certain appearance meant for the users that it had to be new and look fresh.

"New commodities, such as floor coverings and furniture had to be added to satisfy the users. Which they desired to look new and fresh". - Technical Manager, Interview, April 12, 2021.

In the initiation phase of the project, the users were ambitious about the CE transition and implementation of the CE strategies to case 1. It has become evident that the users had changed their demand in the execution phase. According to the technical manager, this was the right of the users to demand. Even though this demand did not lead to a delay in the project it did lead to additional work to meet the expectations of the users.

"The project is actually finished, but there is still some additional work that has yet to be done due to the expectations of the users. And so yes, this has happened, that barrier was there and did not lead that everything could be done in an ideal way." - Technical Manager, Interview, April 12, 2021.

6.1.5 Conclusion

It has become evident that for case 1, the main objective was to accommodate the users in another building. CE plans came in later phases to the project from a bottom-up approach. In addition, most of the CE plans were not realised due to the fact that there were not reusable materials available.

Since the CE ambition came from a bottom-up approach to the project, it also meant that time and cost outweighed the search, quality assessment and refurbishing of the reusable materials. This made the implementation of CE strategies into the existing building difficult since there was no budget specified for CE ambition.

The existing installations were revealed to have complications that led to barriers for further CE transition. Firstly, the contractors do not take responsibility for maintaining existing systems. Secondly, existing installations get susceptible to disruptions over time. Maintenance can be difficult as there is no guarantee that old systems will have available resources to maintain the service. In case 1, material or parts of certain systems were stored locally to solve this issue. This was done by either leaving the material in place or storing it locally in a stockroom. Nonetheless, this can still be seen as a temporary solution. Eventually, the stocked commodities will still run out. Then the existing services still need to be maintained, but when there isn't a contractor or supplier to maintain these services anymore, then a new barrier will be evident that could be an obstruction for further CE transition. Thus, the ideal would be to have a contractor that could maintain these existing services for years to come, in which the commodities could circulate in the CE.

As of last, user satisfaction hindered further implementation of CE strategies for case 1. Users demanded spaces with a specific function. If this function is not currently available in the existing building then a new space needs to be added. This was the situation in case one, where new spaces were added. This led to existing building elements having to be removed. Furthermore, in the Stuff building layer, existing commodities were outdated in the existing building. The users of case 1, demanded that in the newly added spaces floor coverings, light fixtures, and furniture had to appear new and fresh. The appearance was an important factor for the user's choice.

6.2 Case 2 - Warehouse Transformation

In case 2 an existing warehouse is transformed into an office building. The project started in 2018 and ended in 2020 CE strategies being implemented during this transformation. Case 2 is part of a larger urban development project of the CGREA. In this urban development project more than 5600 houses, commercial, social and recreational facilities will be developed. The main ambition of this project is to become a sustainable district.

CASE 2	Old	New
Function	Warehouse	Offices
Year	1952	2018 - 2020
m2	775 GFA	775 GFA
Development Budget	-	830.000,- ex. VAT
Users	Military	6 various firms from the creative sector

6.2.1 Strategic Site

A residential area is planned to be developed around case 2. The strategy was to use case 2 as a spin-off for the residential area. In other words, there was not a well-defined vision for the site of case 2, other than it had to be developed for placemaking.

"Placemaking is meant to be achieved with the circular development of case 2. In a circular building, you have stories about where the materials come from. It gives an extra dimension to the building and also to the site. The place will have a background, a history for the future users of the sustainable district" - Projectleader_2A, Interview, March 23, 2021.

The site where case 2 is located is shared by three buildings that are also being renovated by implementing the CE strategies. The strategy to implement CE strategies for case 2 and the other four buildings was planned. The existing building with its history in the area is preserved with the implementation of CE strategies. The architect states:

"What we have done there is to completely transform the existing buildings with low-tech means, to make the area an attractive place." - Architect_2B, Interview, April 14, 2021.

With this transformation of case 2, a value is given to the soon to be realised sustainable district. Preserving the history of the area is seen by the project team as an important factor for realising placemaking.

"If you demolished the existing building and just put another box there. Then you would fall into an ordinary industrial area. And then you will not get the spin-off that was desired."- Architect_2B, Interview, April 14, 2021.

The newly added offices in case 2, were successful in attracting firms from the creative and technology sector. They are currently the new users of case 2. By renting these offices, revenue is being generated for the CGREA. This is eventually used to also manage the grass, sewers, and lights on the whole site where case 2 is located. The strategy is to be the owner of the site for 10 to 15 years and sell it. In the end, a "circular centre" is developed and given to the sustainable district.

Development process

Case 2 is not a classical CGREA transformation project. Land and existing buildings will be developed and sold by the CGREA. This gave the development freedom to experiment with new ways to develop an existing building. Therefore, case 2 was chosen by the CGREA to implement CE strategies during the development. This demand has led to contracting an architecture firm, which has 20 years of experience in the field of circular designing. They developed their own circular business case and also has a CE network around the Netherlands. In this network contractors and demolition firms take part, which also works with CE strategies. This aided the architectural firm in searching and harvesting circular materials. There was not a tender process for the architect firm; they were chosen based on their CE expertise. Their experience was of great value to the CE transition of case 2.

For the contractor, there was a tender process. The three contractor candidates had to demonstrate that they had the experience and the willingness to implement CE strategies to case 2. The projectleader state that:

"The architectural firm was basically chosen due to their expertise in the field of CE development." - Projectleader_3A, Interview, March 23, 2021.

CE Ambition

For case 2 the main goal was not that the building had to be 100% circular. It would be challenging to develop it 100% circular since there was not enough time and budget. The project was developed in a market conform situation, with all the existing regulations and procedures that the CGREA currently uses. The architect stated:

"Implementing all forms of circularity was a plus. I did not aim to get everything 100 per cent circular as some kind of ideology. Instead, I looked at how far we can get with the existing building in regards to circularity." - Architect_3B, Interview, April 14, 2021.

Thus, the strategy was to come close to the realisation of a 100% circular building. This meant that if it was possible to implement CE strategies to a building layer, then it was implemented. Yet, if this was not possible, due to time and financial reasons, then it would not be an issue to add new materials to the building layer. The main reason for this strategy was because the project was financially driven but also due to the availability of resources. If there were no CE materials available then CE strategies could not be implemented. But the search for the resources was of importance, which took more time than necessary. In the end, CE materials were found. Yet, the time that was needed to find the available resources led to project delay.

As the projectleader stated:

“There was always the thought of can we implement CE strategies to something when renovating, instead of buying new resources. However, if it wasn't possible to realise these strategies then it would not do it. We had certain planning and a budget. Therefore, if an implementation of a certain CE strategy costs a lot and hinders a project then that circular strategy would not be executed.” - Projectleader_2A, Interview, March 23, 2021.

In practice, considerations were taken from the scale of case 2, whether to implement certain CE strategies or not. CE was not a leading factor in case 2. There were no hard requirements that only CE strategies should have been implemented. Additionally, there was no assessment framework determined in which the implemented CE strategies had to comply.

“If you did not determine a circular assessment framework at the beginning of the project. Then you will have difficulties telling the designer or contractor that they have to work with circular materials and strategies, that they must comply with this. So, leaving the market parties to solve it.” - Architect_2B, Interview, April 14, 2021.

For case 2 the client wanted to implement CE strategies to their existing building. Yet, there were no contractors able to realise it at the time. The contractors did not want to be responsible for searching and maintaining existing materials in a building. They want new materials which have a manufacturer warranty. In essence, CE strategies are implemented to case 2, but since there was no assessment framework in which it had to comply, it is difficult to assess whether or not the desired CE ambitions are realised. However, this did not mean that there was no CE ambition in the project. As the architect states:

"We tried everything to make the implementation of CE strategies in case 2 possible. On the scale of the Netherlands, this can be seen as a completely radical project." - Architect_2B, Interview, April 14, 2021.

Circular Materials

CGREA took the responsibility to search and select circular materials and commodities that had to be implemented into case 2. In Figure 20 the process of procuring the circular materials is shown. For roof insulation, the CGREA took the most responsibility, while for the facade, sandwich panels, and Trespa panels, the contractor. Yet, all the circular materials were chosen by the CGREA. Therefore, the contractor could only work on the materials if they were already found and selected by the CGREA.

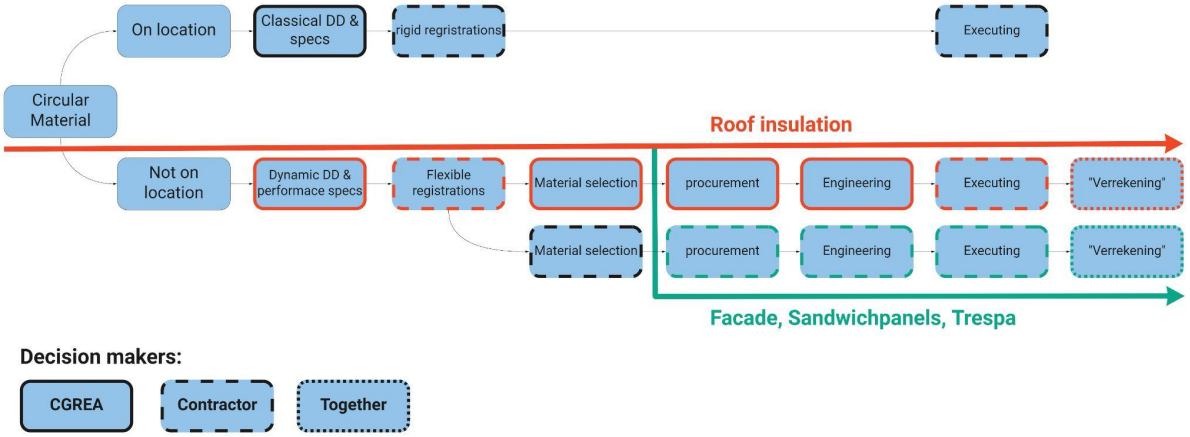


Figure 20: procurement process of circular materials for case 2. (own illustration, based on Projectleader_2A, Interview, March 23, 2021).

The reason for the CGREA to take responsibility for searching and selecting circular materials is explained by the projectleader as:

"It was because three years ago the CE transition of existing buildings was a new concept, and still is. The contractors did not have the experience of searching, selecting and harvesting of circular materials, which made it difficult for CE development." - Projectleader_2A, Interview, March 23, 2021.

Yet, project delays had occurred due to this decision. CGREA needed more time than expected to search for circular materials. The availability of resources was unknown. The overtime that was needed for the searching of circular materials led to the contractor also being delayed. They had to wait for the materials in order to work with it. This was especially the case for the meranti wooden exterior frames and sandwich panels that were reused in the project. Essentially, these building elements were found, but it took more time than expected. The contractor was also delayed because they needed more time for engineering and implementing the circular materials into the project. Moreover, from the tender phase, it was already unknown with which material the contractor was going to work with. Yet, this responsibility and risk were laid down to the contractor in the specifications. In essence, the project was delayed due to the availability of resources. The search, engineering, and implementation of the circular materials to the project took more time than expected. The projectleader stated that: *"CGREA made themselves vulnerable by taking this responsibility to search and select circular materials. (....) Searching and selecting circular materials will either be in the beginning phases of the project or we leave it to the contractor in the realisation*

phases. Otherwise, you as a client will be too vulnerable, all blame would fall to the client." - Projectleader_2A, Interview, March 23, 2021.

6.2.2 Financial

For case 2, budget and planning were the main drivers for this project. This meant that if an implementation of a certain CE strategy costs more than expected and hinders the project process, then that CE strategy would not be executed.

"There weren't specific CE goals, which you could assess in %. Realisation of CE strategies in the project was made possible by financial opportunities that were available". - Projectleader_2A, Interview, March 23, 2021.

Furthermore, reusing circular materials were mostly seen as an economical opportunity. Procuring materials that were formerly planned to be thrown away, could be procured for an acceptable price. Yet, finding, selecting, procuring, and implementing the materials to the existing building brought financial difficulties.

Estimating how much this would cost was a challenge for the client as well as for the contractor. For the contractor, it was difficult, as he could not know how much work was needed to implement the circular material. And for the client, it was difficult to estimate how much overtime it could cost. The chosen circular materials had to fit the building but also its requirements.

"Circular materials are cheap, but you need to pay for refurbishment, which costs more labour time. New materials are expensive, but then you can use them directly in the project, with no extra work time." - Projectleader_2A, personal communication, March 23, 2021.

The chosen circular materials are cheaper than new materials. Yet, the process (searching, procuring, and implementing) and labour, closes the gap between new and circular material.

"All the constructive improvements that had to be made to get to the current situation, were quite substantial. Still, the character of the existing building was preserved. Economically this was not necessarily more favourable, nor was it negative. It came out fairly even, despite the fact that you buy reused materials which are cheaper than new." - Architect_2B, personal communication, April 14, 2021.

Even though there was no financial incentive to implement CE strategies to the cases. It has become evident that implementing CE strategies is driven by realising the CE ambition of the government by 2050. And implicitly,

Contractual challenges

The architectural firm worked 20 years on transitioning existing buildings to a CE. From their experience, complications were also identified in contract forms. As the architect states:

"Committing a contractor to the project and how the budget is released to implement CE strategies, are the complications in contract forming." - Architect_2B, Interview, April 14, 2021.

Most of the time in a building project, the budgets are not released until the housing supervision permit is granted. This is a permit obtained by the municipality. The developer of a project is not willing to invest earlier prior to receiving the permits. After the permit is granted and the budget is released, a contract with the contractor could be formed. And after signing an agreement CE materials could be procured. This is not seen as preferable by the architect of the project:

"This is too late. Knowledge of which materials you are going to work with is needed for a circular design. And preferably in the design phase, because then you can be integrated into your final design. Otherwise, you have to redo that in later phases, which leads to project delay." - Architect_2B, Interview, April 14, 2021.

This was not necessarily a reason for project delay for case 2. The building permits were demanded in May 2018, and in October 2018 the contractor started, and in December of 2018, the permits were granted. Thus, the contractor started prior to the permits being granted. This was only possible because the CGREA owns the whole sustainability district. This is a unique situation where it was possible to start prior to the permits. Therefore, the most favourable solution would be to have all the permits and CE plans ready in the specification before beginning the project.

6.2.3 Physical

Facade

The new concept of the existing building was known. The warehouse would be used as an office. Daylight was necessary to enter the building for such a concept. In the existing situation, not enough daylight entered the building. The existing situation was not fit for the new purpose. Therefore, changes had to be made. The existing building had a closed facade. During the transformation, this has changed to make it aesthetically attractive and to let daylight enter the building. The south facade of the existing situation was stripped down, which made it possible to fill the facade with windows. During the design phase, it was unknown how the facade would look.

"Since you don't have the window frame yet, you could never know what it would look like." - Projectleader_2A, Interview, March 23, 2021.

The circular materials were not yet found and harvested to implement in the existing situation. Therefore, in the specification drawings, a grid was given where the facade and its windows would be positioned. How the facade would look was not the most important factor in this project. The availability of the circular material and the possibility to reuse and implement in the existing situation was.

"A window frame is a rectangle, and the dimensions of window frames are known. If you look at existing frames in the market, then you can already make preparations. You would say we don't know exactly, but roughly this is what we will do." - Architect_2B, personal communication, April 14, 2021.

During the execution phase, the window frames were harvested from another project and used for case 2. The harvested circular material was meranti wooden interior frames. The thickness of the frames was enough to use it for exterior frames as well. The windows are refurbished and reused frames. The architecture firm has found and advised the CGREA that these wooden windows could be implemented in the existing situation.

Eventually, the contractor had to implement the found circular materials to the existing situation. The contractor had to make an estimation on how much budget would be needed to realise it. They were aware of what sort of materials they will have to work with, and how they had to implement the reused facade to the existing building. Yet, what sort of material and how it looked was an unknown given that created uncertainties for the contractor.

"It was the first time for the contractor to work with CE strategies. Even though it was a relatively simple procedure, it was still seen as quite exciting and stressful work." - Architect_2B, Interview, April 14, 2021.

The procured facade was refurbished and repaired to fit in the existing building. It was a challenge for the contractor since the execution drawings were not known half a year prior to procuring the facade.

Even after estimating time and cost, project delays still occurred as mentioned in the strategic section. The implementation of the reused circular materials needed to fit the existing situation of the building. The contractor had to extrude parts of the procured facade to make it possible for reuse. And this endeavour took more time than expected, which led to project delay.

Roof

For the roof, circular roof insulation is being used and topped off with a green roof. The insulation material for the roof was made of PIR plates that were harvested from another building. The concrete underlayer of the roof could not withstand the tension of the plates above. During the anchoring process of the upper layer of the roof, the high tension almost led to the concrete trusses breaking. More anchoring was needed to keep the roof in place. Yet, more anchoring could be avoided if the mechanical and physical condition of the circular material was known beforehand.

"Therefore, you need to know a lot about the mechanical and physical state of the material that you will be working on. Because you're going to do things that an existing building might not withstand. In case 2 improvements had to be made to make CE strategies implementation possible. " - Architect_2B, Interview, April 14, 2021.

The roofing is demountable and can be demounted and replaced during maintenance periods. In addition, the PIR plates and steel plates have demountable properties, which makes them reusable for other projects in the future.

Floors

For case 2, a cast floor with underfloor heating is chosen; it is a sustainable solution as it is also connected to a heat pump. Yet, the casted floors are not demountable nor are they made from biobased materials. The reason behind this decision and not implementing CE strategies was due to technical complications. Case 2 has high ceilings and heating such a building only with radiators was seen as impossible. In addition, ceiling heaters could solve this issue but they were seen as boisterous systems, which is not favoured in offices in general.

"Circularity on technical installations is difficult, as there are really strict regulations on installations that need to be realised and also because of safety. Currently, that aspect is under-researched on how to circulatory harvest installations. There is not a lot of information on how to do it." - Projectleader_2A, personal communication, March 23, 2021.

Furthermore, when the choice for underfloor heating was made, the casted floor was the first option. In theory, the underfloor heating could also have been made demountable. Yet, the floors of case 2 in the existing situation were irregular, and casting was the most cost-efficient method to make the floor regular. Moreover, since the project was cost and plan-driven, the choice for casted floors was quickly made. The floors needed to be made ready in order to start to fit out the building.

"It was possible to do that in a dry system with Fermacell plates, only mechanically mounted and not wet. We could have done that, but your yield return would have been less. The costs would go up enormously, and the comfort would not have been any different." - Architect_2B, personal communication, April 14, 2021.

6.2.4 Functional

Users

The CE transition of the existing buildings in the area attracts new industries and companies. Companies that work with new technological developments are mostly interested in such areas. The users of case 2 are newly starting technological companies. The users do not see it as an old building with reused material, they adore the CE development of the project and area.

"The young designers and engineers feel good in this building, it is not clinical and not with suspended ceilings as you can see in a regular office. It's rugged but also inventive at the same time, so that matches each with the users very nicely." - Architect_2B, personal communication, April 14, 2021.

Space plan

Six office units were realised for case 2. In the space plan, various CE strategies are being used to realise the new functional demand. Reused sandwich panels were used to insulate the building from the inside. The sanitary facilities are coated with circular respa panels. Most of the newly added commodities are demountable or biobased materials.

"If it was possible to implement demountable or biobased elements to case 2 then this was done." - Projectleader_2A, personal communication, March 23, 2021.

Storage

During the procurement of CE materials it is always difficult to know exactly how many materials are needed to implement on the existing building. This leads to materials being left over, which if there is no plan on what to do with the leftover then it can be seen as a waste. There are two reasons for leftovers. Firstly, there is no exact design and knowledge of how many materials are needed for the development. Secondly, procuring CE materials are mostly done in whole units and not in seperate parts. For case 2 the CE materials that were leftover were mainly the meranti sandwich panels and roof insulation. But instead of discarding the leftovers, the choice was made to store it in a separate warehouse in order to reuse it in another project.

6.2.5 Conclusion

In essence, there were no hard CE requirements for case 2. The CE strategies that were implemented were not assessed by any sort of framework in which they had to comply. This makes it hard to assess whether the implementation of the CE transition of the existing property was successful or not. Future projects need assessment framework and CE requirements, in order to assess what worked and what did not. The architect stated that, on the scale of the Netherlands, the project was a radical one. Meaning it could be seen as a successful project. He further stated that 70% of circularity is being realised for case 2. Yet, the question arises whether this is enough for realising the circular ambitions for 2050. There is no adequate evidence, which indicates that all the actions taken to realise CE transition in case 2 are being realised.

Furthermore, the material selection was done by the CGREA. Project delay occurred because the CGREA needed more time than expected to search for circular materials. The overtime for searching and also engineering and implementing circular materials to the project also led to the contractor being delayed. In essence, the project was delayed due to the search and implementation of the circular material to the project by the client.

Implementing CE strategies in case 2 was not financially more favourable than using new materials. In essence, circular materials are cheaper than new materials. Yet, the process and labour, closes the gap between applying new materials and circular materials. Furthermore, from the experiences of the architectural firm, the release time of the budget is a barrier to CE transition in existing buildings. The budget for the project is released by investors after permits are granted. Afterwards, contracts with contractors can be signed, in which they can procure materials. This is too late and can lead to project delay, in which further CE strategies implementations can be cancelled.

The procured circular materials for case 2 showed that additional work was needed to implement it in the existing building. Having information on the current state of the circular material is essential for further CE transition in the building. Barriers do occur if the procured materials don't fit or the state of the materials is in poor conditions. In addition, strict

regulations did hinder harvesting existing technical installations for case 2. This led to new technical installations being used.

6.3 Case 3 - Building Complex

Case 3 is an ongoing project that consists of three separate buildings that are connected, making it a whole building complex. From the start, the project had a clear sustainability ambition. One of the three buildings of the building complex was planned to become a zero-energy building.

CASE 3	Old	New
Function	Offices	Offices
Year	1996	2020 (ongoing)
m2	37.000 m2 GFA	37.000 m2 GFA
Development Budget	-	72.000.000 euros
Users	Civil servants	Civil servants

6.3.1 Strategic

Tender Phase

In the scope of the project, the three separate buildings were planned to be transformed into one large energy-efficient building. The client wanted to make a part of the building complex a zero energy building. During the tender phase, award criteria were set to realise the sustainability ambitions. The parties that could realise these criteria would win the tender. Circularity was not part of the award criteria. The reason for this was stated by the sustainability advisor:

“For the award criteria, we wanted to put a focus on one aspect of sustainability which is energy. We didn’t want to put the focus on too many aspects, otherwise, it would confuse the market parties, which could result in an undesirable final design. That is also why we wanted one aspect that should get the focus. And since the main ambition of the project was sustainable energy, we kept the focus on that.” - Sustainability advisor_C3, interview, March 22, 2021.

However, realising the CE ambitions of the government for this project was also desired by the sustainability advisors. With the demand of the sustainability advisors, the circularity theme came later to the project from the bottom-up. This had led to circularity requirements being made for the project. These requirements were the basis that the contractors had to follow during the execution of the project.

“Strategically, we could not realise everything. So not on circularity and sustainability and architecture. When it comes to sustainability, we do one thing well and that is the energy part of sustainability. So that's been the strategy. We did not forget the CE ambition, and we have tried to include it by creating the circularity requirements.” - Head of the Technical advice department_C3, interview, April 6, 2021.

The existing building is an enormous building complex. It was preferred by the sustainability advisors that the existing materials could be reused after renovation. Therefore, the demand arose for the market parties on what to do with the existing materials of the project.

“We wanted to trigger the market parties to think of what could be done with the existing materials of the building during renovation. And finding the best circular solutions with it. So finding the highest possible CE strategy that could be implemented to the project.” - Sustainability advisor_C3, interview, March 22, 2021.

Furthermore, new materials were added to the existing building complex. For all the new materials and installations, minimal requirements were set. The newly added materials had to be recyclable, demountable and had to be free of certain toxicity.

Circular Requirements

In addition to the award criteria, case 3 has circular requirements. These circular requirements were set prior to the tender phase together with an external consultancy party. The winning parties of the tender had to adhere to these circular requirements. Simultaneously, the requirements were used as an assessment framework. These circular requirements consist of technical and process-related requirements.

There are six technical requirements. First, the usage of circular materials. These materials are demanded to be 95-100% recyclable at the same quality level. Second, reusability of newly added materials, in which 25% of the weight of each new material consists of recycled raw materials or from rapidly renewable resources.

Both circular materials and the reusability of newly added materials should be at least applicable to the space plan and technical layers of the building complex.

Third, the separability of materials. The contractors should use methods in which materials are detachable and demountable. Fourth, the negative effects of materials. The applied materials and products should have no negative impact on people and the environment during their production, use and reuse. Applied materials and products meet at least the requirements of the C2C Banned List of Substances certificate. This is a certificate in which substances and chemicals are banned due to their hazardous characteristics to the CE. Fifth, non-toxic materials will be used in the technical and space plan layers of the building. The added materials will meet the C2C Certified Silver certificate, which shows the toxicity level of the used materials and products. Sixth, the materials used for the building will be materials with minimal environmental impact.

The second circular requirements are the process requirements, which are separated into process activity (1) and process output (2). The requirements in process activity are related to how the circular requirements of the client should be realised. In the process, output requirements are the products (mostly reports) that demonstrate that the circular requirements are realised. In Table 8 the two process requirements can be seen.

Process requirements	
Process Activity	**Process Output**
Investigating existing material potential	Setting up a disassembly and demolition plan
Setting up a plan of reuse of existing materials	Reporting the product categories in which the selection based on circular criteria is explained
Maximal reuse of existing materials	Defining the disassembly plan, the take-back logistics, the required parties, the planned reuse strategy for all products
Determining the products that need to be changed or replaced after or during the contract period of 15 year	Reporting the non-toxic materials
Setting up a material passport for the added materials and products	Reporting a material passport
	Setting up a reuse plan for after 15 years (end of contract)

Table 8: Circular process requirements of case 3 (source: author).

Business case

Prior to the definitive design phase, an audit is planned in order to inspect the contractor with regard to the realisation of the circular requirements. The contractor will present the process of how the circular requirements will be conducted. The client will test the contractor based on how good the plan of approach is and assess it with the circular requirements. Moreover, the project is ongoing it is not clear if the contractor could possibly realise the circular requirements that were set. As it was stated earlier in this section, the client wanted to challenge the market parties with the demand of implementing CE strategies to the project. There was no clear business case done to see if these requirements were realistic.

“If prior to the tender business case studies were made specifically for the circular requirements, then more realistic requirements would be required. Now the intention was to challenge the market with the given circularity requirements.“ - Sustainability advisor_C3, interview, March 22, 2021.

“In the front end of future projects, business cases will be done regarding the realisation of CE ambitions. And assess it with the existing criteria that we have, such as comfort requirements and other requirements.” - Head of the Technical advice department_C3, interview, April 6, 2021.

Main strategy

It is expected that with the set circular requirements that the building complex will not be a 100% circular building. The aim is to learn from the project and create better circular requirements for future projects. In addition, the requirements are related to the space plan of the project, which are the interior walls, ceilings, doors, and floors. Furthermore, the technical layer of the building complex will be renovated to fit the current demand. Other layers of the building are not the focus of this project.

“The expectation is that we will not have a 100% circular building with the requirements that we have set. The focus is more on the “space plan and services layer” of the building complex, where a lot is going to happen. The expectation is that we will learn from this project and create better circular requirements for future projects.” - Sustainability advisor_C3, interview, March 22, 2021.

In addition, the head of the technical advice department stated that:

“We as the client could not demand that the building complex had to be a zero-energy building completely and also be 100% circular. And also that it had to be the most aesthetic, high quality of materials, high-end finishes. That was not possible with the budget that was given. Especially for circularity.” - Head of the Technical advice department_C3, interview, April 6, 2021.

6.3.2 Financial

During the initiation phase of the project, the road map to CE was new and there were no policies made to realise CE ambitions for projects. In addition, making one of the buildings a zero-energy building was not in the scope of the project and therefore not in the budget of the project. Since energy was the focus of the project, two million euros were given to realise the zero-energy demand. There was no separate budget given to realise the CE ambition.

Yet, the sustainability advisors together with the head of the technical advice department gave the assignment to still realise CE ambition for the project. This was realised by challenging the market parties to think of circular solutions when implementing materials and products to case 3.

“Since the circular requirements originate from the bottom-up, it is a theme that was added later. We are demanding this from the market parties; we have not zoomed in on what extra it would cost. As sustainability advisors, we just added the CE ambition as requirements.“ - Sustainability advisor_C3, interview, March 22, 2021.

Furthermore, the circular requirements were created within the limits of the project budget. Yet, since the project is still ongoing to that end it is not clear if the circular requirements will need more budget than expected. As the head of the technical advice department stated:

“If I have to make a price for the contractor on the demand specification, then I have to know what to do, in order to reserve money. I need to know exactly which CE strategies will be applied to the project. What is possible and what is not, and how much will it cost? And then

you really have to think about it at the front end of the project. It was difficult to know the needed budget because there were many ambiguities." - Head of the Technical advice department_C3, interview, April 6, 2021.

As it was mentioned in the Strategy section, most of the implementation of the CE strategies is planned to be executed in the space plan layer of the building. It is stated by the head of the technical advice department, that it would be otherwise unfeasible and unaffordable to realise it in all the other building layers.

"We did not demand that CE strategies should be implemented in all the layers of the building. Because there is so much material in the building complex, it would be unfeasible and unaffordable. That's why we focus mostly on the common materials that mainly exist in the space plan layer of the building." - Head of the Technical advice department_C3, interview, April 6, 2021.

6.3.3 Physical Services

During the business case, the situation of the existing technical services was tested. The air handling units that were being used in the existing building complex were nearly half in good condition. Therefore, the parts that were in good condition were reused. Reusing the services that were in good condition was not a prevalent approach as it sometimes comes in conflict with other sustainability demands. This was evident with the existing pipes of the building. They were in good condition and could be reused. Yet, due to the set comfort criteria, the existing pipes had to be changed. As the head of the technical advice department stated:

"The existing pipes came in conflict with the comfort criteria that we had set. Instead of high-temperature heating, we needed low-temperature heating. Otherwise, we could not realise the zero-energy building demand. This meant that we could not reuse the existing infrastructure of pipes, because they were dimensioned too small." - Head of the Technical advice department_C3, interview, April 6, 2021.

Facade

The facade of case 3 was kept as it is, as the aesthetics of the building was in desirable condition. Yet, the glasses of the facade had to be changed as they did not fulfil the sustainability criteria.

"So the facade remains intact, but a lot of glass needs to be changed. It is not done in a circular manner, because an important goal of the project was to transform the building into one that was as energy-efficient as possible. This aspect was included in the tender as an award criterion. " - Head of the Technical advice department, interview, April 6, 2021.

6.3.4 Functional

Space plan

As it was mentioned in the strategy section, most of the CE strategies are being implemented in the space plan of the project.

The demolition of the building complex has started and the definitive design for the whole building complex is in its final stages.

The contractor has hired a subcontractor that does the demolition. The subcontractor looked specifically to the existing materials of the building and to the value of the harvested materials. The harvested materials that could not be reused elsewhere are put on an online circular market space where they get a second life.

Interior walls

The client expects the contractor to carefully consider CE strategies. In the current stage of the project, the interior walls are currently the main focus to implement the CE strategies. During the initiation phase, the question arose to the contractor whether they could reuse the interior walls of the building complex. The client did not only give the option that the walls could be reused in the same building, but also that they could be reused elsewhere. The interior walls could not be reused in the existing building, since it was not fulfilling the acoustic criteria. Therefore, the sub-contractor will extract the interior walls and reuse them in other projects.

“The contractors did not go into much detail with the interior walls. It seemed that they made the decision very quickly to reuse the interior walls elsewhere. The interior walls get a second life. Only it would have been nicer if they could be reused in case 3. But if the contractor can reuse it on a donor project, which the contractor did prefer, then it was also good. In retrospect, we did give them freedom and It is a decision that we have accepted.” - Sustainability advisor_C3, interview, March 22, 2021.

The materials for the newly added interior walls are not yet chosen by the contractor. This will happen after the definitive design phase. The newly added walls have to be in alignment with the circular requirements of the project. Therefore, the input from the contractors about the newly added interior walls has still to be added to case 3.

“The circular requirements that we together created with external parties are feasible.
The demand should not be difficult for the contractor, as information on the existing materials are known and also are common materials over the building. In addition, we also conducted research, and the known existing materials have a circular market in which could be sold and reused by third parties. The materials I’m talking about are from the space plan layer of the building. For example, the interior walls, floor coverings, ceiling tiles, etc.” - Head of the Technical advice department_C3, interview, April 6, 2021.

6.3.5 Conclusion

In conclusion, the goal of case 3 was to realise one large energy-efficient building. The demand to add the CE ambitions into the project came from the bottom up. Therefore, prior to the tender phase, circular requirements were created with an external party to make the implementation of CE strategies to case 3 possible. The market parties are challenged to realise the circular requirements of the project. Yet, how exactly they are going to do it is still not known. This makes it difficult to assess whether the requirements could lead to barriers in the future. As the sustainability advisors stated, the tensions are currently shifted towards the back end of the project.

The project is still ongoing to that end; it is not clear if the circular requirements will need more budget than expected. Moreover, no separate budget is reserved for the implementation of the CE strategies. This could lead to the contractor implementing lower levels of CE strategies due to cost overrun.

From the scope, case 3 had a clear sustainability ambition regarding the energy efficiency of the project. This had led to existing materials, such as the existing pipe infrastructure, being removed. The existing pipes came in conflict with the comfort criteria that were set for case 3 and were therefore removed. The project criteria was an obstacle to reusing the existing pipes.

7. Synthesis

In this chapter, the collected data will be combined and analysed to identify the barriers. The cross-case analysis will combine the three cases, from the empirical research. The results will be used as an input for the expert panel in which the results will be validated and improved. Afterwards, the validated results will be used to conclude the study.

7.1 Cross Case Analysis

In Appendix F tables are created for each case. These tables give a brief overview of what exactly has been done for each case. The three cases of CGREA's existing PRE are being cross-case analysed. First, the implemented CE strategies for each case will be analysed. Second, the identified barriers from each case are analysed.

7.1.1 Identified CE strategies

From the case studies, implemented CE strategies were identified. In each building, the layer suggests a different and similar implementation of the CE strategies. In the table below the implemented CE strategies are cross-case shown.

Layers	Case 1	Case 2	Case 3
Site	R0-Refuse	R1-Rethink	R0-Refuse
Structure	R0-Refuse R3-Reuse	R0-Refuse R4-Repair	R0-Refuse
Facade	R0-Refuse	R2-Rethink	R2-Reduce
Services	R3-Reuse	-	R3-Reuse
Space Plan	R0-Refuse R3-Reuse R7-Repurpose	R2-Reduce R3-Reuse	R3-Reuse
Stuff	R1- Rethink R3- Reuse	-	-

Implementation

At the CGREA, CE strategies are implemented during renovation, maintenance and demolition project phases. Each case has shown a different approach in realising CE ambition in existing buildings. In case 1 four methods were created: 1- reusing existing building materials, 2- reusing building materials from donor projects, 3- using new circular materials, and 4- reusable materials for other projects. In case 2 there were no reusable materials available in the existing building. Therefore, materials had to be procured, which the client took responsibility for. In case 3 circular requirements were created to which the contractor had to adhere. Moreover, these requirements are used as an assessment framework.

Compared to the scientific literature, no significant differences were found with the four circular approaches for the existing building of Kyro (2020). The existing buildings of the case studies are all (1) preserved by refusing that the existing building had to be demolished, (2) made adaptable by reusing the existing building, (3) shared by creating new spaces in the existing buildings for new users and (4) rethought on how to work and implement the CE strategies to the existing buildings.

Kirchherr et al. (2017) state that most of the used CE strategies were R8-Recycle, R3-Reuse, and R2-Reduce. Moreover, Anastasiades et al. (2020) and Stijn & Gruis (2019) state that the focus in the construction industry is mostly on dealing with waste and recycling. However, results from the case studies do not support the previous studies on this matter. The results from the case studies suggest that recycling is not a commonly implemented strategy in the building layers of existing PRE. In the site, structure, and facade layers are the highest form of CE strategies implemented, which are R0-Refuse, R1-Rethink, and R2-Reduce. While in the Service, Space Plan, and Stuff layers, R3-Reuse is the most commonly implemented CE strategy.

It has become evident that reusing building elements is the most implemented CE strategy in the case studies. A possible explanation for this might be that the R8-Recycle strategies are only applied to building rubble that arises when a building (parts) is demolished. Since the case studies are done on existing buildings, in which the existing elements could be reused, implementing the R8-Recycle strategy was therefore not seen as favourable.

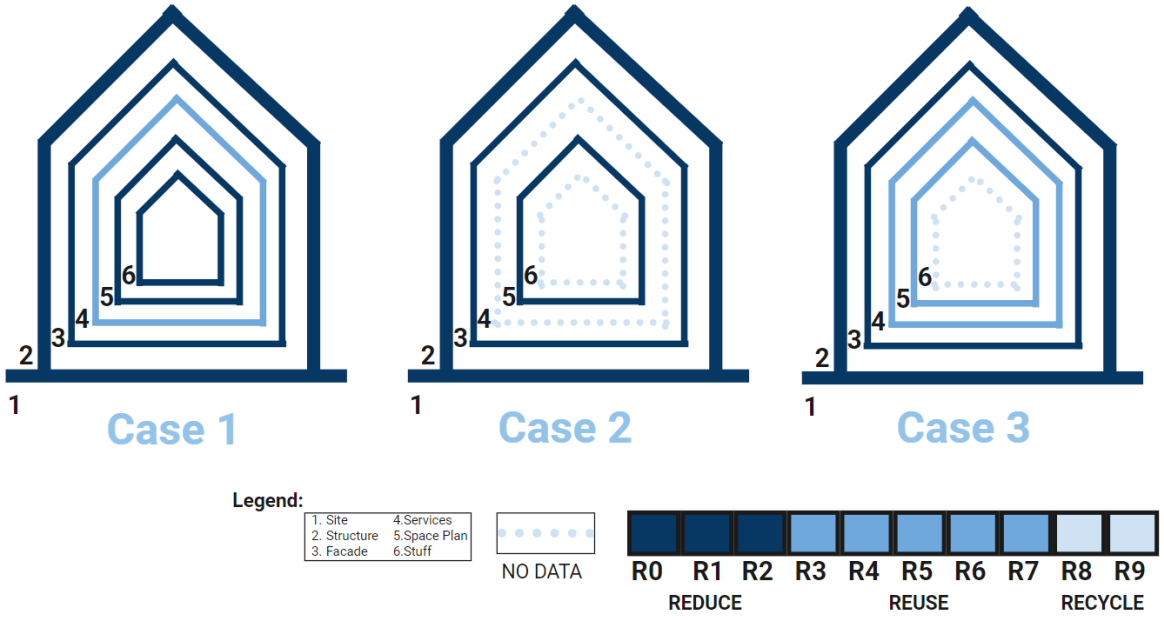
Layers

The case studies suggest that for all the cases the highest form of CE strategies (R0-Refuse, R1-Rethink, and R2-Reduce) is implemented in the Site, Structure, and Facade layers of existing PRE. This result may be explained by the fact that the existing buildings are not demolished. By applying this strategy alone, the highest form of CE strategies can be reached (R0-Refuse).

In addition, the case studies suggest that most CE development is done in the space plan, while the least CE implementation was found in the Stuff layer and Technical layers. The R3-Reuse strategy is mostly implemented in the Space Plan layers of existing PRE. Case 1 and case 3 suggests that the reuse of interior walls is the building element that is reused the most. Moreover,

Interestingly, the case studies suggest that in the Service layer of the three cases have low levels or none implementation of CE strategies. In Case 1, only the safety systems, fire systems and blinds were reused. First, these systems were in good condition and were ready for reuse. Second, the contractor did not agree in maintaining old systems, which led to procuring new systems to the Service layer. In Case 2 and Case 3 existing installations did not comply with current demand. Therefore new systems had to be installed to the existing buildings, which were not in alignment with the CE. These findings are consistent with that of Ploeger et al. (2018) who were in agreement that existing systems, which are seen as fixtures, bring challenges for the CE.

Implementation of CE strategies was not evident in the Stuff layer of case 2 and case 3. The materials in the Stuff layer of Case 1 were in good condition. Therefore, these materials were refused to be replaced with new materials.



7.1.2 Identified Barriers

From the case studies, barriers were found that were an obstruction for further implementation of CE strategies in existing PRE. The barriers were identified from four different perspectives. In the table below the identified barriers are shown.

Perspectives:	Case 1	Case 2	Case 3
Strategic	- Bottom-up approach - Unknown resource availability	- No assessment framework - Material selection by the client - Unknown resource availability	- Bottom-up approach
Financial	- Time and cost driven - No separate budget for CE strategies	- Time and cost driven	- No separate budget for CE strategies
Physical	- Quality of existing building elements - Current regulations - Finding CE installations	- Quality of existing building elements - Current regulations - Finding CE installations	- No CE award criteria
Functional	- User satisfaction	- Surplus of materials	

Strategic: Bottom-up approach

In cases 1 and 3, the CE ambition came to the project from a bottom-up approach, meaning that in the initiation phase of the project there was not a CE ambition. In the later stages of the project, CE ambition came forth on the agenda to realise it for both cases. An enabler to realise the CE transition late in case 1 was due to the acceptance of the design team. They were enthusiastic and looked positively to realise the CE demand by the client. Yet, since the CE ambition came forth from later stages, not every CE ambition could be executed as it was not planned in the early stages. In case 3, the CE requirements were created to realise the CE strategies in the ongoing project. However, since the CE requirements came from a bottom-up into the project, business cases were not done to see if these requirements were feasible. In case 2, the CE ambition was there from the scope. Yet, even from top-bottom, CE ambition was not the main driver for the project.

The analysis shows that cases 1 and 3 had a similar approach, while case 2 differs. The difference can be explained due to the fact that case 2 was a project in which CE strategies came from a top-down approach. The cases have different approaches to realise the CE ambition, but both cases showed that obstruction to implementing CE strategies did take place in the building process. Nonetheless, did case 2 succeed more than cases 1 and 3

regarding the CE transition, as the existing building is now seen as 70% circular (Architect_2B, Interview, April 14, 2021).

Strategic: Unknown resource availability

In cases 1 and 2, the availability of resources was another barrier that hindered further implementations of CE strategies. From the opportunity session in case 1, ideas came forth on how to implement CE strategies to the project. Harvesting building elements of other projects that were planned to be demolished was the main idea to find resources. For example, safety systems are systems that could easily be harvested and implemented in the existing situation of a building. Yet, there was no knowledge on where to find these systems. The availability of the resources was unknown. Therefore, the implementation of CE strategies was hindered.

In addition, the availability of resources was in case 2 unknown. It led to more time being spent searching for CE materials to implement in the existing building. The meranti wooden exterior frames that were used for the facade and the sandwich panels that were used in the interior took more time to find. Overtime was needed to find the right circular materials. Moreover, The contractor was also delayed because they needed more time for engineering and implementing the circular materials into the project. In essence, The project was delayed due to the availability of resources.

Strategic: No Assessment Framework

In case 2 it has become evident that there was no assessment framework, in which the implemented CE strategies had to comply. The strategy was if a certain CE strategy could be implemented without it affecting the planning and budget of the project, then it would be implemented. Case 1 analysis did not reveal that assessment on the implemented CE strategies was conducted. It has become evident that the main goal was to accommodate the users as quickly as possible temporarily to another building and CE ambitions came later into the project. Therefore, the case studies suggest that for case 1 no assessment framework was made in which the implemented CE strategies had to comply. This makes it difficult to assess whether or not the desired CE ambitions are realised.

This finding was not surprising as the case studies from Vergara D'Alencon et al. (2019) had similar results. In the construction industry the circular activities, ambitions and goals can be identified, but there isn't adequate evidence that all the actions taken are being correctly realised.

Strategic: Material selection by the client

The CE material selection is done in both cases 1 and 2 by the client. In case 2 project delays occurred, due to the decision of the client to become the searcher of CE materials. Project delay related to the material selection by the client did not occur in case 1. With the help of the design team, methods (See Appendix E) were created to reuse what was already there, reuse from elsewhere, use new (circular) materials, and use the leftovers of case 1 elsewhere.

The difference is that in case 1 most materials in the existing building were in good condition and could be reused in the same building. This was not possible for case 2, in which more CE materials were needed for the transformation of the building. Yet, if case 2 was on the same scale as case 1, then more CE materials would have been needed to be searched. Meaning that it is possible that the bigger the project is the more CE materials are needed to transition the existing building to the CE.

Financial: Cost and time driven project

In cases 1 and 2, the planning and budget of the project were of great importance. Both cases indicate that if a certain CE strategy exceeds the given time and cost then it would not be executed in the project. This leads to CE strategies being neglected in a project.

In case 1, most of the ideas that came forth from the opportunity session that were not realised were due to the fact that time and cost outweighed the search for CE materials. This was the situation with the six kitchen units that were available for harvesting in the building prior to the accommodation. But since the harvesting exceeded the cost and time, it was not reused for case 1.

Even for case 2, where there were CE ambitions from the start, if a certain CE strategy costs more than expected and hinders the project process, that CE strategy would not be executed. This was especially evident for the casted floors, in which cheaper non circular materials were used. The main difference is mostly that for case 2 there was a project planning to find and search for CE materials. While case 1 had to follow the regular project planning.

Financial: No separate budget for CE strategies

There was no separate budget made to realise the CE transition for cases 1 and 3. Since the CE ambitions came from a bottom-up approach, the budget was already divided into other parts of the project. Therefore, realising CE strategies were neglected if they exceeded the given project budget. However, it is not a guarantee that separate budgets for CE strategies lead to successful implementation of CE strategies. This was evident in case 2, in which a budget was given for the implementation of CE strategies. Yet, the project is also cost and time driven and therefore, if the planned CE strategies exceeded the time and budget then the CE strategy would not be implemented.

Physical: Finding CE installations

In case 1 the existing installations are reused and the needed new installations are procured. Difficulties arose when the contractor would not take the responsibility to maintain the existing installations in the building. The contractor is only willing to maintain only the new systems that are being integrated into the building. The architect from case 2 also confirmed that contractors are not willing to maintain existing systems. They prefer to have new systems in the building as they have a manufacturer warranty (Architect_2B, Interview, April 14, 2021). Moreover, reusing existing installations means that over time they will become susceptible to disruptions. And since there is no guarantee if the existing systems will have maintenance services in the future, this could mean that eventually, the existing systems have to be removed. In case 2 it has become evident that installations of other buildings were not capable of being reused. Therefore, new systems were installed in the existing building of case 2. Both cases 1 and 2 indicated that finding installations that are in alignment with the CE is a barrier.

Physical: Unknown quality of existing building elements

Not knowing the quality of existing building elements can lead to delay in the further implementation of CE strategies. In the service layer of case 1, existing fire and safety systems were put through the testing phase in which they both passed successfully. Testing the systems gave an assurance of their quality and therefore it was reused in the existing building. This assurance made it possible that CE strategies could be implemented. Yet, if there was no guarantee of their quality then existing systems would not be reused. This happened to the safety systems from another demolished project that was mentioned in case 1 interviews. The safety systems could not be reused since the quality of it was unknown and therefore removed.

In the structure layer of case 2, the concrete trusses could not withstand the tension of the implemented CE strategies on the roof. The quality of the trusses was not known prior to the implementation of the CE strategy. This led to more concrete being needed to support the existing structure, a non-circular way of solving the issue.

Physical: Current regulations

Existing products have to comply with the current building regulations. Yet, not all the existing installations of case 1 could meet the current building requirements and therefore new installations were needed to be added to the project. In case 2 there were no existing installations and this meant that new installations had to be implemented to the project. In addition, strict regulations did hinder harvesting existing technical installations of other projects. Existing installations can be in poor condition, which makes it difficult to reuse them in existing buildings.

In essence, barriers do occur if the procured materials don't meet the requirements of building regulations, it could be used as an argument to go for new products. Moreover, if the

existing materials are in good condition it can still be removed if it does not comply with the current regulations.

Physical: No CE award criteria

For the tender of case 3, there was a sustainability award criteria focussed on energy efficiency not not on CE. This means that energy efficiency is a driver for the project and can cancel out CE plans if it goes against energy efficiency plans. This was evident for the existing pipes of the building that had to be removed. The existing pipes were dimensioned too small, in which low-temperature heating could not be achieved. This was necessary to realise the zero-energy demand. In addition, the glasses of the facade were removed as well for the same reason.

Functional: User satisfaction

In the Space Plan layer of case 1, obstruction of further implementation of CE strategies took place due to the users' demand. They need rooms with a specific function to be available in the accommodated building. Yet, the existing building did not have the specific room that was demanded, therefore new spaces were added. This led to existing building elements having to be removed to make space. Furthermore, in the Stuff building layer, existing commodities were outdated in the existing building. The users of case 1, demanded that in the newly added spaces floor coverings, light fixtures, and furniture had to appear new and fresh. The appearance was an important factor for the user's choice in case 1. As Zavadskas et al. (2021) state, Real estate management of public property can be challenging due to its user needs, differences in desired public requirements, and various real estate plans.

The users of case 2 did not need a specific function nor did they complain about the appearance of the building. Yet, the differences can be explained in case 1 the users were accommodated while the users of case 2 were tenants. Therefore, users of case 2 were more satisfied than the users of case 1. Moreover, the users in case 3 are the regular users (civil servants), which had no issue in the overall CE development in the existing building.

Functional: Surplus of CE materials

All three cases did not have a definitive design in which all the added CE materials were integrated. In case 2 the exact amount of newly needed CE materials to the existing PRE was not known, which led to a surplus of CE materials at the end of the project. The issue of surplus of CE materials was solved in case 2 by reusing the materials in another project in the same area. In case 1 and 3, there were no leftovers of CE materials identified. The CE materials were either saved in the same building or reused in another building.

A surplus of CE materials can be seen as a barrier since it has the potential that it can be discarded and become waste. This is not in alignment with the CE as there is no space for waste.

7.2 Circular C's

From the case studies, several interviewees and experts have shared their views on the subject of CE transition in existing PRE. Implicit recommendations are gained that can aid the practice in further CE development of their building portfolio. The data regarding this are collected and structured under the Circular C's. The Circular C's are meant as field recommendations for better CE project development.

7.2.1 Commitment

Commitment from all actors (from the start to finish) is needed in regards to the implementation of CE strategies. Especially, in the project scope and briefing, this commitment has to be made clear This way the CE transition in project development can be assured. No commitment by one of the actors can lead to challenges in the development process. An example is the users that demand non-circular solutions or contractors that implement lower levels of CE strategies into a project.

7.2.2 Communicate: translating the CE policies into practice.

Currently, the CGREA is working on creating a route map for the CE. This route map will translate the policies that are planned for the CE to the practice. The Head of the technical department had his concerns around this.

"How do you translate the policies around the CE to the projects? To the market demand? So we want something, we have a task and we are an agency that executes the demand of the government. Well, how do you translate that into a market demand? Currently, that does not appear to be so obvious." - Head of the Technical advice department_C3, interview, April 6, 2021.

The case studies indicated that the CE ambition came to projects without CE plans from a bottom-up approach. The key actors that realised the CE ambition in these projects were the sustainability and technical managers. They had convinced the project leaders and project development team that there was a possibility of applying the CE ambition to the project. Communicating is important in order to translate the CE policies into practice. This makes the process of the CE transition smoother in the built environment.

7.2.3 Continue

Imbedding the CE ambition into a project is not a one-time development. It is a continuous process that has to be conducted in every building layer and in every project phase. From the empirical research, it became evident that no existing PRE is made 100% circular. Meaning that the building is not fully designed, planned, built, operated, maintained and deconstructed in a manner consistent with the CE.

Therefore, continuing to add more CE materials in the renovation and maintenance phases of existing building properties will make the building surely part of the CE. The head of technical management mentioned that this can be achieved through asset managers. They can create strategies and visions regarding the CE ambition, and implement CE strategies during the

Multi-year maintenance plan (MJOP in dutch). This could be achieved throughout the whole real estate portfolio of the CGREA.

"It should be viewed from the whole building stock. Then the question should be asked, "what do I have in my building stock?". That is really at the portfolio level. And then you also look at when are the natural moments that a renovation or maintenance will take place. And then you can apply the CE ambition with its strategies in projects. Doing this on a portfolio level can create a continuous process, in which you don't have to waste searching for CE materials, suppliers etc. You can simply plan it and implement the CE strategies into the next project." - Head of the Technical advice department_C3, interview, April 6 & August 17, 2021.

7.2.4 Conscious

During the implementation of CE strategies in the existing PRE, certain challenges arose for the CE development in the project. Being aware of these challenges can lead to making the CE ambition practical and specified.

Procurement

Searching and procuring CE materials by the client should be avoided, as many uncertainties take place. In case 3 the decision to take responsibility leads to project delay. As the Projectleader stated:

"Searching and selecting circular materials will either be in the beginning phases of the project or we leave it to the contractor in the realisation phases. Otherwise, you as a client will be too vulnerable, all blame would fall to the client." - Projectleader_3A, personal communication, March 23, 2021.

This was also in alignment with the architect of the project.

"The moment you (client) become the supplier of material. Then the contractor will always use your demand for implementation of CE strategies, as excuses for project delay if things do not go as planned. Because working with circular materials can be seen as an uncertainty for them." - Architect_3B, personal communication, April 14, 2021.

Therefore, this responsibility should be left to the contractor. Yet, the client should be aware that the contractor is committed to realising the CE strategies into the project. Setting only CE criteria to a contractor is not sufficient. Clear goals have to be set before rendering.

Linear economy

The current building process is fit for the linear economy, which makes the process for CE transition in the existing building difficult. As a client, you have to be aware of the limitations that the linear economy brings. Being aware of the constraints can limit the mismatch between the supply and demand of circular solutions to future projects. Currently, demanding circular solutions from the market parties can challenge the creativity of the market in order to realise the CE ambition of the project. This strategy was done in case 3 and it can be used in the first stages as a learning process for further CE development in future projects.

Transportation

Another challenge was the gap that materials/commodities such as the kitchen in case 1, had to move from one building to another. Thus, When working with accommodation projects, one should keep in mind that commodities with installations in a previous building can not be extracted, refurbished, and reused in a short time. Therefore, planning such a CE strategy is a difficulty that should be avoided.

As the technical manager from case 1 stated:
"You will always have the gap which is very short so that you cannot easily transfer the existing commodities". - Technical Manager, Interview, April 12, 2021

Thinking about how predictable the accommodation demands are within the central Government is of essence to the circular portfolio strategy.

CE materials

When reusing circular materials, whether it is harvested from the existing building and reused on location or harvested from elsewhere, complications can occur. The complications are related to quality demand and are mostly encountered during project realisation. After procuring the materials issues can be found that are

In case 1, an issue came forth when reusing the existing installations. During realisation, it had become clear that the existing installations needed repair or were not fit for further use. In case 3 this also had been the issue, during the search for circular materials. More work was needed to implement the facade to the existing building.

The possibility for complications on circular materials exists, which one did not expect. And fixing these complications can lead to project delays as more work is needed. Therefore, when reusing circular materials, time needs to be given to assess the quality of the procured materials.

Tender procedures

Traditional tender procedures are not designed for CE development. From case 3 it became evident that it could be favourable for the project process to have the contractor involved in the early stages. The architectural firm does not make a definitive design but makes a preliminary design-plus. This means that the design process does not end till materialisation. The architectural firm could have a directorial and advisory role during the execution phase, aiding in detailed drawings and realisation of CE strategies implementation on the project.

"We could experiment with it. For example, I no longer make a definitive design, but a preliminary design plus. This means designing together with the contractor till materialisation." - Architect_3B, personal communication, April 14, 2021.

This could solve the issue that the architectural firm does not design something that could be difficult for the contractor to realise. In a traditional project, the contractor receives the definitive design and works on it. Yet, in CE development the contractor comes in contact with circular drawings, which are not certified. For instance, circular materials are not

products that you could procure easily. This could lead to uncertainties that should be avoided.

"If you offer all the design drawings as a set to a developer or contractor, then they will feel uncertain since they do not know what you are prescribing them." - Architect_3B, personal communication, April 14, 2021.

Budget release

In case 2, it was stated by the architect that the release time of the budget brings challenges to the CE transition in existing buildings. The budget for the project is released by investors after permits are granted. Afterwards, contracts with contractors can be signed, in which they can procure materials. This is too late and can lead to project delay, in which further CE strategies implementations can be cancelled. Even though this was not the situation for case 1 and case 3. The most favourable solution would be to have all the permits and CE plans ready in the specification before beginning the project.

"Knowledge of which materials you are going to work with is needed for a circular design. And preferably in the design phase, because then you can be integrated into your final design. Otherwise, you have to redo that in later phases, which leads to project delay." - Architect_3B, Interview, April 14, 2021.

7.2.4 Concession

From the case studies, it became evident that concessions had to be made in regards to the user's demand and sustainability goals.

Users concession

In the early stages of the project, concessions between the expectations of the users and the CE ambitions have to be dealt with. If this is not done, such as in case 1, then discussions arise with the users in the execution phase of the project, because the expectations could vary. Hence, to avoid this, consultation with the users is needed on the subject of CE. And if an agreement is made with the users to reuse certain stuff in the building, then obstruction for CE transition in this layer can be avoided. Yet, it is still possible that even after the concession the users can change their minds. Thus, a clear agreement is necessary to avoid this.

Sustainability concession

From the case 2 it has become evident that implementation of CE strategies could be hindered by sustainability demand. The existing pipes infrastructure which were in good condition had to be removed to meet the sustainability energy demand of the project. Concessions have to be made whether the sustainability ambitions or the CE ambitions will be realised in the project. As these two ambitions can contradict each other in project development.

8.3 Conclusion synthesis

The three cases were compared and analysed. Through comparison, it has become evident that CE strategies are being used and implemented in the existing PRE. Differences and similarities between the cases were identified with the help of the theoretical framework. This led to the identification of the barriers that were evident in the cases. In the following chapters, the findings from the syntheses will be validated and used to answer the research and sub-research questions.

8. Expert Panel

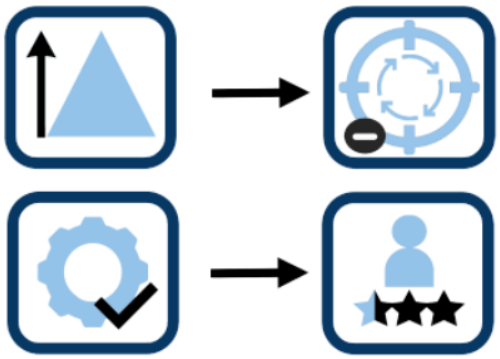
The input of the expert panel is presented in this chapter. The input from seven respondents is used to validate and improve the draft results from the conducted case studies. The validated and improved results are then used to conclude this study.

8.1 Improvements of the barriers

During the expert panel, the experts were asked if there are improvements needed for the results. One of the respondents had mentioned that the identified “Bottom-up approach” and “Material selection by the client” barriers needed improvements. The reason was that these were actions taken because of challenges that were at hand during the project development.

CE ambition was not in the scope of cases 1 and 3. The Bottom-up approach was seen in these cases as an action that made the application of the CE ambition possible. Therefore the real barrier to the CE transition is not the bottom-up approach, but the CE ambition that was not in the scope of the project. Moreover, the material selection by the client was a reaction to the inexperience of the contractor regarding the CE transition of case 2. That is the reason the client took the responsibility to select the CE materials themselves. Therefore, the real barrier was the inexperience of the contractor regarding the CE.

Identified action	Validated barrier
Bottom-up approach	No CE ambition in the project scope
Material selection by the client	Inexperience of the Contractor with the CE

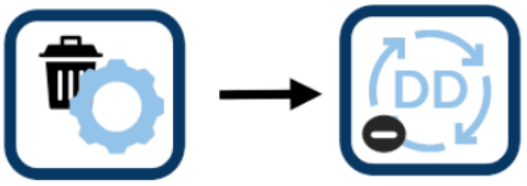


8.2 Clarity of the barriers

The identified surplus of CE materials was not well understood by the experts and had led to discussion. This was a barrier that became evident in case 2. While cases 1 and 3 had enough existing products and materials to work with, many new products and materials had to be added to case 2. The exact amount of needed circular materials was unknown in the definitive design phase of the project. This had led to a surplus of circular materials that

were not used in the existing building. The issue was solved by using the surplus of CE materials in another renovation project in the same area.

In essence, not knowing the exact amount of materials that are needed for a project can lead to a surplus of CE materials. The reason that it was not known was due to the fact that CE materials and how to implement it into the existing PRE were not integrated in the definitive design. Therefore, the validated barrier is a definitive design without implementation of the CE strategies .

Identified result	Validated barrier
Surplus of CE materials	Definitive design without CE strategies
	

8.2.1 Relevance for case 3

Since case 3 is an ongoing project, new data did come forth during the expert panel. The experts gave input that some barriers that were relevant for the other two cases were also relevant for case 3.

Barriers that are also relevant for case 3:
Finding CE installations
Unknown quality of existing building elements
Availability of resources
Regulations
Cost and time driven projects

8.3 Missing barriers

The experts were asked if there were barriers in the field that were missing. Yet, none of the experts claimed that any barriers were missing. One expert mentioned that the identified barriers from the case studies overlap the barriers that exist in the field. This was the case for the Unknown resource availability and Finding CE installation barriers.

The experts further explained that there is currently insufficient insight into what is already available in the market in terms of circular resources. This makes it difficult to demand specific circular solutions from the market, without even knowing how the market will respond to such demand. All experts agreed that this is especially the case for circular

technical installations. Which explained that the Service layer of all the cases showed difficulties in implementation of CE strategies.

8.4 Current situation

As a last question, the experts were asked if any action is currently being taken to the identified barriers. One expert reported that currently a portfolio strategy is being made to bring CE ambition to the project scope and project briefing. This means that the bottom-up approach strategy is being changed into a top-down approach strategy. Moreover, when CE ambition is in the scope of the project assessment frameworks and CE award criteria, barriers will vanish.

One expert mentioned that the No separate budget for CE strategies and Regulations are barriers in which nothing is currently being done. The first barrier was reported to be a difficult one. The experts mentioned that there is no budget release for the implementation of CE strategies.

The experts reported that arguments are needed to gain a budget for realising CE ambition in projects. If the CE ambition is aligned with the ambition that the users have, then budget release would be gained easilier to realise the demand of the users. Currently, sustainable energy ambitions are easier realised in projects. This ambition can be specifically achieved by sun panels. Moreover, the financial benefits in future stages for the users can be seen as an incentive to realise the sustainable energy ambition.

In addition, experts mentioned that CE ambition is difficult to explain to users and is too abstract. Value of healthier materials, scarcity of resources, and CO2 impact of non-circular materials are vague terminologies currently for clients. This is the main reason why gaining a budget for realisation of CE ambition in existing PRE is difficult.

Validated results

These are the current barriers that hinder the CE transition in existing PRE. These barriers are an obstruction for further CE development in the built environment. The Barriers are:

1. No CE ambition in the project scope
2. Unknown resource availability
3. No assessment framework
4. Inexperience of the Contractor with the CE
5. Cost and time driven project
6. No separate budget for CE strategies
7. Finding CE materials
8. Unknown quality of building materials
9. Current regulations
10. No CE award criteria
11. User satisfaction
12. Definitive design without CE strategies

9. Discussion

In this chapter, the research outcomes are discussed. First, the interpretation of the outcome is discussed. Second, the implications to understand why the results matter. Third, the limitations on what the results do not tell us. Finally, the recommendations with practical actions that future scientific studies should follow.

9.1 Lessons Learned

PRE

Prior to the theoretical research assumptions were made regarding the research topic. The main assumption was that the PRE were different from non-public real estate. In regards to users and owners it is certainly different. Yet, in regards to the CE transition in the existing buildings it was expected to be different as well. Yet, the results were gained through analysing the existing PRE only. The identified barriers did not indicate its specific relation with the PRE, it is possible to be a relevant barrier for non-public real estate as well. Therefore, the assumption prior to the research is not justified. Further studies could focus on the identified barriers relevance with non-public real estate.

CE

In addition, the study did not reveal a significant difference between the academic literature and field research, regarding the emphasis of existing buildings. From the academic literature it had become evident that the existing buildings were neglected regarding the transition to the CE. This was also confirmed from the field research. During case selection for the empirical research, it has become evident that the CGREA is working on transitioning its real estate portfolio to the CE. A total of 74 projects are planned to develop with the CE strategies. From these 74 projects, only 20 projects were existing buildings. The most striking result to emerge from the analysis came from the Service building layer of the existing buildings. In the academic literature, it was mentioned that contractors will have difficulties when they implement CE strategies to a project, as implemented commodities are seen as fixtures. This leaves legal uncertainties for the contractor since the commodities can not be part of a multi-cyclic behaviour, as they can not circulate in the CE.

Moreover, from the field research it became evident that there is more worth mentioning. In both cases, it came forth that the contractors were not willing to maintain existing building elements. They preferred new building elements with manufacturer warranties. This was also the situation for the existing installations of a building. Therefore, in case 1 existing installation was maintained by the client himself. They did this by overhauling and stocking commodities that were needed for the services to function in future as well. Yet, the existing systems over time become susceptible to disruptions. Moreover, existing installations' quality is difficult to assess, and are discarded if the quality can not be guaranteed. Additionally, since there is scarcity of resources, future support of electrical parts of these existing systems during maintenance periods can be hard to find. Old systems might not be supported and manufactured anymore. Furthermore, the projectleader of case 2, states that harvesting existing installations to be reused, is under-researched. There is insufficient circular solution known from the market in the field of technical installations.

9.2 Interpretations

The research methods of this study consist of a review of previous scientific literature studies on the subject of CE in existing PRE, three case studies and interviews, and an expert panel to assess, validate and improve the results of the study.

In the scientific literature, it has become evident that there is little emphasis on the CE transition in existing PRE. Initially, it was thought that little was done around the CE transitioning of the existing PRE. From the 74 projects of the CGREA, in which the CE ambition is currently being realised, only 20 are existing buildings. Therefore, this study supports evidence in the scientific literature that the emphasis is more on new buildings. However, this does not mean that existing PRE regarding the CE transition is neglected as it was mentioned in the literature conclusion. In addition, in the research conducted by Vergara D'Alencon et. al (2019), it has become clear that there isn't adequate evidence, that all the actions taken to realise CE transition in the construction industry, are being correctly realised. This is also supported by the outcome of this study as the cases have shown that not all demanded CE strategies could be realised. Yet, it has to be mentioned that various barriers that were identified did hinder the further realisation of CE transition of existing PRE. Moreover, cases 1 and 2 did not have an assessment framework, which made it difficult to assess the implemented CE strategies to gain adequate evidence.

This study supports the theory of the implementation of CE strategies in buildings. The collected data from the case studies indicate that the implementation of CE strategies in existing PRE is an ongoing process. Moreover, there are different strategies used on how the CE ambition could be realised in the existing PRE. In case 1, this was done through organising opportunity sessions. In case 2, through a pilot project in which CE was integrated into the scope of the project. In case 3, circular requirements were created that the market parties had to comply with. Different strategy approaches were taken in each case. This is contrary to the study of Kyro (2020) who states that transitioning towards the CE in the built environment demands a more structured approach.

Brands (1994) six layers of a building made it possible to collect the data from the case studies in a structured manner. In line with studies by Ploeger et al. (2018) and Brink et al. (2017), the Service layers of the cases indicated the most difficulty for implementing the CE strategy. In addition, The results from the cases contradict the claims of Anastasiades et al. (2020) and Stijn & Gruis (2019), who state that recycling is the most used CE strategy in the construction industry. However, The results from the case studies suggest that recycling is not a commonly implemented strategy in the building layers of existing PRE. In the site, structure, and facade layers are the highest form of CE strategies implemented, which are R0-Refuse, R1-Rethink, and R2-Reduce. While in the Service, Space Plan, and Stuff layers, R3-Reuse is the most commonly implemented CE strategy.

From the expert panel, the research gained validation from the experts around the field of sustainability and CE. The initial results are also improved with the knowledge and feedback that the experts had shared.

In essence, this study contributes a nuanced view on the subject of CE transition of the built environment focused on the existing PRE view. The theoretical research indicated that the CE transition in existing PRE was neglected. Yet, empirical research indicated that the CE transition in existing PRE projects is being realised. Moreover, this study has found that, even if the CE ambition is integrated into the later stages of a project, it is still difficult to realise this ambition with the current economy we live in. The analysed cases have indicated the challenges that are an obstruction for further transition to the CE. The challenges in this study identified and validated as barriers that will hinder the future transition to the CE if not dealt with.

9.3 Implications

This study is a contribution to the theory and practice around the subject of CE in existing PRE. The study provides an overview of the facts and barriers that currently exist to the transition of existing PRE to CE. Providing data around this subject makes the CE development in the built environment more nuanced and could provide new insights for future researchers. In addition, this study provides data for the practice that can be used as an assessment of what the current situation is on CE transition of their own existing PRE. One of the aims of this study was to be a starting point in dealing with the current barriers that hinder further CE development in existing PRE. Therefore, implicitly aiding the further CE development in the built environment.

9.4 Limitations

The results do not indicate the level of complexity of the whole project. Instead, the results give an overview of the CE strategies that are being implemented in six different layers of the three chosen cases. In addition, from four different perspectives barriers were identified that hindered the further implementation of CE strategies in the existing PRE. Moreover, the implementation of CE strategies to the existing PRE does not make the whole building 100% circular, in which all building elements are maintained and used in a circular manner. This study does not indicate the level of circularity a building has in percentage. Instead, it indicates what is currently being done in the existing PRE.

In addition, the results do not tell what new materials are integrated into the existing buildings that are not in alignment with the CE. It has become clear that if certain CE strategies could not be implemented then non-CE aligned solutions were used. Yet, what the non-CE aligned solutions were was not the focus point of this study. Moreover, in case 3 the circular requirements will be used as an assessment framework. Yet, since the project is ongoing it is difficult to assess. In addition, cases 1 and 2 indicated that there was no assessment framework. This limits the analysis of what the current situation is on the other parts of the building in which CE strategies were not implemented.

These limitations highlight the difficulty and complexity of collecting the data on the CE transition in the existing PRE.

9.5 Recommendations

The results from this study suggest that the current situation of existing PRE in the transition towards the CE has a lot of barriers. These barriers need to be dealt with otherwise it will be an obstruction for further CE development. Brand (1994) his six building layers is a sufficient tool that aids in identifying and structuring the implemented CE strategies on a building level (meso-scale). However, further research is needed to understand what can be done to enhance further CE development in the current existing building stock of the public sector. This study has focussed on the CGREA and gained a glimpse of what is currently being done on existing public building stock. Yet, this study suggests that there are barriers that have to be dealt with for future CE projects. This needs to be addressed in order to realise the Paris ambitions that the Government of the Netherlands has accepted for 2050. Even for the CGREA themselves, improvements are needed to reach the 2030 goal in maintaining and tendering projects in regards to the CE. The results of this study have implicitly gained knowledge on what the practice should do for better CE development in future projects. This is shown in the study as the Circular C's in the Synthesis chapter. There is not one solution to make existing PRE part of the CE. Therefore, future studies should assess and validate the mentioned field recommendations which are the Circular C's.

The study has found current barriers that were identified from three different existing PRE cases. In this study the first task of the DAS framework was used with its respected four perspectives (strategic, financial, fysical, and functional perspectives). The first task was assessing what the current situation was of the existing PRE transition to the CE. Future studies should be conducted with the next three steps of the DAS framework regarding this subject. With the DAS framework strategy can be created to match the current supply and demand with the future demand and supply. The results could then give organisations essential knowledge to design an accommodation strategy for their existing PRE.

In addition, further research is needed to establish its relevance with non-public existing buildings. Hence, it can be stated whether the results are only of relevance for existing PRE or not. Further studies then could focus on non-public existing buildings to see if different or similar barriers can be identified.

Future studies should take into account that when researching existing buildings to look in more detail in the Services, Space plan and Stuff layers of existing buildings. As this study has indicated, in these layers most CE strategies are implemented, and therefore more barriers can be identified. Moreover, further studies do not have to focus only on the building scale (meso-scale), it can be recommended to research also in the building elements (micro-scale) and in the urban area (macro-scale). The main reason is to gain more knowledge on the CE transition of the existing building on a smaller scale.

10. Conclusion

The aim of this study was to provide an overview of the current facts and barriers of the CE transition in existing PRE. With this study, a more nuanced view on the subject of CE transition in existing PRE is presented as indicated in the discussion chapter. This chapter focuses on concluding the study by answering first the sub-questions and then the main question.

10.1 Sub-question 1:

"How is the CE ambition integrated into CGREA's existing PRE?"

The CGREA is working on different strategies to realise the government's CE ambition for 2050. The CGREA themselves have a goal to procure and maintain their portfolio with regards to the CE by 2030.

From the theoretical research, it has become evident that the realisation of CE ambition in existing buildings of the CGREA is being realised in the renovation, maintenance, and demolition project phases. Currently, 79 projects are being developed in a manner that is aligned with the CE. From these 79 projects, 20 are focussed on the existing PRE of the CGREA. Three projects of the 20 existing PRE are selected and analysed.

The CE is gaining momentum in the organisation's culture. This became evident since CGREA organizes several activities around the CE ambition. This is done through advice days, workshops, and creating new tools and roadmaps. The latest tool is the BLOEI-instrument, which is often applied to new construction projects. Furthermore, sustainability advisors are the key actors that demanded the CE ambitions into the projects. From the bottom-up, the CE ambition is integrated into the existing PRE projects. This shows that an adaptable approach is taken in realising the CE ambition even if it was not included in the project scope. The slogan "learning by doing" is the main driver as it was indicated in the grey literature.

In addition, this was confirmed in the empirical research, as it had become evident that each case had its own unique style of realising the CE ambition into the projects. In case 1, four methods were created: 1- reusing existing building materials, 2- reusing building materials from donor projects, 3- using new circular materials, and 4- reusable materials for other projects. In case 2 there were no reusable materials available in the existing building. Therefore, materials had to be procured, which the client took responsibility for. In case 3 circular requirements were created to which the contractor had to adhere. Moreover, these requirements are used as an assessment framework.

10.2 Sub-question 2:

"How are CE strategies implemented in existing PRE?"

From the empirical research, it has become evident that CE strategies are being implemented into the existing PRE. Different CE strategies are being implemented in different building layers. The renovation and maintenance project phases are the natural stages in which CE strategies are implemented to the existing PRE.

From the empirical research, it has become evident that the Site, Structure, and Facade building layers had the highest form of CE strategy implementation. These building layers are often kept the way they are. Making these layers redundant by offering the same function as they previously had. This was applicable for all three analysed cases.

In the Service layer of the existing PRE, the installation systems that were in good condition and which indicated that they still worked were often reused. Reusing existing systems was the most applicable strategy in the Service layers of the cases. If existing systems could not indicate that they were in good condition then they would be removed to make space for new systems. The cases that did not have existing systems or systems that could not be reused were removed as well.

In the Space plan building layers, most CE strategies were implemented. The reason for this was due to the fact that there were existing materials and products available that made the application of the CE strategy possible. The function of the cases was often offices that were kept as it was if they met the demand of the new users. Moreover, interior elements that were in good condition were reused. From the empirical research, it was evident that efforts were conducted to make the newly added materials and products to the Space plan layer to be either demountable or biobased materials.

In the Stuff building layer, the least CE strategies are implemented. The main reason for this was the current state and availability of materials and products. Moreover, the reuse of existing materials and products highly depends on the approval of the user. Case 1 has indicated that if it does not meet the user's demand, then the materials in the Stuff layer can be discarded.

In essence, the R0-Refuse CE strategy was mostly implemented in the Site, Structure, and Facade building layers. The R3-Reuse CE strategy was mostly implemented in the Service, Space plan, and Stuff building layers. The R8-Recycle and R9-Recover CE strategies were not implemented in the existing PRE projects.

10.3 Sub-question 3:

"What challenges arise when implementing CE strategies in existing PRE?"

The implementation of the CE strategies to the existing PRE brought challenges to the overall project development.

From the empirical research, it has become evident that the Service layer had the most challenges compared to other layers of the building. The study indicated that reusing existing systems from other projects was not an option. The main reason was due to the fact that these existing systems did not indicate to be in a good condition. These existing systems of donor projects did not comply with the current building regulations. Moreover, several challenges do remain even if the systems were in good condition and did meet the current building regulations. The main challenge is to find a contractor that is willing to maintain the existing installations of the existing PRE. They are often willing to maintain the new systems as they have a manufacturer warranty, which minimises the risk. In addition, reusing existing systems means that over time they will become susceptible to disruptions. Moreover, there is no guarantee that services, technical parts, and maintenance will be provided to such systems in the future. Meaning that together with the scarcity of materials, the availability of these services will not be self-evident, which makes it a challenge to reuse existing systems.

In addition, physically implementing the CE strategies to the existing PRE are done by the contractors and their subcontractors. In order to do that, the contractor needs to have experience working with the CE materials. From the empirical research, it became evident that if this was not the case then searching and selecting CE materials was a challenge to the project.

10.4 Sub-question 4:

"How are these challenges currently managed in order to realise the CE ambition?"

The challenges that arose when implementing CE strategies to the existing PRE were related to maintaining existing systems and the CE related experience of the contractor. Both challenges were managed by the client taking the responsibility. The maintenance of existing systems was done by the client themselves. The mentioned challenges that are evident in existing systems were solved by making an additional maintenance plan. In this plan, the existing systems and their representative technical parts were overhauled and stocked. In addition, contractors that had no experience with the CE were aided by the client. Together with the architect, the client took the responsibility for searching and selecting CE materials.

In essence, if implementing certain CE strategies brought challenges to the project then these CE challenges would not be implemented due to the fact that the challenges exceeded the time and budget of the project. In this study, the challenges that were observed became a barrier. These barriers are then identified and validated and are used to answer the main research question. Implicitly, recommendations were formed that can aid the practice in further CE development of their building portfolio. This was stated as the Circular C's in this report.

10.5 Main Question:

"What are the current barriers to the circular economy transition for existing public real estate?"

In this study, data and knowledge are gained to answer the main research question. First, barriers were identified from empirical research. Through an expert panel, these barriers were then validated and improved. In total, 12 barriers are currently a barrier for further CE transitioning in the existing PRE. These barriers are:

No CE ambition in the project scope

Existing PRE projects that have no CE ambition in their project scope hinders the further CE transition, as CE strategies get neglected to other ambitions and demands in later stages of the project.

Unknown resource availability

Existing PRE often do not have material passports. Not having the knowledge on the availability of resources in existing PRE leads to neglecting the potential of implementing more CE strategies to an existing PRE.

No assessment framework

Not having an assessment framework in which the implemented CE strategies have to comply, makes it difficult to assess whether or not the desired CE ambitions are realised. Adequate evidence indicates the further realization of the CE ambition in the existing PRE.

Inexperience of the Contractor with the CE

The inexperience of the contractor leads to project delay. More time is needed to search, select and procure CE materials to implement CE strategies in existing PRE. Since time is an important asset in current projects, implementing the CE strategies is neglected. Moreover, the inexperience of the contractor could lead to the implementation of the lower level of CE strategies (R8-recycle and R9-Recover)

Cost and time-driven projects

If existing PRE projects exceed the given cost and time for a project then the CE ambition gets neglected and therefore CE strategies are not implemented.

No separate budget for CE strategies

Due to cost overruns, the implementation of CE strategies can get neglected. Having separate budgets for CE strategies can give assurance for implementation into the project.

Finding CE installations

In the current linear economy, it is difficult to find CE installations. The existing installations have the potential to be susceptible to disruptions over time. Moreover, there is no guarantee if the existing installations will have maintenance services available.

Unknown quality of building materials

If the quality of existing building materials is not indicated then these materials could be discarded and qualified as non-usable materials. Moreover, if existing building materials are being reused without assessing their quality, then this could lead to difficulties in later project phases.

Current regulations

Not all existing materials and products comply with the current building regulations. Strict regulations hinder harvesting existing materials and products. Moreover, this could be used as an argument to go for new materials and products.

No CE award criteria

Not having an award criterion could lead to other projects' ambitions being seen as a priority. The necessity of the CE ambition is then neglected.

User satisfaction

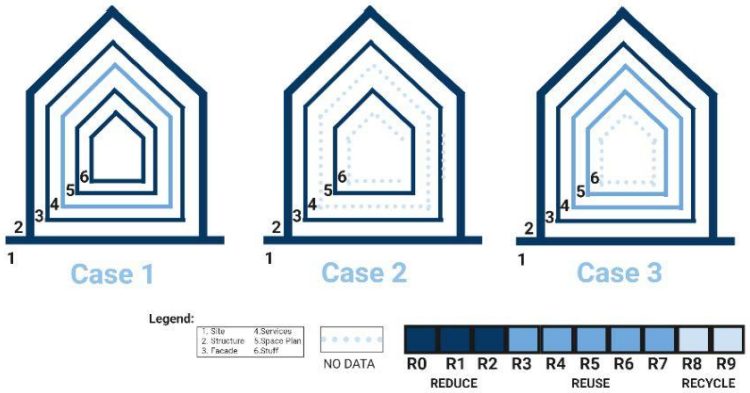
It is possible that the users are not satisfied with the implementation of CE strategies. If the CE ambition is not aligned with the users' demand, then the implementation of CE strategies will be hindered.

Definitive design without CE strategies

A definitive design without the integration of the CE strategies leads to not knowing the exact needed amount of materials. This could lead to a surplus of CE materials that can be discarded in the later project phases. Moreover, not knowing what CE materials are going to be worked with could lead to project delays.

Circular Economy in existing Public Real Estate

Current implementation of CE strategies in exisdting PRE:



Future circular project development: Circular C's

Commitment
Communicate
Continue
Conscious
Concession

Barriers to the CE transition in existing PRE:

- No CE ambition in the project scope
- Cost and time driven project
- Current regulations
- Unknown resource availability
- No separate budget for CE strategies
- No CE award criteria
- No assessment framework
- Finding CE materials
- User satisfaction
- Inexperience of the Contractor with the CE
- Unknown quality of building materials
- Definitive design without CE strategies

11. Reflection

11.1 Research Methods

Literature Review

The subjects in this study were mainly on CE in the Built Environment, especially focussed on the CE transition in existing PRE. The main approach was to find a gap in the scientific literature, to which I could contribute to. I experienced difficulties in selecting and finding relevant literature to analyse and use for this study. My mentors gave me good advice to catalogue the literature that was used. This aided in structuring my Theoretical Research section in this study. In addition, this gave me the right overview to create a Theoretical Framework that contributed to structuring and analysing the results.

Interviews

During the Empirical research case studies were conducted to gain data that could be used in answering the research questions. In these case studies, three types of interviews were held. First, were the exploratory interviews. Second, the In-depth interviews. Third, an expert interview. All these interviews were done through online platforms. I experienced it to be really easy to conduct interviews through an online platform. Yet, there were some drawbacks. The main drawback was the lack of personal and social atmosphere, which must have affected the way the interviewees responded to the questions. I solved this issue to give more time in building a rapport in the beginning with the interviewees in order to create a transparent and open interview session.

Data Collection

The data collection went effortlessly, everything was stored offline in a safe setting. And thanks to the protocols that were created respondents felt safe over the given data. Yet, the main issue arose after all the data was collected. Too much data was gathered in such a short time, which resulted in losing the overview of the gained data. As a result, too much time was spent on writing and structuring the data. In future studies, I should order every gained data from the beginning. Moreover, write the lessons learned from each data, even if it is only a draft, to make sure to not lose the overview.

“Barriers are the path forward, when identified it creates a mental process in people that makes seeing opportunities possible.”

- Robert Greene, 2020

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Appendix A: Exploratory Interview

List of requirements

The interviewee must have the following requirements to do this interview:

- Knowledge on the CE developments of the CGREA's PRE.
- Knowledge of who the decision makers are, regarding the 4 PREM perspectives, in realising the CE strategies to CGREA's PRE.

Basic info

Date:
Organisation:
Location:
Interviewer:
Interviewee:

The interview set up:

1. Introduction
A: Case discussion
B: Decision makers
2. Conclusion

The interview:

Introduction

First of all, I would like to welcome and thank you for participating in this interview. The research title is Towards the Circular Economy with Public Real Estate. As you know the CGREA wants to manage and procure their real estate portfolio in a circular manner by 2030. Nationally this aim, Towards the Circular Economy, is due by 2050. This research will focus on the current situation of the real estate portfolio of the CGREA regarding the Circular Economy developments.

Before we start conducting the interview do you accept that this interview will be recorded? <yes>. Thank you, I'll have to ask you the same question again so that it is also included in the recording. <starts recording>. Do you accept that this interview will be recorded? <yes> Thank you for your collaboration. During the research, all recorded data will be saved locally and in the end, it will be discarded when not needed.

A: Case Discussion

1. What are the projects where CGREA is currently implementing their CE strategies?
2. What kind of project are they? (renovation, new build, demolition, and or maintenance)?
3. Are the CE goals achieved for these projects?

B: Decision Makers

For this research four perspectives are being analysed for six different layers of a PRE. The perspectives are related to the strategic, financial, functional, and physical aspects of the project. While the six layers of a building are the stuff, space plan, services, skin, structure, and the site. I am looking for stakeholders that oversee those aspects in decision making about circularity. Moreover, these stakeholders should have a good insight in critical stages of the project.

1. Who is involved for the mentioned projects regarding the four perspectives?
2. Do these stakeholders also have a say about the circularity on the project?

C: Conclusion

Thank you for your contribution to this study.

Appendix B: In-Depth Interview Protocol

List of requirements:

The interviewee must have the following requirements to do this interview:
- Have worked on the case and have good insights in the critical stages of the project.
- Knows the CE strategies that are being applied to the case
- And has to say something from either two of the following perspectives: Strategic, Financial, Functional, and Physical of the case.

Basic info

Date:
Organisation:
Location:
Interviewer:
Interviewee:

The interview set up:

1. Introduction
A: Background information
B: CGREA
C: Case background information
D: Perspective Analysis
2. Conclusion

The interview:

Introduction

First of all, I would like to welcome and thank you for participating in this interview. The research title is Towards the Circular Economy with Public Real Estate. As you know the CGREA wants to manage and procure their real estate portfolio in a circular manner by 2030. Nationally this aim, Towards the Circular Economy, is due by 2050. This research will focus on the current situation of the real estate portfolio of the CGREA regarding the Circular Economy developments.

Before we start conducting the interview do you accept that this interview will be recorded? This recording will only be used to analyse and take notes of this interview. <yes>. Thank you, I'll have to ask you the same question again so that it is also included in the recording. <starts recording>. Do you accept that this interview will be recorded? <yes> Thank you for your collaboration, the recording will be used to transcript the interview. The transcription will then be analysed, your name will be left out in the analysis. During the research, all recorded data will be saved locally and in the end, it will be discarded when not needed.

A. Background information interviewee

The question In this first part of the interview is related to you. These questions are needed to understand your role in the case better.

1. Can you introduce yourself briefly?
2. What is your background at CGREA?
3. How long have you been involved in the redevelopment of CGREA's PRE?
4. How important is the CE within these redevelopments?

B. CGREA related questions

In this second part of the interview, the questions are related to the CGREA. As mentioned earlier CGREA wants to become part of the CE by 2030. The following questions will give insights on how the CGREA is working towards this goal.

1. How does the CGREA deal with the demand to transit the current real estate portfolio to the CE?
2. What are the challenges that CGREA faces in realising the CE goal?
3. Do you think that there are enough resources to realise the CE goal?
4. Is there anything that can be done better or different to achieve the CE goal?

C: Case Background Information

In this third part of the interview, questions related to the background information of the case will be asked.

1. What is your relationship with the project?
2. With who did you work the most with for this project?
3. What were the main objectives for this project?
4. What kind of assessments were made for this project?
5. What were the challenges for this project?

D: Perspective analysis

The following questions are divided into four perspectives. These are strategic, financial, functional and physical. As you know CGREA is implementing their circularity strategies per layer of a building. The layers of Brand are stuff, space plan, services, skin, structure, and the site.

Main questions:

1. What perspectives do you oversee?
2. What kind of tensions did you experience when implementing the CE strategies for this project?
3. Did these tensions delay or even cancel the implementation of further CE strategies for the project?
4. How did you manage these tensions afterwards?

Appendix C: Letter of Consent

Betreft: Geïnformeerde toestemming

Geachte heer/mevrouw,

Zoals u wellicht weet, wil het RVB hun vastgoedportefeuille tegen 2030 circulair beheren en aanbesteden. Landelijk moeten de Circulair Economische ambities in 2050 al behaald worden. Dit onderzoek zal zich richten op de huidige situatie van de bestaande vastgoedportefeuille van het RVB met betrekking tot de ontwikkelingen in de circulaire economie.

U wordt uitgenodigd om deel te nemen aan het onderzoek met de titel: “The Circular Economy transition in existing Public Real Estate”.

Verwachting van de geïnterviewde:

- Alleen de titel/werkfunctie van de geïnterviewde zal geopenbaard worden, persoonlijke naam en gegevens zal anoniem gehouden worden.
- Dat het duidelijk is, over de aard, methode, doel en belasting van het onderzoek.
- Dat het duidelijk is, dat het geluids- en/of beeldmateriaal (of de bewerking daarvan) en de overige verzamelde gegevens uitsluitend voor analyse en wetenschappelijke presentatie en publicaties zal worden gebruikt.
- Dat de geïnterviewde het recht voor om op elk moment zonder opgaaf van redenen de deelname aan dit onderzoek te beëindigen.

Aan het eind van het interview zal een samenvatting van de resultaten van het onderzoek gedeeld worden met de geïnterviewde. De geïnterviewde heeft het recht om wijzigingen en fouten te melden aan de gedeelde samenvatting. Ook vertrouwelijke informatie, die niet geopenbaard mag worden aan het einde van het onderzoek, kunt u melden aan mij.

Als u akkoord gaat met de bovengestelde aspecten, wil ik u alvast bedanken voor uw deelname aan het onderzoek. Mocht u vragen hebben over dit onderzoek, kunt u altijd contact opleggen via de telefoonnummer:

Met vriendelijke groet,

Çağrıhan Aslan

Appendix D: Case Selection

There are 74 projects of the CGREA which are being developed with the CE strategies. Of which 12 projects are New built projects. And 6 projects, which are demolishing projects. Of the 74 projects, 3 are being sold. And in 18 projects only a part of the building or a layer of the building is CE developed. And there are also 15 projects, which are uncertain or yet to be started to be developed. This leaves us 20 projects of which are existing buildings that are being either renovated or maintained. From these 20 projects 5 are chosen, in which 3 will be used for the case study and 1 will be a reserve case. As explained in Chapter 4 Methodology, the CGREA is a governmental organisation. Therefore, information and data that is gathered from there is mostly confidential information. Hence, the project names are numbered and not named by their original project name. The CGREA is informed of which case belongs to which project.

Cases	Selection Criteria								
Projects	similarities						differences		
	Owned	Existing	CE	Recent (3y)	Tensions	Offices	Phase	Strategies	Situation
Case 1	+	+	+	+	+	+	Renovation	+	Finished
Case 2	+	+	+	+	+	+	Transformation	+	Finished
Case 3	+	+	+	+	+	+	Renovation	+	Ongoing
(Extra) Case 4	+	+	+	+	+	+	Renovation	+	Ongoing
(Extra) Case 5	+	+	+	+	+	+	Renovation	+	Ongoing

Table 1: Chosen projects for the case study (Source: Author).

Appendix E: Case 1 methods in detail

Method 1: **Reuse of case 1**	**Method 2:** **Elsewhere to case 1**	**Method 3:** **New materials to case 1**	**Method 4:** **Case 1 to elsewhere**
Reused structure: stairwells, ceiling restaurant, events counter, spiral staircase, VIP parking garage lounge, toilet units	**Reusing furniture of other projects:** Mainly used for main entrance and first floor	**The ceiling entrance is demountable**	**For case 1 steel construction is used for the new parts of the building (entrance + special conference hall): it is made demountable**
Disassemble ash wood wall finishes and reuse in new positions: from three conference halls to the entree of case 1 and first-floor event hall	**Using old building elements differently:** interior walls made of discarded material, entrance.	**3D printing of building elements:** "'Building a seamless digital supply chain from design to production to quick instalment. By introducing new technologies we offer a user-friendly, tailor-made, cleaner and quicker building process."	**Woodwork and walls in the special conference hall are also made demountable**
Reusing bricks from walls to be removed (cleaning stones or processing masonry in stucco): first-floor restaurant and park garage	**Procuring used floor coverings and leasing floor coverings**	**In smaller conference halls using reused fabric elements for soundproofing:** also used in the special conference hall of the users of case 1.	**to build:** as many mechanical connections as possible instead of chemical ones **dismantle instead of demolish:** - circular 'demolition': specialized (sub)contractor

Interior elements and blinds from 9th to 11th floors in reuse and storage on other office floors: systeemwanden inzetten, zonweringen hergebruiken, beschadigde systeemplafondplaten vervangen en vieze tapijttegels vervangen door schone en/of gebruiken als isolatie in wanden			
reuse grid ceilings in the same or new position: in all floors			
reuse lockers and/or interior lockers lock: event hall and all office floors			
Reuse counters in a new position: To conference hall third floor			
Trees and water on-site reuse: keeping the green and water in front of the entrance			
Furniture: refurbished and reused			

Appendix F: Case studies overview

<table>
<tr><th colspan="4">OVERVIEW: CASE 1 Temporary Accommodation</th></tr>
<tr><th></th><th colspan="2">Strategical
Financial</th><th>Physical</th><th>Functional</th></tr>
<tr><td>Site</td><td rowspan="5">Opportunity sessions were held to discuss the opportunities in which CE strategies could be implemented. From the session, four methods to implement CE strategies came forth. The first method was to reuse the existing materials in case 1. Second, reusable materials are searched and selected from other projects. Third, new circular materials are added. Fourth, reusable materials from case 1 are reused elsewhere. These strategies were conducted within the financial capacity of the case.</td><td>R0-Refuse: The site is kept as it is.</td><td rowspan="3"></td></tr>
<tr><td>Structure</td><td>R0-Refuse: The Structure is kept as it is.
R3-Reuse: Stairwells, ceiling restaurant, events counter, spiral staircase, VIP parking garage lounge, toilet units are reused as well.</td></tr>
<tr><td>Facade</td><td></td></tr>
<tr><td>Services</td><td>R3-Reuse: - Safety and fire systems were reused.
- Blinds from 9th to 11th floors in reuse and storage on other office floors.</td><td>New security-, fire safety- and climate installations were added due to the functional needs of the users.</td></tr>
<tr><td>Space Plan</td><td>R0-Refuse: - Office spaces were kept as it is.
R3-Reuse: - Interior elements from 9th to 11th floors in reuse and storage on other office floors.
- Existing ash wood wall reused.
- In all floors grid ceilings are reused
R7-Repurpose: Interior walls made of discarded materials.</td><td>Functional needs of the users led to adding specific rooms with certain routes in them.</td></tr>
<tr><td>Stuff</td><td>R1- Rethink: Leasing floor coverings
R3- Reuse: - Lockers on office floors and event hall are reused.
- Furniture is reused.</td><td></td></tr>
</table>

<table>
<tr><th colspan="5">OVERVIEW: CASE 2 Warehouse Transformation</th></tr>
<tr><th></th><th>Strategical</th><th>Financial</th><th>Physical</th><th>Functional</th></tr>
<tr><td>Site</td><td colspan="3">With the implementation of CE strategies, the history of the area is preserved. This was seen as an important factor for realising placemaking. Which attracted firms from the creative and technology sector to be the current users. The revenue is generated for the coming 10 to 15 years and is used to manage the grass, sewers, and lights of the whole site.</td><td rowspan="6">The CE transition of the existing buildings in the area attracts new industries and companies. The users do not see it as an old building with reused material, they adore the CE development of the project and area.</td></tr>
<tr><td>Structure</td><td rowspan="5">The strategy was to come close to the realisation of a 100% circular building. This meant that if it was possible to implement CE strategies to a building layer, then it was implemented. Yet, if this was not possible then it would not be implemented.
According to the architect, the building is 70% a circular building.</td><td rowspan="5">Budget and planning were the main drivers for this project. This meant that if an implementation of a certain CE strategy costs more than expected and hinders the project process, then that CE strategy would not be executed.</td><td>R0-Refuse: The Structure is kept as it is.
R4-Repair: Roof trusses are repaired.</td></tr>
<tr><td>Facade</td><td>R2-Rethink: Searching and using a facade from another project.</td></tr>
<tr><td>Services</td><td></td></tr>
<tr><td>Space Plan</td><td>R2-Reduce: Depending on the possibility, newly added commodities are demountable or biobased materials.

R3-Reuse: reused sandwich panels for interior insulation and reused trespa panels in the sanitary facilities.</td></tr>
<tr><td>Stuff</td><td></td></tr>
</table>

OVERVIEW: CASE 3 Building Complex				
	Strategical	**Financial**	**Physical**	**Functional**
Site	Prior to the tender phase, circular requirements were created with an external party. These requirements were created to implement CE strategies to the project. These requirements had to trigger the market parties in finding circular solutions. The aim is to learn from the project and create better circular requirements for future projects.	The circular requirements were created within the limits of the project budget. Yet, since the project is still ongoing it is not clear if realising the circular requirements will need more budget than expected.	**R0-Refuse:** The site is kept as it is.	The subcontractor looked specifically to the existing materials of the building and to the value of the harvested materials. The harvested materials that could not be reused elsewhere are put on an online circular market space where they get a second life.
Structure			**R0-Refuse:** The Structure is kept as it is.	
Facade			**R2-Reduce:** Only new glasses are added to the facade.	
Services	The circular requirements are related to the space plan of the project, which are the interior walls, ceilings, doors, and floors. Furthermore, the technical layer of the building complex will be renovated to fit the current demand.		**R3-Reuse:** 50% of the air handling units were in reusable condition.	
Space Plan			**R3-Reuse:** Interior walls, ceilings, floors, and floors are being reused.	
Stuff				