Tax Shift for Circularity

- a policy-oriented life cycle costing analysis of two construction case studies at the Floriade

Thesis

submitted in partial fulfilment of the
requirements for the degree of

Master of Science in
Industrial Ecology

by

Manon van Ginkel

Universiteit Leiden

TU Delft

"*Economics is the mother tongue of public policy, the language of public life and the mindset that shapes society*." - Kate Raworth (2017, p. 5)

Author	Manon van Ginkel s2589443	
Date	November 2022	
Universities	Leiden University Faculty of Science	Delft University of Technology Technology, Policy and Management
Supervision	First supervisor: Second supervisor: Daily supervisor:	David Peck Karel Van den Berghe Felipe Bucci Ancapi
Company	Copper8 James Wattstraat 100, 1097 DM Amsterdam	Marijn Polet Cécile van Oppen

Cover page image credit: gyn9038 / iStock.

Abstract

The Circular Economy (CE) has emerged as an economic paradigm that could provide a pathway to sustainable development. The transition to a CE is a complex process requiring wide multi-level and multi-stakeholder engagement, which can be facilitated by appropriate policy interventions. As value retention processes in the CE require additional labour, the transition from a linear to a circular economy can be viewed as a transition from a capital-based economy to a labour economy. Consequently, a 'circular tax shift', based on an introduction of environmental taxation paired with a reduction of labour taxation, could be a powerful lever for public policy.

The aim of this research was to assess the effect of this tax shift on the financial feasibility of circularity in the construction sector. The main research question is: 'What is the effect of a circular tax shift on the financial feasibility of circular construction, in relation to linear construction?'

To answer this question, a micro-economic analysis has been applied on two circular construction case studies: the 'The Voice of Urban Nature' and 'Circuloco' pavilions that were built at the Floriade World Expo 2022. A linear and circular variant have been developed for both case studies, for which a life cycle costing analysis has been conducted. A life cycle assessment has been applied to determine the environmental impacts, on the basis of which environmental taxation was applied under the taxation scenarios, which reflected varying levels of the circular tax shift.

The results show that under the current taxation system, the total life cycle costs for the circular variants are 2,0 - 2,7% higher than for the linear variants, though environmental impacts are lower by 38,7 - 52,7%. The effect of the tax shift is that the cost differences between the linear and circular variants decrease, and in two of the high level tax shift scenarios, the circular variant of the Circuloco pavilion becomes more financially feasible than the linear variant. Although the external validity is low, the results of the research imply that the suggested circular tax shift could create incentives to use secondary and biobased materials in construction.

The tax circular shift also implies many other effects, which are outside the scope of this research, but have been suggested as subjects for follow-up research.

Keywords: Circular Economy . Economic Policy Instruments . Environmental Fiscal Reform . Sustainable Development . Circular Built Environment

Acknowledgments

This document marks the end of a journey. Although I am relieved that this journey has come to an end, I have very much enjoyed every step of the way. Conducting this research has been a huge learning process, in terms of hard knowledge, but even more so in terms of soft skills, such as expectation management and identifying what motivates me personally.

I would like to thank my supervisors for facilitating this process. David and Karel have provided me with inspiration, guidance and gave me the freedom to explore this challenging topic. It was great to have Felipe by my side for support, requested and unrequested advice.

Thanks to my colleagues from Copper8, in particular Cécile, Marijn, Floris and Gerben, for being my sparring partners, helping me in making decisions and giving me the possibility to let these results land in the policy and business spheres.

This would not have been the same without my dear study friends Anne-Linn, Floor and Simon, who profoundly inspired and helped me in finding my passion and were always available for support.

Lastly, I would like to thank all of my friends, family and those who helped and supported me along the way. It has been a pleasure!

Contents

List of Figures

1. Introduction

In an era of ambitious sustainability pledges by both public and private actors, one of the most important questions within present-day society remains how economic, environmental and social sustainability can be achieved. The current linear economic thinking is resulting in overexploitation of resources and the corresponding pollution, waste generation and dependence on complex global supply chains, which have demonstrated their associated risks in recent times. If the current path of resource consumption is continued, society will be exposed to all kinds of risks, such as price volatility and supply chain disruptions.

The Circular Economy (CE) has emerged as a an alternative economic paradigm (Ghisellini et al., 2016; Hartley et al., 2020; Korhonen et al., 2018). The CE aims at closed-loop utilization of materials and energy, sustaining the value of resources within the economy (Bruel et al., 2019; Ghisellini et al., 2016; Lakatos et al., 2021), through the narrowing, slowing and closing of material loops and substitution of finite resources for renewable resources (Hanemaaijer et al., 2021). This reduces the economic importance of resource extraction, which provides perspectives for dealing with problems regarding raw materials scarcity, security of supply, environmental pressures and conservation of natural capital, as well as creates economic opportunities (SER, 2016). Although interpretations of the CE have been criticized for neglecting the social dimension of sustainability, the CE could provide a pathway to sustainable development (Clube & Tennant, 2020; Hartley et al., 2020; Kirchherr et al., 2017; Moreau et al., 2017).

The concept of CE has gained attention by scholars, private parties and policymakers in the last decades, although its implementation is clearly hampered. Previous research devoted to the barriers for CE highlights the multitude of obstacles to be overcome. This applies for the CE in general (Geissdoerfer et al., 2017; Ghisellini et al., 2016; Kirchherr et al., 2018; Masi et al., 2018), and for CE in specific economic sectors, such as the construction industry (Adams et al., 2017; Hart et al., 2019; Kooter et al., 2021; Munaro et al., 2020). Hart et al. (2019, p. 1) stated that "*after decades of discussion and research around CE and related concepts (e.g. Industrial Ecology, Industrial Symbiosis, Industrial Ecology, Cradle to Cradle), the make-use-dispose model of resource consumption […] is still deeply entrenched*". Laktuka at al. (2021, p. 1) highlighted that "*national governments must play an active role in developing national planning documents, creating a clear vision for the future, and building a sustainable policy environment*".

In the Netherlands, policies aimed at the transition to a CE have demonstrated little success so far. The set ambitions to reach a fully circular economy by 2050 and halve the use of abiotic materials by 2030 are not on their way of being met. Therefore, the Netherlands Environmental Assessment Agency (PBL) advocated for an intensification of circular economy policies with more "pressure and compulsion" (Prins & Hanemaaijer, 2022). Simultaneously, both Dutch and European climate policies have been criticized for their failure to address the many socio-ecological implications of the transition (Calisto Friant et al., 2021), and for being socially unjust (Jhagroe, 2022).

While research on the barriers, definitions and interpretations has provided valuable contributions to CE literature through which levers and goals for CE policy can be identified, the time has arrived to focus on possible solutions. As Beeks and Lambert (2018, p. 5) have expressed it, *"climate change, ecological systems destruction, and species decimation have reached a point of criticality that now calls for real action, a viable response."* In a review on the relation between the circular built environment and policy instruments, Bucci Ancapi et al. (2022) point out that CE literature focusses on technically driven and arguably 'easy to understand and implement' approaches and that there is a need for envisioning new policy perspectives, as comprehensive approaches towards implementation in academia are lacking.

A holistic solution that could address the economic, environmental and social dimension of sustainability simultaneously is found in fiscal policy, through the creation of financial incentives that stimulate CE practices. An example of such fiscal policy is an environmental fiscal reform. By levying taxes on the use of materials and pollution and using the revenues to lower the tax on labour, theoretically two stimuli for circularity can be created simultaneously, by addressing the additional labour required for CE and the reduced need for material inputs. Because they affect prices, fiscal policy instruments are potentially effective and efficient in influencing the behaviour of economic actors (Vence & López Pérez, 2021). As a matter of fact, a substantial body of literature promotes the use of market instruments based on prices and taxation in environmental policy (Andrew et al., 2010; Baumol, 1972; Metcalf, 2019; Milne, 2014; Nordhaus, 2012; OECD, 2010; World Bank, 2017; Zhu et al., 2018).

Vence & López Pérez (2021) elaborately discussed some of the fiscal frameworks for CE suggested in literature, including a proposal for a circular tax shift by The Ex'tax Project, a Dutch think-tank that advocates for the use of fiscal instruments for social and environmental policy. Macroeconomic analyses showed that the suggested tax shift, from labour to resource use and pollution, can have positive effects on economic growth, employment, import dependency and the climate (Groothuis, 2016, 2022), demonstrating the potential of the tax shift to contribute to sustainable development. Vence & López Pérez (2021) and Peter Gersen, cofounder of The Ex'tax Project (personal communication, August 17, 2021), highlight that reduced labour taxation stimulates employment in all labour-intensive economic sectors, e.g. in care, education or crafts industries. As activities in these sectors tend to be located closer the user, this results in geographical decentralisation of economic activities (López-Bermúdez & Vence, 2020).

Although the potential benefits of the suggested tax shift are plural, the subject tends to be surrounded by political sensitivity, which makes implementation challenging. Granted that it changes the boundary conditions in which the entire economy operates, numerous actors will be affected, some of whom will profit from the new situation, and some of whom will not. As fiscal policy instruments aim to change the behaviour of actors, it is essential to assess how single actors are affected before implementation is considered. Some micro-economic research has been conducted by Copper8, a Dutch research and consultancy firm specialised in circularity. The case study-based cost analysis assessed the effect of a tax shift for circularity on the investment and demolition costs of several case studies in the construction sector, and concluded that (Copper8, 2022). However, only one life cycle phase is covered in each case study. Only one previous academic study by Labandeira et al. (2007) was found, which addressed fiscal reform for sustainability on micro-scale level, which assessed the effect of fossil energy taxation on household expenditures from an integrated micro- and macro-economic perspective.

1.1 Research aim

This research was initiated to further explore the circular tax shift as a policy instrument for the transition to a CE, building on to the previous research by Copper8 and following the case study-based approach. The contribution of this research lies in providing additional case studies and including a more holistic, full life cycle perspective through the application of tools from the fields of industrial ecology and economics.

To make the research feasible within the set timeframe, some choices regarding the research scope were made. Firstly, the construction sector has been chosen as subject of analysis. Different economic sectors have different labour, resource and pollution intensities, and therefore the effect of the tax shift will vary. The construction sector makes an interesting case study for micro-economic analysis, as it is both material and labour intensive. Ness & Xing (2017) and Munaro et al. (2020) pointed out that the construction sector has a crucial role to play in the transition to a CE, as it is both the largest consumer of natural resources worldwide, and a major source of greenhouse gas emissions an waste. Secondly, financial feasibility has been chosen as the unit of analysis. Rooted in economic theory, it is assumed that economic actors are motivated by, among others, financial reasons. Consequently, in order to influence the behaviour of actors, it is effective to influence the financial feasibility of these behaviours. A benefit of this choice is that it allowed for quantification of the results. Lastly, the financial feasibility is viewed from the perspective of the project developer, as this is the actor that initiates, plans, executes and controls the construction process.

These scoping choices resulted in the following main research question: 'What is the effect of a circular tax shift on the financial feasibility of circular construction in relation to linear construction?' To answer this question, a three-fold of sub questions is specified:

1. How do circular and linear construction currently compare in terms of financial feasibility?
2. What are the environmental impacts of circular and linear construction?
3. How is the financial feasibility of circular and linear construction affected by the different taxation scenarios?

The structure of this thesis is as follows. First, the theoretical foundations that this thesis resorts to are elaborated. Second, the Analytical framework discusses the applied industrial ecology and economic tools. In the Methodology section, the case studies are introduced and it is explained how the quantitative study of two circular construction projects has been executed, and how the findings have been analysed. Then, the findings from the analyses are presented per research question in the Results chapter. In the discussion, the findings are reflected on, and limitations are addressed. In the Conclusion, the most important conclusions are summarised. Finally, suggestions for future research are highlighted in the Suggestions for follow-up research.

2. Theoretical framework

Before elaborating on the research approach, this chapter discusses the key concepts and theories, all within the context of the Netherlands. First, it is explained how the CE is viewed in this research, discussing its related definitions, strategies and implications. Second, the construction sector is described within the context of the CE. Lastly, the policy options regarded in this research are elaborated and the circular tax shift is conceptualised.

2.1 Circular Economy

The concept of CE developed in the 1990's, building onto related fields, such as Industrial Ecology and Environmental Economics (Ayres & Ayres, 2002; Bruel et al., 2019; Ghisellini et al., 2016), and drawing inspiration from the way natural ecosystems are organised. After more than 30 years of development, still no commonly accepted definition exists. In an analysis of 114 definitions, Kirchherr et al. (2017) identified some general principles that recur in most definitions in literature, including the reduction, reuse, recycling and recovery of materials, taking a systems perspective on production systems.

Some authors argue that over the years, the concept definition has become more diluted rather than more pronounced (Harris et al., 2021; Lazarevic & Valve, 2017). Calisto Friant et al. (2021, p. 1) state that: "*the CE is a contested paradigm, for which many competing interpretations exist, each seeking varying degrees of social, ecological and political transformation*". However, circularity in and of itself does not ensure social, economic, and environmental performance (Walzberg et al., 2021). Some authors emphasize the objective of decoupling economic growth from resource consumption as a core concept within the CE, reflected in the focus on resource efficiency (Ghisellini et al., 2016; Gregson et al., 2015; Ness & Xing, 2017). However, as pointed out by Ness & Xing (2017), a focus on efficiency may lead to rebound effects or a "Jevons paradox", in which increased efficiencies at the product level lead to increased usage and impacts at the macro-level (Figge et al., 2014; Harris et al., 2021). This makes the case for a more systemic approach to viewing the CE, and a focus on effectiveness (doing the right things), rather than efficiency (doing things right) (Chertow, 2000; McDonough & Braungart, 2010; Webster, 2013).

This thesis follows the strand of literature that regards the CE not as an aim in itself, but rather a, means, strategy, pathway or roadmap to achieve sustainable development in all three dimensions: environmental quality, economic prosperity and social equity (Anastasiades et al., 2020; Harris et al., 2021; Korhonen et al., 2018; Munaro et al., 2020; Sassanelli et al., 2019). Green & Healy (2022) make the case for addressing these three dimensions simultaneously, by stating that: "*socioeconomic inequalities drive emissions-intensive consumption and production, facilitate the obstruction of climate policies by wealthy elites, undermine public support for climate policy, and weaken the social foundations of collective action*."

The definition framed by Korhonen et al. (2018, p. 39) is adopted, viewing the CE as:

> *"an economy constructed from societal production-consumption systems, that maximizes the service produced from the linear nature-society-nature material and energy throughput flow. This is done by using cyclical materials flows, renewable energy sources and cascading-type energy flows. Successful circular economy contributes to all the three dimensions of sustainable development. Circular economy limits the throughput flow to a level that nature tolerates and utilises ecosystem cycles in economic cycles by respecting their natural reproduction rates."*

This description recognizes the physical limits to circularity, such as the dependence on biological cycles and thermodynamic constraints (Cooper et al., 2017), as well as the aim for sustainable development. The CE's potential advantages identified by Korhonen et al. (2018) are illustrated in Figure 2-1.

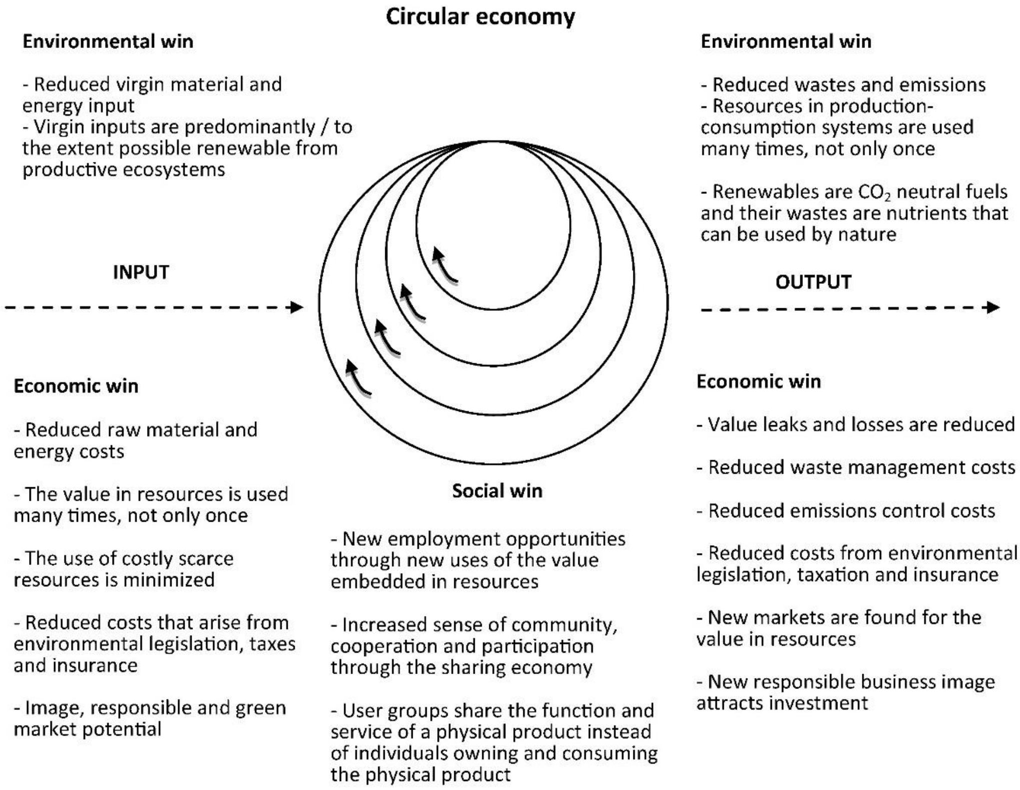

Figure 2-1 Circular Economy for sustainable development: the win-win-win potential of circular economy (Korhonen et al., 2018).

2.1 CE strategies

The CE is operationalised at multiple levels of the economy: the micro level (products, companies, customers), meso level (eco-industrial parks, economic sectors) and macro level (national, regional) (Ghisellini et al., 2016; Harris et al., 2021; Kirchherr et al., 2017). Shifting to a CE therefore requires a wide multi-level and multi-stakeholder engagement from all societal levels (Ekvall et al., 2016).

Gregson et al. (2015) have differentiated two main strand of CE strategies. First, utilizing closed-loop, system approaches, whereby waste streams from one company becomes feedstock for another, as in an eco-industrial park. The approaches of Industrial Symbiosis and Urban Metabolism address the systemic material and energy flows at the meso and macro level. The second strand refers to the need to extend the longevity of products by maintaining and improving their value, quality, and performance. This is coined the extended product life approach, and focuses on the micro level.

On the product level, different value retention options are identified in literature. These so-called R-strategies are illustrated in Figure 2-2 and build upon the Ladder of Lansink: a hierarchy for waste management (Lansink, 1979). The strategies are ordered by priority depending on their level of circularity, involving different life cycle stages and stakeholders. The strategies such as reuse and repair aim to preserve resources in their lowest entropy state, i.e. the highest level of order (finished products), while recycling and recovery deal with the most disperse and diffuse material forms (particles and molecules) and thus require more energy and efforts (Blomsma & Tennant, 2020).

The prioritization should not be interpreted as a strict hierarchy. Due to the systemic nature and context dependency of industrial activities, the preferred stock management option is not an inherent property of the theory, but a function of the circumstances under which it will be implemented (Diaz et al., 2021; Traven, 2019). For example, geography and transport distances play a role here (Vadenbo et al., 2017), and, to a lesser extent, transaction costs and packaging (Stahel, 2013).

The R-strategies have been captured in different frameworks, including 3R, 4R, 6R, 9R (Kirchherr et al., 2017), and even 10R (Reike et al., 2018). The 3R framework generally constitutes of Reduce, Reuse and Recycle, corresponding to the blue blocks in Figure 2-2, with the 9R strategy as a more elaborate approach to the same notion. The PBL adopts an approach that is similar to the 3R framework, but adds a fourth strategy regarding the substitution of finite materials by renewable or less harmful materials (Hanemaaijer et al., 2021).

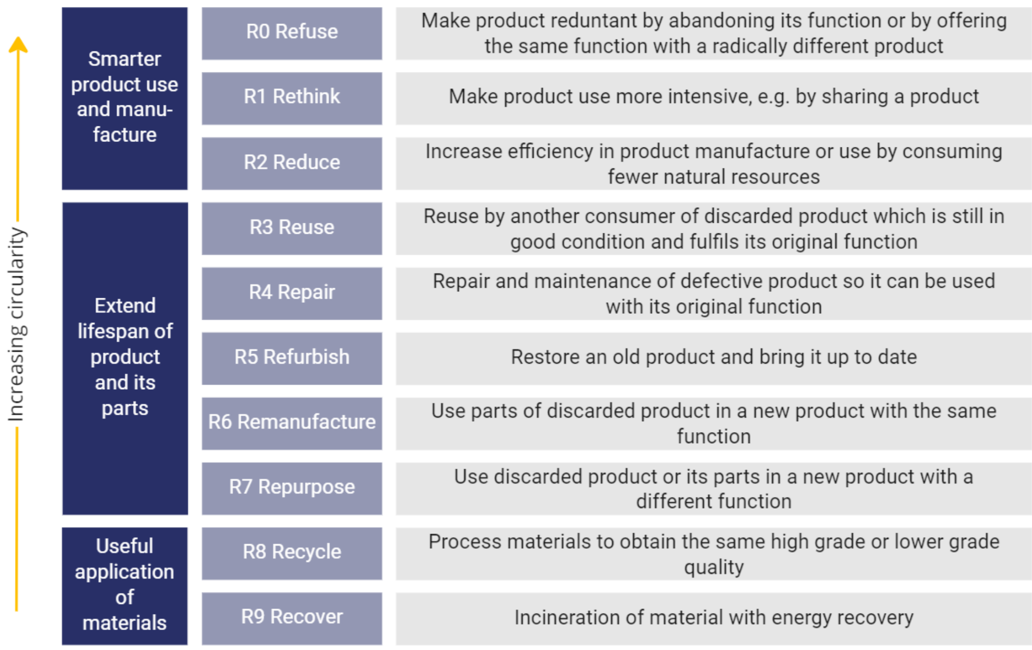

Figure 2-2 The 9R framework, adapted from Potting et al. (2017, p. 5).

The basic premiss of the R-frameworks is that each step down the R-hierarchy represents a net loss of value, either in economic or entropy sense. Generally speaking, it applies that the higher the R-strategy, the smaller the activity loop and the larger the component of the product that stays intact. Each loop involves some level of human labour to retain value within in the products and materials, or, in the lowest Rs, at least the embodied energy. In this sense, the transition from a linear to a circular economy can be seen as a substation process from value from materials to value from labour. As Stahel (1982, p. 72) puts it: "*Compared to fast-replacement, product-life extension is a substitution of service activities for extractive and manufacturing industries, and a replacement of largescale capital-intensive companies by smaller, labour-intensive, locally integrated work units*".

2.2 Circularity in construction

The built environment is characterised by long life spans, complex supply chains with numerous stakeholders, and hundreds of components and ancillary materials that interact dynamically in space and time (Eberhardt et al., 2019; Hart et al., 2019). Circular construction starts with a design that takes into account all phases in the life cycle of a building, including subsequent life cycles of the building, building components, products and materials, as well as the associated technological challenges (Schut et al., 2016). As a result of these complexities, the transition to a CE in the construction sector is challenging. To understand how and when to intervene, it is relevant to take a closer look at the involved components and associated lifespans and life cycle stages.

2.2.1 Shearing layers

A building can be viewed as a collection of Stewart Brand’s “shearing layers", each of which is characterised by different life cycle durations or ‘rates of replacement’. Brand (1995, p. 12) argued that there is no such thing as a building and “*a building properly conceived is several layers of longevity of built components.*” According to Brand (1995), a building primarily consists of the layers depicted in Figure 2-3. The *Site* is the location of the building, which is considered eternal. The *Structure* refers to the materials from which the building is constructed, lasting between 30 and 300 years, although the lifetime often does not exceed 60 years for many reasons. *Services* include the electrics, boiler, plumbing, etc. These have a typical lifespan of 15 years. The *Skin* refers to the exterior surfaces, such as windows and doors; lasting typically 20 years. The S*paceplan* includes the interior walls, ceilings and floors. In a domestic building, these may last 30 years. Lastly, the *Stuff* category refers to is characterised by the very short lifespan to the furniture; these tend to move around very frequently. Due to the differences in functionality and lifespan, a different R-strategy can be prioritised for each shearing layer to give substance to circular construction.

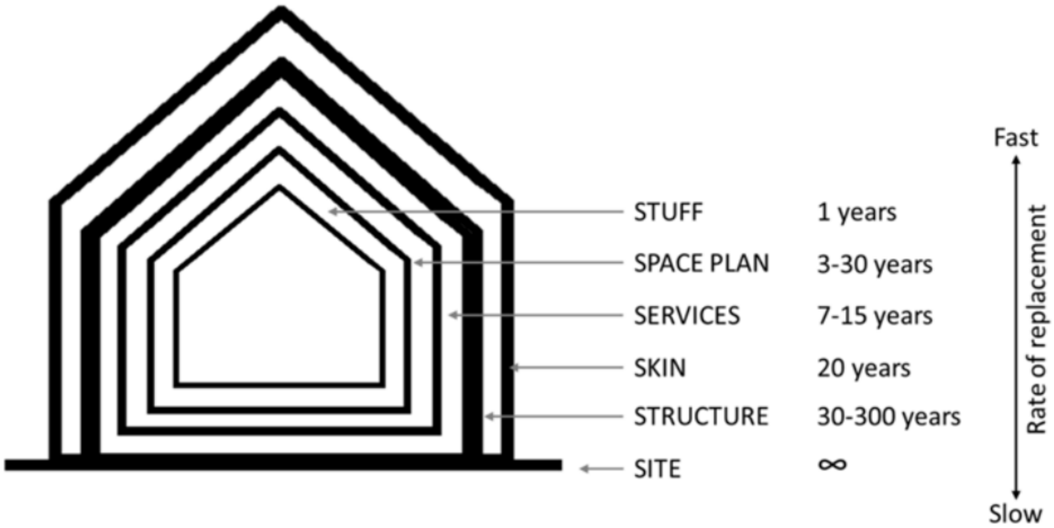

Figure 2-3 Building elements in relation to lifespan and rate of replacement, adapted from Brand (1995) and retrieved from Eberhardt et al. (2019).

2.2.2 Life cycle stages

Figure 2-4 shows the different life cycle stages of a building or component, and the R-strategies associated with each stage. The production stage includes design, raw materials extraction, processing and transport. During the construction stage, the building takes its form. The use stage is usually the longest in the building life-cycle and includes activities such as maintenance. The end-of-service stage refers to the disassembly or demolition process. In each of the life cycle stages, different R-strategies can be applied to increase circularity.

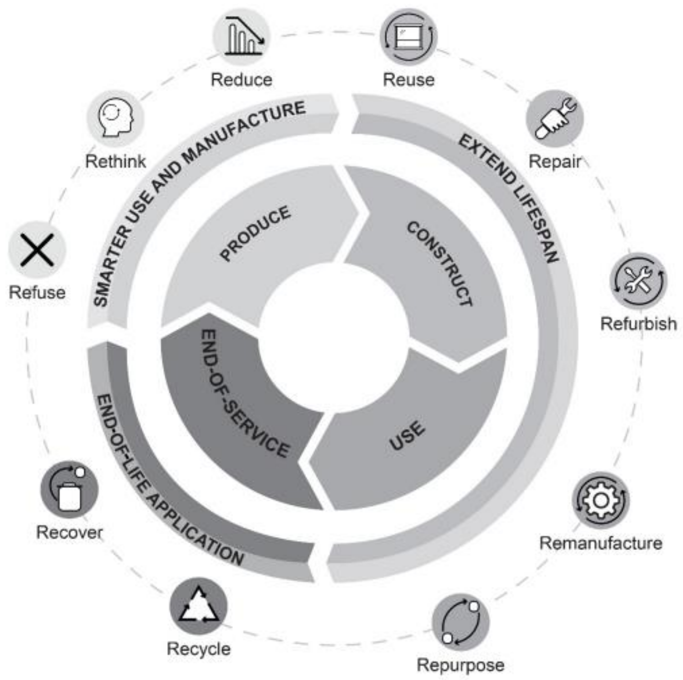

Figure 2-4 Life cycle stages of a building in relation circularity strategies (Klein, 2019).

2.2.3 Barriers to circularity in construction

Circularity is still far from evident in the Dutch construction sector. Currently in North-West Europe, only 1% of construction components are reused following their first application (Gobbo et al., 2021). Although many components are technically reusable, they are frequently downcycled into other applications (Gobbo et al., 2021; Reike et al., 2018). In the Netherlands, the majority of construction and demolition waste is recycled into foundation materials for roads, new residential areas and industrial estates (Schut et al., 2016). In terms of the share of biobased materials, application in the Dutch construction sector is still limited. Approximately 2 wt% of the materials used in construction is wood and only 0.1 wt% consists of other biobased materials (van Kampen & van den Oever, 2021).

There is a growing body of literature devoted to the identification of factors explaining the laborious transition towards CE in construction. For example, Manuro et al. (2020) mentioned the lack of clarity on circular business models and governmental support, such as laws, taxes and subsidies. Adams et al. (2017) provided three sets of challenges to the transition, related to the economics of circular construction projects, the structure of the construction industry, and building design. Hart et al. (2019) provide similar findings and add cultural and regulatory barriers. They also noted that barriers are perceived different by stakeholders and therefore it is difficult to prioritise barriers in terms of influence or importance.

Research by Adams et al. (2017, p. 21) identified that "*one of the largest challenges for adopting circularity in the built environment is the unclear financial case, which ranked number one for the majority of stakeholders*". More recent research from Bucci Ancapi et al. (2022) has shown that economic incentives are amongst the least researched instruments for circularity in the built environment. Financial barriers in include 'short-term blinkers', referring to the prioritisation of capital expenditure over operational expenditure and expectations for rapid returns on investment, high upfront investment costs, poor business cases and unconvincing case studies, limited funding, low virgin material prices and even lower end of life (EoL) values (Adams et al., 2017; Hart et al., 2019). This is supported by research from Copper8 (2017) and Dijken (2021), which show that the investment costs of circular construction are higher than of conventional construction. One explanation for this is that circular approaches require extra labour for additional efforts, for example in building design, sourcing of materials, quality checks on materials and selective demolition (Coelho & de Brito, 2011; Di Maria et al., 2018; Llorente-González & Vence, 2020).

2.3 Economic policy and taxation

To increase circularity in the construction sector and beyond, many authors highlight that government support and policies are crucial (Gobbo et al., 2021; Hartley et al., 2020; Laktuka et al., 2021; Munaro et al., 2020; Nußholz, 2017). Public policy can be defined as *"a theoretical or technical instrument that is formulated to solve specific problems affecting, directly or indirectly, societies across different periods of times and geographical spaces"* (Estrada, 2011, p. 524). The available instruments include enforcing standards and rules, encouraging developments through taxes, subsidies and investments, providing infrastructure, information and skills, exemplifying good practices through procurement, and engaging the public and industry (Gobbo et al., 2021).

To address the financial barriers for CE in construction, economic policy instruments could be an effective instrument for promoting the transition to a more circular construction sector. As the iron triangle of time, scope, and budget is the main guiding principle in construction projects (Kooter et al., 2021), overcoming the struggle to develop a financial case for circularity in construction could be a powerful policy lever. This is underlined by Calisto Friant et al. (2021), who stated that "as long as the price signals favour linear models, circular options will likely remain niche sectors of the economy".

2.3.1 Environmental Taxation

Traditionally, one of the most common policy measures advocated by economists is the use of taxes as a means of addressing the efficiency losses that are associated with environmental externalities (Chaturvedi et al., 2014; Engström & Gars, 2015). Externalities occur where "*a transaction between A and B has unwanted, positive or negative, consequences for third party*" (Pigou & Aslanbeigui, 1932). In the context of environmental economics, external effects frequently refer to environmental externalities such as emissions. The purpose of a Pigouvian tax is to impose an extra cost on the producer of the externality so that the final cost of production also reflects the damage done to third parties. As illustrated in Figure 2-5, the tax fills the wedge in social costs created by the externality, so that marginal and social benefits become realigned and the new equilibrium shifts to the socially optimal outcome (Q*).

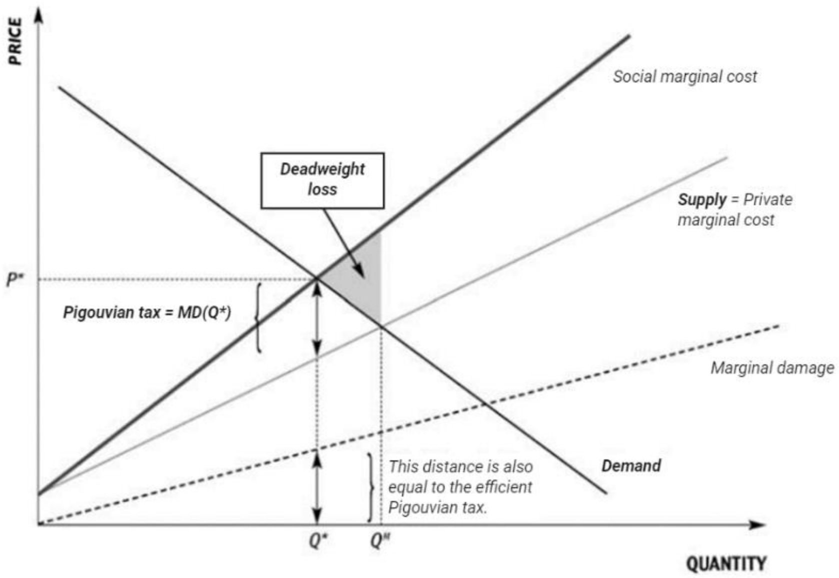

Figure 2-5 The efficient (Pigouvian) tax in the supply and demand framework, adapted from Keohane & Olmstead (2007). The tax equals the marginal damage from pollution at the efficient quantity, Q.*

Environmental taxes and fiscal reforms are increasingly regarded as powerful tools for promoting a transition to sustainable economies (Government.nl, 2014; Sorensen, 2017). The term "environmental taxation" generally refers to various 'green' taxes levied by the state to achieve environmental protection through intervention in resource allocation, following the polluter-pays principle (Bakker, 2009; Deng & Huang, 2020). In addition to enhancing environmental quality, and in contrast to command-and-control-type policies, environmental taxes also have the advantage of raising government revenues. Other, more distorting, taxes could then be reduced using these revenues. This notion has been termed the double dividend of environmental taxation, or, alternatively, "second dividend" or "revenue recycling" (Klenert et al., 2018; Morello & da Silva e Silva, 2022).

Environmental taxation is criticized for a number of reasons, even though market-based tools like fiscal reforms are generally regarded as effective, i.e. cost-minimizing, climate policy measures. One criticism is the inability to accurately determine the cost to society imposed by negative externalities. Beeks and Lambert (2018) contended that a rough estimation of an externality cost could (and should) be sufficient, similar to how "sin taxes" on tobacco and alcohol work. Another major concern with environmental taxation is that the taxes may be regressive, which means that low-income households are affected disproportionately (Fodha & Chiroleu-Assouline, 2014). This potentially makes the taxes politically unpopular and socially unjust (Ekins & Dresner, 2004; Fodha & Chiroleu-Assouline, 2014). This is where revenue recycling can be particularly valuable (Klenert et al., 2018).

2.3.2 Circular Taxation

There are numerous ways in which the tax system can be reformed and how the environmental tax revenues can be utilized, although the plurality of literature advocates for increased taxation on resources and energy extraction, combined with decreased taxation on labour. According to Groothuis (2022), labour taxes are among the most economically distortive taxes. Daly (2012) suggested a substitution of the current value-added (VAT) taxes on labour and capital by a tax on resource extraction and pollution. Raworth (2017) advocated for a tax on non-renewable resources, land value tax, and property taxes to reduce the taxation on labour and income and subsidies for renewable energy and investment in the efficient resources usage. More ways to alter the taxation system have been described by Vence & López Pérez (2021), who distinguish two overall classifications: 1) an integral tax reform that covers all externalities, based on the proposal by Beeks and Lambert (2018), and 2) an integral tax reform based on taxation of natural resources and relief of labour taxes, based on the Ex'tax approach (Groothuis, 2016, 2021; Groothuis & Damen, 2014) and the ideas of Stahel (2013). Chiroleu-Assouline and Fodha (2014) stated that "*an ambitious environmental tax policy must be part of a broader reform that addresses several problems simultaneously: the equity and progressivity of the tax system, reducing social security withholdings, pension finance, and paying down the debt*".

The proposal by The Ex'tax Project (Groothuis, 2021; Groothuis & Damen, 2014) has been designed specifically for the Netherlands and captures the advantage of double dividend. It aims to contribute to CE in several ways: by financially incentivizing circular use of materials and compensating the burden on low-income households through reduced costs of labour. Labour is considered the ultimate renewable resource and is required for many of the value retention processes in the CE, such as the recollection of goods for remanufacturing, repair, and material recovery for reuse. Therefore, the Ex'tax approach (Groothuis, 2021), hereafter termed the "circular tax shift", forms the basis of this research.

What distinguishes the circular tax shift from environmental taxation is that it is not about correcting the most serious single impacts, but rather advocates a comprehensive reconstruction of the entire taxation and economic system. Unlike other policy instruments, e.g. described by Milios (2018) and Nußholz et al. (2019), the circular tax shift tackles all life cycle phases and all elements in the supply chain of a product. The intention is to modify or eliminate taxes that imply costs for renewable and circular practices, increase taxation on non-renewable resources and capital (intensive activities in the linear economy), and eliminate subsidies for practices that harm the environment. Conventional environmental taxation is considered insufficient, as in most cases it is aimed at taxation at the end of the product chain, overlooking many external factors, such as resource extraction and depletion, increasing waste production, pollution, biodiversity loss, etc. (Vence & López Pérez, 2021).

3 Analytical framework

CE is an approach to sustainability that per definition takes into account all the phases in a product life cycle and value chain (Hart et al., 2019). Due to the systemic nature of the CE, a comprehensive analysis is required to assess multi-faceted aspects of the transition. This chapter describes the assessment tools that can be used to assess the financial feasibility and environmental impacts of construction projects, based on a life cycle approach.

3.2 Life Cycle Costing

Commonly in construction, a Life Cycle Costing (LCC) approach is used to determine the financial feasibility of a construction project. LCC summarizes all costs associated with the life cycle of a product that are directly covered by one or more of the actors in that life cycle, e.g., supplier, producer, user or consumer, and those involved at the EoL stage (Gundes, 2016). The rationale for this is that the product decisions should not be based solely on the initial acquisition cost, but also on the costs for operation and maintenance and disposal (Copper8, 2017; Hunkeler et al., 2008). The procedure to perform LCC analysis is standardised by the International Standardisation Organisation (ISO) in the norm ISO 15686-5. In a conventional LCC analysis, the costs relate to real money flows. Other versions of LCC have been developed, including environmental LCC, which includes environmental externalities as costs, and social LCC, which is similar to social cost-benefit analysis. The term 'Life Cycle Costing' is used interchangeably with Life Cycle Cost Analysis, Whole Life Cost and Total Cost Assessment (Miah et al., 2017).

3.1 Costs factors

The ISO 15686-5 defines the costs that are involved per life cycle stage as follows:

A. In the Production and construction phase, the acquisition cost and capital cost are regarded. These refer to respectively all costs included in acquiring an asset by purchase/lease or construction procurement route, and costs of initial construction and initial adaptation.
B. Costs in during the Use phase are referred to as maintenance costs, which is defined as the total of necessarily incurred labour, material and other related costs incurred to retain a building or its parts in a state in which it can perform its required functions.
C. Costs included in the EoL phase are referred to as end-of-life cost. These are the net costs or fees for disposing of an asset at the end of its service life or interest period.

3.1.2 Discounted cash flow method

In finance, a discount rate reflects the time value of money. In assessment of the cost performance of constructed assets, future cash flows are valued different from present cash flows. Therefore, financial decisions are generally based on the Net Present Value (NPV) of an asset. The method for assessment of life cycle costs is traditionally a discounted cash flow analysis over a normative life cycle of 50 years with a real interest rate of 4%. The calculations are standardised the ISO 15686, in which cash flows are projected on a timeline and discounted to their present values conform the formula below, in which CF_t refers to the net cash flow of each period from t = 0 to t = T, T refers to the normative life cycle of the asset and r refers to the used discount rate.

$$NPV = \sum_{t=0}^{T} \frac{CF_t}{(1+r)^t}$$

3.2 Life Cycle Assessment

Life cycle assessment (LCA) is a widely recognized method for evaluating the environmental impacts associated with a product, which has been standardised in the ISO 14040 norm. By identifying and quantifying material and energy flows throughout a product's life cycle, it avoids burden shifting from one environmental impact or life cycle stage to another (Hellweg & Milà i Canals, 2014). The life cycle stages of a building a visualised in Figure 3-1 and consist of technological processes from raw materials extraction to the product's EoL processing. The basis for any LCA is the functional unit - a measure that quantifies the product or service produced from the life cycle and over which a product's life cycle impacts are normalized. Similar to LCC, LCA studies for buildings may be concerned with the whole building or its constituent parts. Most of the LCA studies undertaken in construction literature fall into the latter category.

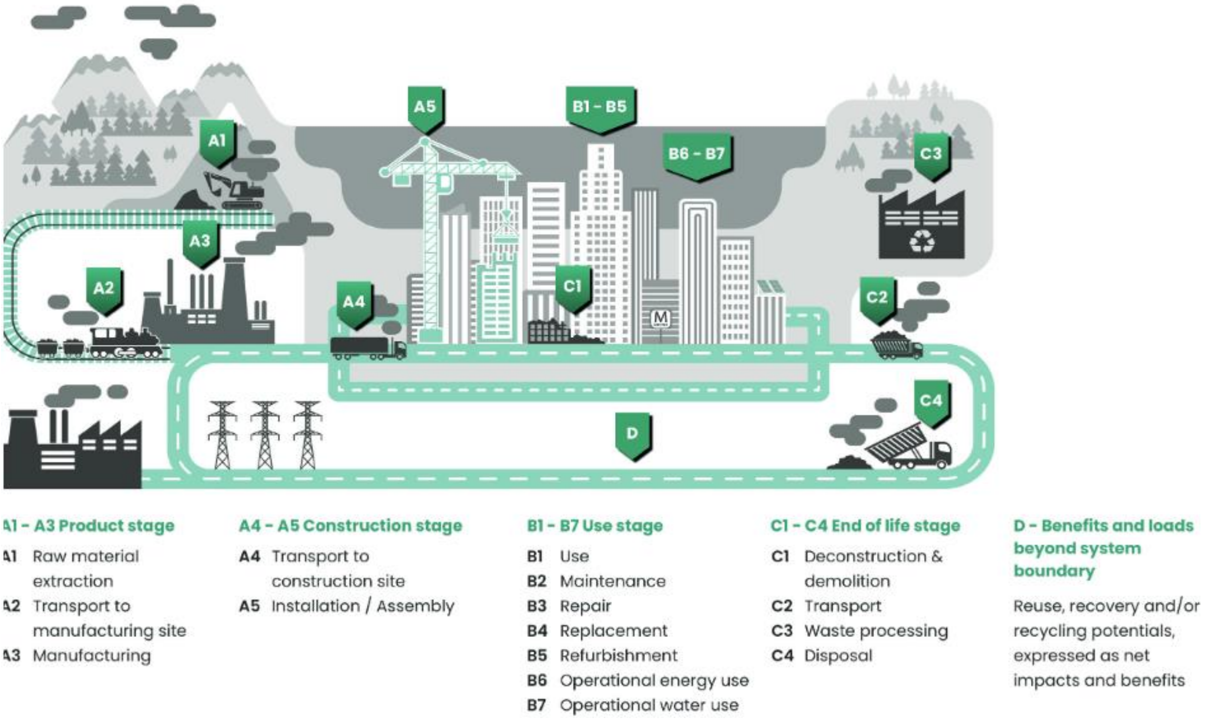

Figure 3-1 The life cycle stages of a building (One Click LCA, n.d.).

The general LCA framework as described in ISO 14040:2006 and illustrated in Figure 3-2, consists of four phases:

1. Goal and scope definition: The system boundaries and impacts to be assessed form the scope of an LCA. The functional units are also chosen for assessment. For instance, an assessment of building can be done using per square meter impact of the product. This makes it easier to compare it with another product and its impact.
2. Life Cycle Inventory (LCI): The individual processes within the assessment scope are analysed to allot input and output values to themselves. This includes resources consumed per functional unit and impacts for specific indicators. These results can be found in datasheets provided by organisations such as Ecoinvent.
3. Life Cycle Impact Assessment (LCIA): This step groups together all the impacts in their respective indicator category and calculate their total impact.
4. Interpretation: The values obtained from the assessment is then analysed in light of the objective of the study. These values can also be used to compare different materials and make an informed decision.

The endpoint LCIA expresses the impacts aggregated into areas of interest (e.g. human health, ecosystems, resource depletion), whereas the midpoint assessment intends to analyse the amount of emissions of various unaggregated impact categories (e.g. climate change, ozone depletion, eutrophication).

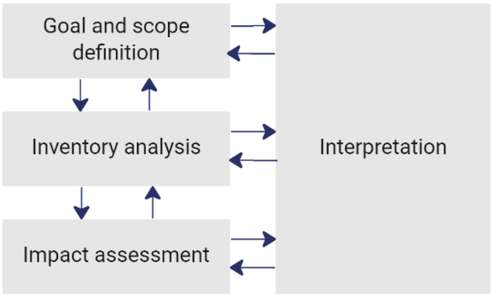

Figure 3-2 Life cycle assessment framework (ISO 14040, 2006)

3.2.1 Milieuprestatie Gebouwen

The standardised method for LCA forms the basis of the Milieuprestatie Gebouwen (MPG). In the Netherlands, it is mandatory to determine the MPG of new construction projects. It is expressed in environmental costs (€/m2/y) and to receive a construction permit, the MPG should be below a set value at the time of development. The current threshold value for the MPG equals a single-score indicator of 0,8 €/m2/y or lower and legislation becomes stricter over time (NMD, n.d.). Rules for the determination of the MPG score of a building are standardised in the The Environmental Performance Assessment Method for Construction Works (Assessment Method) (Stichting Bouwkwaliteit, 2019), which is based on the European norm for LCAs, EN 15804. The MPG includes only the material related impacts of a building. The energy performance of a building, which is reflected in a complementary standardised calculation called the Energy Performance Coefficient (EPC). When combined, the two form an integral environmental performance score.

3.3 Combining LCC and LCA

When a financial analysis is performed for an LCA system, all costs for fulfilling the functional unit (or units) should be included (Carlsson Reich, 2005). Financial costs are defined here as the present value of all monetary costs for the system studied, negative or positive. The Goal and scope definition of an LCC is therefore similar to that of an LCA. Various parts of the product system may fall below relevant cut-off criteria for the separate LCC and LCA components. For example, the early research and development may impose significant costs but little environmental impact. The key is that both studies refer to a consistent definition of the product system, and that cut-off criteria do not conflict with the intended goal and scope of the study (Swarr et al., 2011). In order to allocate costs, the use of standard economic tools such as the discounted cash flow method is necessary.

4 Methodology

The main research question that was addressed is: 'What effect will a circular tax shift have on the financial feasibility of circular construction projects?' To answer the research question, quantitative financial analysis was applied to a circular and linear variant of two construction case studies under different taxation scenarios. The case studies that were selected are construction projects that were built at the Floriade Expo 2022 (Floriade) in the Netherlands. This chapter describes the case studies selection, scoping, research design and limitations of this research.

4.1 Case study selection

This research was commissioned by Copper8, as part of a larger project in cooperation with Arcadis, The Ex'Tax Project, PRICE, Het Groene Brein and Superuse. The larger project addresses several construction projects that were built as pavilions for the Floriade, the world horticulture exhibition that is held in the Netherlands once every ten years. The Floriade was selected because of the attention it receives from policymakers and industry, focus on circular and biobased innovations, and willingness to participate and share data in the project. The short lifespan of the pavilions allowed for a life cycle analysis within the timeframe of this research.

The cases from the larger project were screened based on the type of project, scale, complexity, availability of information and access to stakeholders. In relation to the scope of the research, the following prioritization of criteria was applied to select two case studies for this research:

1. Since the analysis depends on real world budgets, the willingness to disclose all financial and material information is of importance. Therefore, the most important criterium was the availability and completeness of data, and related to this, the willingness of stakeholders to participate in the project.
2. Some of the Floriade constructions have the character of an exposition rather than a building, so not all building components are considered to be useful for real world applications. For the ability to generalise the outcomes, the second case study criterium was the presence of elements that are suitable for conventional, durable constructions.
3. Lastly, to identify similarities or contrasts in the results, variations in the level of circularity have been selected.

These criteria led to the selection of the two case studies presented in Table 1, for which more details can be found in Appendix.

Table 1 Case study selection

The Voice of Urban Nature	**Circuloco**
	
Circular features: reused wood, biobased materials, designed for disassembly	**Circular features**: reused windows, wood beams and steel, designed for disassembly

4.2 Goal and scope

The goal of the LCA and LCC was to make a comparison between the linear and circular variant per case study under each tax shift scenario. As the LCA results translated into taxes and thus costs to be included in the LCC, the scope of the analyses was the same. In the Assessment method (NMD, 2022), material related impacts for all life cycle stages are included: the production phase [A1-3], construction phase [A4-5], use phase [B1-5], end of life phase [C1-4] and module D. An overview of these life cycle stages can be found in Figure 4-1. The largest environmental impacts are generally associated with the so-called cradle-to-gate stage, which regards phase A1-A3 (Pomponi & D'Amico, 2020).

All of the life cycle stages have been included in this research, with some exceptions. Module D refers to impacts outside of the life cycle of the building. Although this is where a large part of the benefits of circular construction are achieved, module D was excluded due to data and software limitations. The operational impacts [B6-7] can make up a substantial part of the total environmental impacts of a building, but are also excluded from the analyses, as there was limited data availability and as these are always excluded in MPG calculations. Additionally, the differences in energy use between a linear and a circular construction would have been minimal, as the linear and circular variants differ not in the choice of which materials are used, but mainly in the origin, e.g. primary or secondary, of the construction materials.

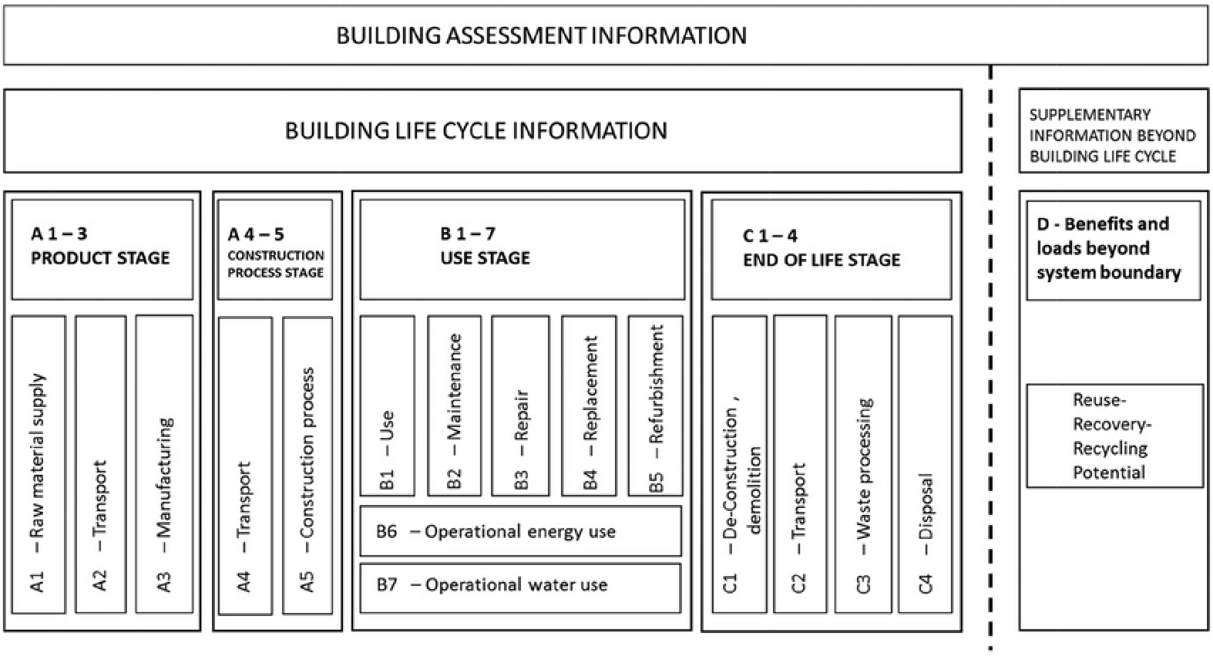

Figure 4-1 Life cycle phases included in determining the environmental performance of buildings, retrieved from Hafner & Rüter (2018).

For generalisability of the results, the theoretical lifetime and application of the building is used, and not the actual use at the Floriade. A lifetime of 50 years is conventional for service buildings (Anink, 2020). In terms of materialisation, the shearing layers that were in included in the analyses are visualised in Figure 4-2 and comprise of the structure, skin and space plan.

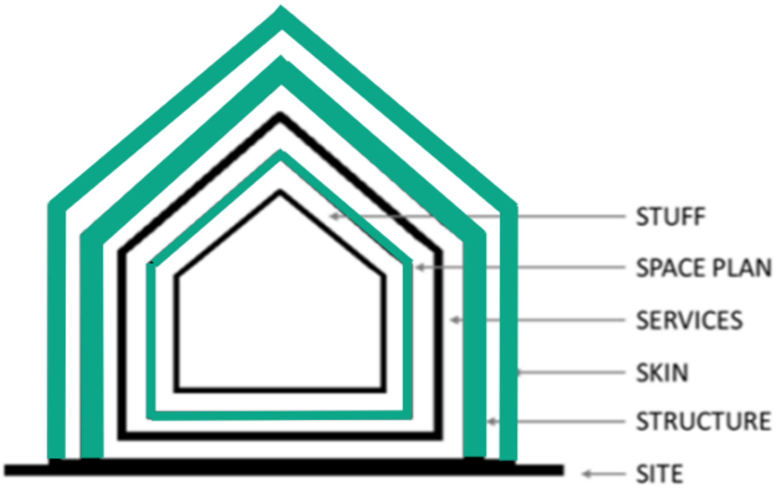

Figure 4-2 The shearing layers in green are included in scope of this research.

4.3 Research design

The main and sub research questions to be answered are:

MRQ: 'What is the effect of a circular tax shift on the financial feasibility of circular construction in relation to linear construction?'

SRQ1: How do circular and linear construction currently compare in terms of financial feasibility?

SRQ2: What are the environmental impacts of circular and linear construction?

SRQ3: How is the financial feasibility of circular and linear construction affected by the different taxation scenarios?

The four-step approach that was used to answer these sub questions is visualised in Figure 4-3. First, the budget from the circular project for each case study was used to draw up a linear variant of the budget. Then, for both variants, the environmental impacts were determined for the materials and construction processes. Subsequently, various scenarios were drawn up for the tax shift, based on a reduction of labour costs by lowering the social contributions for employers; and increase of the costs of using (polluting) raw materials and production processes by linking an environmental tax to environmental impact. Finally, the financial feasibility was analysed based in these inputs in a life cycle costing analysis. In the following sub chapters, each research step is discussed in more detail.

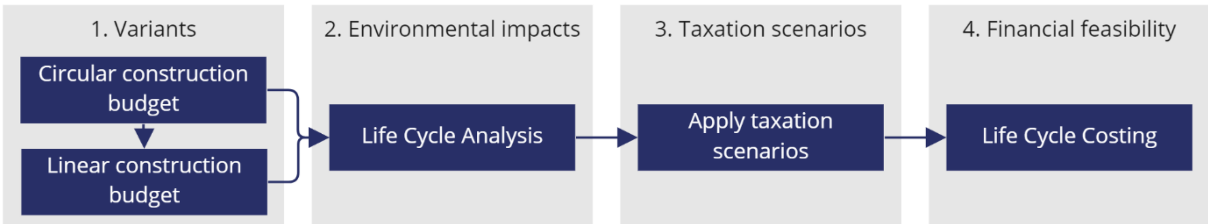

Figure 4-3 Research design and steps.

4.3.1 Variants

Because of the complexities in CE strategies and approaches, circularity is hard to define and measure (Corona et al., 2019; Walzberg et al., 2021). Many tools have been developed to quantify circularity, such as the Material Circularity Indicator by the Ellen MacArthur Foundation. However, all of these tools know their criticism (see for example Kirchherr, 2022). This research therefore did not refer to circularity as a continuous variable, but rather determined two variants: one linear and one circular variant per case study.

The circular variant is based on the actually implemented circularity features in the design of the pavilions and upfront budgets provided by the project developers. The cost estimations for the linear variant are based on previous research by Copper8 (2022), in which costs for circular construction were 5,18% higher in terms of labour, and 1,82% in terms of materials, compared to linear construction. At the EoL, deconstruction costs were 7,75% higher in terms of labour, and the same in terms of materials. Costs for the use phase are assumed to be the same for both versions. The outcomes for the different variants can be compared in terms of environmental impacts and life cycle costs. In any case where the division between labour and materials was unclear, for example in the cases when work was outsourced to a subcontractor, respectively 32% and 68% of the total budget was allocated to labour and materials, based on the judgement of industry experts and the previous project by Copper8 (2022).

4.3.2 Environmental impacts

The calculation of environmental impacts is implemented using the One Click LCA software, following the standardised NMD Assessment Method. Because the NMD has limited product cards available, the product cards that were most similar to the original building inputs were selected based on the following order of criteria: type of material, origin, material composition. In some cases, the material quantities have been altered to best approximate the actual impacts. When secondary materials were used in the circular variants, the impacts of those materials have been excluded from modules A and C. Materials have been regarded as secondary if strategies R4-7 have been applied.

The midpoint impact categories for which impacts have been identified are showed in Table 4.2. This table also shows the environmental prices that are used by the Dutch government. These 'shadow prices' reflect the maximum allowable avoidance costs for environmental impacts, i.e. the cost level per unit of emission prevention. These environmental costs are also used as weights to aggregate the results of the environmental impact analysis into a single-score indicator, following to the Assessment Method.

Table 4.2 Environmental impact categories and current environmental prices (Stichting Bouwkwaliteit, 2019, p. 39).

Midpoint impact category	**Shadow price**	**Unit**
Climate change	€ 0,05	kg CO2 eq
Ozone layer degradation	€ 30,00	kg CFK-11 eq
Photochemical oxidant formation	€ 2,00	kg C2H4 eq
Acidification	€ 4,00	kg SO2 eq
Eutrophication	€ 9,00	kg PO4 eq
Human toxicological effects	€ 0,09	kg 1,4-DB eq
Freshwater ecotoxicological effects	€ 0,03	kg 1,4-DB eq
Seawater Ecotoxicological Effects	€ 0,00	kg 1,4-DB eq
Ecotoxicological effects, terrestrial	€ 0,06	kg 1,4-DB eq
Depletion of abiotic raw materials	€ 0,16	kg Sb eq
Abiotic depletion potential for fossil resources	€ 0,16	kg Sb eq

The reliability of the sources for inventory data impacts the reliability of the results. The Nationale Millieudatabase (NMD) is a central database developed for determining the environmental performance of buildings in the Dutch context. It provides environmental information in the form of product cards, including lifespans and functional units (NMD, n.d.). In addition, the NMD Foundation manages a process database, which is an LCA database of raw materials and background processes based on Ecoinvent 3.62 'allocation, cut-off by classification'. This information can be accessed by anyone, and different products can easily be compared. However, the underlying assumptions made when calculating the environmental impact are not transparent and up-to-date information is lacking for some materials. Also, the reliability of the data in the NMD can be questioned, as most of the product cards that were used in the environmental impact analysis are category 3 data, which means that the data is not verified by the NMD Foundation. Where category 3 data has been used, One Click LCA increased the calculated impacts with an additional 30% to correct the possible underestimations.

4.3.3 Taxation scenarios

The effect of a tax shift was analysed based on four different taxation scenarios, compared to a baseline scenario that resembles the current taxation system. The scenarios represent different combinations of reduced labour taxes and applied environmental taxation. An overview is presented in Table 4.3.

Table 4.3 Taxation scenarios

	Scenario 0 Baseline	**Scenario 1** Current shadow prices 2017	**Scenario 2** Expected shadow prices 2022	**Scenario 3** Higher shadow prices	**Scenario 4** Higher prices + extra CO2 tax
Tax 1: Labour taxes	21,0%	18,3%	12,6%	7,4%	7,4%
Tax 2: Environmental taxation (factor)	0x	1x	3x	5x	5x
Climate change impact					+ additional 3x

The current labour taxation in reality consists of a multitude of taxes. For practicality reasons, these are reduced to one tax variable based on the social contributions for employers which are currently 21% (Copper8, 2022). In reality, the labour taxation could be designed to benefit the employer as well as the employee to achieve mutual social benefits. The labour taxes vary from 18,3% to 7.4% in the scenarios, based on previous research from Copper8. The labour tax should be higher than 0%, to ensure government revenues in the long term.

The environmental taxation in scenario 1 was based on the shadow prices in Table 4.2. It is expected that these shadow prices will be updated in 2022, and then increase by a factor 3 (Copper8, 2022), as implemented in scenario 2. Some argue that these shadow prices do not reflect the real costs of environmental impacts. For example, the Climate Association proposes a carbon price of €0,70/kg CO2 (Bosch, 2022). Scenarios 3 and 4 therefore include even higher environmental taxation, with an additional factor for climate change impacts in scenario 4. The taxation on climate change effects has been multiplied with an additional factor 3, which means that the climate change effects are taxed 14 times higher than in scenario 1.

4.3.4 Financial feasibility

To assess the financial feasibility of the case studies and variants, a LCC analysis has been applied under the different taxation scenarios. The present value of the project development costs was calculated based on the discounted cash flow method. For one case study, The Voice of Urban

Nature, the budgets for the construction and EoL phase were available. For the other, Circuloco, only data for the construction phase was available, and the EoL costs are estimated based on the ratio between construction and EoL costs of The Voice of Urban Nature, normalized over the gross internal area. Cost estimations for the use phase were based on the real estate conventions for maintenance costs of office buildings: 7,70 €/m2/y (Instituut Voor Vastgoed & Duurzaamheid, n.d.).

The costs for production and construction and environmental impacts in life cycle phase A are accounted for in year 0. Years 1-49 constitute the use phase, i.e. life cycle phase B. The yearly costs accounted for in this phase include maintenance costs and the environmental costs over life cycle phase B divided by the number of years. The EoL costs and impacts are accounted for in year 50. Wherever emissions are negative, the environmental taxation for that life cycle phase has been set to 0.

5 Results

The results per research question are discussed in this chapter. This chapter is accompanied by Excel file Appendix 2 – Calculations and data, which is available upon request.

5.1 Current financial feasibility

The total life cycle costs for each variant have been determined and disaggregated into costs for labour, materials and transport, and taxation. The cost composition for each variant is shown in Figure 5-1. The difference in life cycle cost between the linear and circular variants are respectively 2,02% and 2,70% for The Voice of Urban Nature and Circuloco. Materials and transport comprise the largest share of the total life cycle cost for every case and variant, although the share of labour is slightly larger for the circular variants.

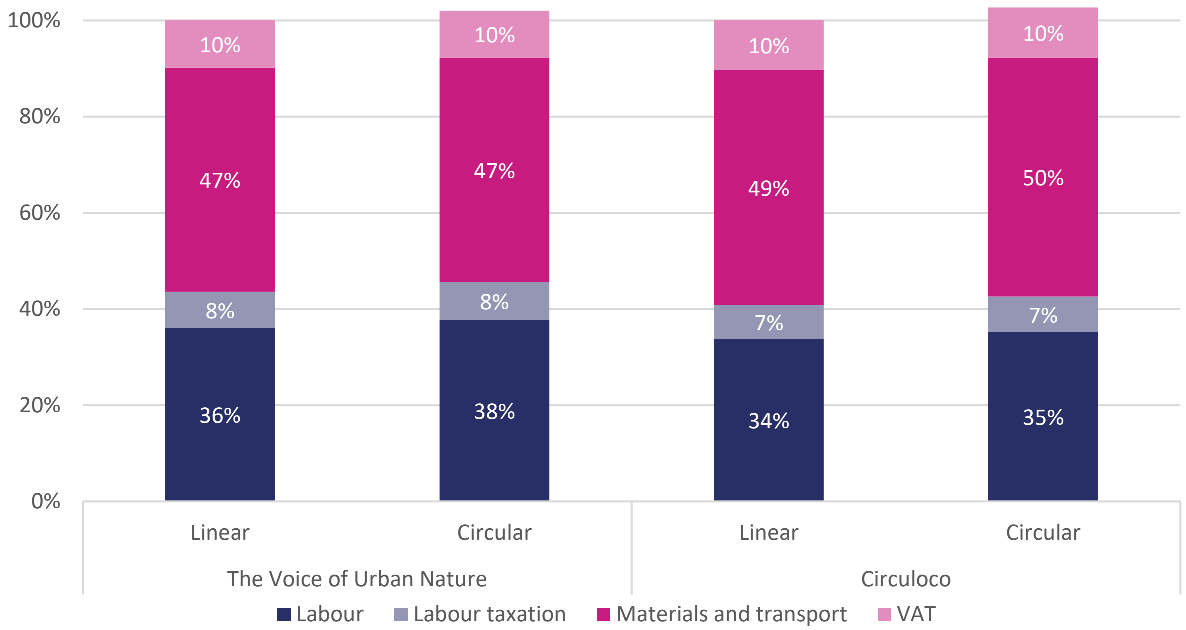

Figure 5-1 Baseline total life cycle cost compositions, indexed on the total life cycle costs for the linear variants.

The total life cycle costs per life cycle phase are visualised in Figure 5-1, showing that the Demolition and processing phase [C1-4] accounts for only 3-4% of the total discounted costs and cost differences between the circular and linear variants are minimal in this phase. The production and construction phase [A1-5] contribute by far the most to the total life cycle costs. As a result, a tax shift may initially have more effect on circularity strategies that affect the construction stage, e.g. the use of reclaimed materials, than those that affect the EoL phase, e.g. design for reassembly. The latter is however a prerequisite for the availability of reclaimed materials.

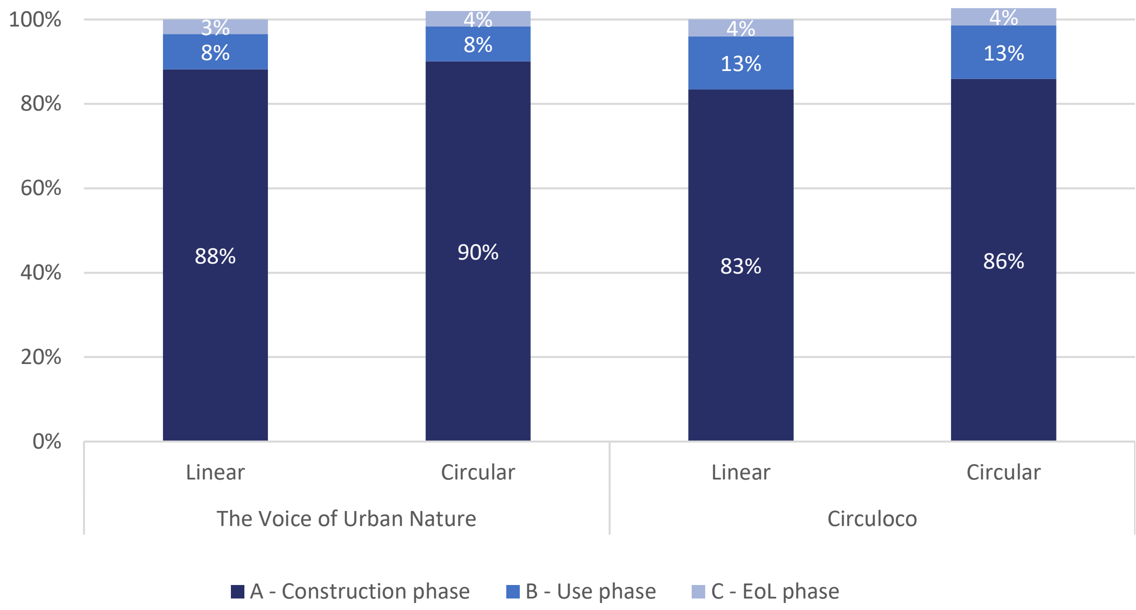

Figure 5-2 Baseline life cycle costs by life cycle phase, indexed on the total life cycle costs for the linear variants.

5.2 Environmental impacts

The weighted and normalised results of the environmental impact analysis are illustrated in Figure 5-3, showing that for both case studies, the environmental impacts of the circular variant are lower, by on average 45,7%. The environmental impacts of The Voice of Urban Nature are 39,9% and 22,0% lower than the impacts of Circuloco for respectively the linear and circular variant. This difference can mainly be explained by the high share of biobased materials in the first case, and the large amounts of glass and steel that have been used in the Circuloco construction. As the latter also has a larger gross internal floor area, the total environmental impacts of Circuloco are even higher, as can be seen in Figure 5-4.

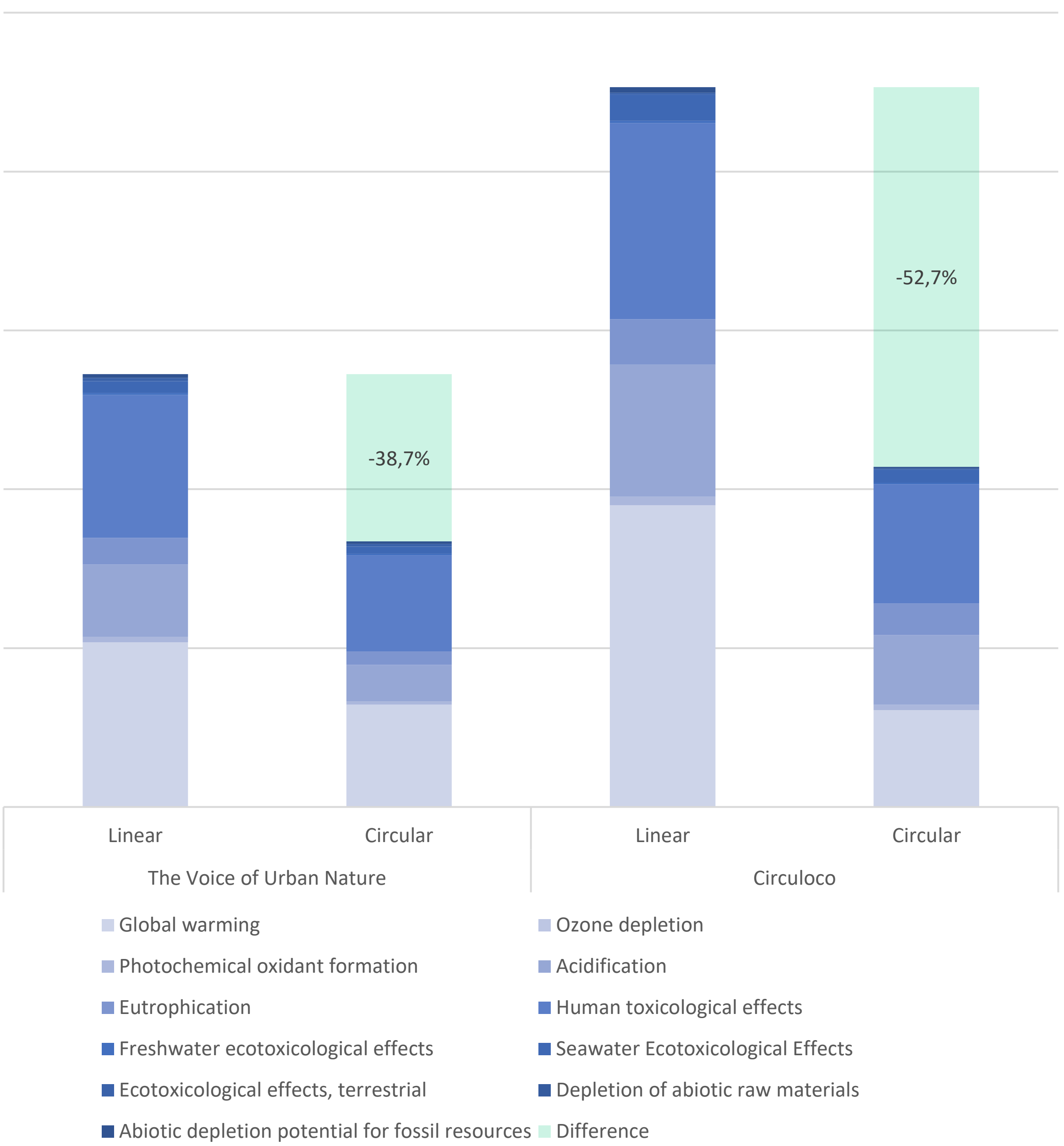

Figure 5-3 Weighted environmental impacts per square meter gross internal area, per impact category. The exact quantities have been left out for confidentiality reasons.

The total environmental impacts per life cycle phase are visualised in Figure 5-4, illustrating that the majority of the impacts are generated in the construction phase [A].

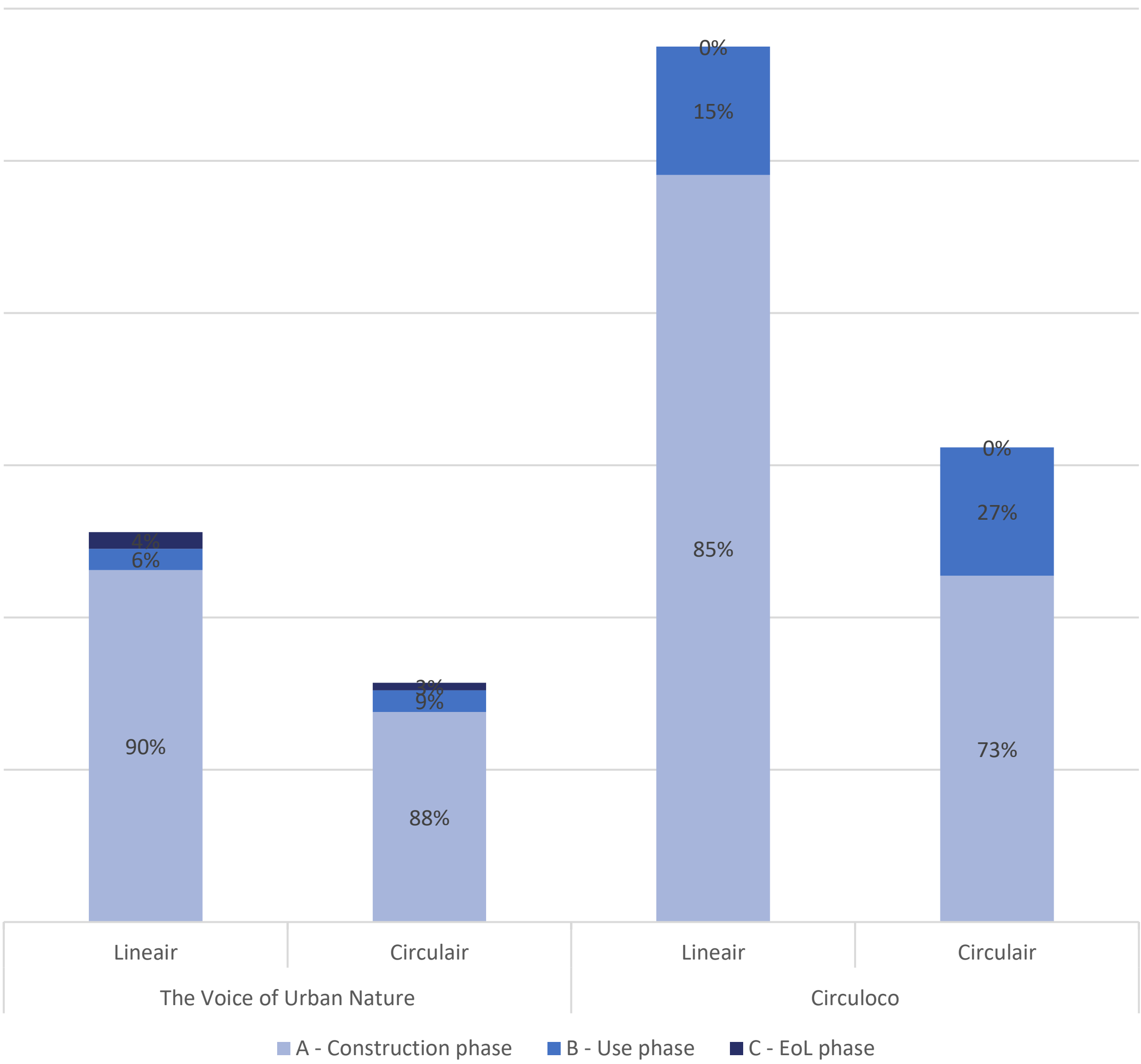

Figure 5-4 Weighted total environmental impacts, per life cycle phase. The exact quantities are left out for confidentiality reasons.

5.3 Effect taxation scenarios

Figure 5-5 and Figure 5-6 show how the life cycle costs of the two variants develop under the taxation scenarios. For The Voice of Urban Nature, the total costs decrease with every scenario for both variants. The only exception is scenario 4, in which the additional climate change effect taxation is applied, and the total costs increase slightly compared to scenario 4.

The results are slightly different for Circuloco, for which the linear variant becomes less financially feasible with each taxation scenario.

Due to the relatively low environmental impact of The Voice of Urban Nature, the environmental taxation has a smaller impact on the total life cycle costs here than in the case of Circuloco.

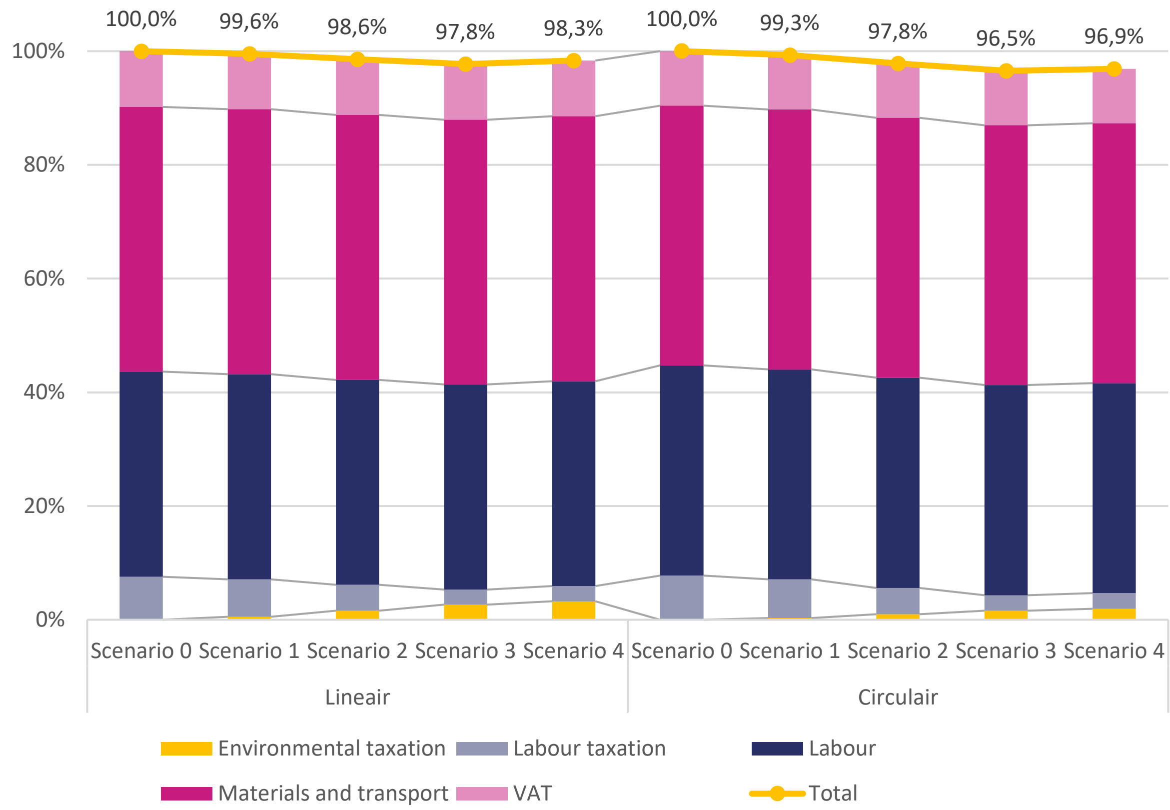

Figure 5-5 Life cycle costs for The Voice of Urban Nature, by variant (index = Scenario 0 for both variants separately)

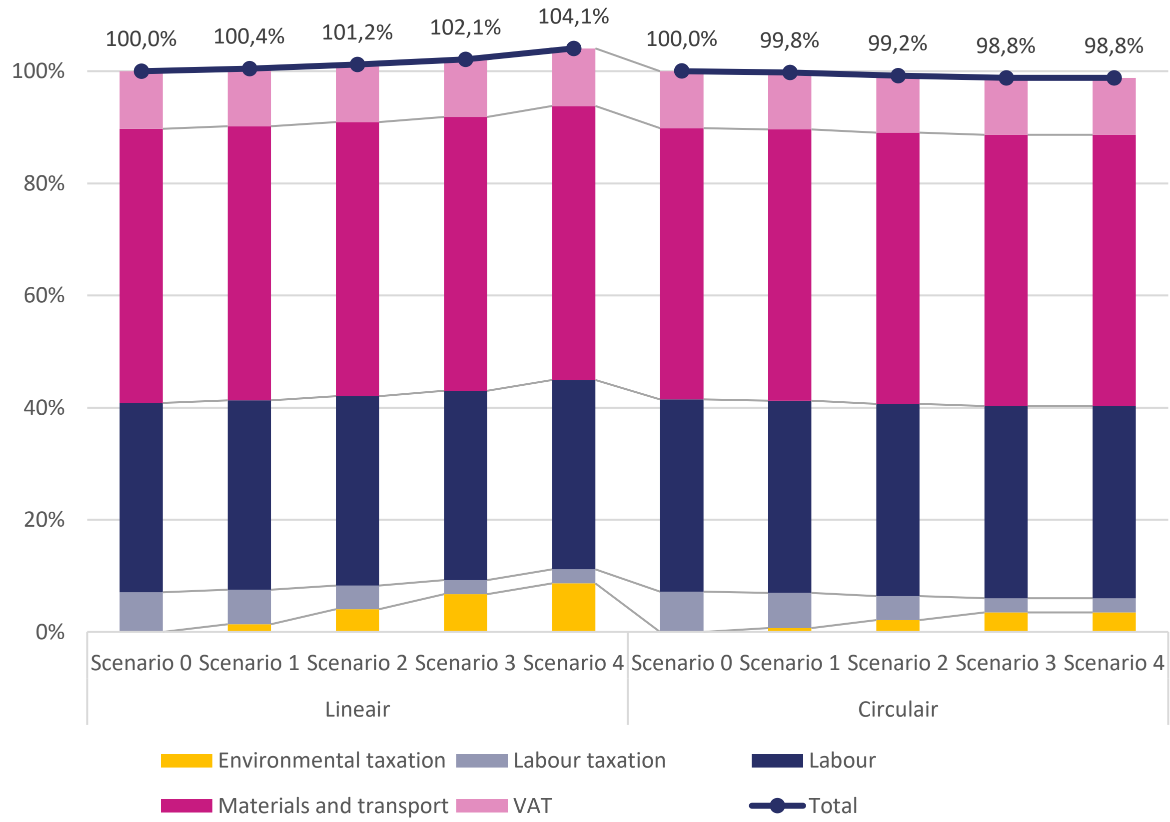

Figure 5-6 Life cycle costs for Circuloco, by variant (index = Scenario 0 for both variants separately)

5.4 Circular in relation to linear

Figure 5-7 and Figure 5-8 show the life cycle costs of the two case studies, and Figure 5-9 illustrates the relative cost differences between the linear and circular variant per scenario in percentage points. In the case of The Voice of Urban Nature, the costs for the circular variant are higher than the costs for the linear variant in each scenario. Although the difference decreases with every taxation scenario, the linear variant remains the financially attractive option in each scenario. For Circuloco, the circular variant becomes more financially feasible than the linear variant in scenario 3 and 4.

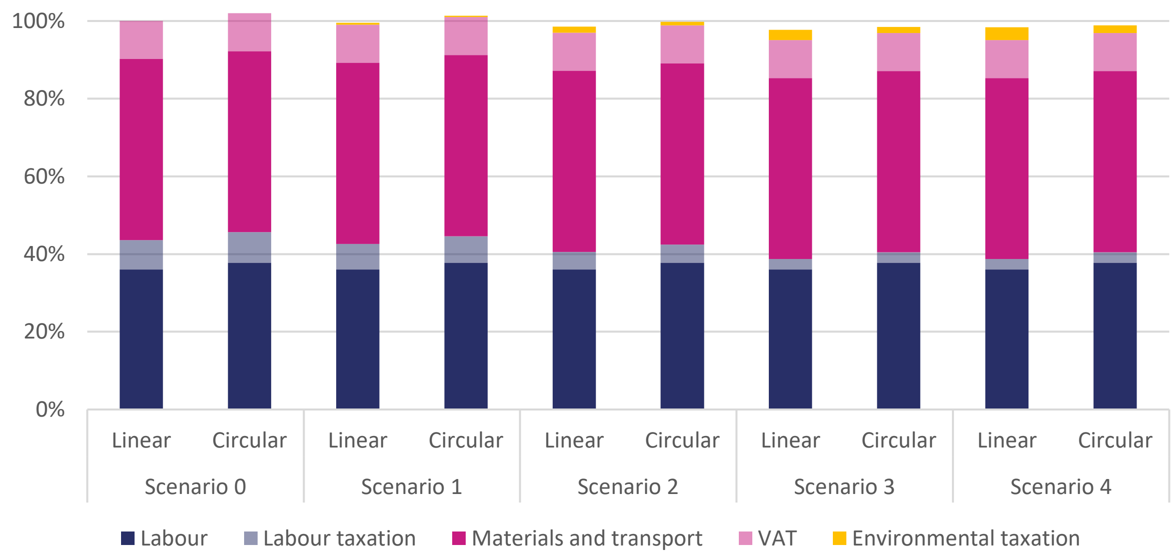

Figure 5-7 Life cycle costs for The Voice of Urban Nature, by scenario (index = Scenario 0 Linear)

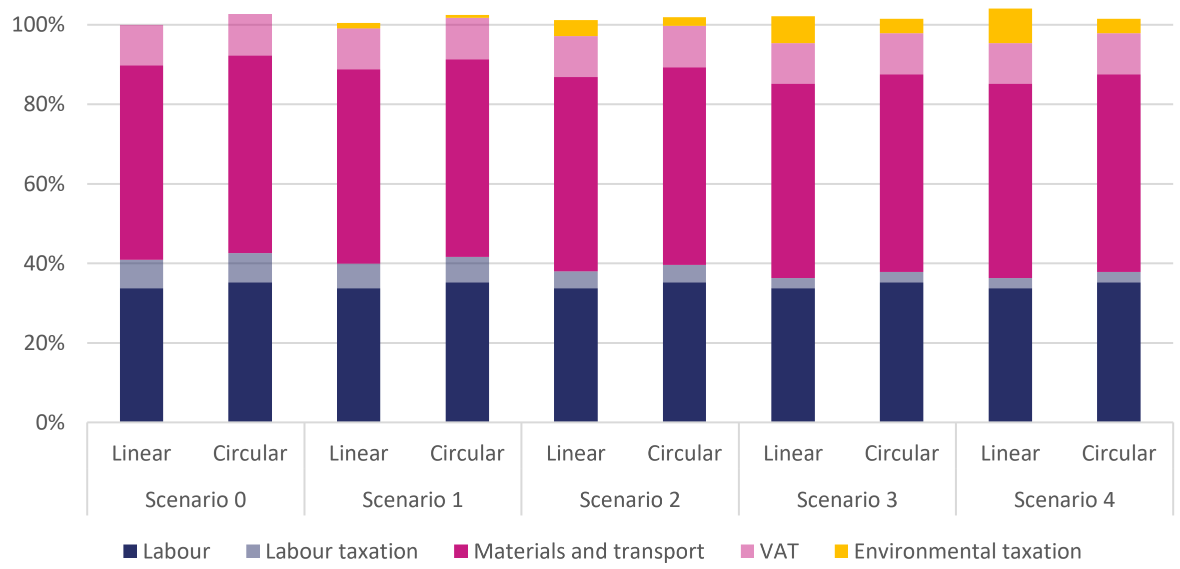

Figure 5-8 Life cycle costs for Circuloco, by scenario (index = Scenario 0 Linear)

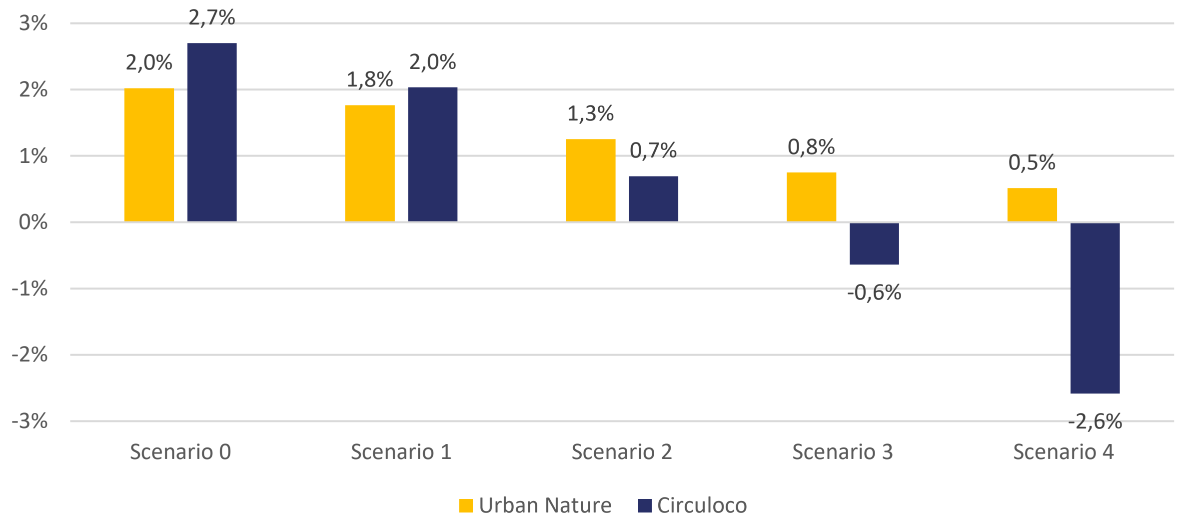

Figure 5-9 The relative cost difference between the linear and circular variants in percentage points, per scenario.

6. Discussion

Before conclusions are drawn in the next chapter, this chapter provides a reflection on the findings in relation to previous research, the limitations, and the implications.

6.1 Reflection on findings per research question

Although previous quantitative studies are limited, some statements can be made about the expected and unexpected outcomes per research question.

SRQ1: How do circular and linear construction currently compare in terms of financial feasibility?

The results for the first sub research question revealed that the total life cycle costs for the circular variants were 2,02% and 2,70% higher. Unsurprisingly, this is similar to the findings from previous research by Copper8 (2022), as the linear variant has been determined on the basis of the identified the cost differences from this study. What is worth noting, is that compared to the previously identified additional labour and material costs for the circular variants of respectively 5,18% and 1,82% for construction, and of 7,75% and 0% for the EoL, these cost differences are relatively low. Although this may seem surprising at first, this is actually an inherent effect of the used discounted cash flow method, as future cash flows are valued differently than present cash flows.

One addition of this research compared to previous research is the life cycle costing approach that takes into account the time value of money. The additional labour requirements for circular strategies arise in later life cycle stages. An inherent effect of the discounted cash flow method is that the effect of costs in the far future on the financial feasibility is smaller than the effect of costs in the near future. This confirms one of the main barriers to circularity identified by Adams et al. (2017), who referred to the short term investment focus from actors in the construction industry. In a true CE, materials retain some value at the EoL. However, in the way financial feasibility is currently determined in the construction sector, using the discounted cash flow method, the benefits diminish.

SRQ2: What are the environmental impacts of circular and linear construction?

The results for the second sub research question revealed that the environmental impacts of the circular variants are lower than their linear counterparts. This is in line with the expectations based on literature by for example Ness and Xing (2017), Munaro (2020) and Stahel (2013). The differences in environmental impacts between the linear and circular variants amounted 38,7% and 52,7% for respectively The Voice of Urban Nature and Circuloco. This is in line with the previous study from Copper8, in which the cost differences ranged from 37-75% for the construction phase and 29-70% for the EoL phase.

The Voice of Urban Nature had a relatively 39,9 - 22,0% lower environmental impact than Circuloco, which is a relatively large difference in total environmental impact per m2 gross internal area. This was expected, as the first case study is mainly constructed with biobased materials and the construction for the latter case study includes large amounts of steel and glass.

SRQ3: How is the financial feasibility of circular and linear construction affected by the different taxation scenarios?

The results for the third sub research question revealed that for both case studies, the total life cycle costs for the circular variant have decreased, thus making circular practices more financially feasible. For the case study with low environmental impacts, the tax shift has a smaller effect. For the biobased The Voice of Urban Nature pavilion, the linear construction variant also became more financially feasible, which could mean that the tax shift also implies a cost incentive for the use of biobased materials, which is seen as a circularity strategy by some institutions, such as the PBL (Hanemaaijer et al., 2021).

MRQ: What is the effect of a circular tax shift on the financial feasibility of circular construction, in relation to linear construction?

The overall results showed that under each tax shift scenario, the cost differences between the linear and circular variants decreased compared to the baseline scenario. For one case study, the circular variant became more financially feasible under the two highest level scenarios.

The effect of the tax shift on the financial feasibility of the construction projects is in the range of a few percentages. Also, as the labour costs differ only slightly for the different variants, the effect of the labour tax reduction is relatively small compared to the effect of the environmental tax influencing the cost differences between the linear and circular variants. This is not surprising, because the reduction in labour taxation is meant to keep the tax shift more or less budget neutral. As taxes are in essence meant to create revenue for government activities, the aim of the tax shift is not to make circular construction cheaper, but to keep costs more or less equal while changing the incentives through cost structures.

6.2 Limitations

Many factors influenced the reliability and credibility of these results, which should be addressed before any conclusions can be drawn. Many assumptions and research design choices have been made, which have impacted the external validity of the results. By being transparent about the limitations, internal validity is strengthened.

6.2.1 Methodological and data limitations

With regards to the research approach and used data, some limitations should be addressed. First, the approach was static, in the sense that it included only the direct effects on the budgets. The dynamics that might occur as a result of the tax shift were not taken into account. In the long term, the tax shift affects the prices of the products used in construction. Consequently, different design or process choices might be made. However, the aim of this research was not to find a new price equilibrium, but to provide an explorative indication of the effect of the tax shift on circular construction relative to linear, conventional construction.

Second, the pavilions at the Floriade did not resemble conventional buildings, but temporary exhibitions that showcase innovative construction methods and materials. This resulted in low external validity towards the rest of the construction sector and challenges in estimating the environmental impacts of the unconventional methods and materials was lacking. To increase the generalisability of the results, the theoretical life span of 50 years was used. However, this created a mismatch with the materialisation of the construction, as the materials used were not selected to last 50 years. This issue has been left unaddressed, as using a different materialisation would have impacted both the environmental impact and budgeting and would have required even more assumptions to be made. What should also be noted is the reporting of information during the process was limited, as the pavilions have been developed in a very short time span. Therefore, the quality of the input data was low and may have been incomplete. Because the results are based on the proportions between budget and environmental impacts, and the missing information affects both, the effect on the research validity is minimal.

The third limitation relates to how the circular and linear variants were developed. Due to time constraints, the budgets for the linear variants have not been calculated in detail by Arcadis, as was the original plan. Instead, estimations have been made based on previous research. Also, the difference between the linear and circular variants is mainly based on the use of secondary materials, referring to product life extension strategies [R4-7]. Although there are strategies that imply a higher level of circularity, including these would have required many more assumptions and estimations for determining the linear variant. If strategies R1-3 would have been included, this would likely have resulted in larger differences in environmental impact. Also, the input data is based on the upfront project budgets instead of actual costing data, due to time constraints and delays in the provision of data by project developers. Best estimations were made on the basis of previous research. In reality, the costs for development of the Circuloco turned out to be higher than the budgeted costs. If this cost difference was caused by additional labour costs, this would have influenced the results in the sense that the cost differences between the circular and linear variants would have increased.

The fourth limitation refers to the choices and assumptions made in the analyses. To determine the environmental impacts of the case studies, many estimations had to be made, especially as unconventional materials and construction methods have been used. Additionally, the shearing layers ‘site’ and ‘services’ have been excluded, which according to Anink (2017) comprise on average 42% of the material related impacts of a residential building. To compensate this effect to some extent, and for practicality reasons, the differences between the linear and circular variant are exaggerated by excluding the impacts of the secondary materials by 100%. Although this is the convention in MPG calculations, more precise LCA calculations could have included a different allocation of the environmental impacts over the current and future life cycles in which the secondary materials are used, for example by economic value. The result is that the determined environmental impacts are rather a rough estimation than a precise calculation and may have been underestimated. The choices made in the LCC analysis and taxation scenarios include estimations for the maintenance costs, the choice not to tax negative emissions, and the choice not to include Module D.

6.2.2 Scoping limitations

This researched only addressed the effects of the circular tax shift on the financial feasibility of circularity in the construction sector, from the perspective of the project developer. The effects on other actor types and all other economic sectors have been left unaddressed. As mentioned in the introduction, the way actors behave is partly, but definitely not only, influenced by financial motivations. As identified in the theoretical framework, actors in the construction are strongly driven by the iron triangle of time, budget and scope, and financial barriers have been identified as the least researched, yet most important barriers to circularity in construction. Therefore, it is likely, but not a given, that actors will change their behaviour based on financial feasibility.

It should therefore be noted that other incentives may be more suitable to bring about the desired behavioural changes. An example of a policy lever that might be more effective is creating psychological awareness among actors. Behavioural science theories point out that using financial incentives to change behaviour based on economic self-interest could have counterproductive effects, as it may undermine intrinsic motivations. This may occur as people value collective interest more than monetary gain. In psychology, this is called the ‘motivation crowding out effect’ (Festré & Garrouste, 2015). This reveals a final limitation with regards to the scoping, which is that this research did not address the effects of the tax shift in relation to other policy instruments.

6.3 Reflection on the bigger picture

As mentioned in the introduction, the circular tax shift is an instrument that aims to transform not only the construction sector, but the economic system as a whole. Because the CE is a means to reach sustainable development in environmental, social and economic terms, the tax shift has the potential to contribute to many policy goals simultaneously.

The list of limitations of this research may seem long, and it is. From a classical science perspective, one could argue that this weakens the outcomes of this research. From a complex policy science perspective, this may be viewed differently. As Kupers (2020) has highlighted, complex systems have irreducible uncertainties that should be embraced.

This research applied a focus environmental sustainability, by internalising the environmental costs through taxation. However, the height of the environmental prices and correct way of determination are a topic of debate. If the current environmental prices, which have been used in scenario 1, are a correct reflection of the minimal avoidance costs of environmental impacts, it could be argued that circular construction is not a cost-effective abatement method. If the environmental prices are indeed higher in reality, as some authors argue, circular construction could be a cost-effective way of avoiding environmental impacts. However, the aim of the CE is not only to address environmental sustainability, but also contribute to sustainable development in economic and social terms. In the light of other sustainability issues, such as impending material scarcities, supply chain disruptions, and social issues, there are other reasons to implement a circular tax shift.

For the same reasons, one could argue that using financial feasibility as a proxy for behaviour of actors puts an excessive focus on economics. As Love and Stockdale-Otárola (OECD, 2017, p. 4) wrote, "*our economies are not closed general equilibrium systems; they are complex and adaptive, embedded in specific societies with their own history, culture, and values, as well as in natural environments governed by biophysical laws.*" From the complex policy science perspective, one could question the micro-economic that was applied in this research. However, economic theory shapes the frame of mind in which most actors currently operate. Kupers (2020) highlighted that the assumptions from neoclassical economics are deeply interwoven with current public policy and are hardly ever questioned and articulated. In the aim to provide a meaningful contribution to the policy debate and help policymakers in addressing the complex and sensitive topics of CE and taxation, it is useful to assess the effect of proposed policies from that economic frame of mind, to identify where resistance to change may come from.

7. Conclusion

The aim of this thesis was to further explore the circular tax shift as a policy instrument for CE, and, to that extent, assess the effect of a circular tax shift on the financially feasibility of circular construction. In the introduction, the case has been made for addressing circularity in construction through a holistic policy measure. In the theoretical framework, the case has been made for the use of economic incentives, and the circular tax shift has been conceptualised. The analytical framework and methodology describe how standard industrial ecology and economic tools have been applied to assess the effect of the circular tax shift on the financial feasibility of circularity in construction, based on a full life cycle analysis of the two case studies. This research has provided a number of valuable insights, which have been reflected on in the discussion section. After presenting and reflecting on the results, this chapter now summarises the main conclusions that can be drawn.

The main research question was '*What is the effect of a circular tax shift on the financial feasibility of circular construction, in relation to linear construction*?' Figure 7-1 summarises the results for the different sub questions into one figure. The analyses have shown that the circular variants are less financially feasible under the current taxation system but do have lower environmental impacts than their linear counterparts. The effect of the circular tax shift is that in the case of Circuloco, the costs for the circular variant decrease with every tax scenario, and the costs for the linear variant increase. In the scenarios with a high level tax shift, scenario 3 and 4, the circular variant becomes more financially feasible.

In the case of The Voice of Urban Nature, the linear variant is more financially feasible under every scenario. In contrast with the effect for Circuloco, the total life cycle costs for the linear variant decrease under every scenario. This can be attributed to the low environmental impact of The Voice of Urban Nature, for which the effect of the environmental taxation is relatively small. As the decrease in labour taxation has a larger effect, the total costs for both variants compared to the baseline scenario are decreasing in every scenario. The additional CO2 tax in scenario 4 slightly counteracts this effect.

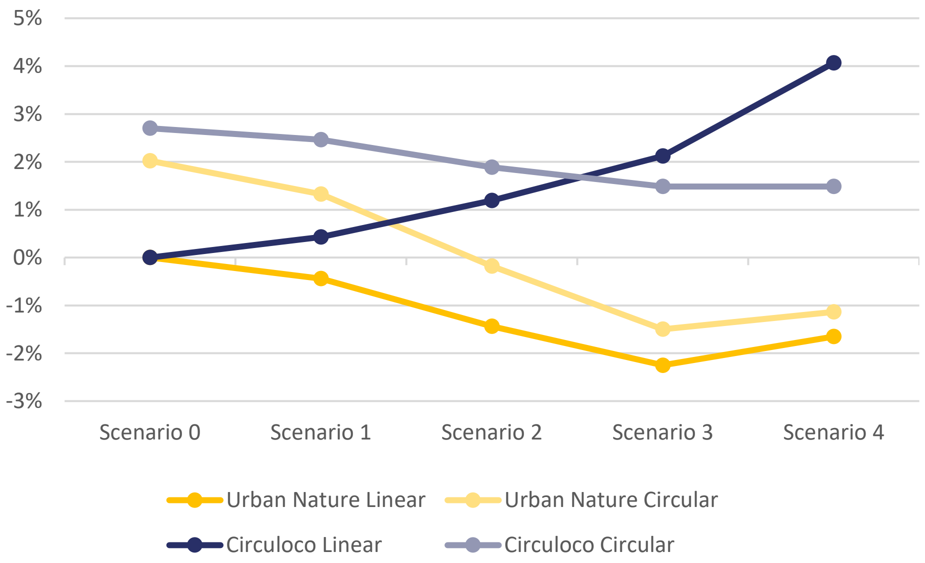

Figure 7-1 Changes in total life cycle costs in percentage points, per scenario (index = Scenario 0 Linear for both cases separately)

The addressed limitations have put these findings in context, and it has been established that the generalisability of the results is low. Consequently, no hard conclusions can be drawn about the effect of the tax shift on the rest of the construction sector. However, the results can be viewed as an additional indication that the circular tax shift has the potential to be an effective instrument in the transition to a CE, as the suggested circular tax shift could make circular and biobased construction more financially feasible, and linear construction, with conventional materials that have large environmental impacts, less financially feasible.

From the perspective of project developers in the construction sector, the results imply that the circular tax shift does not necessarily impose higher costs for project development. From a policy perspective, this means that project developers have little reason to oppose the development circular tax shift policies. Lastly, from an academic perspective, this has provided many starting points for potential follow-up research, which are addressed in the next and final chapter.

8. Suggestions for follow-up research

The overarching goal of this research was to help policymakers in addressing the complex and sensitive topics of CE and taxation. Although this research has been one small link in the chain, many questions remain unanswered. On the basis of what can and cannot be concluded from this research, many suggestions for follow-up research can be done.

First of all, this research identified that the tax shift potentially has positive effects on the financial feasibility of circular activities. Further research is needed to determine how financial feasibility would in turn influences the behaviour of actors, for example which choices would have been made differently. These behavioural science results could be integrated with economic research to provide more detailed models.

Again, this researched only addressed the effects of the circular tax shift on the financial feasibility of circularity in the construction sector, from the perspective of the project developer. It is however acknowledged that a change in the tax system will have a ripple effect on many other actors and sectors within the economic system. Another suggestion for follow-up research is to evaluate the effects on other economic actors, to identify who will benefit from the new situation and who will not. This is important to ensure the equity of the policy and to identify from where resistance to change may arise and how to address this.

A relevant actor in all of this is the government, because the primary function of taxation is to fund government activities. All reductions in the costs for producers as a result of the tax shift will result in lower government revenues. As a result of structurally lower economic dependence on resources and reduced environmental impacts, it may be that over the course of time, governments revenues decrease. The problem that arises here is that government revenues become more dependent on polluting or undesired activities. On the other hand, government expenditures may also decrease, as an effect of improved environmental and social quality. It would make an interesting topic for follow-up research to assess the overall effect on government budgets.

The aforementioned suggestions advocate for the use of other, dynamic methods and perspectives, which allow for analysis of the effects in the longer term. All of the identified effects could then be evaluated against other policy options to ensure coherence. Subsequently, other practical issues arise, such as how to best design and implement such a circular tax shift.

Although additional links in the chain of theoretical information can help create policy support, it should be remarked the clock to address environmental problems may be running out. Therefore, the final and perhaps most important suggestion for future research is to start and set up practical experiments to already start evolving decision making today.

9. Epilogue

Paraphrasing Beeks & Lambert (2018), the goals of the tax shift are obvious: use capitalistic forces and governmental incentives and disincentives to influence consumer and producer behaviours, in order to promote sustainability. This may reflect both its strength and weakness simultaneously. The effects could be strong and immediate, but at the same time this is a measure within the same paradigm of the 'homo economicus' that has created the linear economy in the first place. Ultimately, a new economic paradigm will be needed. The circular tax shift can potentially provide a springboard for alternatives, by creating different incentives, norms, interests and dynamics. If the creation of lock-ins is avoided, this can open windows of opportunities for new economic paradigms.

The most important take-away should be that societal systems are shaped by people. Therefore, the state of our economic system is a choice, and not a historical inevitability.

10. References

Adams, K. T., Osmani, M., Thorpe, T., & Thornback, J. (2017). Circular economy in construction: Current awareness, challenges and enablers. *Proceedings of the Institution of Civil Engineers - Waste and Resource Management*, *170*(1), 15–24. https://doi.org/10.1680/jwarm.16.00011

Anastasiades, K., Blom, J., Buyle, M., & Audenaert, A. (2020). Translating the circular economy to bridge construction: Lessons learnt from a critical literature review. *Renewable and Sustainable Energy Reviews*, *117*, 109522. https://doi.org/10.1016/j.rser.2019.109522

Andrew, J., Kaidonis, M. A., & Andrew, B. (2010). Carbon tax: Challenging neoliberal solutions to climate change. *Critical Perspectives on Accounting*, *21*(7), 611–618.

Anink, D. (2017). *Onderzoek principes en parameters MPG*. https://milieudatabase.nl/wp-content/uploads/2019/05/Eindrapport-Onderzoek-principes-en-parameters-MPG-24-02-2017.pdf

Anink, D. (2020). *Onderzoek 'Richtlijn specifieke gebouwlevensduur'*.

Ayres, R. U., & Ayres, L. (2002). *A handbook of industrial ecology* (Vol. 10). Edward Elgar Cheltenham.

Bakker, A. (2009). *Tax and the environment: A world of possibilities*. IBFD.

Baumol, W. J. (1972). On taxation and the control of externalities. *The American Economic Review*, *62*(3), 307–322.

Beeks, J., & Lambert, T. (2018). Addressing Externalities: An Externality Factor Tax-Subsidy Proposal. *European Journal of Sustainable Development Research*, *2*. https://doi.org/10.20897/ejosdr/81573

Blomsma, F., & Tennant, M. (2020). Circular economy: Preserving materials or products? Introducing the Resource States framework. *Resources, Conservation and Recycling*, *156*, 104698. https://doi.org/10.1016/j.resconrec.2020.104698

Bosch. (2022). *Effectiever sturen op milieu-impact in de bouw. Verkenning aandachtspunten doorontwikkeling MPG MKI stelsel.* https://circulairebouweconomie.nl/wp-content/uploads/2022/05/Verkenning-aandachtspunten-doorontwikkeling-MPG-MKI-stelsel.pdf

Brand, S. (1995). *How buildings learn: What happens after they're built*. Penguin.

Bruel, A., Kronenberg, J., Troussier, N., & Guillaume, B. (2019). Linking industrial ecology and ecological economics: A theoretical and empirical foundation for the circular economy. *Journal of Industrial Ecology*, *23*(1), 12–21.

Bucci Ancapi, F., Van den Berghe, K., & van Bueren, E. (2022). The circular built environment toolbox: A systematic literature review of policy instruments. *Journal of Cleaner Production*, *373*, 133918. https://doi.org/10.1016/j.jclepro.2022.133918

Calisto Friant, M., Vermeulen, W. J. V., & Salomone, R. (2021). Analysing European Union circular economy policies: Words versus actions. *Sustainable Production and Consumption*, *27*, 337–353. https://doi.org/10.1016/j.spc.2020.11.001

Carlsson Reich, M. (2005). Economic assessment of municipal waste management systems—Case studies using a combination of life cycle assessment (LCA) and life cycle costing (LCC). *Journal of Cleaner Production*, *13*(3), 253–263. https://doi.org/10.1016/j.jclepro.2004.02.015

Chaturvedi, A., Saluja, M. S., Banerjee, A., & Arora, R. (2014). Environmental fiscal reforms. *IIMB Management Review*, *26*(3), 193–205. https://doi.org/10.1016/j.iimb.2014.06.004

Chertow, M. (2000). Industrial symbiosis: Literature and taxonomy. *Annual Review of Energy and The Environment - ANNU REV ENERG ENVIRON*, *25*, 313–337. https://doi.org/10.1146/annurev.energy.25.1.313

Clube, R. K. M., & Tennant, M. (2020). The Circular Economy and human needs satisfaction: Promising the radical, delivering the familiar. *Ecological Economics*, *177*, 106772. https://doi.org/10.1016/j.ecolecon.2020.106772

Coelho, A., & de Brito, J. (2011). Economic analysis of conventional versus selective demolition—A case study. *Resources, Conservation and Recycling*, *55*(3), 382–392. https://doi.org/10.1016/j.resconrec.2010.11.003

Cooper, S. J., Giesekam, J., Hammond, G. P., Norman, J. B., Owen, A., Rogers, J. G., & Scott, K. (2017). Thermodynamic insights and assessment of the 'circular economy'. *Journal of Cleaner Production*, *162*, 1356–1367.

Copper8. (2017). Onderzoek naar impact circulair bouwen. *Copper8*. https://www.copper8.com/en/projects/onderzoek-naar-impact-circulair-bouwen/

Copper8. (2022). *Circulair bouwen: Hoe reken je het rond?* https://www.copper8.com/wp-content/uploads/2022/02/Circulair-Bouwen-Hoe-Reken-je-het-Rond_def.pdf

Corona, B., Shen, L., Reike, D., Rosales Carreón, J., & Worrell, E. (2019). Towards sustainable development through the circular economy—A review and critical assessment on current circularity metrics. *Resources, Conservation and Recycling*, *151*, 104498. https://doi.org/10.1016/j.resconrec.2019.104498

Daly, H. E. (2012). Moving from a failed growth economy to a steady-state economy. In *Towards an Integrated Paradigm in Heterodox Economics* (pp. 176–189). Springer.

Deng, X., & Huang, H. (2020). Green Tax Policy, Environmental Decentralization and Energy Consumption: Evidence from China. *Modern Economy*, *11*(9), 1528–1543.

Di Maria, A., Eyckmans, J., & Van Acker, K. (2018). Downcycling versus recycling of construction and demolition waste: Combining LCA and LCC to support sustainable policy making. *Waste Management*, *75*, 3–21. https://doi.org/10.1016/j.wasman.2018.01.028

Diaz, A., Schöggl, J.-P., Reyes, T., & Baumgartner, R. J. (2021). Sustainable product development in a circular economy: Implications for products, actors, decision-making support and lifecycle information management. *Sustainable Production and Consumption*, *26*, 1031–1045. https://doi.org/10.1016/j.spc.2020.12.044

Dijken, C. van. (2021). *Energieneutraal en circulair bouwen, een goede match? Een vergelijkend onderzoek naar het materiaalgebruik en de kostenimplicaties van het energieneutraal en circulair bouwen van publiek vastgoed.* [Master thesis]. https://frw.studenttheses.ub.rug.nl/3732/

Eberhardt, L. C. M., Birgisdottir, H., & Birkved, M. (2019). Potential of Circular Economy in Sustainable Buildings. *IOP Conference Series: Materials Science and Engineering*, *471*(9), 092051. https://doi.org/10.1088/1757-899X/471/9/092051

Ekins, P., & Dresner, S. (2004). *Green taxes and charges: Reducing their impact on low-income households*. Joseph Rowntree Foundation.

Ekvall, T., Hirschnitz-Garbers, M., Eboli, F., & Śniegocki, A. (2016). A systemic and systematic approach to the development of a policy mix for material resource efficiency. *Sustainability*, *8*(4), 373.

Engström, G., & Gars, J. (2015). Optimal Taxation in the Macroeconomics of Climate Change. *Annual Review of Resource Economics*, *7*(1), 127–150. https://doi.org/10.1146/annurev-resource-100814-124951

Estrada, M. A. R. (2011). Policy modeling: Definition, classification and evaluation. *Journal of Policy Modeling*, *33*(4), 523–536. https://doi.org/10.1016/j.jpolmod.2011.02.003

Festré, A., & Garrouste, P. (2015). Theory and Evidence in Psychology and Economics About Motivation Crowding Out: A Possible Convergence? *Journal of Economic Surveys*, *29*(2), 339–356. https://doi.org/10.1111/joes.12059

Figge, F., Young, W., & Barkemeyer, R. (2014). Sufficiency or efficiency to achieve lower resource consumption and emissions? The role of the rebound effect. *Journal of Cleaner Production*, *69*, 216–224. https://doi.org/10.1016/j.jclepro.2014.01.031

Fodha, M., & Chiroleu-Assouline, M. (2014). Is the Environment the Key to Tax Reform? *Books & Ideas*. https://booksandideas.net/Is-the-Environment-the-Key-to-Tax.html

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

Ghisellini, P., Cialani, C., & Ulgiati, S. (2016). A review on circular economy: The expected transition to a balanced interplay of environmental and economic systems. *Journal of Cleaner Production*, *114*, 11–32.

Gobbo, E., Ghyoot, M., Bernair, C., & Paduart, A. (2021). *A roadmap to foster reuse practices in the construction sector*. FCRBE. https://www.nweurope.eu/media/16570/20220127-fcrbe-newdesign_layout_v07.pdf

Government.nl. (2014, April 3). *Environmental taxes—Taxation and businesses*. Ministerie van Algemene Zaken. https://www.government.nl/topics/taxation-and-businesses/environmental-taxes

Green, F., & Healy, N. (2022). How inequality fuels climate change: The climate case for a Green New Deal. *One Earth*, *5*(6), 635–649. https://doi.org/10.1016/j.oneear.2022.05.005

Gregson, N., Crang, M., Fuller, S., & Holmes, H. (2015). Interrogating the circular economy: The moral economy of resource recovery in the EU. *Economy and Society*, *44*(2), 218–243. https://doi.org/10.1080/03085147.2015.1013353

Groothuis, F. (2016). *New Era. New Plan. Europe: A Fiscal Strategy for an Inclusive, Circular Economy*. Ex'tax Project Foundation.

Groothuis, F. (2021). *Deltaplan Belastingen voor een Circulaire en Sociale Economie*. The Ex'tax Project. https://ex-tax.com/wp-content/uploads/2021/01/Extax-rapport-Deltaplan-Belastingen-voor-een-Circulaire-en-Sociale-Economie-def.pdf

Groothuis, F. (2022). *The Taxshift An EU Fiscal Strategy to Support the Inclusive Circular Economy*. https://circulareconomy.europa.eu/platform/sites/default/files/the-taxshift_eu-fiscal-strategy_extax-project-2june22def.pdf

Groothuis, F., & Damen, M. (2014). New era, New plan. Fiscal reforms for an inclusive, circular economy. Case study the Netherlands. *New Era, New Plan. Fiscal Reforms for an Inclusive, Circular Economy. Case Study the Netherlands*.

Gundes, S. (2016). The Use of Life Cycle Techniques in the Assessment of Sustainability. *Procedia - Social and Behavioral Sciences*, *216*, 916–922. https://doi.org/10.1016/j.sbspro.2015.12.088

Hafner, A., & Rüter, S. (2018). Method for assessing the national implications of environmental impacts from timber buildings-an exemplary study for residential buildings in Germany. *Wood and Fiber Science: Journal of the Society of Wood Science and Technology*, *50*, 139–154. https://doi.org/10.22382/wfs-2018-047

Hanemaaijer, A., Kishna, M., Koch, J., & Gerdien, A. (2021). *Mogelijke doelen voor een circulaire economie*. PBL Planbureau voor de Leefomgeving.

Harris, S., Martin, M., & Diener, D. (2021). Circularity for circularity's sake? Scoping review of assessment methods for environmental performance in the circular economy. *Sustainable Production and Consumption*, *26*, 172–186. https://doi.org/10.1016/j.spc.2020.09.018

Hart, J., Adams, K., Giesekam, J., Tingley, D. D., & Pomponi, F. (2019). Barriers and drivers in a circular economy: The case of the built environment. *Procedia CIRP*, *80*, 619–624. https://doi.org/10.1016/j.procir.2018.12.015

Hartley, K., van Santen, R., & Kirchherr, J. (2020). Policies for transitioning towards a circular economy: Expectations from the European Union (EU). *Resources, Conservation and Recycling*, *155*, 104634.

Hellweg, S., & Milà i Canals, L. (2014). Emerging approaches, challenges and opportunities in life cycle assessment. *Science*, *344*(6188), 1109–1113. https://doi.org/10.1126/science.1248361

Hunkeler, D., Lichtenvort, K., & Rebitzer, G. (2008). *Environmental life cycle costing*. Crc press.

Instituut Voor Vastgoed & Duurzaamheid. (n.d.). *Kengetallen Benchmark gemeentelijk vastgoed 2019*. Retrieved 13 October 2022, from https://www.ivvd.nl/wp-content/uploads/2020/03/20200210-Kengetallen-Benchmark-Gemeentelijk-Vastgoed.pdf

Jhagroe, S. (2022, July 22). *Kap met duurzaamheid, wees rechtvaardig*. OneWorld. https://www.oneworld.nl/lezen/essay/kap-met-duurzaamheid-wees-rechtvaardig/

Keohane, N. O., & Olmstead, S. M. (2007). *Markets and the Environment (Foundations of Contemporary Environmental Studies)*. Island Press.

Kirchherr, J. (2022). Bullshit in the Sustainability and Transitions Literature: A Provocation. *Circular Economy and Sustainability*. https://doi.org/10.1007/s43615-022-00175-9

Kirchherr, J., Piscicelli, L., Bour, R., Kostense-Smit, E., Muller, J., Huibrechtse-Truijens, A., & Hekkert, M. (2018). Barriers to the Circular Economy: Evidence From the European Union (EU). *Ecological Economics*, *150*, 264–272. https://doi.org/10.1016/j.ecolecon.2018.04.028

Kirchherr, J., Reike, D., & Hekkert, M. (2017). Conceptualizing the circular economy: An analysis of 114 definitions. *Resources, Conservation and Recycling*, *127*, 221–232.

Klein, T. (2019). *Framework and Terminology of the Circular Built Environment*.

Klenert, D., Mattauch, L., Combet, E., Edenhofer, O., Hepburn, C., Rafaty, R., & Stern, N. (2018). Making carbon pricing work for citizens. *Nature Climate Change*, *8*(8), Article 8. https://doi.org/10.1038/s41558-018-0201-2

Kooter, E., Uden, M. van, Marrewijk, A. van, Wamelink, H., Bueren, E. van, & Heurkens, E. (2021). Sustainability Transition through Dynamics of Circular Construction Projects. *Sustainability*, *13*(21), 12101. https://doi.org/10.3390/su132112101

Korhonen, J., Honkasalo, A., & Seppälä, J. (2018). Circular Economy: The Concept and its Limitations. *Ecological Economics*, *143*, 37–46. https://doi.org/10.1016/j.ecolecon.2017.06.041

Kupers, R. (2020). *A climate policy revolution: What the science of complexity reveals about saving our planet* (Vol. 1–1 online resource (185 pages)). Harvard University Press. https://www.degruyter.com/openurl?genre=book&isbn=9780674246812

Labandeira, X., Labeaga, J. M., & Rodríguez, M. (2007). Microsimulation in the analysis of environmental tax reforms: An application for Spain. *Microsimulation as a Tool for the Evaluation of Public Policies: Methods and Applications. Madrid: Fundación BBVA*.

Laktuka, K., Pakere, I., Lauka, D., Blumberga, D., & Volkova, A. (2021). Long-Term Policy Recommendations for Improving the Efficiency of Heating and Cooling. *Environmental and Climate Technologies*, *25*(1), 382–391. https://doi.org/10.2478/rtuect-2021-0029

Lazarevic, D., & Valve, H. (2017). Narrating expectations for the circular economy: Towards a common and contested European transition. *Energy Research & Social Science*, *31*, 60–69. https://doi.org/10.1016/j.erss.2017.05.006

Llorente-González, L. J., & Vence, X. (2020). How labour-intensive is the circular economy? A policy-orientated structural analysis of the repair, reuse and recycling activities in the European Union. *Resources, Conservation and Recycling*, *162*, 105033. https://doi.org/10.1016/j.resconrec.2020.105033

López-Bermúdez, F., & Vence, X. (2020). Circular economy and repair activities: An analysis of the industrial structure and regional distribution in the EU. *International Conference on Innovation and Circular Economy*, 26–27.

Masi, D., Kumar, V., Garza-Reyes, J. A., & Godsell, J. (2018). Towards a more circular economy: Exploring the awareness, practices, and barriers from a focal firm perspective. *Production Planning & Control*, *29*(6), 539–550. https://doi.org/10.1080/09537287.2018.1449246

McDonough, W., & Braungart, M. (2010). *Cradle to Cradle: Remaking the Way We Make Things*. Farrar, Straus and Giroux.

Metcalf, G. E. (2019). On the economics of a carbon tax for the United States. *Brookings Papers on Economic Activity*, *2019*(1), 405–484.

Miah, J. H., Koh, S. C. L., & Stone, D. (2017). A hybridised framework combining integrated methods for environmental Life Cycle Assessment and Life Cycle Costing. *Journal of Cleaner Production*, *168*, 846–866. https://doi.org/10.1016/j.jclepro.2017.08.187

Milios, L. (2018). Advancing to a Circular Economy: Three essential ingredients for a comprehensive policy mix. *Sustainability Science*, *13*(3), 861–878. https://doi.org/10.1007/s11625-017-0502-9

Milne, J. E. (2014). Environmental taxes and fees: Wrestling with theory. In *Environmental Taxation and Green Fiscal Reform*. Edward Elgar Publishing.

Moreau, V., Sahakian, M., van Griethuysen, P., & Vuille, F. (2017). Coming Full Circle: Why Social and Institutional Dimensions Matter for the Circular Economy. *Journal of Industrial Ecology*, *21*(3), 497–506. https://doi.org/10.1111/jiec.12598

Morello, T. F., & da Silva e Silva, L. F. (2022). Garnering support for Pigouvian taxation with tax return: A lab experiment. *Environmental Economics and Policy Studies*. https://doi.org/10.1007/s10018-022-00345-x

Munaro, M. R., Tavares, S. F., & Bragança, L. (2020). Towards circular and more sustainable buildings: A systematic literature review on the circular economy in the built environment. *Journal of Cleaner Production*, *260*, 121134. https://doi.org/10.1016/j.jclepro.2020.121134

Ness, D. A., & Xing, K. (2017). Toward a Resource-Efficient Built Environment: A Literature Review and Conceptual Model. *Journal of Industrial Ecology*, *21*(3), 572–592. https://doi.org/10.1111/jiec.12586

NMD. (n.d.). *An introduction to the NMD*. Nationale Milieudatabase. Retrieved 13 November 2022, from https://milieudatabase.nl/en/about-us/an-introduction-to-the-nmd/

NMD. (2022). *Bepalingsmethode Milieuprestatie Bouwwerken*. Nationale Milieu Database. https://milieudatabase.nl/wp-content/uploads/2022/04/Bepalingsmethode_Milieuprestatie_Bouwwerken_maart_2022.pdf

Nordhaus, W. D. (2012). 27. Carbon Taxes to Move Toward Fiscal Sustainability. In *The Economists' Voice 2.0* (pp. 208–214). Columbia University Press.

Nußholz, J. L. K. (2017). Circular Business Models: Defining a Concept and Framing an Emerging Research Field. *Sustainability*, *9*(10), Article 10. https://doi.org/10.3390/su9101810

Nußholz, J. L. K., Nygaard Rasmussen, F., & Milios, L. (2019). Circular building materials: Carbon saving potential and the role of business model innovation and public policy. *Resources, Conservation and Recycling*, *141*, 308–316. https://doi.org/10.1016/j.resconrec.2018.10.036

OECD. (2010). *Taxation, innovation and the environment*. OECD.

OECD. (2017). *Debate the Issues: Complexity and Policy making* (P. Love & J. Stockdale-Otárola, Eds.). OECD. https://doi.org/10.1787/9789264271531-en

One Click LCA. (n.d.). *Life Cycle Assessment for Buildings—Why it matters and howto use it* [Ebook]. Retrieved 5 October 2022, from https://oneclicklca.drift.click/building-lca-ebook

Pigou, A. C., & Aslanbeigui, N. (1932). *The economics of welfare*. Routledge.

Pomponi, F., & D'Amico, B. (2020). Low Energy Architecture and Low Carbon Cities: Exploring Links, Scales, and Environmental Impacts. *Sustainability*, *12*(21), Article 21. https://doi.org/10.3390/su12219189

Potting, J., Hekkert, M. P., Worrell, E., & Hanemaaijer, A. (2017). Circular economy: Measuring innovation in the product chain. *Planbureau Voor de Leefomgeving*, *2544*.

Prins, A. G., & Hanemaaijer, A. (2022). *Voortgangsbericht Circulaire Economie 2022*. https://www.pbl.nl/publicaties/voortgangsbericht-circulaire-economie-2022

Raworth, K. (2017). *Doughnut Economics: Seven Ways to Think Like a 21st-Century Economist*. Chelsea Green Publishing.

Reike, D., Vermeulen, W. J. V., & Witjes, S. (2018). The circular economy: New or Refurbished as CE 3.0? — Exploring Controversies in the Conceptualization of the Circular Economy through a Focus on History and Resource Value Retention Options. *Resources, Conservation and Recycling*, *135*, 246–264. https://doi.org/10.1016/j.resconrec.2017.08.027

Sassanelli, C., Rosa, P., Rocca, R., & Terzi, S. (2019). Circular economy performance assessment methods: A systematic literature review. *Journal of Cleaner Production*, *229*, 440–453. https://doi.org/10.1016/j.jclepro.2019.05.019

Schut, E., Crielaard, M., & Mesman, M. (2016). *Beleidsverkenning circulaire economie in de bouw: Een perspectief voor de markt en overheid*.

SER. (2016). *Werken aan een circulaire economie: Geen tijd te verliezen*. SER, Sociaal-Economische Raad.

Sorensen, P. B. (2017). *The Basic Environmental Economics of the Circular Economy* (SSRN Scholarly Paper No. 3064684). https://doi.org/10.2139/ssrn.3064684

Stahel, W. (1982). *Product-Life Factor*. http://www.product-life.org/en/major-publications/the-product-life-factor

Stahel, W. (2013). Policy for material efficiency—Sustainable taxation as a departure from the throwaway society. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, *371*(1986), 20110567. https://doi.org/10.1098/rsta.2011.0567

Stichting Bouwkwaliteit. (2019). *Bepalingsmethode Milieuprestatie Gebouwen en GWW-werken*. https://milieudatabase.nl/wp-content/uploads/2019/05/SBK-Bepalingsmethode-versie-3.0-1-januari-2019.pdf

Swarr, T. E., Hunkeler, D., Klöpffer, W., Pesonen, H.-L., Ciroth, A., Brent, A. C., & Pagan, R. (2011). Environmental life-cycle costing: A code of practice. *The International Journal of Life Cycle Assessment*, *16*(5), 389–391. https://doi.org/10.1007/s11367-011-0287-5

Traven, L. (2019). Circular economy and the waste management hierarchy: Friends or foes of sustainable economic growth? A critical appraisal illustrated by the case of the Republic of Croatia. *Waste Management & Research*, *37*(1), 1–2. https://doi.org/10.1177/0734242X18818985

Vadenbo, C., Hellweg, S., & Astrup, T. F. (2017). Let's Be Clear(er) about Substitution: A Reporting Framework to Account for Product Displacement in Life Cycle Assessment. *Journal of Industrial Ecology*, *21*(5), 1078–1089. https://doi.org/10.1111/jiec.12519

van Kampen, A. M., & van den Oever, M. J. A. (2021, December 13). *Milieu-prestatie Biobased bouwmaterialen in de Nationale MilieuDatabase*. WUR. https://www.wur.nl/nl/Onderzoek-Resultaten/Onderzoeksinstituten/food-biobased-research/Show-fbr/Milieu-prestatie-Biobased-bouwmaterialen-in-de-Nationale-MilieuDatabase.htm

Vence, X., & López Pérez, S. de J. (2021). Taxation for a Circular Economy: New Instruments, Reforms, and Architectural Changes in the Fiscal System. *Sustainability*, *13*(8), Article 8. https://doi.org/10.3390/su13084581

Walzberg, J., Lonca, G., Hanes, R. J., Eberle, A. L., Carpenter, A., & Heath, G. A. (2021). Do We Need a New Sustainability Assessment Method for the Circular Economy? A Critical Literature Review. *Frontiers in Sustainability*, *1*. https://www.frontiersin.org/article/10.3389/frsus.2020.620047

Webster, K. (2013). What Might We Say about a Circular Economy? Some Temptations to Avoid if Possible. *World Futures*, *69*(7–8), 542–554. https://doi.org/10.1080/02604027.2013.835977

World Bank. (2017). *State and Trends of Carbon Pricing 2017* [Serial]. World Bank. https://doi.org/10.1596/978-1-4648-1218-7

Zhu, Y., Ghosh, M., Luo, D., Macaluso, N., & Rattray, J. (2018). Revenue recycling and cost effective GHG abatement: An exploratory analysis using a global multi-sector multi-region CGE model. *Climate Change Economics*, *9*(01), 1840009.

Appendix 1 - Case study descriptions

The Voice of Urban Nature

Project size: 188 m^2 gross internal area
Number of floors: 1
Project partners: Overtreders W, Fiction Factory, Exie, New Horizon

General description:
With the pavilion, the garden and the exhibition, Almere and Amsterdam show how they are building the green city of the future together with their residents, and how they give nature a voice in this process. The Voice of Urban Nature's structure is built from a mix of pink-hued hempcrete and reclaimed timber that is finished with a biobased coating of linseed oil and carbon.

Picture:

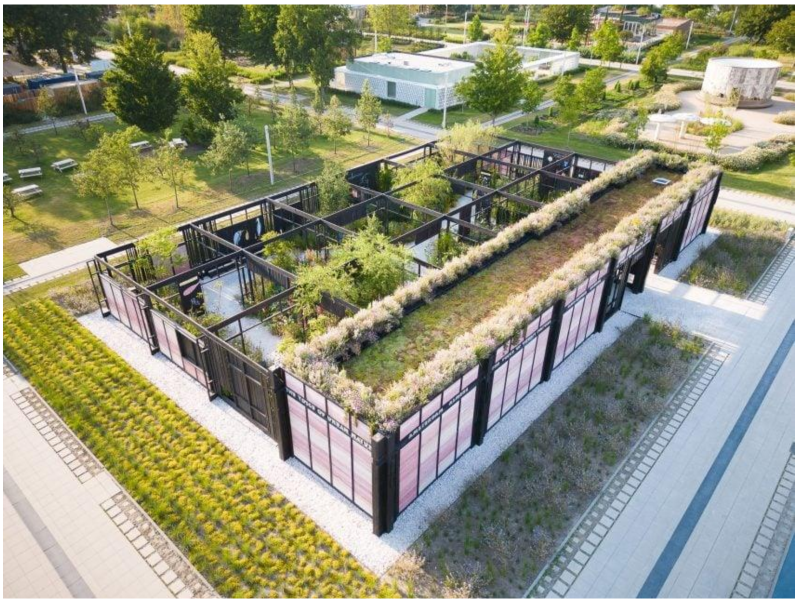

Image credit: Jorn van Eck.

Circuloco

Project size: 234,7 m^2 gross internal area

Number of floors: 2

Project team: Van Wijnen, Boombom2022, Mac3park, Comma, Leadax, Iedp, donker groep, PRICE, atelier Dutch, The Crazy Smile, de Realisatie, Houtbaar

General description: The Circuloco pavilion by Van Wijnen serves as a living lab for circular construction and experimentation, and as a showroom for circular projects by local artists. The pavilion is built with secondary materials and life-extending solutions and is designed for reassembly.

Picture:

Image credit: [Cirkelstad](#).