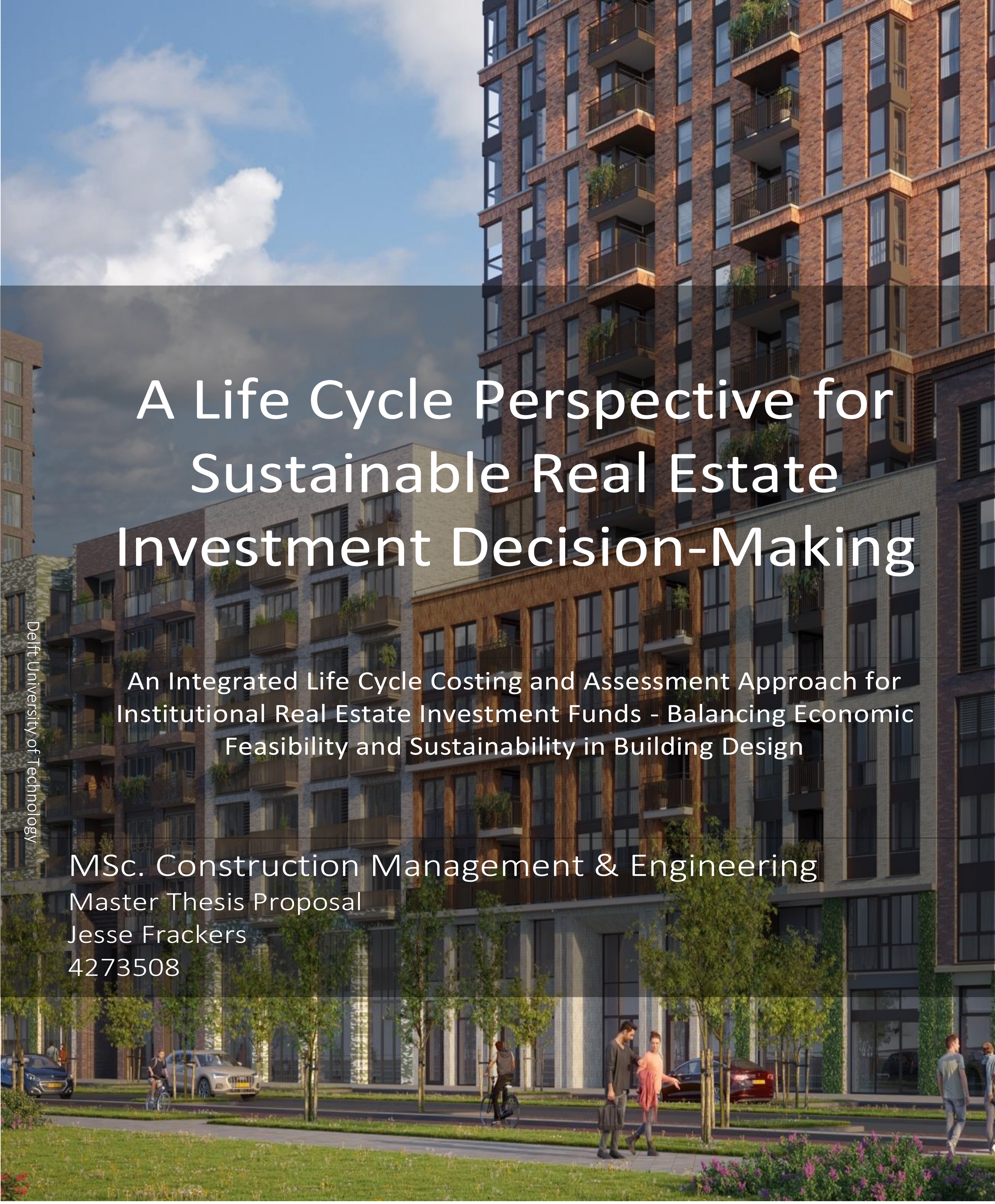

A Life Cycle Perspective for Sustainable Real Estate Investment Decision-Making

An Integrated Life Cycle Costing and Assessment Approach for Institutional Real Estate Investment Funds - Balancing Economic Feasibility and Sustainability in Building Design

Delft University of Technology

MSc. Construction Management & Engineering

Master Thesis Proposal

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TU Delft

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Master Thesis

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"It always seems impossible until it is done." - Nelson Mandela

Written by
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[10-10-2023]

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Graduation thesis

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Preface

Beginning on a deeply personal note, I dedicate this Graduation Thesis to my late grandfather, who passed away on the day I received my official approval to proceed. Alongside my grandmother, they have been major supporters of my dream to earn a master's degree. This thesis signifies not merely the completion of my academic journey but also the conclusion of a winding, unpredictable road that started in Delft in 2013. Life threw a curveball in the form of a devastating scooter accident in 2018, leaving me with non-congenital brain damage. Doctors warned that the consequences might be enduring, putting a cloud of uncertainty over my full recovery. Despite this, I persevered, earning my bachelor's degree while stumbling in my initial attempt at a Master's program. Almost abandoning academics, I realized that the void of unfulfilled aspirations would haunt me. Driven by this understanding, I discovered the Master's program in Construction Management & Engineering (CME), which truly resonated with my passion for the integration of sustainability with the built environment to build tomorrow's world as a better place for future generations.

The golden opportunity to marry these interests appeared when I began my Graduation Research at Vesteda, an Institutional Real Estate Investment Fund. I owe tremendous gratitude to my company supervisor, Raymond Schäperkötter, whose visionary stance on sustainable built environments made him an excellent mentor. His consistent support and guidance have been invaluable. The entire Vesteda team has also been instrumental, revealing to me an organizational culture deeply rooted in sustainability.

Turning my appreciation towards the academic arena, I want to thank the members of the graduation committee at TU Delft for their trust, insights, and patience, notably during the 'superviseren' (progress meetings). My primary supervisor, Quirien Reijtenbagh, provided continual guidance, helping me navigate the complexities of research. Special thanks to Dr. Gerard van Bortel for his valuable feedback from a Real Estate Management perspective, and to Dr. Daan Schraven for his crucial, at times intensified, supervision as deadlines neared, enabling me to keep sight of the broader research objectives.

On a personal front, I extend heartfelt thanks to my girlfriend, Marije, who provided unwavering support, making this long-held dream a reality. Gratitude is also due to my family for their constant encouragement and to my friends, who were there in the difficult moments, always reassuring me that this dream was possible.

As I step into my role as Vesteda's new Sustainability Advisor, I'm excited about the prospect of working alongside a company that can act as a catalyst for sustainable change in the built environment. This thesis marks both the end of a challenging yet fulfilling journey and the dawn of a promising new chapter. Enjoy reading!

Abstract

It is observed that both cost and environmental impact are underemphasized criteria in the investment decision-making process of Institutional Real Estate Investment Funds (IREIFs). The limited adoption of Life Cycle Costing (LCC) and Life Cycle Analysis (LCA) within IREIFs' Performance Management Systems (PMS) hampers improved investment substantiation. This study aims to develop an LCC tool that accounts for environmental impact and to explore its potential implementation within an IREIF's PMS. The research question addressed is: 'How can an IREIF incorporate sustainability, defined here as both environmental and economic factors, into its decision-making process through LCC?' A double diamond design research approach led to the development of an Environmental Impact (EI)-LCC tool that monetizes environmental impact. This tool serves as a performance measurement instrument, offering insights into the environmental and cost implications of building elements over their lifespan. The study also discusses the tool's integration into an IREIFs existing Internal PMS as their Environmental, Social, and Governance (ESG) performance framework. Preliminary findings indicate that the EI-LCC tool, although in a nascent stage, has the potential to enhance the quality of sustainable investment decisions within IREIFs. The results provide a foundation for the tool's further development and broader implementation within the PMS of IREIFs.

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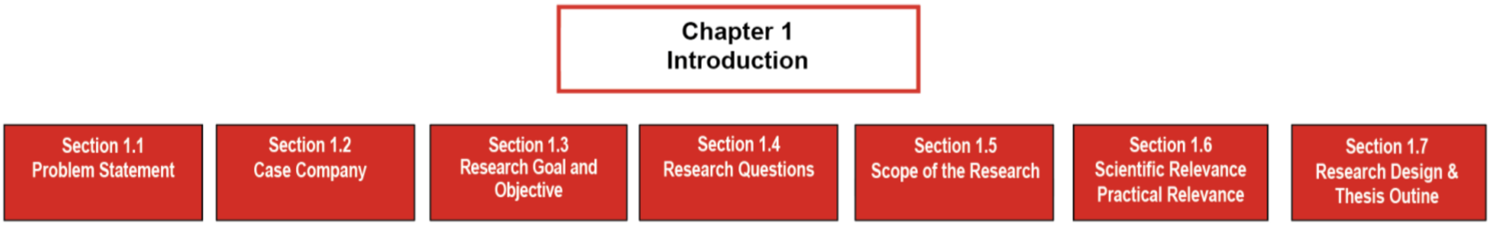
List of Abbreviations

BENG	– Bijna Energie Neutrale Gebouwen (Almost Energy Neutral Buildings)
CE	– Circular Economy
EI-LCC tool	– Environmental Impact-Life Cycle Costing tool
EPD	– Environmental Product Declaration
ESG	– Environmental Social Governance
GFA	– Gross Floor Area
GHG	– Green House Gas
GPR	– Gemeentelijke Praktijk Richtlijnen (Municipal Practice Guidelines)
IREIF	– Institutional Real Estate Investor
KPI	– Key Performance Inidicator
LCA	– Life Cycle Analysis
LCC	– Life Cycle Costing
LCT	– Life Cycle Thinking
MKI	– Milieu Kosten Indicator (Environmental Cost Indicator
MPG	– Milieu Prestatie Gebouwen (Environmental Performance of buildings)
MRA	– Metropole Region Amsterdam
MVP	– Minimum Viable Product
NMD	– Nationale Milieu Database (National Environmental Database)
KPM	– Key Performance Measures
PMS	– Performance Management System
PaaS	– Product as a Service
PV	– Present Value
RTD	– Research Through Design
SDG	– Sustainable Development Goals
SFDR	– Sustainable Finance Disclosure Regulation
SIS	– Sustainability Impact Score
SPI	– Sustainable Performance Indicator
WLC	– Whole Life Cost



1| Introduction

The world is currently facing major environmental problems i.e., depletion of natural resources for building materials and climate change caused by Green House Gas (GHG) Emission resulting in global warming and loss of biodiversity (Cabeza et al., 2022). These issues represent only a fraction of the challenges arising from human activities on a global scale. One significant contributor is the building sector and the built environment, which is responsible for 31% of CO2 emissions of which 50% is linked to the operational phase and the energy use of residential buildings worldwide (Cabeza et al., 2022). Since the human populations continues to grow, society and companies must rethink their practices to keep the earth a habitable place (Bocken et al., 2013).

In follow-up on the Paris Agreement of 2015, the European Commission proposed the European Green Deal in 2019 which took effect in 2020. The Green Deal stipulates what the sustainable transitions in the pursuit to net-zero in 2050 should look like in the EU (Fetting, 2020). The Green Deal is gradually being incorporated into laws and regulations by policy makers in various EU countries. In the Netherlands, these sustainable policies have come to fruition in the formulation of the Dutch Climate Agreement. (Wiebes, 2019). A broad coalition of companies, organizations, and governments have signed the agreement, outlining specific measures to reduce greenhouse gas emissions in various sectors, including the building sector. The goal of the Climate Agreement is to reduce the Dutch environmental impact and contribute to the global effort to combat climate change in line with the United Nations' Sustainable Development Goals (SDGs) (Omer & Noguchi, 2020). The sectors have agreed to reduce CO2 emissions by 49% by 2030 and the Netherlands is aiming for climate neutrality by 2050 (Wiebes, 2019). Therefore, building regulations are gradually becoming stricter to reduce the impact of buildings on the environment (Kanters, 2020).

The Dutch policy of minimizing the environmental impact of the built environment stands in contrast with the existing housing crisis. Both issues are important on the political agenda and represent a major challenge to be addressed. To tackle the housing crisis, the Dutch government has agreed to build 900,000 new housing units in a period between 2022 and 2030 (De Jong, 2022). The result is that the environmental impact is not expected to decrease soon (Circle Economy et al., 2022). Dealing with the challenge of constructing sufficient housing in an environmentally sustainable manner is a critical issue faced by the building sector.

Amidst the various challenges faced by the building sector, sustainability has emerged as a key focus area for many stakeholders. Notably, Institutional Real Estate Investment Funds (IREIFs) have shown a growing interest in investing in more sustainable housing projects (Leskinen et al., 2020). Recognizing the long-term financial stability and environmental benefits associated with sustainable investments, IREIFs are actively seeking opportunities to incorporate sustainability considerations into their investment strategies (Christensen et al., 2021). By investing in more sustainable real estate, these funds aim to align their portfolios with the principles of environmental responsibility, energy conservation, and long-term value creation.

Large institutional real estate investors have the capability to play a crucial role in driving the transition towards a more sustainable built environment. With their substantial financial resources, they have the ability to invest in and promote sustainable real estate development practices that fits their ambitions and objectives. When an institutional investor purchases a substantial part of a development project in advance, it provides the necessary financial backing to accelerate the project's start and is known as the "the flywheel effect" caused institutional investors (Ministerie van Binnenlandse Zaken en Koninkrijksrelaties, 2022).

Overall, in light of the aforementioned, the urgency for a transition towards a built environment with less environmental impact is evident. For IREIFs to spur this transition, they need performance measurement tools to monitor and assess their sustainable ambitions and objectives, along with the financial implications associated with them (Epstein & Buhovac, 2014).

While many performance measurement tools and indicators, including those related to the circular economy (CE), are widely available and discussed by academia, the EU, Dutch Government, and businesses (Hartley et al., 2020b; Fetting, 2020; Ministerie van Infrastructuur en Waterstaat, 2021), they do not fully capture the integrated approach necessary for considering financial aspects. These tools, some of which are mandatory for obtaining building permits or used by companies in the real estate sector to disclose their sustainable efforts, often fall short in offering a comprehensive solution due to the complexity and multifaceted nature of environmental problems. Difficulties in measuring and combining environmental and financial metrics, plus the involvement of a wide range of actors throughout the life cycle and value chain without clear consensus present significant barriers to finding effective solutions (Hart et al., 2019).

This necessitates the need for a more comprehensive and holistic performance measurement tool that accounts for both the environmental impact and financial implications of their investments. Such a tool could aid the investment decision-making process, monitoring IREIFs' ambitions and objectives, thereby spurring the transition towards a built environment with a reduced environmental impact.

1.1| Problem statement

IREIFs are key players in the building sector, a sector that plays a pivotal role in mitigating environmental impacts and achieving climate targets. As part of their investment decision-making process, IREIFs need to balance financial, and sustainability considerations. However, current performance measurement tools often fail to provide a comprehensive view that integrates financial implications with environmental impact. This lack of integration can lead to economic considerations overshadowing environmental ones, hindering the transition to more sustainable practices (Schneider-Marin et al., 2022).

Life Cycle Thinking (LCT), which encompasses environmental Life Cycle Assessment (LCA) and life cycle costing (LCC), has been proposed as a solution (Ingrao et al., 2019). LCA is a well-established technique for sustainability studies in the built environment (Pomponi & Moncaster, 2017), and LCC is often used to assess economic benefits and functions (Giorgi et al., 2022). The benefits of LCC and LCA for economic and environmental sustainability[1] have been demonstrated through successful implementation in various industries (D'Incognito et al., 2015). However, despite their potential, LCT and its methods have not been widely adopted by IREIFs due to the complexity of the methods, lack of knowledge within companies operating in the real estate sector, the need for extensive data, and the lack of standardization (Cabeza et al., 2014; Altaf et al., 2022; Zhang et al., 2021; Rahim et al., 2016).

The challenge, therefore, lies in developing and implementing a tailor-made LCC model that can

[1] Environmental sustainability refers to the responsible interaction with the environment to avoid depletion or degradation of natural resources and allow for long-term environmental quality. It emphasizes preserving the environment's capability to support human life.

be utilized by an IREIF. Such a model should integrate both the environmental impact and financial implications of their investments, providing a more holistic view to aid in the decision-making process. This would lead to more substantiated and sustainable investment decisions, contributing to the transition towards a more sustainable built environment (Braakman et al., 2021) and will overcome the uncertainties opposed by Kambanou & Sakao, 2020) about whether sustainable mitigating measures are economically feasible.

The above summarized, results in the following problem statement:

In the face of urgent environmental challenges and the need for sustainable development, the current lack of comprehensive and integrated tools for IREIFs to balance financial and environmental considerations in their investment decision-making process presents a significant barrier to the transition towards a more sustainable built environment.

1.2| Case company

This graduation research is conducted in collaboration with Vesteda, an IREIF operating in the Dutch residential real estate sector. The research aims to *Discover* the broader context of Institutional Real Estate Investment Funds. Subsequently, the focus will be narrowed down to the specific context of Vesteda in order to develop a customized LCC tool for the company. Vesteda's valuable data and insights will play a crucial role in conducting the research effectively.

Vesteda has a portfolio of 27,718 houses valued at €10.1 billion, Vesteda is committed to providing high-quality and affordable housing for tenants while offering attractive returns for investors (Vesteda, 2022). As part of their strategic vision, Vesteda places a strong emphasis on continually improving the quality and sustainability of their portfolio.

A significant trend that aligns with Vesteda's values is the growing focus on creating a more sustainable built environment. In addition to complying with regulations and laws, Vesteda actively participates in industry initiatives such as the covenant on timber construction by the Metropole Region Amsterdam (MRA) and is a participant in 'Het Lente Akkoord 2.0'. Through close collaboration with supply chain partners, including material suppliers, contractors, developers, and architects, Vesteda strives to drive sustainability advancements throughout the construction process.

To further advance their sustainability goals, Vesteda not only acquires new *sustainable* residential properties but also focuses on the redevelopment of their existing housing stock in a sustainable way. Investment decision-making plays a crucial role in determining where to allocate financial capital, whether in new propositions or redevelopment projects. During this decision-making process, Vesteda assesses the economic feasibility and compliance with their program of requirements, as well as the alignment with their sustainability goals and ambitions.

Vesteda recognizes the challenge of limited quantitative insights on environmentally sustainable considerations in investment decisions, leading to undervaluation of ambitious sustainable projects. To address this, Vesteda aims to develop a model that provides insights into the environmental impact and associated costs of building elements. This model will enable them to determine the total costs throughout the lifecycle of these investments in buildings with circular and sustainable products, ensuring that the financial and environmental aspects are taken into account.

Vesteda, being proactive in the transition to a more sustainable built environment, recognizes the need to substantiate their sustainable investment decisions process by considering both financial feasibility and environmental impact reduction of sustainable measures. Building upon prior research of Zhang et al. (2021), stating that there is a need for consensus on LCC and its practical application, Vesteda wants to further research and apply an LCC-framework serving IREIFs. The opportunity that a LCCA provides for real estate investment decisions, spurred Vesteda's adoption and resulted in the first steps that are already been taken towards the development of an LCC model.

By integrating economic feasibility assessments with sustainability evaluations, Vesteda aims to make informed investment decisions that are both economically viable and aligned with their sustainability objectives. This approach enables them to contribute to a more sustainable built environment while achieving their mission of providing high-quality and affordable housing for tenants and delivering attractive returns for investors.

1.3| Research Goal and Objective

The aim of this study is to develop an integrated life cycle costing tool accounting for environmental impact to assist institutional real estate investors in making investment decisions that balance economic feasibility and environmental sustainability in building design and investment choices.

The primary objective is to develop an LCC model that enhances understanding of the total life cycle costs (investment and maintenance) of building elements and enables comparison between various purchasing options. This model will facilitate the evaluation of different building design options during project proposals.

A secondary objective is to quantify the environmental impact associated with these design options by incorporating an environmental impact indicator in the LCC model, enabling comparison of various designs.

Ultimately, the LCC model aims to enhance decision-making in the investment process of building elements, particularly in justifying additional expenditures for environmental impact reduction. The model's results and insights are designed to supplement the existing sustainability assessment framework used for project proposals.

1.4| Research Questions

The problem statement and research objective are translated into the following Main research question:

"How can an Institutional Real Estate Investment Fund incorporate sustainability into the decision-making process by the implementation of Life Cycle Costing?"

The following sub-questions further refine and clarify the main research question. They are used to break down the main research question into smaller, more manageable components, which can be explored in more detail. Furthermore, the sub-questions provide a clear direction for data/information collection and analysis, and structure the design-research report making it more organized and logical.

Sub-question 1

"How is sustainability currently incorporated in the real estate investment decision-making process, and what challenges do Institutional Real Estate Investment Funds (IREIFs) face when implementing Life Cycle Costing within this process?"

Sub-question 2

"What opportunities provide the implementation of the LCC tool for IREIFs?"

Sub-question 3

"What methodology can be applied to develop an LCC-tool for buildings, accounting for environmental impact, for implementation in the real estate investment decision-making process of an IREIF?"

Sub-question 4

"Where in the investment decision-making process of IREIFs can the LCC be utilized for more enhanced evaluation of sustainable decision-making?"

Sub question 5

"How can the results obtained from an LCC-tool be utilized in real estate investment decision-making to include sustainability?"

1.5| Scope of the research

This research is conducted in collaboration with Vesteda, a large institutional real estate investment fund in the Netherlands. The scope of this research will therefore be on Dutch residential market from the perspective of an institutional real estate investor. The focus of the research is on the development of an LCC-model assessing *design choices* of residential buildings that can be influenced/chosen by Vesteda[2] .

Within the scope of this research, the primary focus will be on the integration of an environmental indicator into an LCC model to assess the environmental sustainability and economic feasibility of building design and substantiate investment decisions. This study specifically examines building elements and their financial and economic aspects, which necessitates excluding the social dimension from consideration.

Although different design options inherently involve social implications, investigating the social influences is beyond the scope of this research. Furthermore, the exclusion of the social pillar of sustainability is due to the complexity of incorporating social indicators, which often requires a separate methodological approach. By limiting the scope of this research to environmental impact and LCC, it aims to provide a more focused and practical contribution to the understanding of how institutional real estate investors, like Vesteda, can achieve a balance between economic feasibility and environmental sustainability.

In summary, the research focuses on integrating environmental indicators into LCC models to substantiate investment decisions about residential building design and investment choices. The perspective within this research is from an institutional real estate investor in the Netherlands, with the aim of striking a balance between economic feasibility and environmental sustainability.

[2] Vesteda evaluates building designs presented in Real Estate Project Proposals. Although the overall building structure is largely fixed, there's room to negotiate with the developer on specific elements like windows, facades, roofs, and interior components like kitchens and bathrooms. The choices around these elements are detailed in the Design Brief in section [4.1.2].

1.6.1| Scientific Relevance

Although LCC has a long history, it has not yet been fully standardized, except for specific applications. The emergence of various LCC variants adds complexity to the standardization process, further hindering its progress of adoption (Zhang et al., 2021). The aim of this research is to critically review and refine LCC research from the perspective of an Institutional Real Estate Investors and contribute to the body of literature regarding the assessment of the total cost of ownership of buildings in a way that encompasses both environmental costs and benefits. A preliminary literature review reveals that an increasing number of studies are being conducted on the use of LCC-tool for evaluating buildings and the sustainability measures implemented. However, due to the complexity involved, most of these studies focus on specific scopes and contexts, not considering the perspective of institutional investors.

There is a need for further research to develop a comprehensive understanding of how to effectively incorporate the appropriate indicators into an LCC-tool tailored for use by institutional investors. This master thesis aims to bridge this gap by synthesizing existing knowledge and findings from LCC-tool research, combined with new insights, to contribute to a more robust understanding of how this performance measurement tool can be employed by institutional investors in the assessment of buildings and sustainable measures.

1.6.2| Practical Relevance

Sustainable Real Estate investments offer numerous benefits to stakeholders, including Institutional Real Estate Investment Funds (IREIFs), as they strive to meet regulatory requirements and respond to various drivers such as energy conservation, improved corporate culture and image, enhanced marketability, customer demand, and reduced operating and maintenance costs (Darko et al., 2017). Figure 2 further illustrates the drivers influencing the adoption of sustainable building practices.

Focusing specifically on IREIFs, they recognize the importance of adopting sustainable investment principles to acquire sustainable buildings, which in turn generate long-term financial stability (Leskinen et al., 2020). This need for stability largely stems from the demands of their primary investors - insurance companies and pension funds - who require a steady return on investment with a low risk profile over a long investment horizon (Jansen & Tuijp, 2021; Hartzell & Baum, 2021).

Consequently, the transition to a sustainable real estate portfolio is essential for IREIFs, leading to the integration of sustainability ambitions and visions throughout the company and the need for performance measurement tools, such as an LCC-tool, for its assessment.

1.7| Research Design & Thesis Outline

The thesis outline follows a design-based research approach to answer the main-research question and the underpinning sub-questions. This design-based researched consists of four phases: 1) Discover, 2) Define, 3) Develop, and 4) Deliver.

Chapter 2 aims to establish a theoretical framework as part of the *Discover* phase, that explores the growing significance of sustainability within the investment landscape where IREIFs operate. This chapter delves into LCT, (inter-)national law and regulation, and performance management systems (PMS). Within this chapter, answers to sub-questions 1 and 2 are provided.

Chapter 3 emphasizes the choice for a design-based research method which was chosen to support the data and information gathering, required for the development of the tool and to substantiate the choices made. This chapter furthermore details the methodologies employed in each phase of the design-based research. This chapter provides an answer to sub-question 3.

Chapter 4 begins by consolidating insights from the Discover and Define phases into a design brief. It then presents the development of the LCC-tool, including its environmental impact integration. The chapter also discusses the tool's results and their relevance to the fourth sub-research question. Finally, it explores how these findings can improve IREIF investment decisions, addressing the fifth research question.

Chapter 5 critically evaluates and discusses the choices made and outcomes obtained during the research and development processes of the LCC-tool. It concludes by validating whether the requirements outlined in the design brief have been met.

Chapter 6 presents an overview of the answers to the five sub-questions, aiming to resolve the main research question: *"How can an Institutional Real Estate Investment Fund incorporate sustainability into the decision-making process by the implementation of Life Cycle Costing?"*. This chapter synthesizes the findings to answer the main research question and addresses the limitations of the research and future recommendations.

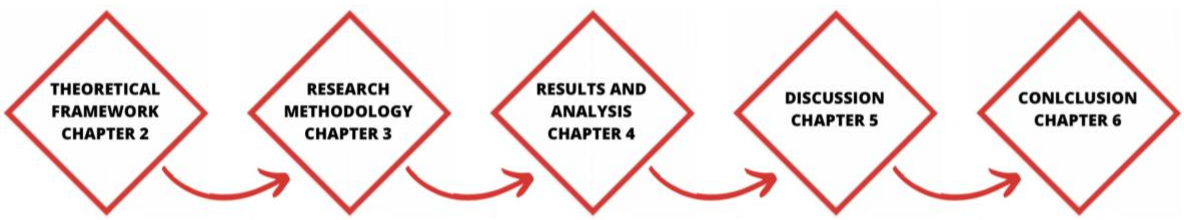


Figure 1 – Thesis outline. (Own work)

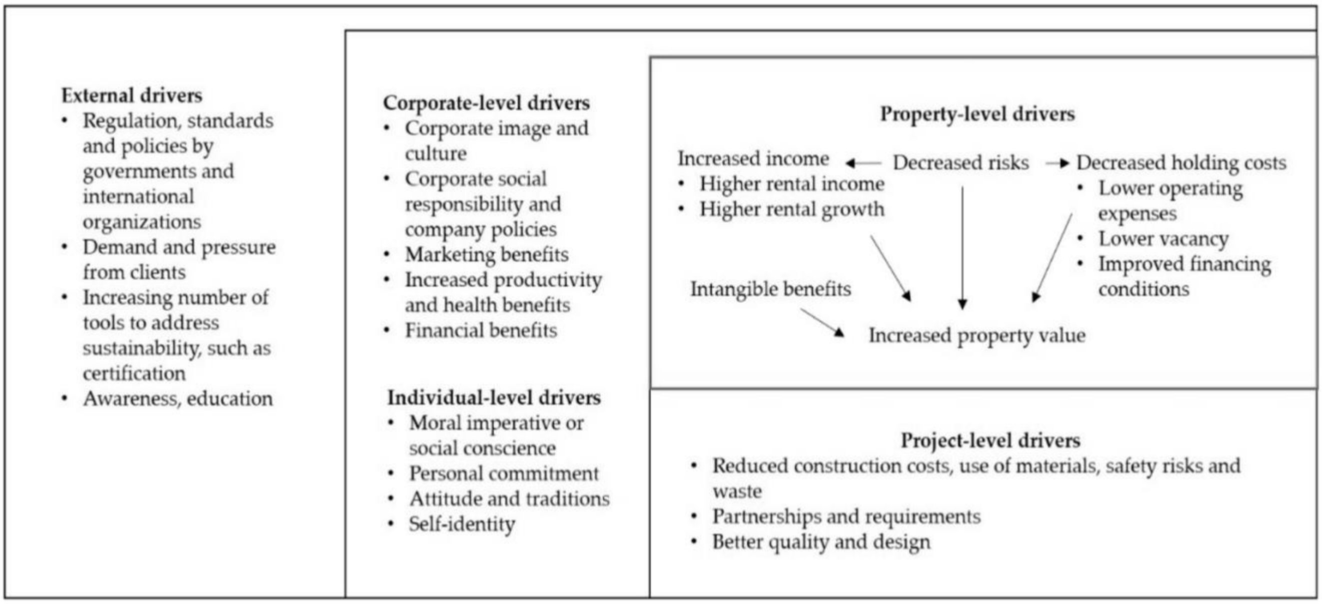
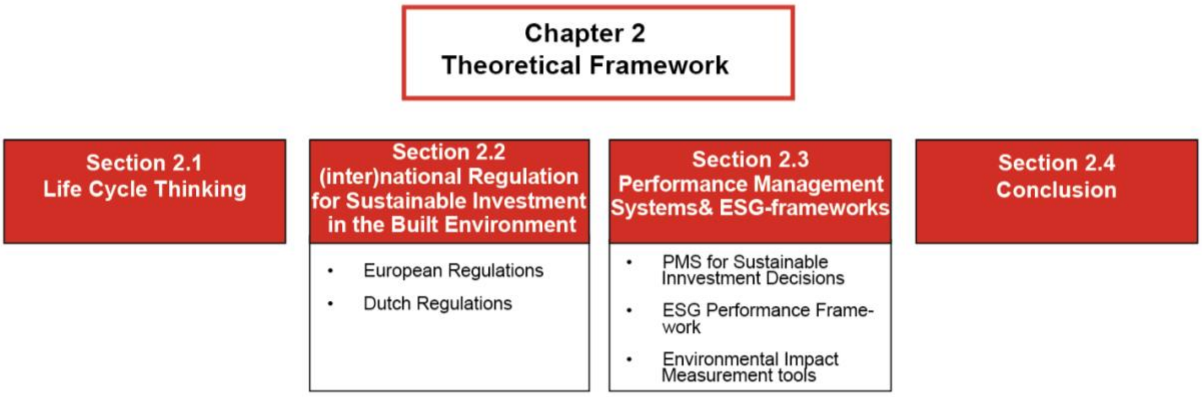


Figure 2 - Drivers influencing sustainable building adoption (Leskinen et al., 2020)



2| Theoretical Framework

In this chapter a theoretical framework is constructed to discover the fundamental aspects of assessing the (sustainable) performance of IREIFs. This framework aims to understand how these aspects interrelate, particularly in how sustainability is incorporated into investment decision-making. IREIFs context and their (Sustainable) performance is inherently a complex multi-level endeavor. As argued by Klein and Kozlowski (2000), to be able to capture much of the nested complexity, a multi-level approach is adopted as foundational framework to understand the intricate interplay of different forces at the macro-, meso- and micro-level

This multi-level approach aims to reveal the current state of the context in which IREIFs operate. Within this context (Figure 3), the macro-level involves the (Inter)national Regulation from the governing bodies and the influence of shareholders. The meso-level is linked to the public and internal (ESG) performance management of the portfolio aligned with the requirements set by the governing bodies and shareholders resulting in strategic choices in line with IREIFs ambition and vision. Finally, the Micro-level reveals the tactical and operational performance assessment aimed at fulfilling the criteria established by the overarching strategy, and how an LCC, accounting for environmental impact, lands within this level.

The knowledge retrieved in this chapter is crucial for the accurate development of the LCC-tool and allows for addressing the associated challenges and the exploitation of its opportunities. This chapter aims to provide answers to the following first two sub-questions in the conclusion:

Sub-question 1

"How is sustainability currently incorporated in the investment decision-making process, and what challenges do Institutional Real Estate Investment Funds (IREIFs) face when implementing Life Cycle Costing within this process?"

Sub-question 2

"What opportunities provide the implementation of the LCC tool for IREIFs?"

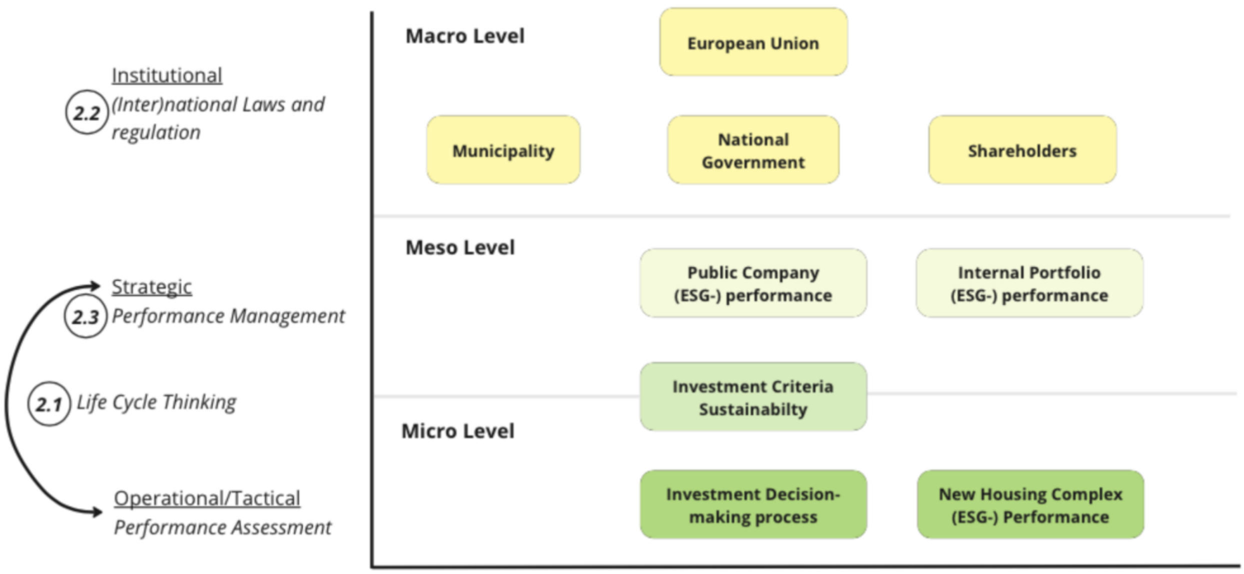


Figure 3 – Outline of the Theoretical Framework: The left side of the figure illustrates a multi-level and the corresponding topics of each section. On the right, an overview of relevant actors and topics is presented.

2.1| Life Cycle Thinking (LCT)

Within this section, the Micro level of the theoretical framework will be discussed, which is the place where Life Cycle Thinking comes into its own. There will be first given background information regarding LCC and how it positions itself within the framework (Figure 4). Subsequently, there will be elaborated on the integration of LCA and LCC.

In the text, numbers corresponding to Figure 4 are found throughout the chapter, illustrating how the topics within theoretical framework influence each other within the broader context.

2.1.1| Life Cycle Costing

LCC is one of the three interlinked methods of LCT, alongside environmental life cycle assessment (LCA), and social life cycle assessment (sLCA)[3]. Collectively, these aim to achieve sustainability's triple bottom line by addressing environmental, economic, and social aspects, respectively (Janjua et al., 2020).

LCC was originally developed as a cost management tool with a purely financial focus (Novick, 1959). Conventional LCC primarily addresses the costs related to acquisition and ownership costs (Zhang et al., 2021). LCC is a well-established approach for assessing economic feasibility throughout a building's life cycle regarding the costs and can be applied for comparing design variants over time (Fouche & Crawford, 2017), and compare alternative designs regarding building elements to determine the most economical option with the lowest life cycle cost in the long run (Abouhamad & Abu-Hamd, 2019). Furthermore, LCC proves to be a useful tool to evaluate the financial feasibility of mitigating measures aimed at reducing environmental impact (3) (Braakman et al., 2021).

LCC analysis, as defined by ISO 15686-5, is a *"technique which enables comparative cost assessments to be made over a specified period of time, taking into account all relevant economic factors, both in terms of initial costs and future operational costs*" (Heralová, 2017, p566). LCC analysis for buildings generally models the total investment costs of design choices, future operational costs, and maintenance and disposal costs (3) (Flanagan & Jewell, 2005). The goal is to identify the opportunity with the lowest life cycle cost or the one that maximizes the net profit in line with the specified criteria (2) (Abouhamad & Abu-Hamd, 2019).

2.1.1.1 The valuation model and its cost component within the investment decision-making process

The investment decision-making process involves a *valuation analysis* of potential real estate investments (3), typically presented by real estate developers. This analysis includes the assessment of various predefined investments criteria and their associated risks (2). For example, it assesses the current and future value, projected rental income, location, rentability, and alignment with the IREIF's

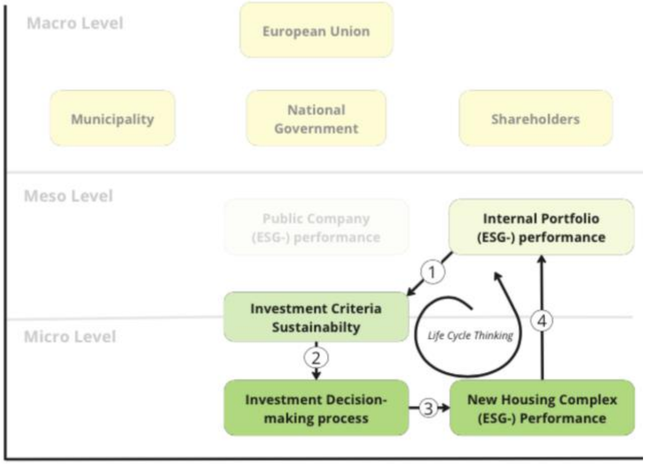


Figure 4 – Part [1/6] of the theoretical framework. It showcases where life cycle thinking is positioned in the context of an IREIF. The numbered arrows indicate how one affects the other. Each number corresponds to the topics which are elaborated on throughout the text in section [2.1].
1. Deriving Improved Investment Criteria: Investment criteria are refined through analysis of the internal Portfolio's (ESG) performance.
2. Compliance with Investment Criteria and Requirements: Investment proposals are assessed using established criteria to ensure alignment with standards.
3. Acquisition and Management: Once approved, the housing complex is added to the portfolio, where it is managed and rented out.
4. Monitoring and Analyzing: The new housing complex is monitored and analyzed continually for benchmarking and performance assessment.

[3] The focus subsequent sections, the focus will solely be on LCC and LCA because the former concerns about the cost and the latter is fundamental method of assessing the environmental impact. It should be noted that while S-LCA is an important component of sustainability, it will not be considered within this study, as argued in section 1.5.

sustainability goals and criteria. If criteria are not met, negotiations with the real estate developer will be held to see if there is a possibility to comply with the criteria and the program of requirements.

Cost considerations play a significant role in shaping the financial returns for IREIFs. As such, a cost component is integrated into the valuation model, as investment criteria, to ensure that expenses align within the strategic bandwidths specified by IREIFs. However, as crucial as is, the cost component is often an underemphasized aspect of this valuation model and does not assess the *lifetime* costs associated with the building. Such *lifetime* costs can be categorized into three main areas: (i) initial investment costs, (ii) maintenance costs, and (iii) operational costs (Berkhout, 2019). Despite its importance, the cost component is frequently overlooked or only roughly estimated in an often very basic way, not in the form of an comprehensive LCC-analysis, which has seen minimal uptake (Bull, 2015).

2.1.1.2 Whole Life Costing

Delving a bit deeper into the LCC, where this analysis includes initial construction and through-life activities associated with a built asset. The LCC furthermore represents a division of the broader concept called Whole Life Cost (WLC). The aforementioned *valuation analysis* shows similarities with the WLC as it encompasses three type of costs and the *income* as depicted in Figure 5. The WLC which is defined by ISO 15686 as: '*all significant and relevant initial and future costs and benefits of an asset, throughout its life cycle, while fulfilling the performance requirements*' (Ballesty, 2021, p6). WLC encompasses both non-construction activities and income generation such as receiving rent from tenants.

Conducting an LCC analysis requires substantial data due to the intricate nature of the building process and the numerous components involved (see Figure 6). This directly shows why LCC analysis is perceived as impractical to use. The accuracy and completeness of the input data significantly influence the final result (Gluch & Baumann, 2004).

Despite the potential benefits of LCC, its implementation in practice is limited. This is due to the complexity of the method, the need for extensive data, and the lack of standardization (Cabeza et al., 2014; Zhang et al., 2021), despite its long-standing presence in construction education and its growing recognition in academic research (Manewa et al., 2021). However, when successfully implemented, an LCC analysis can provide valuable insights into the long-term costs of different design options, aiding the investment decision-making process. An LCC model could furthermore analyze the cost of the real estate portfolio IREIFs. Such insights, in turn could help to shape the investment criteria (1), which will enable a more substantiated investments decision-making process (2).

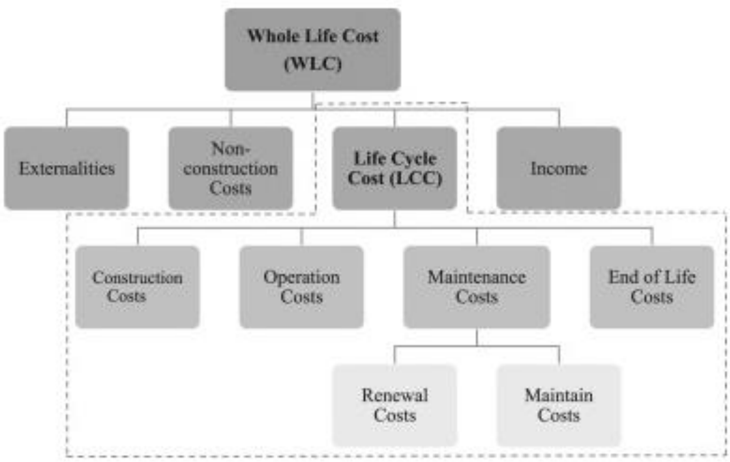


Figure 6 – Definition of Whole Life Cost and Life Cycle Cost based on ISO 15686-5 (Ahmed & Tsavdaridis, 2018))

Investment costs data	**Operation and Maintenance data**	**Project specific data**
Building element costs	Material	Type of building material
Salvage value	Cleaning	Lifetime periods
Demolition costs	Maintenance	
Design fees	Rates	
	Taxes	
	Inflation	

Figure 5 - Example of input data needed to perform an LCC for a building (adapted from: Gluch & Baumann, 2004)

2.1.2| Integration of LCC and LCA[4]

Environmental LCA is a well-established technique for sustainability studies in the built environment, quantifying a building's environmental impact over its lifetime, including raw material extraction, production, use, and disposal (Pomponi & Moncaster, 2017; Hauschild, 2012). LCA is often used in conjunction with LCC, a tool for assessing economic and environmental feasibility throughout a building's life cycle (Giorgi et al., 2022).

Despite the demonstrated benefits of LCC and LCA in various industries (D'Incognito et al., 2015), their application in the building industry has been limited (Cabeza et al., 2014). This is largely due to the complexity of these methodologies, the need for extensive data, and the lack of standardization (Altaf et al., 2022).

According to Bernardino-Galeana et al. (2019), recent studies have proposed diverse approaches for integrating LCA and LCC in the built environment, resulting in new methods and tools such as Circular Economy LCC (CE-LCC), Environmental-LCC (E-LCC), and Societal-LCC (S-LCC) (Wouterszoon Jansen et al., 2020; De Menna et al., 2018). However, the gap between scientific knowledge and practical application remains. This is largely due to insufficient knowledge among and within companies, and the need for tailored models to meet the specific needs of companies operating in the real estate sector (Rahim et al., 2016).

Despite these challenges, the integration of LCA and LCC presents opportunities for the development of a more comprehensive methodological approach. As França et al. (2021) state, these challenges can be turned into opportunities, allowing projects, products, and services to reduce environmental and economic impacts, which can be quantified and compared through improved assessment of potential trade-offs adhering to defined sustainable investment criteria (3).

After acquiring the real estate object, aligned with the criteria used in the investment decision-making process, the real estate is part of the portfolio (4). Resulting in improved performance of the portfolio, of which an improved/updated benchmark could be established, and future potential investment must adhere to (1).

Thus, it becomes evident that for IREIFs to effectively integrate LCC into their investment decision-making, a tailored model that synergizes both LCC and LCA is imperative. This integration not only harnesses the potential of these methodologies to mitigate environmental and economic repercussions but also fosters enhanced sustainability in the built environment. The collective insights regarding the performance measurement derived from the evaluation of the two components of LCT, respectively LCC and LCA, could be best incorporated and applied in associated domains, as illustrated in Figure 4, for performance assessment to comply with the predefined criteria.

[4] LCA is not described in detail in this chapter because it is done in section [4.2.3], which better suits its purpose. Furthermore, an additional description is given in Appendix A [Explanation of Life Cycle Analysis (LCA)].

2.2| (Inter-)national Regulations and Laws for Sustainable Investments in the Built Environment

This section *discovers* the macro level of the theoretical framework and will therefore delve into the regulatory framework for sustainable practices, established by the European Union for real estate investment companies. It will first, highlight the key regulations and directives that govern the disclosure of sustainable activities, which thereby influence the investment decision-making of these companies. Secondly, and lastly, a brief overview will be provided of the relevant Dutch national regulations and policies that impact real estate investment decision making.

Additionally, this section will touch upon sustainable measurement tools to assess the sustainability performance of real estate investments, mandatory in the Netherlands. These tools will be considered for their valuable insights and metrics for evaluating environmental aspects, contributing to a more comprehensive understanding of sustainable investment practices in the real estate sector. In the text, numbers corresponding to Figure 7 are provided, illustrating how the presented *macro-level* is influencing the broader context.

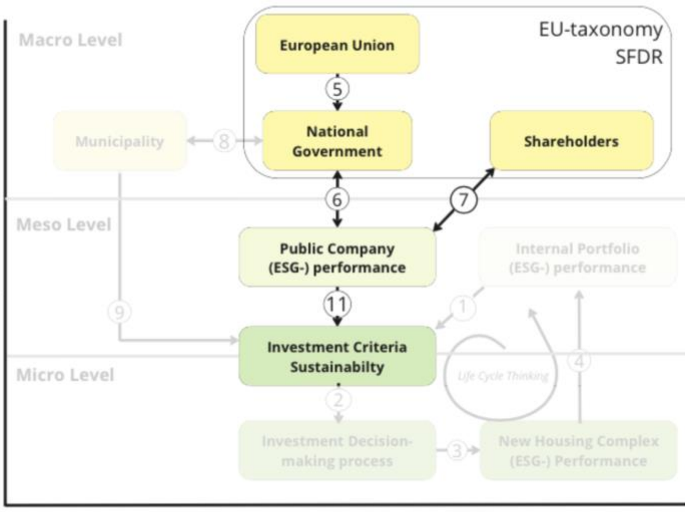


Figure 7 -Part [2/6] of the theoretical framework. Showcasing the topics and stakeholders related to the (inter)national laws and regulatory landscape. It shows how the institutional and strategic level both, directly and indirectly, influences the investment criteria and thus investment decisions-making process. Each number corresponding to the topics elaborated on throughout the entire section [2.2] (Own source)

5. Imposing Policies and Regulations EU wide

6. Establishing Laws and Regulations tailored to the dutch context

7. IREIFS (ESG) Performance Disclosure according to the SFDR

11. Improving the public (ESG) performance of an IREIF by defining and establishing criteria to which adherence is required.

2.2.1| European Regulation for Sustainable Investment Disclosure

Firstly, considering the European Union, it is crucial to underscore the significant influence its regulatory mechanisms exert on promoting sustainable real estate investments (5). The heightened emphasis on sustainable buildings emerges from a growing awareness about the environmental impact of the built environment (Saidani et al., 2019). Every country within the EU is obliged to comply with the 'Building and renovating in an energy and resource-efficient way' focus area of the European Green deal (5) (Fetting, 2020).

To meet the approaching deadlines of a) the EU's climate and energy targets of the Paris Agreement, b) the UN Sustainable Development Goals (SDGs), and c) the European Green Deal by 2030, the European Commission is certain that a common language and definition of what constitutes as sustainability needs to be established. To achieve this goal, the action plan on financing sustainable growth (European Commission, 2020c) has proposed the development of a common classification system for sustainable economic activities, known as the "EU taxonomy" (European Commission, 2020b). The European Commission describes: *"The EU Taxonomy is a classification system that helps companies and investors identify "environmentally sustainable" economic activities to make sustainable investment decisions. Environmentally sustainable economic activities are described as those which "make a substantial contribution to at least one of the EU's climate and environmental objectives, while at the same time not significantly harming any of these objectives and meeting minimum safeguards." (European Commission, 2020a).*

The European Union recognizes IREIF's as crucial part of the financial sector and an essential driver for mobilizing capital to realize the EU's sustainability agenda (Becker et al., 2022). As of March 10, 2021, the Regulation (EU) 2019/2088 on sustainability-related disclosure in the financial services sector, called the Sustainable Finance Disclosure Regulation (SFDR), published by the

European Parliament and Council, came into effect. The SFDR primary objective is to increase transparency and sustainability in financial markets by ensuring consistent and standardized Environmental, Social and Governance (ESG) disclosure. The regulation requires asset managers, investment firms, and advisers to disclose certain information about how they integrate sustainability into their investment decisions (6,7). The SFDR stipulates a classification system for funds based on their sustainability characteristics. There are three categories of funds under the SFDR (INREV, 2023):

- Article 6 funds: Funds that do not have a sustainable investment objective, and do not actively take into account sustainability risks.
- Article 8 funds: Funds that promote environmental or social characteristics, or have a sustainable investment objective, but do not have a specific focus on sustainable investments.
- Article 9 funds: Funds that have sustainable investments as their objective and promote sustainable investments explicitly.

Furthermore, This ESG framework serves the needs of real estate fund investors (7), like pension funds and insurance companies, who are requiring greater transparency, for a) better incorporating long-term financial risks within their investment decision-making process, attributed to climate change, resource depletion, environmental degradation, and social issues, and b) to better align their investments with their own sustainable objectives and to justify their investment decisions (Boffo & Patalano, 2020).

Figure 8 provides an explanatory illustration of how the EU Taxonomy and the SFDR intertwine in the policy landscape of the financial sector. Driven by legal obligations under the SFDR, a sense of ethical responsibility, and accountability to investors, IREIFs and the sector are proactively working to assess the ESG performance of potential investments (Da Cunha et al., n.d.). The importance of ESG performance reporting has grown substantially, becoming an increasingly critical factor for defining investment criteria and thus in the investment decision-making processes (11) (Bichet et al., 2022) and will therefore, be further elaborated on in section [2.3.2].

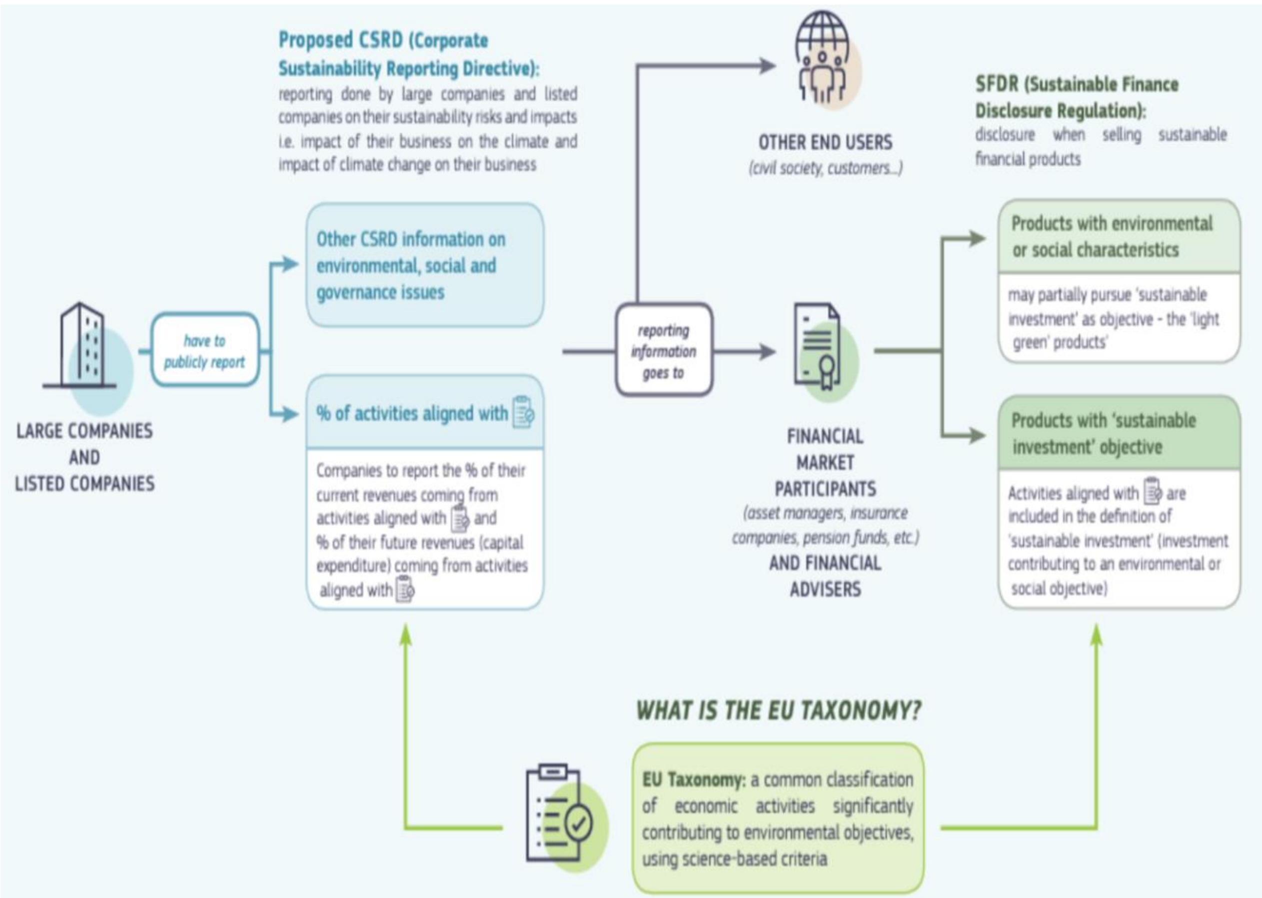


Figure 8 – Two examples when the taxonomy will be used: in disclosures of financial products and reporting by large companies and lister companies (source: Pettingale et al., 2022)

2.2.2| Dutch Regulation and Policy for Sustainable Investment

Within this section the Dutch rules and regulations are explained which is reproduced form EU-regulations (5). Because the sustainable policy pathway of the EU goes beyond the rules and regulations adopted by the Dutch regulatory framework, there will also be looked at Dutch Policies, more specifically: Het Nieuwe Normaal (HNN) (translated: The new Normal). In the text, numbers corresponding to Figure 9 are provided, illustrating how the presented topics influence each other within the broader context.

2.2.2.1 Dutch Regulation

In addition to ESG-disclosure policies guiding the sustainable investments decision making, the Netherlands has enacted a robust and evolving body of sustainability laws and regulations regarding requirements of technical specifications which buildings must meet (6.1). These criteria continually adapt to align with both the increase of standards of the European Union outlined in chapter 1 and its own national ambitions.

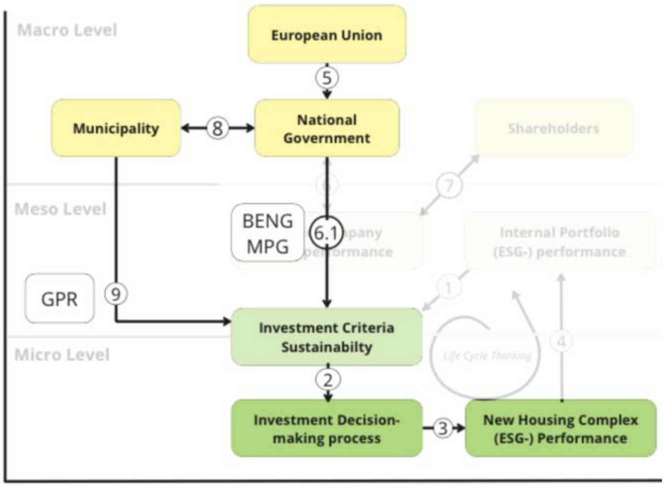


Figure 9 - Part [3/6] of the theoretical framework. Showcasing the topics and stakeholders related to the Dutch regulation and policies. It shows how the institutional and strategic level both, directly and indirectly, influences the investment criteria and thus investment decisions-making process. Each number corresponding to the topics elaborated on throughout the entire section [2.2] (Own source)
2. Compliance with Investment Criteria and Requirements: Investment proposals are assessed using established criteria to ensure alignment with the policies established.
5. Imposing Policies and Regulations
6.1 Policies and regulations influencing the investment criteria
8. Enforcing national laws and regulations and tailoring the rules to the municipals own policies and ambitions.
9. Outlining the requirements and criteria to comply with policies for building related Investment

Two regulations relevant to mention (6.1) are the "Bijna Energie Neutrale Gebouwen" (BENG), translated as "Almost Energy Neutral Buildings," and the "Milieu Prestatie Gebouwen" (MPG), translated as "Environmental Performance of Buildings" (see Figure 9). These two regulations can be used as reporting and monitoring principles for the ESG-disclosure. These regulations, which respectively address energy neutrality and the environmental impact of material choices, are notable as they are used as strict criteria during the investment decision process and can be incorporated as indicators within the previously mentioned ESG performance framework (Circle Economy et al., 2022). Each of these criteria are periodically reviewed, tightening the criteria, which sometimes leads to changes in the investment decision-making process.

Another regulatory tool available for measuring sustainability, alongside the BENG and the MPG, is the Municipal Practice Guidelines, known in Dutch as 'Gemeentelijke Praktijk Richtlijnen' (GPR) (Aantoonbaar Duurzaam Bouwen – GPR Gebouw, n.d.). While not mandated by national laws and regulations, some municipalities may require the GPR for building permit applications (9). Both the mandatory and non-mandatory regulations will be elaborated upon in the subsequent section [2.3.3.2], which discusses the available tools.

2.2.2.2 Dutch policies

A wide range of policies have a significant impact on investment decisions when they are transformed into regulations. This is evident in the case of circular economy (CE) policies implemented by both the EU and the Dutch government (5), which prioritize the construction of buildings that embrace circular principles to achieve sustainable development goals.

As a result, there is a growing demand for assessment tools that can effectively monitor the adoption of circularity and provide support to decision makers, practitioners, and policy makers in promoting CE practices (Saidani et al., 2019). While traditional environmental impact assessment methods offer valuable insights into the environmental impacts of buildings, they may not fully capture the comprehensive nature of circular strategies and their potential benefits. This is exemplified by the Circular Indicators incorporated in the GPR (Soeteman, 2021), which will be discussed in more detail later on.

The need for practical methods to measure and quantify progress in circular economy has been recognized by academia, including Saidani et al. (2019), as well as the European Commission (European Commission, 2015). Consequently, numerous circular measurement tools have been developed, each employing different CE measurement methods, utilizing diverse input data and databases. This variation arises from the fact that there are multiple pathways to achieve circularity.

Vesteda conducted research on CE performance methods and identified the Building Circularity Index (BCI) as the most suitable tool for assessing the circularity of buildings (Schipper, 2022). However, it should be noted that the BCI has not yet been integrated into the ESG framework.

2.2.2.4 Initiatives

Several initiatives have been launched including, Het Nieuwe Normaal (HNN), The New Normal, which is introduced to spur the Dutch ambition to achieve a fully circular economy by 2050 (6.1, 9), including the construction sector (Ministerie van Infrastructuur en Waterstaat, 2023). It is noteworthy to mention that in order to meet this goal, the program "*Samen Versnellen*" (*English: Accelerating Together*) was established by frontrunners of CE, to provide guidance and support (9).

Achieving this ambition requires a significant change in the way buildings are designed, built, used, and dismantled, which requires collaboration between stakeholders throughout the whole supply chain to identify solutions. An integral approach is needed for the transition towards a circular economy and is expected to result in the signing of a covenant called "*Circulaire Bouwen: Het Nieuwe Normaal*" (*English*: *Building Circular: The New Normal*) (Verhulst, 2021). This covenant aims to provide further direction by offering practical tools to achieve the Dutch circular economy ambition. HNN is a framework for circular construction, focusing on creating a common language and a new standard for circular building. It consists of three main components: (i) the standard for materials, (ii) the sustainable context, and (iii) the accelerators. The standard for materials has four sub-themes with ten indicators (Verhulst et al., 2023):

- *Environmental impact & Material use:*
  - *Environmental impact (MPG)*
  - *Embodied carbon (MPG-2)*
  - *Construction stored carbon (CSC)*
  - *Material use, divided by Shearing-Layers*
  - *Reuse potential, divided by Shearing-Layers*
- *Building flexibility:*
  - *Adaptive capacity*
  - *Disassembly potential*
- *Handling residual materials:*
  - *Handling residual material from demolition*
  - *Handling residual material from construction*
- *Healthy materials:*
  - *Material toxicity*

The framework, although still at a conceptual phase, has demonstrated that it utilizes a more comprehensive analysis of environmental impact compared to existing methods, as indicated by the indicators it employs.

Lastly, additional legislation and initiatives from both bottom-up and top-down approaches is pushing for sustainable change within the built environment. As an example, the Metropolitan Region of Amsterdam (9) has set a requirement that 20% of all newly constructed buildings must be composed of bio-based materials by the year 2025 (Metropool Regio Amsterdam [MRA], 2021). Resulting in significant changes in the investment criteria and thus the investment Decision-making process (2). Similarly, upcoming European Union regulations concerning CO2 taxation are anticipated to increase costs associated with unsustainable building materials *(Circle Economy et al., 2022)*. Within the ongoing sustainability transition, the circular economy (CE) is extensively debated and considered an integral part of the solution by various stakeholders, including academia, the European

Union (EU), the Dutch Government, and businesses. As a response to the European Green Deal and its objectives of promoting a more sustainable Built Environment, the European Commission introduced the EU Circular Economy Action Plan as a potential solution pathway as early as 2015(Hartley et al., 2020; Fetting, 2020; Ministerie van Infrastructuur en Waterstaat, 2021).

2.3| Performance Management Systems and ESG-Framework

In this section, three topics will be explored which are influencing the way of how sustainability is incorporated into the investment decision making process at the Meso level. Starting with [1] Performance Management Systems (PMS) for Sustainable investment decision making, [2] ESG framework and Benchmarking, [3] Mandatory tools for measuring the environmental performance to obtain permits. *An overview of how these components hang together is presented in Figure 10 and will be discussed accordingly. The numbers within the text correspond with the numbers in this Figure for throughout the entire text.*

2.3.1| PMS for Sustainable Investment Decisions

Developed by Otley (1999), the PMS is a comprehensive managerial framework that supports organizations in tracking, managing, and assessing their performance against strategic goals. The PMS is depicted in figure 10. The core premise of the PMS is that companies can bolster their performance using Key Performance Measures (KPMs). These KPMs are drawn from company objectives, critical success factors, strategies, and plans (Ferreira & Otley, 2009), and are then converted into quantifiable Key Performance Indicators (KPIs) that benchmark an organization's progress towards its goals.

A PMS has dual functionality as it caters to (a) a *company's publicly disclosing of performance*, and (b) *the internal performance assessment of the real estate portfolio*. Because both are ultimately, influencing the Investment Criteria and thus the investment decision-making process, these two are further investigated.

Firstly, company's publicly disclosed performance informs (potential) shareholders about its progress (7) and is aligned with formalized and standardized reporting frameworks. IREIFs leverage these frameworks for benchmarking, setting themselves apart from competitors and attracting potential investors (see also 2.3.2). Shareholders, in turn, can influence the company by making demands or requesting implementation of performance-related requirements (7), including those concerning sustainability. This feedback indirectly influences investment criteria (11).

Secondly, the internal performance analysis of the portfolio is a vital facet of the PMS, intertwined with the overall (public) performance of the company (10). This internal performance measurement evaluates if the assets align with the company's strategic objectives. These insights help update portfolio strategy and define investment criteria (1).

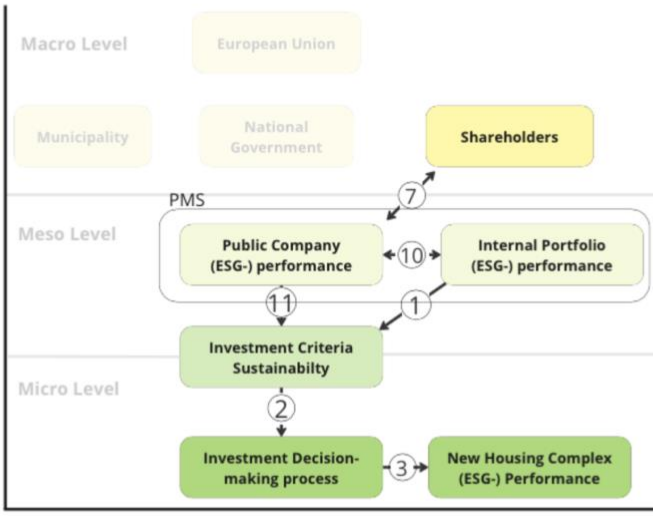


Figure 10 Part - [4/6] of the theoretical framework, showcasing topics and stakeholders related to PMS within the meso-level and how it directly and indirectly, influences the both the macro and micro level. Each number corresponding to the topics is elaborated on throughout the entire section [2.3.1] (Own source)
1. Improving the Investment Criteria: Investment criteria are refined through performance analysis of the internal real estate Portfolio.
2. Compliance with Investment Criteria and Requirements: Investment proposals are assessed using established criteria to ensure alignment with the policies established.
3. Acquisition and Management: Once approved, the housing complex is part of the portfolio. The asset is managed and rented.
7. IREIFS (ESG) Performance Disclosure according to the SFDR, shareholders setting the minimum criteria
10. Analysis of how the public benchmarking and internal performance could be improved through synergie
11. Improving the public (ESG) performance of an IREIF by defining and establishing criteria to which adherence is required

In addition to the overall company performance, in investment decision-making, PMS provides a structured methodology to evaluate potential investments against predefined objectives and KPIs (Rodriguez et al., 2009) during IREIFs investment decision making process. This process enables organizations, including IREIFs, to make informed, rational investment decisions in harmony with their strategic objectives (3).

The PMS incorporates various KPM methods to evaluate a company's financial and sustainability performance. One prominent financial KPM is the LCC method (Demartini, 2014). The LCC method is integral for calculating the full lifecycle cost of a built asset and can be utilized to appraise the costs of building elements that fall within the range of influence of IREIFs during the investment decision-making process. To substantiate investment decisions, the results from the LCC tool should be compared with substantial KPIs and benchmarks which in turn could be derived from the existing real estate portfolio (1).

Further enhancing the effectiveness of the LCC method in the context of sustainable investment decision-making, could be done by incorporating an environmental indicator. This expansion of the LCC's parameters allows it to assess more than just financial performance, adding a crucial layer of environmental performance evaluation. This environmental component should be included in the internal portfolio assessment to derive meaningful KPIs and benchmark for the utilization of an LCC as such resulting in improved Investment Criteria (1), providing the basis for more substantiated investment decision-making process (2).

The introduction of an LCC and an environmental indicator into a PMS of an IREIF is not one to be taken lightly. Incorporating these elements into the PMS alters numerous facets of the system, impacting the organization's overall operations and strategic orientation. Therefore, the subsequent section will *discover* how a PMS and its KPMs are the foundation of the ESG framework and benchmarking, which assesses a company's sustainable performance. It further explores the workings of sustainable performance measurement, to deepen the understanding of how embedding an LCC with an environmental indicator will affect the current performance measurement processes.

2.3.2| ESG-Performance Framework and benchmarking

When it comes to assessing a company's sustainable performance, an ESG framework is utilized, functioning much like a PMS (1, 11). This ESG-framework provides a structured methodology for evaluating the sustainable performance of both a company as a whole and individual projects (10). By incorporating a environmental sustainability-related KPM, both the company and its projects can be gauged against a set of predefined Sustainable Performance Indicators (SPIs)[5] specified in the ESG-performance frameworks. This approach, akin to the PMS for financial performance discussed in the previous section, offers a comprehensive means of evaluating a company's dedication to sustainability (10). It allows for the integration of SPIs related to environmental sustainability, such as energy efficiency or carbon emissions.

By juxtaposing ESG-performance with financial KPIs, investment decisions can be informed by more than just potential financial returns (3); the environmental impact of the investments also becomes a critical consideration. This integrated approach empowers organizations like IREIFs to align their investment strategies more effectively with sustainability goals. As a result, they can fulfill their fiduciary responsibilities to shareholders (7), comply with regulatory requirements such as the SFDR (6), and showcase their commitment to sustainable practices[6].

[5] Sustainable Performance Indicator (SPI) are indicators that just like KPI's measure the performance of buildings but unlike KPI's focusing on financial management, these indicators have a focus on sustainability.

[6] Before the SFDR came into force and sustainability reporting became mandatory, there were several bodies that sought to eliminate the problem of sustainable real estate reporting. Bodies such as the Carbon Disclosure

An ESG framework, akin to the PMS, in combination with the financial performance measurement tools, promotes a more holistic approach to investment decision-making, as it facilitates simultaneous consideration of financial and environmental factors. Moreover, ESG benchmarks are frequently employed as ESG rating metrics, which impacts investment decisions (Newell et al., 2023). These ESG-frameworks and benchmarks will be elaborated next.

2.3.2.1 Public Disclosure and Benchmarking

As outlined by Newell et al. (2020), both external (11) and internal ESG benchmarks (1) play a vital role in establishing investment criteria for effective real estate investment decision-making (2). Within their study, a general sentiment was discerned; public benchmarks were predominantly utilized for investor benefits, whereas internal benchmarks found their main application for operational purposes.

This perspective is further endorsed by Feng and Wu's (2021) analysis regarding public Global Real Estate Sustainability Benchmark (GRESB) ESG data, drawn from public disclosures. They contend that IREIFs can enhance their access to capital markets and boost corporate financial flexibility by improving their ESG-disclosure (7).

In addition to the interlink of mandatory ESG reporting mandated with the SFDR classification, Becker et al. (2022) found that ESG becomes increasingly significant for IREIFs. Their research found that funds showcasing a higher degree of sustainability integration, as indicated by their classifications, experienced notably increased net fund flows following the public disclosure of fund labels (7). This emphasizes the crucial role of ESG performance and its transparent disclosure in attracting and securing investment.

According to Newell et al. (2020) four styles of ESG benchmarks and reporting standards capturing information at various levels:

1. Listed property level
2. Reporting level
3. Delivery Level
4. Property fund/asset level

Firstly, at the Listed Property Level, numerous ESG initiatives from leading providers[7] such as: MSCI (Morgan Stanley Capital International), S&P DJ (Standard & Poor Dow Jones), Fitch, *and* Global Property Research (GPR), are readily available for adoption within the ESG frameworks of IREIFs (Newell et al., 2020). Given the substantial influence of ESG disclosure, the adoption of such ESG frameworks can considerably impact investment decisions. Hence, it becomes essential to align investment criteria to fulfil the adopted ESG benchmarks. However, except for MSCI, these frameworks are generally high-level and utilize more global indicators. For example, Vesteda has adopted the MSCI reporting. Therefore, MSCI will be looked at more deeply in section 2.3.3.1.

Secondly, the Reporting Level, the situation is similar, with notable benchmarks from leading providers like: Principles for Responsible Investment (PRI), Carbon Disclosure Project (CDP), Global Reporting Initiative (GRI), and Task Force on Climate-related Financial Disclosures (TCFD) employing high-level frameworks (Newell et al., 2020).

Thirdly, at the delivery level, a wide variety green building standards are available that assess sustainability aspects like water usage, waste management, carbon emissions, and energy efficiency at the property level. These include

Project (CDP), the European Association of Unlisted Real Estate Investors (INREV), the European Public Real Estate Association (EPRA), the Global Reporting Initiative (GRI) and the Global Real Estate Sustainability Benchmark (GRESB) proposed standardized but voluntary frameworks for the presentation of sustainability information (Ionașcu et al., 2020). These frameworks are still being used as part of the ESG assessment.

[7] The term "leading providers" in this context refers to organizations that offer specialized financial services, often serving as benchmarks or guides for investment decisions. These providers offer ESG initiatives that can be integrated into the ESG frameworks of IREIFs, thereby aiding in the adoption of sustainable practices at the Listed Property Level.

noteworthy examples like LEED, EnergyStar, and BREEAM (Roderick et al., 2009). Additional standards, such as the International WELL Building Institute's WELL Building Standard, specifically concentrate on health and well-being in buildings.

However, within the scope of this research, and the fact that Vesteda adopted the reporting on BREEAM, the focus will be solely on BREEAM[8], which will be discussed further in section 2.3.3.1.

Lastly, the focus is on GRESB and GeoPhy/427 benchmarks at the property fund/asset level. GRESB is a key benchmarking tool for assessing the ESG performance of real assets. According to Devine et al. (2022), GRESB has become a leading ESG benchmark globally. GRESB participation and performance are significant predictors of fund returns, making it a central consideration for investment decision-making. While it continues to evolve and improve, it has been noted that GRESB should enhance its focus on actual portfolio performance. Due to the fact that Vesteda also reports to the GRESB, this benchmark will be further discussed[9].

In conclusion, while each ESG-framework contributes to comprehensive sustainable disclosure, this research will only delve further into MSCI, BREEAM, and GRESB in Section [2.3.3] due to the aforementioned reasons. These ESG-performance measurements and frameworks position themselves as depicted in Figure 11.

[8] This choice is primarily due to BREEAM's widespread use and acceptance in the Netherlands. While an examination of other frameworks would certainly be insightful, it exceeds the boundaries of this study.

[9] GeoPhy/427 was mentioned by Newell et al. (2020), known for providing granular projections of climate change impacts on Real Estate Investment Trusts (REITs), has been acquired by Walker & Dunlop Corporation (Sandlund, 2022). GeoPhy equips commercial real estate (CRE) professionals with immediate access to distinctive data and detailed local insights. This enables them to identify, assess, and finalize more transactions swiftly and with enhanced certainty, thus driving efficiency, speed, and transparency in the world of commercial real estate (Sandlund, 2022). However, little insights are available on this benchmark and will therefore, not be further explored in this study.

2.3.2.2. Internal Benchmarking

Newell et al. (2020) recognize the inflexibility of the aforementioned external ESG-benchmarks for IREIFs as they do themselves. This results in the development of internal benchmarks (10) by many companies, despite their resource-intensive nature. In-house developed ESG-benchmarks offer companies greater flexibility and customization than external ones (1). This approach allows firms, particularly large and diversified ones, to account for their unique characteristics and operations, providing a more focused perspective on in-house ESG issues, shaping their investment decision-making process (2) (see figure 11). Despite challenges, the templates provided by existing external benchmarks can simplify the process of creating tailored internal benchmarks. The internal benchmarking framework of Vesteda will be looked into in section [4.1.2]: "Internal Research".

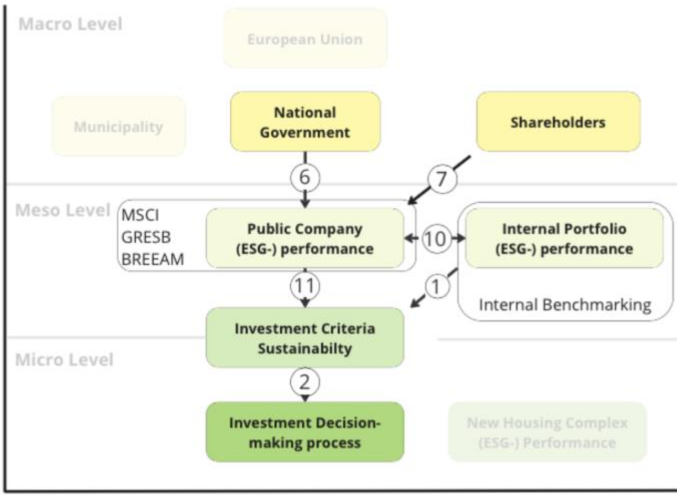


Figure 11 –[5/6] of the theoretical framework. Showcasing the topics and stakeholders related to Public and internal Benchmarking. It shows how the institutional and strategic level both, directly and indirectly, influences the investment criteria and thus investment decisions-making process. Each number corresponding to the topics elaborated on throughout the entire section [2.3.2] (Own source)
1. Deriving Improved Investment Criteria: Investment criteria are refined through analysis of the internal Portfolio's (ESG) performance.
2. Compliance with Investment Criteria and Requirements: Investment proposals are assessed using established criteria to ensure alignment with the policies established.
6. Establishing and enforcing Laws and Regulations tailored to the Dutch context
7. IREIFS (ESG) Performance Disclosure according to the SFDR, shareholders setting the minimum criteria
10. Analysis of how the public benchmarking and internal performance could be improved through synergie
11. Improving the public (ESG) performance of an IREIF by defining and establishing criteria to which adherence is required

2.3.3| ESG reporting and Dutch Mandatory Assessment Tools

For a broad overview of the external landscape and how sustainability is reported and measured and communicated to the shareholders (7), this section discovers the different Sustainable Performance Indicators (SPIs) utilized in a range of ESG benchmark frameworks and tools that have the potential to enrich an LCC model. However, to ensure that the LCC model effectively guides sustainable investment decisions, it is crucial to account for the environmental impact generated by these building elements.

The environmental impact is measured in different ways within the variety of ESG benchmark frameworks and tools which will be reviewed. Evaluation will focus on three key aspects: (i) the specific *Environmental* SPIs quantified by these tools, (ii) the measurement method they employ, and (iii) their suitability for evaluating building materials.

2.3.3.1 ESG-benchmarking Frameworks

Starting with **MSCI**, of the in section [2.3.2] mentioned ESG public benchmarking frameworks that will be evaluated: MSCI is a leading provider of ESG ratings and benchmarking frameworks for real estate. MSCI's ESG ratings and benchmarks provide *investors* with insights into the sustainability performance of real estate companies and funds.

I. MSCI evaluates real estate entities based on various ESG criteria and assigns them a rating or score. MSCI's ESG framework covers a range of sustainability factors, including environmental impact (MSCI ESG Research LLC, 2023b). The used SPI's are shown in Figure 12. However, it does not have a specific SPI that focuses on the environmental impact of specified building products. Instead, MSCI assesses environmental performance within the wider context of a company through broader indicators and metrics related to climate change, natural capital, waste and pollution, and Environmental Opportunities.
II. The measurement method employed by MSCI involves gathering data from publicly available sources, company disclosures, and direct engagement with the real estate entities. MSCI uses a robust data collection process to ensure the accuracy and reliability of the information used for their ESG ratings and benchmarks. The used data serves as input for a weighted calculated with regards of the Environmental impact (MSCI ESG Research LLC, 2023a).
III. In terms of suitability for evaluating building materials, MSCI's ESG ratings and benchmarks primarily focus on the overall sustainability performance of real estate companies and funds rather than specific building materials. They provide investors with a comprehensive assessment of the environmental, social, and governance practices of these entities, enabling them to make more informed investment decisions aligned with their sustainability objectives.

Broadly, MSCI is an important ESG-framework for both investors in IREIFs, as IREIFs self. It offers significant insights in the sustainable efforts of companies and enables comparison between these. However, in the context of an LCC-tool However, in the context of an LCC tool, the two are too divergent for any form of integration.

GRESB

GRESB (Global Real Estate Sustainability Benchmark) is a globally recognized standard for ESG reporting in the real estate sector. It provides investors and managers with validated ESG performance data and peer benchmarks to enhance business intelligence, industry engagement, and decision-making (GRESB, 2023). The GRESB assessment requires participants to report on various indicators such as Energy, GHG (Greenhouse Gas) emissions, Water usage, Waste, Management, Building Certifications, and Efficiency Measures at the asset level.

Environmental	Climate Change	Carbon Emissions
		Climate Change Vulnerability
		Financing Environmental Impact
		Product Carbon Footprint
	Natural Capital	Biodiversity & Land Use
		Raw Material Sourcing
		Water Stress
	Pollution & Waste	Electronic Waste
		Packaging Material & Waste
		Toxic Emissions & Waste
	Environmental Opportunities	Opportunities in Clean Tech
		Opportunities in Green Building
		Opportunities in Renewable Energy

Figure 12 - Overview of the core building blocks of MSCI ESG Ratings Methodology (MSCI ESG Research LLC, 2023)

I. Within the GRESB framework, SPIs are categorized into three components: *Management*, *Performance*, and *Development*. Each component contributes to an overall score obtained from different aspects (GRESB, 2023). For the purpose of this research, the focus will be on the Development component, specifically examining the aspect of materials.
II. GRESB's measurement method relies on data provided by participating companies. The accuracy and completeness of the data play a crucial role in determining the points awarded. The assessment involves a questionnaire that covers various indicators and how companies address different topics. The scoring system considers the level of detail provided, ranging from simple yes/no responses to more comprehensive documentation. The questions related to materials include aspects regarding 1) material selection requirements, assessment of life cycle emissions in development projects, and disclosure of embodied carbon.
III. While GRESB assesses the way companies handle materials, it does not directly evaluate the sustainability of building materials themselves. Instead, it focuses on how companies approach material selection and management. Therefore, it may not be considered suitable for evaluating the intrinsic sustainability of specific building materials.

Overall, GRESB serves as a valuable tool for assessing ESG performance in the real estate sector, providing standardized data and facilitating benchmarking among industry participants. However, for a comprehensive evaluation of building materials' sustainability, additional tools and frameworks specifically designed for that purpose may be more appropriate.

BREEAM

Building Research Establishment Environmental Assessment Method (BREEAM) is a widely recognized sustainability assessment method for the built environment in practice (Certificaten En Keurmerken Duurzame Gebouwen, n.d.) and is often cited in academic literature regarding Environmental Impact research (Hromada et al., 2021). It was developed by the Building Research Establishment (BRE) and later adapted to local contexts, such as the Dutch situation, by the Dutch Green Building Council.

I. BREEAM assesses projects on various aspects of sustainability, including Materials, Energy, Waste, Health, Transport, Water, Land-use/Ecology, and Management (DGBC, 2020). It covers a broad range of indicators compared to other tools, such as Milieu Prestatie Gebouwen (MPG) [in English: Environemtal performance of buildings] (DGBC, n.d.), which will be elaborated on in the subsequent sections. The overall BREEAM score is based on the score of each topic.
II. Measurement Method: The overall BREEAM score is determined using a scoring system that assesses the design, construction, and operational aspects of buildings. Points are assigned to different categories based on percentage-weighting factors, resulting in a final score and certification level. Regarding the Material assessment, BREEAM evaluates four topics for which it assigns points: Environmental performance (up to 4 points), a material passport (1 point), specifications of construction materials (1 point), and material and building installations (1 point) (DGBC, 2020).
III. Regarding the evaluation of building materials, BREEAM's comprehensive assessment of environmental impact, which includes materials, is deemed suitable for assessing the sustainability of construction materials from a broader perspective. To enhance the scores of building elements that are currently rated low, an LCC-tool could potentially offer a solution by making these aspects quantifiable.

In general, BREEAM provides a robust framework for assessing sustainability in the built environment, encompassing multiple aspects and delivering a comprehensive evaluation. The specific assessment of materials within BREEAM, utilizing the MPG-tool, enables the evaluation of building material sustainability.

2.3.3.2| Dutch (Mandatory) Assessment tools

In the Netherlands, sustainability assessment tools ensure that buildings are designed and constructed to meet specific standards, aiming to reduce environmental impact. Two of these assessments already mentioned, are the BENG and MPG, both mandatory, whereas the GPR is optional in determining whether building permits are granted. How these assessments position themselves in the context of an IREIF is displayed in Figure 13. These tools will be elaborated on in the subsequent sections.

2.3.3.2.1 BENG

Starting with the *"Almost Energy Neutral Buildings"* in dutch "Bijna Energie Neutrale Gebouwen" (BENG), compliance with the BENG is a requirement stipulated in the Dutch Building Decree. BENG is a set of regulations in the Netherlands that aims to achieve nearly zero-energy buildings. The specific SPI's that are quantified by the BENG are about the energy performance of buildings determined based on following three specific measurement methods and the requirements following that need to be met (RVO, 2022):

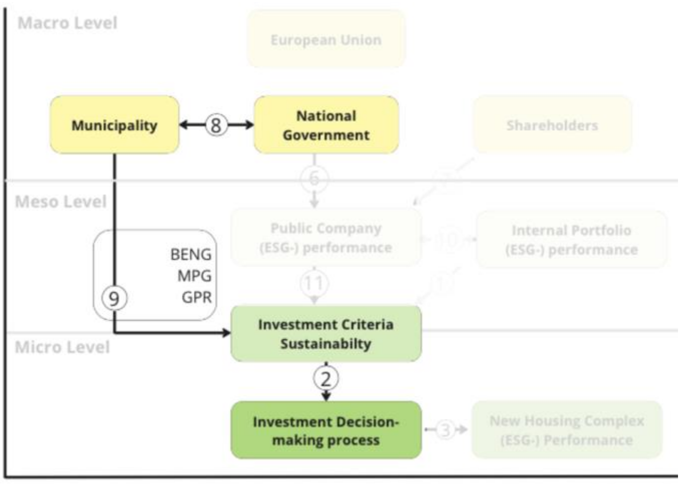


Figure 13 - [6/6] of the theoretical framework. Showcasing the topics and stakeholders related to assessments tools and policies influence each other. It shows how the institutional level, directly and indirectly, influences the investment criteria and thus investment decisions-making process. Each number corresponding to the topics elaborated on throughout the entire section [2.3.3.3/2.3.3.3] (Own source)

2. Compliance with Investment Criteria and Requirements: Investment proposals are assessed using established criteria to ensure alignment with the policies established

8. Enforcing national laws and regulations and tailoring the rules to the municipals own policies and ambitions

9. Technical building requirements and criteria that needs to be complied with e.g.: BENG, MPG, GPR

1. Maximum Energy Demand (kWh/m2.yr): This requirement sets the limit for the maximum energy needed per square meter of usable floor area per year. It focuses on reducing the overall energy demand of the building.
2. Maximum Primary Fossil Energy Use (kWh/m2.yr): This requirement specifies the maximum amount of primary fossil fuel energy that can be consumed per square meter of usable floor area per year. It aims to limit the reliance on fossil fuels and promote energy efficiency.
3. Minimum Share of Renewable Energy (%): This requirement sets a minimum percentage of renewable energy that should be utilized in the building's energy consumption. It encourages the use of sustainable and renewable energy sources to reduce greenhouse gas emissions and promote environmental sustainability.

By mandating these three individual requirements, BENG aims to ensure that buildings in the Netherlands are energy-efficient, have reduced reliance on fossil fuels, and incorporate renewable energy sources. The BENG requirement is used as SPI within Vesteda benchmark framework.

2.3.3.2.2 MPG an LCA Derivative

A second tool evaluates the environmental impact of buildings through the material and resources that are used for construction and is called the *Environmental Performances of Buildings* in dutch "Milieu Prestatie gebouwen" (MPG) (Circle Economy et al., 2022). This tool makes use of the MKI (Milieu Kosten Indicator, (in *English - Environmental Cost Indicator) a* derivative of LCA, and is a method which assigns a monetary value to the environmental impact of products (Stichting Nationale Milieudatase, n.d.; Ministerie van Algemene Zaken, 2022). An indepth explanation about LCA can be read in Appendix A. The MPG has been established and adopted and serves as uniform assessment method to align the variety of perspectives of different actors (Investors, clients, builders and users) about environmental impact (Ministerie van Algemene Zaken, 2022).

The MPG method measures the environmental impact of a building based on the products used for construction. Determining the environmental impact of a building is done in line with the computational rules of life cycle analyses (LCA) stipulated in EN 15978 (MilieuPrestatie Gebouwen - MPG, 2021). The input for this calculation consists of the data resulting from environmental product declarations (EPD) of products according the EN 15804-A1. The EPD is a summary of the LCA and consists of eleven indicators for the environmental impact of a building. These 11 indicators are combined into a single value: The MKI, Environmental Cost Indicator (ECI) is also known as shadow cost. Measure in euro's, per unit of the product (kg, m3, m2, or equivalent). Since 2013, this the MPG has been included in the building code (section 5.2 building code 2012) and is therefore required when submitting the environmental permit (Westerhof, 2022).

$$MPG = \frac{MKI}{GFA \times Building\ Lifecycle}$$

- MPG = Milieu Prestatie Gebouwen (Environmental Performance of Buildings)
- MKI = ECI/Shadowcost [€]
- GFA = Gross Floor Area [M_2]
- Buildings Lifecycle [Year]

For a building, all shadow costs of used materials, plus additional buildings parts are added up over a building's lifetime. To calculate the MPG, the resulting total of shadow costs (MKI) are divided with the building's lifetime [Years] times the Surface (gross floor area) of the building [m2]. Only after this step, a comparison between building performance or with respect to a requirement is possible (SBK, 2019a).

The underlying database used for the calculations of the MPG Assessment is the 'Nationale Milieu Database' (NMB). This database contains a collection of environmental impact information regarding building products and additionally a process database which contains generic basic processes of materials (processes and semi-finished products for use in LCAs) (Stichting Nationale Milieudatase, n.d.; Ministerie van Algemene Zaken, 2022)

However, the MPG method has been disputed by market and research-oriented parties for not considering the negative emissions resulting from growing wood. A case study by TNO found that accounting for the carbon storage potential of natural wood can halve emissions and result in negative net emissions for cross-laminated wood, which can be more sustainable than the MPG suggests (Keijzer et al., 2021). The current failure of the MPG method to consider the positive environmental impact of materials, creates an inequitably negative stigma for sustainable materials. As a result, concrete is favored more than wood in Dutch building structures.

2.3.3.2.3 GPR

An additional benchmarking system used in the Netherlands, which is not mandatory by law or regulations but could be used as a requirement for obtaining permits is the Municipal Practice Guidelines, in dutch *'Gemeentelijke Praktijk Richtlijnen' (GPR).*

While the GPR is not included in the building code, it is yet, a more extensive demonstrating the overall sustainability of a building. The six sustainable criteria that GPR covers, with as overarching topics are: energy, environment, health, usage quality and future value and the building process. These topics could be used as ESG criteria. Due to the focus on materials and resources only the environmental topic will be elaborated on. The Environmental topic consists of four topics: Materials, Water and Space&Quality. The MPG is included in the Material topic together with seven other indicators which can be considered circularity indicators (Aantoonbaar Duurzaam Bouwen – GPR Gebouw, n.d.):

- Reuse products (input stream)
- Circular materials (bio-based with long-term CO2 storage, bio-based other and secondary)
- Wood from sustainably managed forests
- Construction method focused on efficient use of materials
- Long building life
- Decoupling layers of Brand (different life span)

- Reuse potential (output stream)

Within this GPR tool all indicators must be given a score resulting in a grade between 1-10. In total it is possible to score 1000 points per overarching topic. Within this the environmental topic, 700 are attributed to material, 100 to water and 200 to Space and Nature. The same applies for the other topics, but with different indicators, resulting in a score between 1-10 as well.

The GPR can be required by a municipality by means of a municipal regulation when issuing permits by requiring a minimum grade. Furthermore, a GPR calculation can serve as a basis for applying for Environmental Investment Allowance in Dutch, 'Milieu Investeringsaftrek' (MIA) or be required as a tender[10] document by the client to demonstrate the sustainability of the building as part of their Corporate Social Responsibility (CSR) and ESG (Westerhof, 2022).

In conclusion, the three mentioned assessments, of which the BENG and MPG are compulsory, when applying for permits for the to be acquired buildings and are therefore integral part of the investment decision making process specified as requirements by IREIFs.

[10] A tender document, also known as an request for proposal (RFP), is a formal document issued by an organization to invite bids or proposals from potential suppliers contractors or developers. It provides project details, requirements, and submission guidelines, facilitating a fair selection process.

2.4| Conclusion of Theoretical Framework

In this sub-section, the first sub-research question will be addressed, followed by the second. The responses to both questions are informed and structured by the theoretical framework.

2.4.1| Answer to Sub Research Question 1

The objective of the development of the theoretical framework was to address the sub-research question:

"How is sustainability currently incorporated in the real estate investment decision-making process, and what challenges do Institutional Real Estate Investment Funds (IREIFs) face when implementing Life Cycle Costing within this process?" This exploration reveals the intricate multi-level landscape of how sustainability is woven into the investment decision-making process of IREIFs. Each level is influenced by various factors, and the theoretical framework's three levels - (Macro) Institutional, (Meso) Strategic, and (Micro) Operational - provide a lens through which it is understandable how sustainability is integrated into the investment decision-making process.

At the macro level, governing bodies exert significant influence by enforcing laws and regulations. These regulations impact the meso and micro levels. For instance, at the meso level, regulations like the SFDR mandate sustainability performance reporting in line with the EU-taxonomy. Shareholders, in turn, are demanding specific sustainability reporting disclosures like the GRESB, MSCI and BREEAM for benchmarking purposes. Furthermore, these regulatory bodies are stipulating sustainable building requirements, like the BENG and the MPG and thereby, influencing the investment criteria within the investment decisions at the micro level (See (9) in Figure 14).

Sustainable initiatives, driven by both top-down and bottom-up approaches, further shape the macro level's influence. An example is the MRA's target for 20% bio-based materials in new constructions in 2025. Such initiative influences the strategy of IREIFs, shifting towards this type of construction, and changing their investment criteria which are used in the investment decision-making process.

At the Meso level, on the hand, are the public ESG benchmarking framework demanded by (potential) shareholders., such as the GRESB and BREEAM. To ensure a good rating, and remain attractive for (future) investors, investment criteria are tailored to fulfill this desire. On the other hand, is the development of the internal benchmarking and portfolio performance analysis by IREIFs to overcome the rigidity of the public benchmarking frameworks (Newell et al., 2020). The internal benchmarking plays a crucial role in strategy formulation and ensuring that the vision and mission of an IREIF are well integrated in the investment decision-making process by tailoring the investment criteria (See (10) in Figure 11).

At the micro level, within the investment decision-making process, it is about evaluating if investment criteria are met. Within this assessment of potential investments, IREIFs are using valuation models assessing a variety of indicators. However, within this valuation model, the cost and environmental impact component within the valuation analysis insufficiently taken into account. Literature states that LCT, and more specifically LCC and LCC, are performance measurement tools to obtain insights therein. It is thought that the described challenges of integrating such performance measurement tools impede adoption.

Consolidating the above three levels of the theoretical framework, to an answer to the *first* part of the question, clearly shows the complexity of how sustainability is incorporated in the investment decision-making process of IREIFs. The multitude of components and stakeholders and their interplay within the realm sustainability of IREIFs, as depicted in Figure 14, are each directly and indirectly shaping how sustainability is incorporated into the investment decision-making process. This intricate interplay results in a complex framework that underscores the multifaceted nature of sustainable investment within the industry.

Answering the *second*, *last* part of the question, addressing the challenges of implementing LCC within this complex framework reveals that substantial adaptations are required in the existing Performance Management Systems (PMS) and Key Performance Metrics (KPMs) of IREIFs. This includes the creation of new benchmarks and strategies, leading to revised investment criteria. Additionally, as highlighted in section [2.1], the vast amount of data and its accuracy and completeness poses a significant challenge. Another challenge observed in literature is the lack of specialized knowledge within companies.

2.4.2| Answer to Sub Research Question 2

Lastly, this chapter sought to address the second sub-research question: *"What opportunities provide the implementation of the LCC tool for IREIFs?"* The findings suggest that the integration of LCC and LCA methods presents significant opportunities for IREIFs.

Starting from the other side of the theoretical framework, at the micro-level, it follows that the implementation of an integrated LCC/LCA approach, originating from LCT, facilitates a comprehensive assessment of both environmental impact and economic feasibility. It enables IREIFs to measure and compare the environmental and financial performances of building element variants during their lifecycle, thereby allowing for a more substantiation trade-off between environmental impact reduction and potential cost reduction.

The obtained insights provide the second opportunity, where the adoption of an LCC/LCA tool by IREIFs would enable them to gain deeper insights, and a better understanding from which decision criteria could be derived, allowing for more substantiated investment decisions.

Lastly, opportunity arises on the Meso-level when the LCC/LCA tool is implemented within an IREIF. It allows for analyzing the current portfolio to establish benchmarks. These benchmarks, in turn, function as criteria and requirements to which potential future investments must adhere. This internal benchmarking as mentioned in section [2.3.2.2], provides the opportunity for IREIFs to fulfill ESG ambitions and achieve targets, which in turn affects the macro level there.

In conclusion, the exploration of the investment decision-making process within IREIFs reveals a multi-level landscape where sustainability is intricately woven. Governed by Macro-, Meso-, and Micro-level influences, the integration of sustainability presents both challenges and opportunities. The challenges lie in the complexity of implementing LCC, requiring substantial adaptations and a keen understanding of data accuracy. Conversely, the opportunities emerge from the strategic implementation of LCC and LCA tools, enabling IREIFs to align investments with sustainability goals, gain deeper insights, and establish meaningful benchmarks. This comprehensive analysis underscores the pivotal role of a well-structured approach in enhancing the decision-making processes of IREIFs, ultimately contributing to more sustainable and responsible investments.

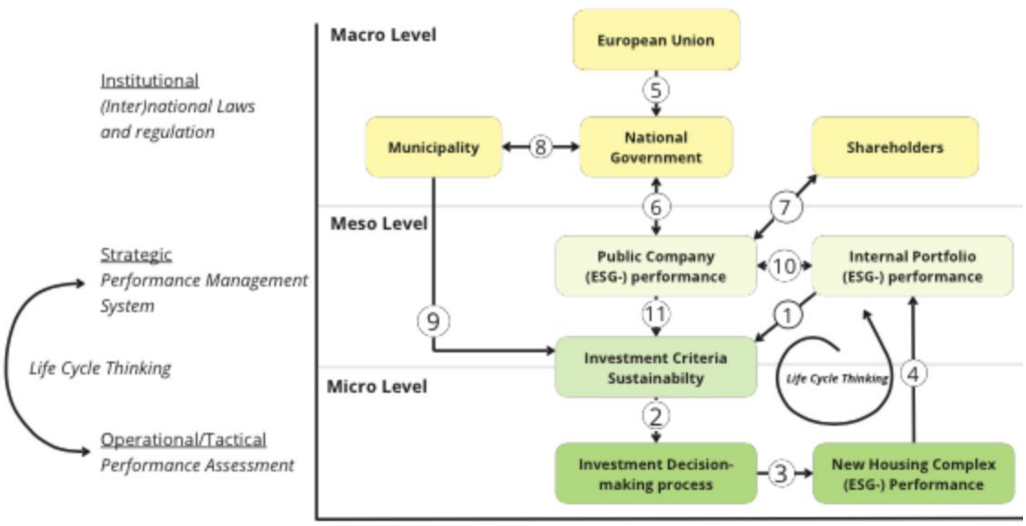
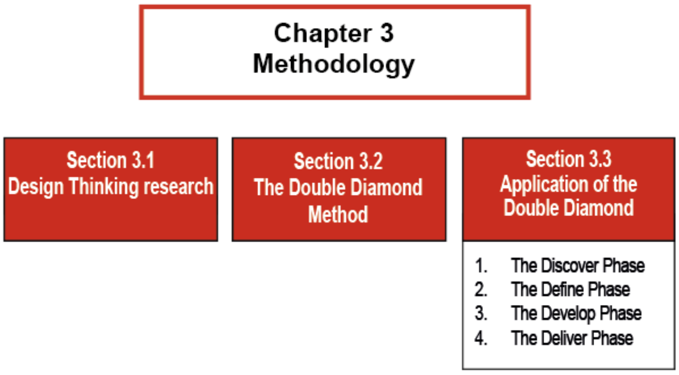


Figure 14 – Resulting overview of the theoretical framework, each topic and stakeholder influencing each other. For detailed insights, refer to the preceding text and their corresponding figure.



3| Methodology

This chapter elaborates on the research methodology that is employed to develop and incorporate an LCC-model, accounting for environmental impact, into an IREIFs, investment decision-making process. The research will consist of mixed methods of research, guided by the double diamond research method. The mixed methods used, comprises quantitative and qualitative methods to design and develop *a LCC model for sustainable real estate investment decision-making*.

In section [3.1] an introduction will be given to design-based research and how it aligns with the research goal of developing an LCC-model tailor made to specific needs and context of an IREIF.

Section [3.2] describes the theoretical foundation of the design-based research methodology applied. Section [3.3] will provide a description of the application of the Double Diamond design-based research method, explaining its implementation within the different phases of the study.

3.1| Research Through Design

Because this research aims to design an LCC-model with incorporated environmental indicators, a methodology that fits the objective, is *Research trough Design (RTD)*. *RTD* is a way of "research" that comes with opportunities to practice the craft of design. Stappers and Giaccardi (n.d.) would describe it as: "*Research through Design* is doing design as a part of doing research". It is a way of materializing knowledge and insights, acquired based on hands-on design work, packaged into a scientific format. It must be noted that Research through Design does not lead to a tested theory next to a working prototype, as is the case in Design Based Research (TU Delft, n.d.). However, within the objective of the this research the *Research through Design* suffices and is an appropriate method in the context of this study.

RTD is strongly connected to product and innovation management through ideas like 'Design Thinking' which provides the possibility to incorporated multiple, well-suited, methods for research and design. According to Plattner et al. (2010): "Design thinking is a catalyst for innovation and bringing new things into the world". The uniqueness of RTD allows for the opportunity to see how things change when we intervene in a situation, for example by developing and implementing an LCC-model.

The ambition of RTD is to fit design knowledge into the format of scientific knowledge and facilitates the allowance to translate the direct experience of building designs and interacting with them, into scientific knowledge (Baytaş, 2022). Stappers and Giaccardi (n.d.) formulate: *"The designing act of creating prototypes, is in itself a potential generator of knowledge (if only its insights do not disappear into the prototype but are fed back into the disciplinary and cross-disciplinary platforms that can fit these insights into the growth of theory)."* Therefore, the *Research Through Design* seems to fit be of best fit in the pursuit of developing and implementing a life cycle costing model for IREIFs without losing valuable insights and knowledge that will be gathered throughout the development process.

Within RTD, multiple research methods are tested and widely utilized in research. These methods are *Design Thinking* and the *Double Diamond method* (Baytaş, 2022). Design Thinking, originating from the 1950 and first proposed by John E. Arnold, is a user-focused method for innovation, emphasizing understanding customer needs, quick prototyping, and creative idea generation, reshaping product, service, and organizational development (IDEO, 2023).

The other methodology used in RTD is the *Double Diamond method*, which was promoted by the UK Design Council around 2005 (Ball, 2022). The Double Diamond is a visual representation of the design and innovation process. It is a simple way to describe the steps taken in any *complex* design and innovation project, to **define the problem,** and **design and develop solutions**. It is a flexible framework that can be adapted to a variety of challenges, and it includes four distinct phases: Discover, Define, Develop, and Deliver.

In essence, while Design Thinking is valuable for understanding user needs and fostering creativity, the Double Diamond's structured and comprehensive approach makes it more suitable for developing intricate and complex model like an LCC tool. Therefore, in continuation of describing the methodology used in this research, the Double Diamond Method, as shown in figure 15, can be seen as a guiding overview of the design and research process of the to be development *LCC model accounting environmental impact, for real estate investment decision-making.* In the subsequent section [3.2] the Double Diamond will be further elaborated on.

3.2| The Double Diamond Method

The Double Diamond method, as mentioned before, is defined as a sequential, repetitive process that offers a structured approach for conducting research. Moreover, it aligns with design research principles that aim to delve into scientific understanding while assisting stakeholders in addressing tangible issues. The Double Diamond Design Process is a visual framework used to describe the process, as shown in Figure 15. It consists of four phases: *Discover*, *Define*, *Develop*, and *Deliver*. These phases are represented by two diamond shapes, where the diverging and converging lines symbolize the process of exploring many ideas and then narrowing down to the best solution.

1. **Discover**: Understanding the problem, gathering insights, and identifying opportunities.
2. **Define**: Analyzing the collected information, defining the core problems, and focusing on the right challenges allows for the consolidation of this understanding into a Design Brief.
3. **Develop**: Generating a wide range of innovative ideas, prototyping, and iterating to find the best solutions.
4. **Deliver**: Finalizing the solution, producing

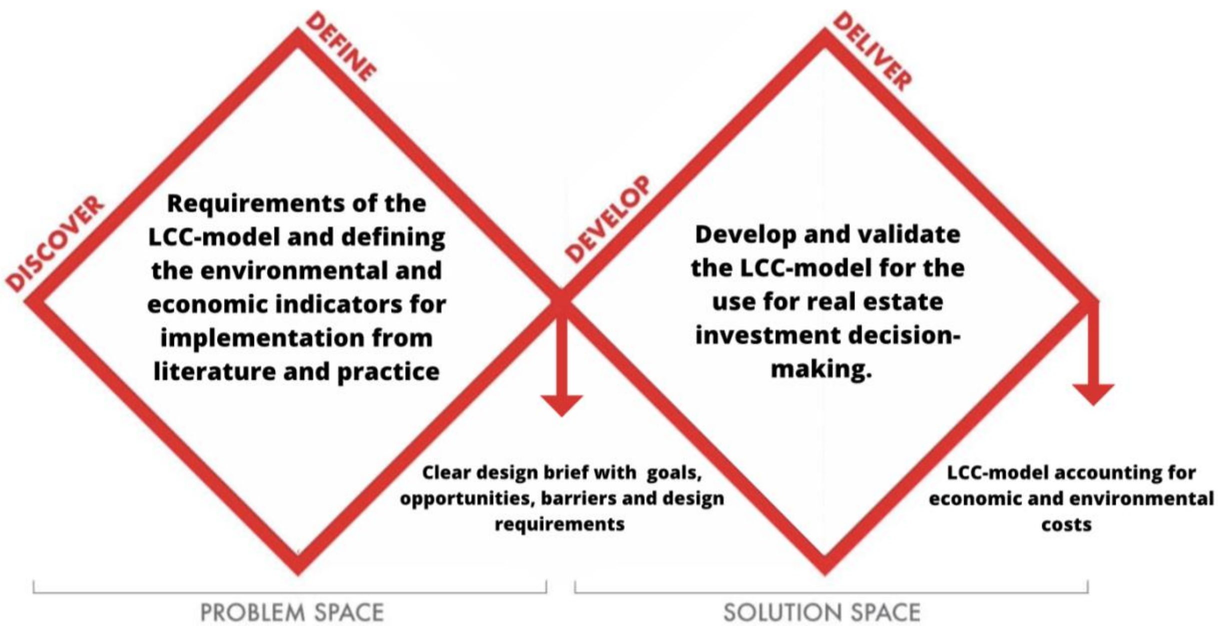


Figure 15 - Application of the double diamond methodology (own source: Adapted from Elmansy, 2022)

and implementing the design, and evaluating its success for the end-user.

The Double Diamond Design Process emphasizes the importance of problem finding before problem-solving and encourages designers to think broadly before narrowing down to specific solutions.

3.3| Application of the Diamond method

This section describes the research methods utilized in each phase of the Double Diamond method. The outline of this chapter is as follows:

I. A general overview of the double diamond
II. The Discover& Define Phase
III. The Develop & Deliver Phase

At the end of this chapter a brief recap is given will be given to answer the second sub-research question:

"What methodology can be applied to develop an LCC-model for buildings accounting for environmental impact, for implementation in the decision-making process of an Institutional Real Estate Investor?"

3.3.1| General overview of the Double Diamond

It was precedingly described that the Double Diamond design research method exists out of four converging and diverging phases. Where the left diamond is focused on defining the problem, and the right diamond about the solution. This chapter is guided along the line of these two concepts.

Figure 16 illustrates an adapted version of the "Double Diamond Method" for the application of this methodology in this research, showcasing the various research activities carried out throughout the process.

- Discover & Define phase: Within this problem space, firstly literature review will be conducted that will consolidate into a theoretical framework. Within this divergent phase, complementing the preceding, desk research, informal talks and semi-structured interviews are conducted. The accumulated information and data provide the possibility to enter de converging phase of the first diamond. Where the information and data analyzed and sorted. At the end of this phase a design brief is be drawn up, containing the requirements the development of an LCC model.
- Develop & Deliver phase: The solutions to the problem will be designed and developed within MS excel, aiming to create a

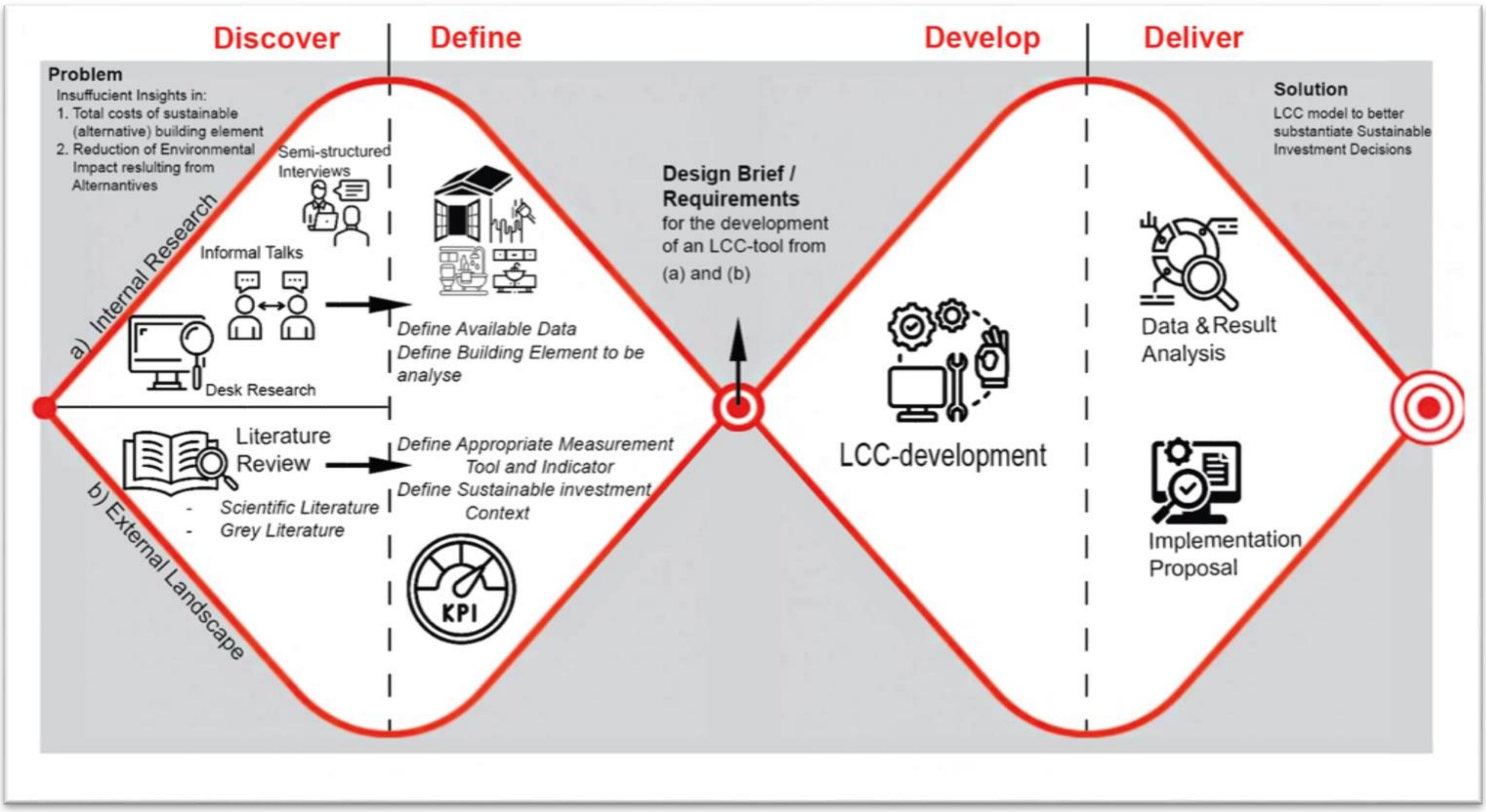


Figure 16 – Research Strategy – Adapted version of the Double Diamond (Own source)

functioning tool to support the sustainable investment decision-making process *sustainable* decision-making. The divergent nature of the development results in a tool, which provides insights in the costs and environmental impact. In continuation of the process and entering the convergent part of the second diamond, the tools outcome will be tailored to the needs of Vesteda. Resulting in how the resulting outcomes could be introduced and implemented in the internal performance benchmarking of Vesteda.

3.3.2| The Discover and Define Phase

The Discover and Define Phase, which corresponds to the first and second phase of the double diamond method, is about emphasizing "Designing the right thing" (Crady, 2021). This phase plays a crucial role in understanding the identified problem to design the appropriate solutions. In this research, the problem revolves around the underutilization of an LCC model in the performance measurement systems of companies in the building sector, including IREIFs. The slow adoption is preventing the incorporation of environmental indicators for better substantiating of sustainable investment decisions.

Firstly, to gain comprehensive insights into the problem space, the Discover Phase is composed of two components, as shown in Figure 16:

I. The ***External landscape*** consisting of a *Literature Review* resulting in *a Theoretical Framework*[11].
II. ***Internal Research*** consisting of *Desk Research* combined with *informal conversations* and *semi-structured interviews* to obtain data and insights about the internal sustainable investment decision-making process of Vesteda.

Findings from the *internal research* step are complementing the literature review and will be described along the line of the Theoretical framework for clarification. Furthermore, information procured through meetings and informal dialogues with industry experts and scholars will be deemed as invaluable data sources.

Secondly, within the Define phase of the double diamond method, a convergent approach is adopted to define a clear *problem statement* and *design brief*. This step is complemented by the execution of interviews with employees of Vesteda to narrow down the requirements for a tailor-made LCC tool accounting for environmental impact. The insights obtained from these interviews are used during Development Phase.

3.3.2.1| External Landscape – Literature review for Theoretical Framework

Scientific Literature

For the initial component of the Discovery Phase, a theoretical framework was constructed in Chapter 2 through a literature review. This framework aims to elucidate the *external landscape* of sustainable investment decision-making by IREIFs along the line of a multi-level approach, with existing knowledge serving as a foundational pillar (Snyder, 2019). Van Wee and Banister (2016) posit that a literature review substantiates the real-world applicability of research, in this case, the development of an LCC-model.

Conducting a literature review can yield significant outputs, including an "overview of knowledge available for real-world applications" and providing "design guidance" (Van Wee & Banister, 2016), which are both desirable outcomes for this research. While there are various methods of literature studies, one method needs to be chosen. Grant and Booth (2009) identified and investigated fourteen different types of literature reviews in their research, which the researchers mapped against the 'SALSA' framework[12].

Based on the findings of Grant and Booth (2009), and complemented with insights from Saunders (2019), a "Literature/narrative Review" was deemed the most fitting for the establishment of the theoretical framework within study. This non-systematic literature review approach, as described

[11] The Theoretical Framework has been established in chapter 2.

[12] A simple analytical framework—**S**earch, **A**ppraisa**L**, **S**ynthesis and **A**nalysis (SALSA) (Grant & Booth, 2009)

by Grant and Booth (2009), offers flexibility without necessitating exhaustive searching or quality assessment of the sourced papers.

The primary goal of the literature review is to deepen understanding of the external landscape of IREIFs' sustainable investments and its implications for LCC-model development. The flexibility inherent in this approach facilitates exploration of the multifaceted and interdisciplinary nature of the sustainable real estate decision-making. Within the domain of IREIFs' sustainable investments and the introduction of a modified LCC-model, the research concentrates on three areas: (i) Life Cycle Thinking, (ii) (Inter)national regulations, and (iii) Performance Management Systems and ESG-Frameworks.

Given the multidisciplinary and multi-level nature of the research topic, a flexible approach to literature review was deemed essential. Each of the research areas spans a broad spectrum, making it challenging to confine them within strict inclusion or exclusion criteria. The chosen "Literature/narrative Review" does not necessitate structured search or a predefined protocol, allowing for a more comprehensive exploration. The adopted literature review is meant to provide in-depth approach, based on knowledgeable selection of current, high-quality articles.

Grey Literature

In the process of retrieving scientific literature, grey literature was encountered and subsequently consulted. This literature offers a broader context for understanding sustainable investment decisions by IREIFs, especially concerning the practical aspects of the research. It complements the insights gained from the primary literature review. Grey literature comprises documents produced by various entities, including government bodies, industry organizations, and institutions. While these documents may not undergo the rigorous academic review typical of scientific literature, they provide key aspects important to clarify the broader context and practicalities of the research topic.

3.3.2.2 | Internal Research

The second component, *Internal Research,* of the discover phase, consists of three methods to gain insights into Vesteda's internal sustainable investment strategy: 1) Desk Research, 2) Informal Talks, and 3) Semi-structured interviews.

3.3.2.2.1 | Desk Research

Desk research serves as a foundational step in this study, offering insights into Vesteda's internal dynamics concerning sustainability and the investment decision-making process. By meticulously analyzing Vesteda's internal documents, this research aims to unravel the intricate ways in which sustainability, and its associated performance measurements, are woven into the company's strategic fabric.

Several key documents were scrutinized, including strategic plans, annual reports, sustainability guidelines, and internal memos. These documents provided a comprehensive overview of:

1. **Vesteda's Sustainability Vision and Mission**: Understanding the company's long-term goals and immediate objectives related to sustainability.
2. **Performance Management System**: Identifying the key performance indicators (KPIs) Vesteda employs to gauge its sustainability and financial efforts and the

	Company	Function	Specialization
Internal	Vesteda	Technical Coordinator 1	Operational Management & Maintenance
		Technical Coordinator 2	Operational Management & Maintenance
		Portfolio Analyst	Data Analyst
Stakeholders and market parties	Bruynzeel	Coordinator Quality and Environment	Manufacturer and supplier of kitchens
	Bribus	Business Developer	Manufacturer and supplier of kitchens
	ATAG	Manager innovation & Sustainability	Supplier of kitchen appliances

Table 1 – Overview of informal talks with employees, stakeholders and market parties

benchmarks set to achieve them.

3. **Investment Decision-Making Process**: Discover how sustainable principles are integrated into the Investment Decision-Making process and the operations, project evaluations, and investment decisions.

This in-depth analysis not only sheds light on Vesteda's current stance on sustainability but also offers a roadmap for understanding where enhancements, particularly in the realm of Life Cycle Costing, can be integrated for more informed and sustainable decision-making.

3.3.2.2.2| Informal Conversations/Meetings

Literature indicates that conducting an LCC analysis requires a substantial amount of input data, given the intricate nature of the building process and the numerous components involved. The accuracy and completeness of this data significantly influence the final outcomes (Gluch & Baumann, 2004).

To address this, informal talks are held with various Vesteda employees and additional stakeholders and market parties to gain insights into Vesteda's IT infrastructure, associated databases, and information management practices. These elements are pivotal for the successful development of the LCC model.

Initial conversations were held with Technical Coordinators, who are responsible for operational management and maintenance. The objective of these conversations is to understand the software systems in use and to identify the type of data available within them.

Subsequent conversations were held with the portfolio analyst, a key figure responsible for managing Vesteda's data and providing valuable insights into their portfolio regarding the cost and additional metrics. The aim of this conversation is to gain insights in how Vesteda handles and processes the data obtained from the different software programs used throughout the organization.

Additionally, informal sessions were organized with market parties and Vesteda stakeholders. These stakeholders range from manufacturers and suppliers of building elements to consultants focused on sustainability. The objective was to comprehend their approach to sustainability and sustainable reporting. An overview of all these informal talks and meetings is presented in Table 2.

The primary intent behind these informal talks is twofold: to gain a comprehensive understanding of Vesteda's internal processes and data management practices, and to understand how market parties approach sustainability within the built environment context. Given the exploratory nature of these discussions, a rigorous analysis is not feasible. Instead, findings will be presented as an overview. Nevertheless, these insights are invaluable, ensuring that the LCC model is meticulously tailored to align with Vesteda's specific operational needs and context.

3.3.2.2.3 Semi-Structured interviews

To develop an LCC-model tailored to the needs of Vesteda, this research employed a qualitative approach, specifically through conducting interviews with Vesteda employees. The reason for including interviews as research method stems from the fact that collaboration and effective communication among parties involved, plays an important role in giving attention to the topic of sustainability and embracing the shift by the stakeholders, and thus,

Department	Specialization	Function	Date
(Technical) Acquisition & Development	Financial and Commercial Side of Acquisitions	Acquisition and Development Manager 1	01-05-2023
		Acquisition and Development Manager 1	11-05-2023
	Technical Side of the Acquisitions	Technical Acq. & Development Manager 1	09-05-2023
		Senior technical Acq. & Dev. Manager 2	15-05-2023
Portfolio strategy	Circular Economy Policy Developer	Portfolio Manager 1	28-04-2023
	Strategic	Portfolio Manager 2	11-05-2023
	Overall Sustainability strategy and reporting	Program Manager Sustainability	16-05-2023

Tabel 2 - Overview of all interviewees participated in the the period between April 2023 – May 2023 the adoption of LCC/LCA (Arayici & Aouad, 2012).

Choice of interview type

Interviews, particularly of the semi-structured type, are a widely acknowledged method for data collection in qualitative research (Taylor, 2005; DiCicco-Bloom & Crabtree, 2006). This format offers flexibility, allowing for an in-depth exploration of the research topic and fostering a comprehensive understanding. The goal of these interviews was to gather rich, detailed insights (Polit & Beck 2010), thereby enhancing the underpinning during the development and boost the the validity and credibility of the research findings. This approach ensures that the resulting LCC-model aligns closely with Vesteda's operational realities.

The foundation of the semi-structured interview lies in a conversation between the researcher and the participant, steered by an adaptable interview guideline and enriched with additional questions, discussions, and remarks (Kallio et al., 2016).

Semi-structured interview set-up

Interviews were conducted to explore Vesteda's approach to implementing sustainability strategies and to identify specific processes related to sustainable investments across various departments. This research step aimed to bridge the theoretical insights about the external landscape of sustainable investment for IREIFs with the practical insights from Vesteda.

The primary objective of these interviews was to understand Vesteda's investment decision-making process, the flow of information within it, and how the LCC-model could be implemented and utilized within its sustainable investment decision-making process. Given the research's goal to develop a tool tailored for IREIFs' decision-making, it was paramount to understand Vesteda's practical operations. Employees from different departments, particularly those involved with sustainability, were interviewed.

Selection of interviewees/participants

Since the developed LCC-model is intended for use within the acquisition process, it will primarily be utilized by the (Technical) Acquisition and Development Department ((T)ADM). Their perspective is crucial. However, the acquisition process involves collaboration with other departments, notably the Portfolio & Strategy department, which sets requirements to align acquisitions with the current portfolio. As a result, interviews were conducted with representatives from both departments, as detailed in Table 3. The interviewees were selected based on level of how sustainability affects their work, and how they influence sustainable investments, and additionally their interest and knowledge about sustainability within the bigger picture. Each of the interviewees meets these criteria.

Executing the Interview

The interviews were conducted in accordance with a predetermined interview strategy (see Appendix B). Recognizing the unique roles and expertise of each department, tailored sets of questions were crafted to align with their specific knowledge and responsibilities. Broadly, the interview can be segmented into three distinct phases:

1. **Introduction:** A brief recapitulation of the research topic was provided, followed by an explanation of the primary objectives of the interview. This set the stage and context for the subsequent discussion.
2. **Main Part:** The interview commenced with questions assessing the interviewee's familiarity with sustainability. This progressed to broader inquiries about Vesteda's processes, gradually narrowing down to discussions about the potential use and implementation of the LCC-tool. The aim was to discern how the insights from the LCC-tool could enhance Vesteda's investment decision-making process.
3. **Ending:** The interview was wrapped up by exploring future perspectives and addressing any queries or concerns the interviewee might have had, ensuring a comprehensive understanding and closure to the discussion.

The interviews, with an approximate lengths of 45 minutes, were conducted in Dutch, reflecting both the predominant language of the building sector and Vesteda's working language. Conducting the interviews in the participants' native language ensured they felt at ease, facilitating a more fluid conversation and enabling the collection of richer, more detailed information without the hindrance of language barriers.

Ensuring the confidentiality of participants' identities and information is crucial when conducting interviews. The measures taken to uphold this confidentiality in this research include:

1. Adhering to the guidelines set by the Human Research Ethics (HREC) committee of TU Delft.
2. Prior to and at the beginning of each interview, the researcher clarified to the participants how their information would be stored and utilized.

3.3.2.3| The Define Phase

Subsequently to the *Discover phase* is the *Define phase* of the double diamond method, where the insights obtained are analyzed and merged into a clear *problem statement* and *design brief*. This phase emphasizes the amalgamation of knowledge sourced from the established Theoretical Framework, Desk-Research, informal dialogues, and semi-structured interviews to formulate a comprehensive *design brief* for the LCC model. The beginning section explores the process of analyzing the interviews, and the following section elucidates the merging of insights from the Theoretical Framework with those derived from practice.

3.3.2.3.1| Interview Analysis

Converting real-life events into a structured narrative is inherently complex. This complexity arises from the representation itself and the methodologies and viewpoints employed. The interview methodology, the techniques used, and the documentation method can profoundly influence the research's conclusions. Furthermore, data interpretation is inherently subjective, with the researcher's discretion playing a significant role in emphasizing certain data and its presentation (Fontana, 2005).

Normally, to navigate these intricacies, a clear analysis method would be established, for example through a thematic analysis, obtaining insights thematic topics, which is, by academics, a recognized analysis (Braun & Clarke, 2006). However, due to the nature of this research, with its aim of developing an LCC-tool complemented environmental impact, there is touched upon a topic which is rather complex, resulting in that an interview analysis method as mentioned is not suitable.

Therefore, to obtain insights and utilize these insights within this interview a new approach has been developed, which sheds light on the processes within Vesteda to tailor the tool to their requirements. The following 2 steps are taken in order to utilize the findings from the interviews.

Step 1: Transcribing the interviews.

Every interview was transcribed, capturing the participant's words as spoken. Accuracy checks were performed on these transcripts, and any identifiable information was redacted to maintain participant confidentiality.

Step 2: Highlighting the insights from which development decisions were taken.

This step involved highlighting the insights obtained from the interviews, in the transcripts. These insights served as substantiation of design choices during the development phase and underpinned how the tool's results could ultimately be utilized in the internal benchmarking of Vesteda. The insights obtained during the interviews have contributed to a comprehensive understanding of sustainability is integrated within Vesteda.

3.3.2.3.2| Bridging the Theoretical Framework with Interview Results

Integrating theoretical knowledge with practical insights is pivotal in research, ensuring that the study remains grounded while also being informed by real-world experiences. This is especially required for the development and implementation of a new tool. The insights from the informal meetings, the theoretical framework, the general understanding obtained during the interviews all contributed to consolidation into a clear design brief and the design requirements.

3.3.3| The Develop Phase

This phase is about developing the LCC-model with environmental impact from LCA integrated. For the resulting tool to fulfill the requirements and allow for implementation and utilization by IREIFs in their sustainable *real estate investment decision-making process*, the following steps are taken:

I. *Demarcating the boundaries of the tool*
The step of demarcating the boundaries of the tool resulted in a minimum viable product (MVP) of the LCC-model which will be developed.
II. The development of the financial part (LCC)
III. The development and integration of the environmental impact (LCA)

The practical part of developing the tool is done in excel. The choices made in the Develop phase were substantiated by consulting literature corresponding to the topics mentioned above and involves the utilization of information and insight of previous chapter, together with data obtained from stakeholders, to create a working model.

It will furthermore be developed and tested with real-world data obtained from Vesteda and manufacturers to ensure its correctness. Additionally, this phase will involve the creation of a user-friendly interface for the model, making it easy to use and interpret the outcomes, for the utilization in the decision-making process. The development will be an iterative process integrated by continuous feedback loops. The resulting tool will undergo verification to check if it fulfills the requirements and if it aligns with the design brief.

3.3.4| The Deliver Phase

The last phase of the double diamond method is the the Deliver phase where the developed LCC-tool for real estate investment decision-making is put into action and tested. This section furthermore aims to discover how the obtained results from the tool could be utilized within Vesteda's internal benchmarking framework, the SIS. This entire process of arriving at an outcome of the tool and the utilization of the outcome in their PMS, presents answers to the fourth and fifth sub-research questions. Within this phase, the insights obtained from during the conducted interviews in the preceding diamond are utilized.

3.3.4| Answer to Sub Research Question 3

In conclusion, this chapter outlines the research methods employed in each phase to develop the integrated LCC/LCA tool, thereby addressing the third research question: *What methodology can be applied to develop an LCC-tool for buildings, accounting for environmental impact, for implementation in the real estate investment decision-making process of an IREIF?':*

The Double Diamond—Research Through Design—approach was identified as the most suitable for this research. This approach not only allows but also necessitates the documentation of each development step, ensuring that no obtained information during the process is lost. It begins by broadly defining the problem space, narrowing down to a Design Brief that outlines the required solution. The development phase then starts broadly and converges to deliver a tailor-made tool, offering insights regarding the environmental impact and the associated cost. This methodology provides the flexibility and comprehensiveness needed for the accurate development of an LCC tool integrated with LCA.

4| Results and Analysis

Chapter four of the research presents the results of each phase of the double diamond design-thinking research method and the thereby obtained insights. The first section will be about the Discover and Define phases, resulting in a design brief for the development of the solution to problem. The second part will elaborate on results and analysis of the Development and Deliver phase. At the end of this chapter an answer will be given to SQ4 and SQ5.

4.1| Discover and Define Results

This section contains three parts. Firstly, a brief recap of the theoretical framework that plays an important part in drawing up the Design Brief will be highlighted. Secondly, the results from the Internal Research will be presented with its link towards the findings from the theoretical framework.

The third section focuses on the design brief, which specifies the requirements for the LCC-tool to solve the problem that arises from the results of the Discover and Define phases. Lastly, the findings from the Discover and Define are consolidated into the demarcating for a minimum viable product.

4.1.1| Theoretical Framework results – External Landscape

The theoretical framework, established in Chapter 2 and depicted on the next page in Figure 17, outlines the external landscape in which an IREIF operates. This context serves as a foundation for the development of an LCC-tool, guiding how it will be situated and implemented within this multi-level framework. The insights obtained from this framework will be linked and compared with the results and insights derived from subsequent steps in the research.

4.1.2| Internal Research

The Internal Research serves a pivotal role in this project, laying the foundation for informed decision-making. Initiated in the 'Discover' phase, this research is instrumental in shaping the 'Define' phase of the Double Diamond method. The findings unearthed in these initial stages not only contribute to the consolidation of the Design Brief but also continue to provide guidance as the project progresses into the 'Develop' and 'Deliver' phases. In this section, the key findings that have informed the Design Brief are detailed, while additional insights that play a role in later stages are referenced in the corresponding sections.

The internal research was conducted using the following methods:

- Desk Research
- Informal Conversations/Meetings

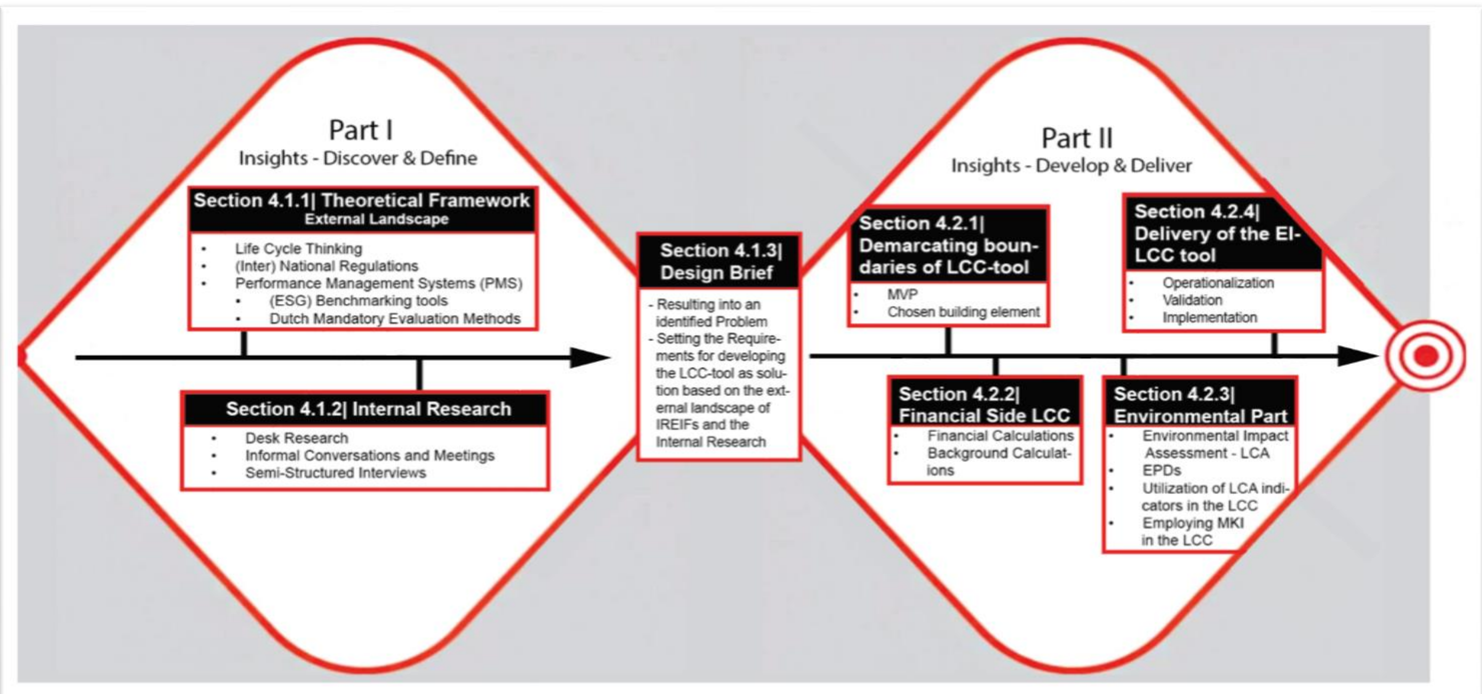


Figure 17 – Overview of chapter 4

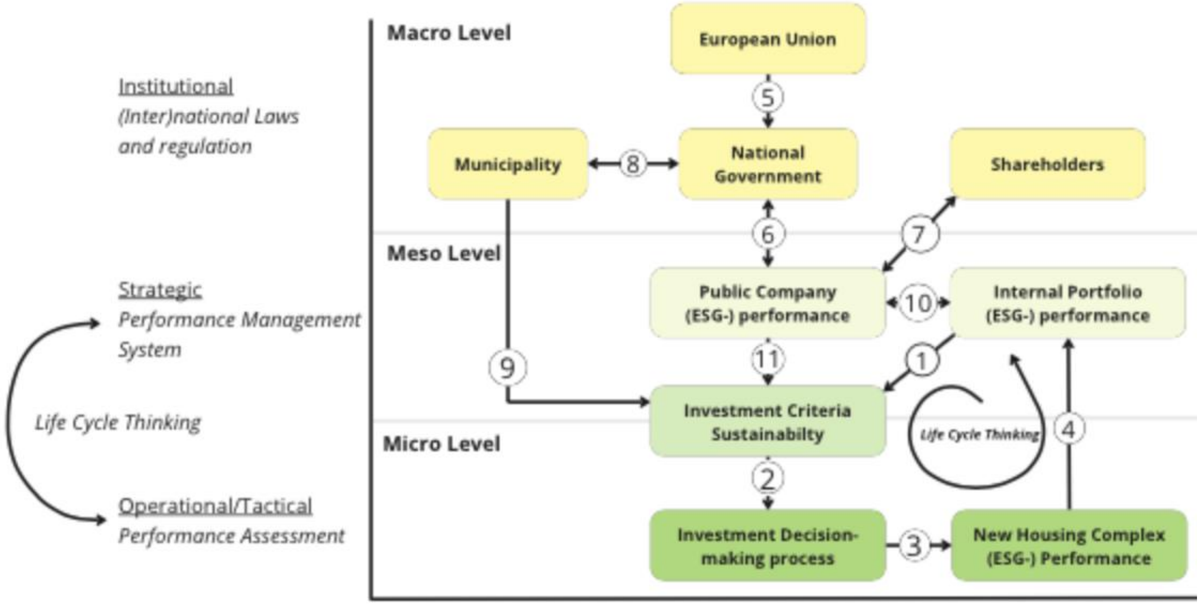


Figure 18 – The resulting context of IREIF containing the relationship of each stakeholder and process. For the description of how they each influence each other there is referred to chapter 2. (own source)

4.1.2.1| Desk Research

This research step has been sub-divided according the three levels used in the theoretical framework:

- Macro level
- Meso level
- Micro level

1. Macro level – (international Laws and regulations)

Starting of on the macro level, where desk research has provided insights into Vesteda's positioning within the realm of sustainable real estate investment. As an IREIF, Vesteda actively promotes its commitment to sustainability. This commitment places Vesteda under the "Article 8" category of the Sustainable Finance Disclosure Regulation (SFDR). As a result, Vesteda is bound by the SFDR's disclosure requirements, obliging the company to transparently communicate its Environmental, Social, and Governance (ESG) performance. This ensures that (future) stakeholders are informed of Vesteda's contributions towards the European Union's sustainability goals (Vesteda, n.d.-b).

For Vesteda this resulted in the adoption of the, in section 2.3.2 mentioned public performance benchmarking framework. However, in line with Newell et al. (2020) in the same section 2.3.2, Vesteda acknowledges the rigidity of these public ESG benchmarks available in the market, resulting in the creation of their internal ESG benchmarking framework – *the Sustainable Impact Score (SIS)*. Given Vesteda's stature as one of the leading IREIFs in the Netherlands, the company seeks to target a specific market of investors. The SIS-framework aims to satisfy and inform their (future) investors regarding their ESG performance and ambitions

Subsequently, *Vesteda's Sustainability Vision and Mission,* shed light on aspects at each level:

<u>Vision & mission:</u>

- Vesteda aims to contribute to future income security for retirees by investing pension savings and insurance premiums entrusted to it by institutional investors, such as pension funds and insurance companies. It further focusses on affordable living for Dutch middle-income households, and the continued improvement of the quality of urban communities (Vesteda, 2021).
- Vesteda sees sustainability as a vital component for the long-term value development of their portfolio, their organization, and the society they operate in. Their sustainability efforts are believed to result in future-proof returns on investments and create value for all stakeholders(Vesteda, 2021).

<u>Long-term goals:</u>

- Vesteda is committed to improving the ESG impact of its investments and will continuously update its Technical Standards, SIS metrics implemented in their Internal PMS for benchmarking purposes, public ESG benchmaring frameworks, and its policy (Vesteda, 2021).
- They aim to ensure that their efforts in sustainability result in future-proof returns on their investments and create value for all stakeholders (Vesteda, 2021).
- Vesteda's sustainability targets are an integral part of their business plan, approved annually by their investors, ensuring that these targets are deeply embedded in their operations (Vesteda, 2021).

Immediate objectives:

- Decision Making: Vesteda incorporated their SIS framework into its Investment decision-making process to ensure potential sustainability risks are explicitly considered in investment decisions. Additionally, this SIS-framework helps to allign potential future investment with the SIS performance of the current real estate portfolio . This allows Vesteda to make well-balanced decisions wihtin their investment decision-making process.
- Reporting and Monitoring: After project completion, Vesteda monitors the performance and impact of sustainability factors by gathering data from properties, conducting tenant questionnaires, and performing property performance tests. The results from these activities inform new investment policies and can lead to adjustments in the SIS Framework and Technical Standards (Vesteda, 2021).
- Governance: Vesteda's policy on the integration of sustainability risks and factors are evaluated annually (Vesteda, 2021).

2. Meso level - Performance Management System:

Vesteda employs a PMS to measure the company's performance on both their financials as their sustainability efforts. The results from this system shape the investment criteria, which are integral to the investment decision-making process (refer to 1, 2, 3 in Figure 18). These criteria encompass both sustainability indicators and financial performance metrics.

Vesteda's *sustainable PMS* hinges on their internal ESG performance framework, the SIS-framework, mentioned earlier, which is designed to monitor, manage, and evaluate potential investments in harmony with their strategic aspirations and targets (refer to Appendix C) (Vesteda, 2021).

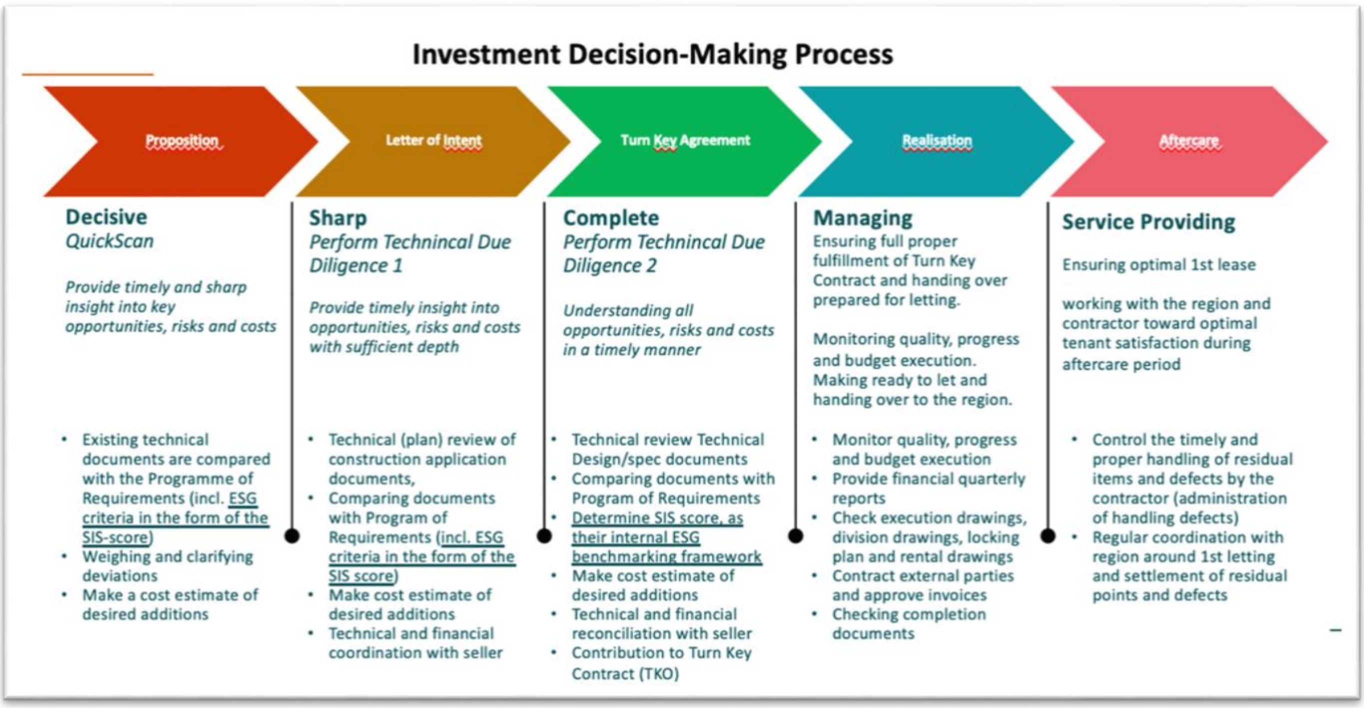


Figure 19 – Investment Decision-making Process of Vesteda (adapted version from internal document of Vesteda)

Sustainability and climate considerations are paramount in Vesteda's investment evaluations for new ventures. The intricacies of this decision-making process will be explored further under "Operational Integration".

Vesteda has their "Technical Standards" in place to determine if potential investments align with their sustainability and technical benchmarks. Through their bespoke framework, Vesteda sets a baseline that all new investments must achieve over time, ensuring the infusion of sustainable practices and responsible investment ethos.

Their comprehensive SIS framework encompasses the domains of Climate, Energy, Material and Resources, Social, Health and Well-being, and Governance (Vesteda, 2021). Each project undergoes scrutiny based on these parameters within this internal ESG framework, resulting in a Sustainability Impact Score (The SIS) (Vesteda, 2021)

While Vesteda relies on their internal sustainability benchmarks for investment, they still utilize public disclosure frameworks like MSCI, GRESB, and BREEAM, as discussed in section [2.3.2.1]. Although these frameworks inform the investment criteria, they do not directly influence the LCC model's development and will not be further elaborated upon.

The *financial viability* of potential investments is assessed through a valuation analysis, as briefly outlined in section [2.1.1]. A notable gap in this analysis is the transparency concerning lifecycle costs of building complexes. Presently, these costs are assumed to be fixed percentages of rental income, escalating every five years. The percentages, rooted in key figures, ensure a consistent return if not surpassed (year 1-5 [5,5%], year 5-10 [8%] and year 10-15 [11%] of the gross rental income) (Internal Documentation Vesteda).

The absence of detailed insights into the lifecycle costs of specific building components hinders informed design decisions. Coupled with the lack of a methodology for gauging environmental impact during project assessment, it underscores the relevance of the LCT, LCC, and LCA discussed in section [2.1.2]. Incorporating the LCC-tool's outcomes, encompassing both cost and environmental impact, could enrich Vesteda's SIS methodology within their PMS.

3. Micro level - Investment decision-making process

Vesteda's investment decision-making process, as depicted in Figure 18, outlines the sequential steps undertaken by the (technical) acquisition and development team, when considering potential investments in real estate. This process serves as a filtering mechanism, rigorously evaluating the proposed projects from developers to determine their alignment with Vesteda's criteria.

The visual representation (Figure 19) shows the available and necessary information within each phase of the investment decision-making process to conduct their valuation analysis. These documents with information and data are crucial input, for an LCC tool aswell.

During the Letter of Intent (LOI) phase, preliminary data populates the valuation model used for the valuation analysis.. As the investment process advances, a richer set of data becomes available, from which both the LCC and valuation model benefits. While the valuation model plays a significant role, this research primarily emphasizes the cost component, traditionally estimated using specified percentages of gross rental income, and therby sidelining a detailed exploration of the valuation model itself.

During the investment decision-making

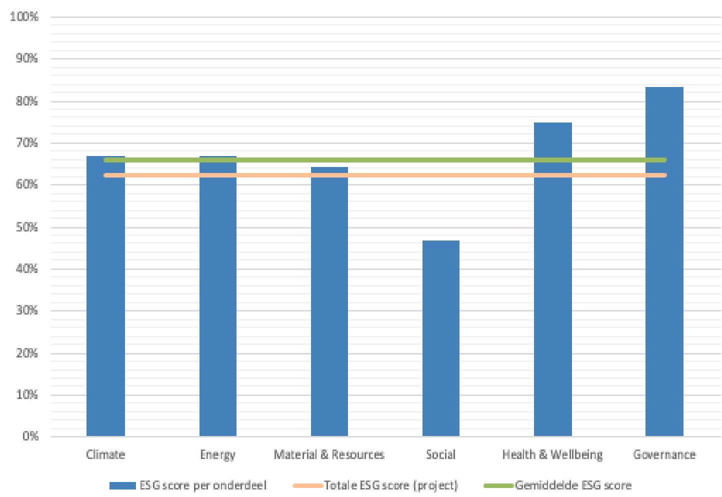


Figure 20 – ESG Score, per topic of a potential investment. With the pink line displaying the aggregated score compared the

process, prior to the Turn-Key Contract, an investment proposal is drawn containing the information gathered during each phase of the process, varying from location specific information, financial expextations, technical details and sustainability assessment of the to potential investment.

The investment proposal summarizes the important findings, which and will be presented to the executive board consisting of the CEO, CFO and the rest of the management team, for them to approve the investment decision and that it alligns with the Vesteda's ambition and strategy. Furthermore, it is important to mention that an investment proposal needs to be ready and approved, before the Turn Key Contract will be signed. An investment proposal, among other things, stipulates the following details making them part of the PMS of Vesteda as KPM:

- Cost deviations for meeting the desire level of quality
- Sustainability Impact Score (SIS) framework

Firstly, regarding cost deviations, the potential real estate investment, is evaluated as such, that it does not exceed the precentages used in the analysis of the Vesteda's current portfolio. The potential cost deviations that could arise are presented within the investment proposal to mitigate or account for this risk.

Lastly, the mentioned internal benchmarking framework of IREIFs in section [2.3.1], is utilized by Vesteda under the name of the SIS-framework. In Appendix C an overview of what the SIS/ESG framework entails has been displayed. The SIS-framework constist of a variety of factors, these factors are compared against a baseline, resulting in a score for each factor. A weighting is assigned to each score, and combined they consolidate into an overal SIS-score. The SIS score shows how sustainable a proposed project is. When the tool has been populated, it provides an overview showing how each factor compares to the benchmark as can be seen in Figure 20. Evalauting each proposed investment by means of this framework is Vesteda's manner to comply portfolio wide strategy

4.1.2.2| Informal Conversations/Meetings

For the LCC-tool to be operational, it requires both cost and environmental impact data. Engaging with building element suppliers offered insights into their environmental impact evaluations and available data. Conversations were held with major Dutch kitchen suppliers, Bruynzeel and Bribus, and kitchen appliance supplier, ATAG, to gain a holistic understanding of kitchens. A brief overview of the insights obtained from the informal meetings will be given:

Technical coordinators

The technical coordinators revealed the use of a software, VastWare[13], which contains a detailed database of budgeted future maintenance costs for every building element in their portfolio. These costs are informed by past expenditures and anticipated maintenance schedules embedded within the software. VastWare is a crucial tool for Vesteda, aiding in maintenance planning and budgeting.

Portfolio Analyst

The portfolio analyst at Vesteda, responsible for data analysis of the whole portfolio explained the analysis methods for available data, including VastWare's maintenance data. The insights gained influence strategy formulation and future portfolio budgeting. The analyst highlighted the use of Power-BI[14] for data analysis, with VastWare serving as a data source. Access to Power-BI revealed a detailed budget overview for the next decade, which influenced decisions made during the LCC's development, further discussed in section [4.2.1].

[13] A Dutch software company providing software for systematic maintenance (Vastware, n.d.)

[14] Power BI is a Microsoft tool for data visualization and analytics. It enables users to create interactive reports and dashboards from multiple data sources. It is widely used for data analysis and decision-making in organizations. (Ferrari & Russo, 2016)

Bruynzeel, Bribus and ATAG

Bruynzeel has committed themselves of assessing the environmental impact of their kitchens through a comprehensive Life Cycle Assessment. However, the analysis has not been completed. Notably, they exclude kitchen appliances from this analysis, as these components are procured from external manufacturers and thus fall outside of Bruynzeel's direct scope. Their goal is to gain detailed insights into the environmental impact of their products and to contribute to the National Environmental Database (NMD) through Environmental Product Declarations (EPDs). This would enable Bruynzeel to benchmark its products against other kitchen manufacturers already included in the NMD. A poignant remark from Bruynzeel highlighted the evolving landscape of sustainability: "A lot of things are going to happen in terms of sustainability. Customers are becoming increasingly concerned and aware. This is also driven by new laws and regulations. Soon, a mandatory sustainability report, audited by an accountant, will be introduced."

Bribus, Bribus, another prominent kitchen manufacturer, has already conducted an LCA for their 'sustainable' kitchen, resulting in an EPD, which they openly shared. Similar to Bruynzeel, Bribus excludes kitchen appliances from their LCA for the same reasons. Their LCA specifically focuses on wall and bottom cabinets. During the conversation, Bribus referenced another kitchen manufacturer, "Chainable", known for its Circular Kitchens, to illustrate the variations in LCA frameworks and the resulting differences in outcomes. This dialogue with Bribus underscored the need for a standardized approach to measuring environmental impact across companies. It also highlighted the challenges of data availability in the supply chain, which can lead to the use of aggregated scores and potentially biased results.

ATAG as a manufacturer of kitchen appliances, also recognizes the significance of environmental impact, albeit their method of measuring this impact differs from that of kitchen manufacturers. The environmental impact analyses for ATAG's products, such as cooktops, range hoods, and washing machines, are expressed in terms of CO2-equivalent emissions, distinguishing between the manufacturing and usage phases of the appliances.

The informal conversations with employees and market parties proved invaluable for the development phase of the LCC model. These discussions facilitated the acquisition of essential data and insights regarding costs and environmental impact, which are pivotal for the LCC tool. A notable observation was the discrepancies in LCAs between kitchen manufacturers, emphasizing the need for harmonized metrics. Additionally, the environmental impact assessments of kitchen cabinet suppliers are conducted differently from those of kitchen appliance manufacturers, likely due to their origins in different sectors. For a holistic view of the environmental impact of an entire kitchen, it is imperative that the results are presented in comparable units.

Throughout each conversation, a recurring theme was the increasing awareness of sustainability among manufacturers, suppliers, and consumers alike. There is a growing consensus on the importance of sustainability reporting, and stakeholders across the entire supply chain are becoming increasingly engaged in these efforts. However, Despite the growing awareness of sustainability, companies vary significantly in their level of engagement and progress in this area.

4.1.3| Design Brief and the Identified Problem

The results obtained from the establishment of the theoretical framework, the insights from the internal research consolidated in the Design Brief.

Problem

Most companies in the building sector, including IREIFs, rarely have LCT incorporated into their Performance Management Systems to measure goals and ambitions. This is due to slow adoption rate, lack of reliable data, lack of knowledge, the labor intensity and context specificity. This results in the identified problem in which currently building design decisions about building elements, in which IREIFs has influence during the investment decision-making process, are not made substantiated. The current investment decision-making process neither account for the total cost during its life cycle nor the environmental impact.

Solution

To resolve this problem, a tool is needed that sheds light on both the costs and environmental impacts of building elements across their life cycle, grounded in LCT principles. This necessitates the creation of a Life Cycle Costing model that integrates Environmental Impact Indicators from LCA, specifically designed for the unique context of an IREIF to evaluate building elements.

Requirements

The design brief encompasses both mandatory requirement and requirements that are highly desirable to solve the identified problem.

Mandatory

The mandatory requirements are a must have for the tool to function properly.

- The tool must employ life cycle costing as its underlying method.
- The tool must be able to assess building elements.
- The tool must assess environmental impact by implementing and utilizing a corresponding SPI.
- The model must assess the costs throughout a building elements' life cycle.
- LCC-tool must consider the time value of money.
- The tool must enable a better substantiation for investment decisions in building elements in which an IREIF has influence, for a better trade-off between cost and environmental impact.

Highly Desirable

The highly desirable requirements as nice to have and will ensure high quality of the tool.

- The development of the life cycle costing tool should adhere to the ISO 15686 standard.
- The duration of the life cycle considered in LCC-model should be aligned with the duration of the already utilized life cycle duration by IREIFs.
- The tool should have the functionality to assess and compare more than one type of a specific building element.
- The LCC-tool should be easy to operate.
- The tool should include a certain degree of flexibility from the beginning, allowing for future adaptions.

4.2| Development and Deliver Phase

This chapter is about the process of the development and delivery phase which was undertaken to create a functioning prototype of the Environmental Impact (EI)-LCC model. While there is a vast body of literature about the various LCC-tools developed, no detailed methodology for the residential construction sector is present (Cuéllar-Franca & Azapagic, 2014). The lack of consensus and standards (Zhang et al., 2021) is due to differing context, the chosen building element/product/process of interest, and most importantly the goal of the research and the subsequent development of a tool.

Therefore, this chapter is divided into four parts:

1) Demarcating the boundaries of the tool
2) The financial development process of the LCC and its financial calculation,
3) The environmental development process for implementation of the LCA environmental Impact
4) Elaboration of the use of the tool and the results obtained.

Throughout this chapter, references to interviews conducted with Vesteda employees are referred to to align the correct assumptions. To ensure the accuracy and traceability of these references, line numbers are appended to each transcription. For instance, a citation like 'ADM1 [1-10]' refers to the interview with Acquisition and Development Manager 1, specifically citing lines 1 through 10 from the transcription. This method enhances the validity of the interviewee's responses. A list of abbreviation references for the interviewees is also for further clarity in Figure 19.

Vesteda Empoyees	Abbreviation
Technical Acquisitions and Development Manager	TADM 1
Senior Technical Acquisitions and Development Manager	TADM 2
Head of Acquisitions and Development	ADM 1
Senior Acquisitions & Development Manager	ADM 2
Portfolio Manager 1	PM 1
Portfolio Manager 2	PM 2
Programme Manager Sustainability	PMS

Figure 21 - All interviewees participated with abbreviation references

4.2.1| Demarcating the boundaries of the tool

As mentioned in section [2.1.1] an LCC-analysis requires a substantial amount of data and information. To tackle the complexity and volume of data, a decision has been made to start the development process aiming for a simplified model, implementing only one building element ensuring the validity of both the model and the input data. Resulting in the development of a Minimum Viable Product.

4.2.1.1|The Choice for a Minimum Viable Product

The term "Minimum Viable Product" was popularized by Ries (2012), in his book "The Lean Startup." In this context, an MVP is defined as the version of a new product that allows a team to collect the maximum amount of validated learning about customers with the least effort. This approach is central to the Lean Startup methodology, which is focused on efficiently building and scaling startups or new product lines within larger companies.

<u>Rationale for Choosing an MVP Approach:</u>

1. *Manageable Complexity*:
   An LCC model can be intricate due to the numerous variables and data points involved. Starting with an MVP allows for a more focused and manageable initial development phase, reducing the risk of becoming overwhelmed by complexity.
2. *Evaluation of Core Assumptions*:
   The MVP approach enables early testing of the model's core assumptions with real data. This is essential for ensuring that the model is built on a solid and valid foundation before additional complexities are introduced.
3. *Efficient Use of Resources*:
   Developing a full model requires a significant investment of time and resources. An MVP allows for a more efficient use of these resources by focusing on the most critical aspects first.
4. *Agile and Responsive Development*:
   Starting with an MVP allows for a more agile development process. Feedback can be

obtained quickly and used to make iterative improvements to the model.

What the MVP Entails for This Development:

1. *Focused Scope:*
   For this MVP, the development process will concentrate on a single building element. This focused scope allows for a deep and thorough analysis, ensuring the validity of both the model and the input data.
2. *Essential Features Only*:
   The MVP will include only the most critical features and functionalities necessary to perform a basic LCC analysis for the chosen building element.
3. *Iterative Development and Improvement*:
   After the MVP is developed and tested, feedback will be used to make iterative improvements. Additional building elements, features, and data points can be incorporated in subsequent versions based on this feedback and further analysis.
4. *User Feedback and Evaluation:*
   The MVP will be shared with key stakeholders for early feedback. This feedback will be invaluable for validating the model's assumptions, improving its accuracy, and guiding its future development.
5. *Data Integrity and Quality Assurance:*
   Given the MVP's focused scope, significant attention will be paid to ensuring the quality and validity of the input data for the chosen building element.

By opting for an MVP approach, this development process is designed to be more manageable, efficient, and responsive, allowing for the creation of a robust and effective LCC model that can be expanded and refined over time based on real-world use and feedback.

4.2.1.2 | The chosen building element

Before delving into the development of a Minimum Viable Product (MVP) and opting for a focus on a single building element, it is essential to address one of the soft requirements: ensuring flexibility. To integrate this degree of flexibility, the Shearing Layers of Brand (Brand, 1995) is instrumental. This concept categorizes building components according to their different lifecycles. Brand posits that a building is not a static entity but a dynamic, evolving assembly of various components, each with its own lifecycle. Brand (1995), identifies six layers, each changing at different rates: Site, Structure, Skin, Services, Space Plan, and Stuff. These layers provide a framework for categorizing building elements based on their expected lifecycles (Figure 22). The eventual incorporation of all these layers in the LCC model will allow for a holistic analysis, enabling better and more informed decisions. Keeping the Shearing Layers of Brand in mind during the development ensures that the model retains a degree of adaptability and freedom.

However, the initial step in the development process involves identifying a specific building element that will serve as the foundation for the LCC model. This is determined by evaluating the contribution of each building element to the overall maintenance costs over the next ten years, with the selection criteria prioritizing the building element with the highest incurred maintenance costs.

To streamline the development of the LCC tool and manage the complexity of data, the focus has been narrowed down to a single building element, as outlined in the previous section regarding the development of an MVP.

The availability of maintenance and exploitation data played a crucial and practical role in the selection process of the building element. By analyzing the data obtained from Vesteda using MS

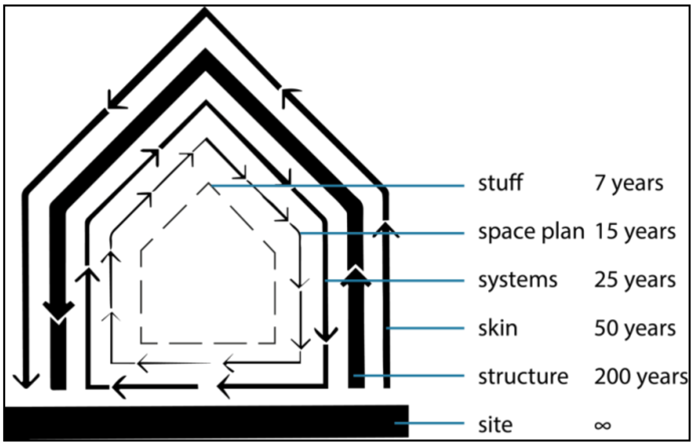


Figure 22 – Shearling Layers of change (Brand, 1995)

Excel, it was possible to identify the building element with the most significant impact on the total maintenance cost across the entire portfolio for the next 10 years. This data-driven approach allowed for an informed selection decision.

The analysis revealed that the second highest budgeted maintenance and exploitation costs were attributed to the kitchens, constituting 21.3% of the total budgeted cost Appendix D. This finding was in contradiction with the insights obtained during the interviews with an employee of Vesteda (PM1[183-187]). These interviews suggested that the kitchens were, in fact, the highest budgeted costs. This discrepancy in the data, both sourced from Vesteda, led to a decision to choose the building element based on another argument: prior informal conversations had already been held with kitchen manufacturers. And because contact had already been made with the manufacturers, this made it easier to obtain the necessary data. These findings ultimately led to the decision to use kitchens as the foundational building element for the development of the LCC model. A more detailed overview of the incurred cost per building element can be found in Appendix D.

The selection method is primarily based on practical considerations and the availability of data. While criteria such as initial investment costs and environmental impact are relevant in the context of an LCC model, they were not the primary focus of this selection process.

The objective was to identify a building element, in a practical manner, that would serve as a starting point for the LCC model. The use of available maintenance and exploitation data for this selection decision is both sufficient and valid in this context. It is important to note that, as the LCC model evolves, it will encompass variables essential for a comprehensive analysis, including initial investment costs and environmental impact.

Referring back to the shearing layers of brand, the kitchens are attributed to the 'Space Plan' layer of the Shearing Layers of Brand, indicating their role as configurable elements within the building's layout that may change as the needs of the occupants change and a technical lifetime of approximately 15 year.

This strategic decision ensures that the LCC tool focuses on a critical element in terms of maintenance expenses within Vesteda's portfolio, while also ensuring that the necessary data is manageable, facilitating the development of a usable tool.

4.2.2| LCC Development Process - Financial Framework

Originally conceived as a financial performance measurement tool, LCC analysis serves as the foundation for understanding the long-term costs associated with building elements. Recognizing the central role of financial analysis in the LCC, this development chapter commences with the formulation of the Financial Framework. This framework is integral to the LCC tool, as it enables detailed and structured financial analysis.

The chapter follows a method to develop the the Economic Framework of the LCC Tool. Firstly, the chapter elucidates the underlying methodology and the associated steps essential for the development of the LCC tool.

4.2.2.1|Development method for the economic framework of the LCC-tool

As this 'Research through Design' project transitions into the 'Develop' phase of the Double Diamond design process model, the emphasis strategically shifts from "Designing the Right Thing," as detailed in the design brief in section [4.1.3], to "Designing the Thing Right." This phase is not merely about crafting a solution; it is a critical juncture where the rigor and precision of the development process come to the forefront. The MVP of the LCC-tool is developed within Microsoft Excel.

Choice of development process

To ensure the effectiveness and efficiency of the LCC tool being developed for Vesteda, it is imperative to adopt a robust and well-defined process. This process serves as the structured approach guiding the development of the LCC tool, ensuring that it is tailored to meet the specific needs and objectives of Vesteda in their decision-making process regarding building elements.

To this end, this section adopts a version of the twelve basic steps of the life-cycle cost analysis process, as identified by Blanchard and Fabrycky (2013). This framework, originally designed for systems engineering and analysis, is particularly focused on the life-cycle cost analysis process. For the purposes of this project, the methodology has been adapted to suit the unique requirements of building elements as a system within the real estate investment framework. This derived process is delineated into five steps, which form the backbone of the LCC tool's development process:

1. Establishing a common language
2. Specify the Cost of the Building Element
3. Identifying required Input Data Requirements
4. Estimation of the Specified Costs
5. Develop a Cost Profile and Summary

It is important to note these six steps are derived from the LCC analysis process of Blanchard and Fabrycky (2013). Some steps are excluded in the current model, while others are merged, nonetheless it offered a starting point for the development of the LCC-tool. This decision was made because the original process was shaped for a more comprehensive analysis. As this project evolves, for example with the incorporation of the Shearing Layers of Brand concept, it is anticipated that the entire LCC analysis process, as outlined by Blanchard and Fabrycky (2013), could become suitable and be fully integrated into the model.

Step 1: Establishing a common language

The first step is about establishing a common language for the development and utilization of the LCC-tool. Quoting Blanchard and Fabrycky's (2013) for the definition of life-cycle cost as "all the costs associated with the system as applied to the defined life cycle," and their emphasize that "a common understanding needs to be established as to what is meant by the life cycle and what is included (or excluded)" in the costs is taken by heart. This results in the following topics that will be discussed to establish a common language:

I. Life cycle terminology
II. Building Life Cycle
III. Kitchen Life Cycle

The resulting common language is imperative to the development of the tool in the subsequent parts.

Firstly, in alignment with Blanchard and Fabrycky (2013), the proper development of a tailor-made LCC tool for Vesteda necessitates the establishment of a common language. This is particularly crucial for the financial aspect of the tool, where time is a vital element. The model was developed in accordance with ISO-15686-5 (Buildings and Constructed Assets — Service Life Planning — Part 5: Life-cycle Costing), which outlines corresponding life cycle phases (Figure 4). However, the terminology within Figure 4 does not align perfectly with the phases as described by Vesteda.

This time element is critical for an IREIF like Vesteda, especially considering the time value of money—a fundamental requirement of the LCC tool. To attribute costs to specific moments in time, it is imperative to adapt the language established in ISO-15686-5 to Vesteda's context, ensuring accurate cost allocation.

The significance of the time value of money[15] for Vesteda lies in its acquisition strategy. When the company acquires a building complex, it may consist of a substantial number of residential units, sometimes as high as 200 at once. During the building complex not all acquired buildings undergo maintenance or renewal simultaneously. Given the fluctuations in inflation rates, interest rates, and construction costs over time, it is vital for Vesteda to budget capital realistically and strategically.

This context led to an adapted version LCC tool, as outlined in Section [2.1.1] in Figure 5. This adaptation considers Vesteda's practice of acquiring assets through turnkey agreements. As a result, 'Construction Costs' are redefined as *'Investment Costs'*. Investment cost and Acquisition cost are used interchangeably, meaning the same thing.

[15] Time Value of Money is explained in the third step of the development.

Furthermore, since Vesteda leases out the acquired buildings and remains responsible for their management and maintenance, and given that the MVP tool focuses on the building element of kitchens, 'Operation Costs' have been excluded from the model because this is included in the maintenance cost. *'Maintenance Costs'* remain, with 'Renewal Costs' playing a dominant role, especially concerning kitchens[16], as well as 'End-of-Life Costs'. This tailored approach is depicted in the adapted version specific to Vesteda's context in Figure 23.

Secondly, in the MVP of this tool, only kitchens are considered, but they are part of a building which is then again part of a larger amount of building. For this context the tool will ultimately be developed. The tool incorporates two building life spans: 20 years and 60 years. The 20-year span aligns with Vesteda's valuation model, used to assess an acquisition's value.

However, considering sustainability, buildings are generally constructed to last much longer. Thus, a 60-year life span is also introduced into the tool. This extended time frame aligns with long-term sustainability goals but increases financial uncertainty due to various factors, such as fluctuating costs and policy changes (Ilg et al., 2016).

To manage these two scenarios, the model is organized into two separate tabs within the Excel tool—one for 20 years and another for 60 years—allowing for clear comparison between different building life spans.

Lastly, Incorporating the kitchen life cycle in the life cycle of the building is done by using the average technical lifetime of a kitchen, which is assumed to be 15 years on average [PM1, line XX]. Vesteda budgets the costs for kitchens only for their renewal when they no longer meet the desired level of quality. This quality is primarily assessed when there is a switch of tenants, called the *mutation rate*.

Furthermore, informal conversations with the Portfolio Analyst revealed that while kitchens are generally *not* renewed all at once when the 15-year lifetime is reached, but that the actual renewal schedule can vary. Some kitchens, used more intensively by tenants, degrade faster, and are renewed earlier, while others exceed the expected lifespan.

The Portfolio Analyst has indicated that after the first life cycle of a kitchen, a stable renewal rate is reached, corresponding to tenant switches. This results in approximately 2.5% of the kitchens being renewed per year. However, before this steady state is reached, only an approximation of the renewal of building elements can be made.

To estimate how many kitchens will be replaced per building complex, a probability density function named the Weibull distribution function was used. This provides a more realistic picture for the renewal rate before the steady state has been reached. See *step 3* of this development process for the elaboration on the Weibull Distribution Function.

These basic but major outlines of the LCC-tool regarding the change of the denomination of the life cycle of ISO15686 and the Life Cycle span of both the residential houses in a building complex as well as the Life Span of a kitchens Facilitates to delve deeper into the development in the subsequent steps.

Step 2. Specify the Cost of the Building Element

In this step, the three cost components conceived in the preceding step are specified. This involves

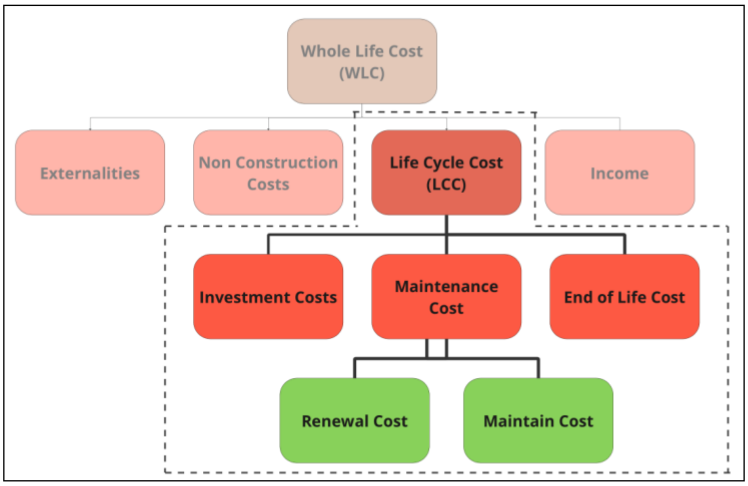


Figure 23 – Adapted version of the Definition of Whole Life Cost and Life Cycle Cost based on ISO 15686-5 (adapted from: Ahmed & Tsavdaridis, 2018)

[16] This is elaborated on in the topic of the kitchens life span.

detailing how and where these costs are allocated within the cost model, and how they are embodied in the life cycle utilized in the model. The three cost components are:

I. Investment Costs
II. Maintenance Costs
III. End-of-Life Costs

Firstly, the investment phase which, entails the procurement and installation of the building element. Costs involved include the purchase price, delivery, and installation expenses. However, in a cost model for IREIFs, only the total costs of acquisition are accounted for, as this is the primary concern for investment decisions. For the MVP regarding the kitchens, the total investment cost is calculated as the sum of the number of acquired buildings multiplied by the price of a kitchen.

Secondly, the maintenance costs are divided into the two categories: maintain cost and the renewal cost. The renewal costs, on the one hand, play a dominant role in the maintenance cost. This cost originates from the findings that little to no maintenance is executed, but that the kitchens are inspected when there is a switch of tenant to ensure that the quality is up to standards. Most of the time, when the condition of the kitchen does not meet the standards, the decision is made to renew the entire kitchen all at once. This MVP is focused on the kitchen without the appliances.

The maintain costs, on the other hand, are related to the regular use of these building elements, including the costs of routine maintenance, cleaning, and minor repairs necessary to keep them in good working condition. Included in the exploitation costs is the Wear and Tear cost. Over time, building elements may degrade due to regular use and exposure to environmental conditions. This wear and tear may lead to more frequent maintenance or repair needs, contributing to the maintain costs. This is mostly attributed to the appliances in the kitchens and not the kitchen itself, which this MVP is about. Therefore, there is little to no expenditure on maintain cost for the kitchen itself.

The maintain cost is, however, included because when switching from a business-as-usual approach—where the kitchens are renewed when they no longer meet the required condition level—to a lease type of contract in the form of a Product as a Service (PaaS), these costs must then be attributed to the maintain cost instead of the renewal cost. Which will be further elaborated on in step 3.

Lastly, the End-of-life costs of building elements encompass expenses tied to decommissioning, deconstruction, demolition, site decontamination, recycling, recovery, disposal of components and materials, transport, and regulatory compliance. Despite its importance and the resulting costs, End-of-Life phase *will not be include*d in the MVP of the LCC regarding a kitchen.

This results in the inclusion of two type of costs are considered. The acquisition costs and the maintenance costs. More cost element could be implemented, however due to the complexity and the available data it was decided to just include these two.

Step 3. Identifying required Input Data

This step involves identification the required data and where and how this could be obtained. The most important data that needs to be retrieved is the data regarding:

I. Time Value of money (TVM)
II. Costs

Both aims to ensures a realistic representation and to gain insights in the foreseeable future regarding the cost during the life cycle

First, the TVM is a fundamental financial principle that describes the concept that money available today is worth more than the same amount in the future (Allen et al., 2013). This is due to its potential earning capacity, which provides the ability to earn interest or yield, and is therefore of utmost importance in financial and investment decisions. Essentially, TVM is based on the idea that investors prefer to receive money today rather than the same amount of money in the future because of money's potential to grow in value over a given period of time. The following concepts are important when considering TVM:

Discount Rate:

In long-term projects, such as building construction and maintenance, costs and revenues occur at different points in time. TVM allows these future costs and revenues to be discounted back to present values (PV) (Allen et al., 2013), enabling a more accurate and comparable analysis. The discount rate is a key input in this process. This discount rate will be provided by Vesteda.

Inflation:

TVM is closely related to inflation. Inflation is the rate at which the general level of prices for goods and services is rising, and subsequently, purchasing power is falling (Allen et al., 2013), which is a crucial consideration when planning for future costs. Accurately accounting for inflation is essential in long-term financial planning. The inflation rate will be provided by Vesteda.

Investment Decisions:

For an Institutional Real Estate Investment Firm IREIF like Vesteda, understanding TVM is fundamental. It helps in making informed decisions about whether the potential returns on an investment property (e.g., a building complex) are worth the costs, considering the time value of money.

Budgeting and Planning:

TVM plays a significant role in budgeting and planning. For instance, when Vesteda budgets for kitchen renewals, it is essential to consider not just the cost of renewal but when this cost will be incurred. Money set aside today for a renewal in the future is an opportunity cost, as it could have been invested elsewhere.

By incorporating the TVM concept into the LCC-tool, Vesteda can make more informed and financially sound decisions, considering both the costs and potential over the entire life cycle of a building or its elements.

Secondly, the Acquisition Costs and Maintenance Costs regarding two different brands of kitchens are retrieved from both their suppliers: Bribus and Chainable. Bribus provides a standard kitchen in a business-as-usual condition, while Chainable offers a circular kitchen. Chainable retains ownership of these kitchens under a Product as a Service (PaaS) model, with a monthly fee per kitchen. The costs associated with Bribus are allocated to the renewal cost category, while those associated with Chainable are designated as maintenance costs.

Renewal Costs for Bribus

To calculate the renewal costs associated with Bribus kitchens, it is necessary to know the replacement cost of the kitchens and the number of kitchens replaced per year. Vesteda should provide the total number of kitchens in its portfolio. With this information, the number of replacements per year can be determined. During the first life cycle of the kitchens, this calculation is performed using the Weibull probability distribution function. After this first life cycle, the 2.5% replacement rate, as mentioned by the Portfolio Manager, is used.

Maintenance Costs for Chainable

The maintenance costs for Chainable kitchens are calculated by multiplying the number of kitchens by the monthly fee charged by Chainable under the PaaS model.

In the next step, the underlying calculations and the Weibull Distribution will be discussed.

Step 4. Estimation of the Specified Costs

In this step the methodology and formulas used for the cost estimation of kitchen will be explained with the input from the preceding steps. This resulted in the following to be discussed:

I. LCC calculations for a general building element and the corresponding formulas.
II. Calculating the amount of yearly scheduled maintenance/renewal
III. Variation in the LCC calculations to account for PaaS.

Firstly, calculating the total life cycle cost per building element (BE) within an acquisition, comprises of initial investment costs + Cost of replacement after the theoretical lifetime. The calculations in this study are performed using the present value, in a nominal way, which accounts for the time value of money and includes the effects of inflation. The maintenance cost is discounted accordingly. A general formula has been devised to calculate the present value of the cost:

$$LCC_{BE} = C_{ii,BE} + C_{M,BE}^{t} \quad (1.1)$$

Where:

LCC_{BE} – denotes life cycle costs of a building element

$C_{ii,BE}$ – presents the total Cost of Initial Investment in building element

$C_{M,BE}^{t}$ – presents the present value of maintenance costs incurred at *t* year.

Starting with the calculation of the total initial investment cost, $C_{ii,BE}$ involves multiplying the number of building elements (#BE) by the initial investment costs per element. The investment costs for a Bribus kitchen, as depicted in the EPD, is €1200 for one kitchen (Bribus, e-mail, 29 June 2023) :

$$C_{ii,BE} = \#BE \times Initial\ Investment\ Costs \quad (1.2)$$

#BE is retrieved from the number of buildings planned for acquisition. The initial investment costs are derived from Vesteda's database of supplier prices.

Subsequently, the present value of maintenance costs, denoted as $C_{M,BE}^{t}$, is calculated using the following formula, adapted from Allen et al. (2013), and results in the sum of the discounted yearly maintenance costs:

$$C_{m,BE}^{t} = \sum_{t=1}^{n} \frac{C_{M},BE}{(1+(r_i-i))^{t}} \quad (1.3)$$

Where, $C_{M,BE}$ represents the annual maintenance cost for each building element, which is calculated by multiplying the yearly amount of scheduled building elements by the maintenance cost per building element and the cumulative Index of construction cost(t):

$$C_{M,BE} = Yearly\ amount\ of\ scheduled\ BE \times Maintenance\ cost\ per\ unit\ BE \times Cumulative\ Index\ of\ construction\ cost(t) \quad (1.4)$$

- R_i – represents the discount rate. This is a can be changed
- t – stands for time in years
- i denotes the inflation rate.
- The maintenance cost per unit BE is sourced from the VastWare software database provided by Vesteda.
- The cumulative index of construction cost at time t is supplied by Vesteda's research department.

Secondly, the process of estimating the yearly amount of scheduled maintenance or renewal of building elements is divided in two: i) The first life cycle (years 1-15) of kitchens and, ii) Renewal after the first life cycle of kitchens.

First, the estimation of first life cycle is conducted using the Weibull Distribution. This distribution is a feature incorporated into Microsoft Excel, which aids in predicting the number of kitchens expected to be renewed at a specific point in time. The Weibull Distribution is chosen for its flexibility and frequent application in reliability and life data analysis, where it excels in modeling various types of failure rates.

In the context of building elements renewal, the term 'failure' is interpreted as the point at which a building element, such as a kitchen, requires renewal. Initially, the plan was to analyze historical data and fit it to a Weibull distribution. This would allow for a realistic representation of the renewal rate per year. However, due to inconsistencies in the data retrieved from Vesteda's database, this approach could not be implemented.

The Weibull distribution is a continuous probability distribution. While the underlying formulas are incorporated into Microsoft Excel and will not be detailed here, the input variables or parameters are crucial. The Weibull Distribution is characterized by two parameters:

- *Shape parameter* (α), also known as the "Weibull slope." For this analysis, an alpha value greater than 1 was chosen, specifically α=10, to achieve the best fit.
- *Scale parameter* (β), which is sometimes referred to as the characteristic life parameter. In this analysis, β was chosen to be 17,

representing the closest approximation to the life expectancy of 15 years for kitchens.

By inserting these parameters and the total number of building elements into the formula, the probability of maintenance work required in a given year is calculated. This probability is then multiplied by the total number of building elements, yielding an estimate of how many kitchen renewals will occur per year.

The final result for each year were integrated into the LCC timeline for both the 20-year and 60-year LCC analyses, covering the first life cycle until year 21 as shown in Figure 24.

Subsequently, the development of the LCC has been an iterative process. In this process, the Weibull distribution function serves its purpose for the first life cycle. However, to achieve a more realistic prediction for the years following the first life cycle, the specific context of Vesteda must also be considered.

Conversations with Vesteda's [portfolio analyst] revealed that, for their analysis and future budgeting purposes, the mutation rate is used to predict the amount of maintenance required for building elements per year. The decision to replace a kitchen is often based on its quality level, which is typically assessed when a tenant terminates their lease.

For the first life cycle, the Weibull function is assumed, and for subsequent cycles, the mutation

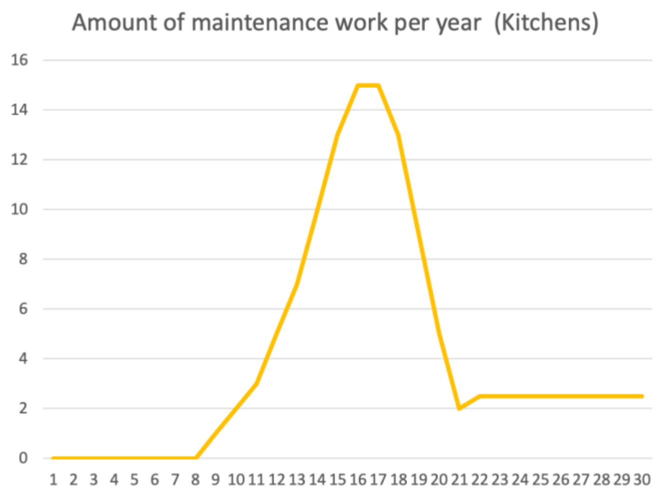


Figure 24 - Graph showing the amount of renewal works per year for kitchens. Up until year 21, the curve represents the Weibull Function. From year 21, a steady renewal state of 2,5% of the total kitchens has been reached (own source)

rate is utilized. This mutation rate is determined by analyzing the data available from VastWare. However, this data presents a heterogeneous distribution, attributed to the varying number of houses within a building complex owned by Vesteda and the mutation rate itself. Combining this heterogeneous data with the distribution function proves challenging to incorporate.

Therefore, within the MVP model, for the years after the 21st year, a standard mutation rate of 2.5% of the total houses within a building complex is used as the renewal rate. This is applied regardless of the number of houses within a building complex owned by Vesteda. This is also represented within Figure 22 from the 21st year.

It is acknowledged that this approach introduces a level of uncertainty into the calculation. However, this limitation has been recognized and is slated for further refinement in subsequent versions of the model.

Third and lastly, the LCC developed in the preceding steps is designed for a business-as-usual context. However, when accounting for a building element that is marketed as a Product as a Service (PaaS), the LCC needs to be adapted. In this model, the kitchen will not be renewed after 20 years, as is the case with regular procurement of kitchens. Instead, it will have a continuous yearly maintenance cost.

Chainables offers two maintenance contract options: a full kitchen maintenance service at a monthly fee of €4.65, or preventive maintenance only at €2.57 per month. Both options are based on a 20-year contract. For this analysis, the full maintenance contract was chosen. This choice allows Vesteda to reduce its level of concern and, consequently, its risk.

Under this PaaS model, Chainables retains ownership of the kitchen. This ownership model results in a shift in Vesteda's balance between Operating Expenses (OPEX) and Capital Expenses (CAPEX). For Institutional Real Estate Investment Firms (IREIFs), this ratio is crucial, as it impacts other financial aspects, such as taxes. While this shift is not explicitly modeled in the current tool, it is an important consideration for future improvements, which could enable more realistic and informed decision-making.

With the PaaS model, the lease price is stable for a 20-year period. After this time, a new price is established, which is assumed to align with the cumulative rate of inflation, and this price will then be fixed for another 20 years.

To calculate the present value of the total cost under this PaaS model, the same discount rate used for traditionally procured kitchens will be applied. The LCC analysis will incorporate the monthly payment of €4.65 per kitchen, as per the terms outlined by Chainables (Chainable, e-mail, 20 June 2023).

Step 5. Develop a Cost Profile and Summary

In this step, we develop and compare the cost profiles for two different kitchen procurement models: Chainable's Product as a Service (PaaS) model and Bribus's traditional procurement model. The objective is to visualize and understand the long-term cost implications of each model.

The differences in the calculations for both Chainable and Bribus, along with the required assumptions made to develop this part of the tool, are designed to maintain a realistic representation and to produce a result that is representative (see Figure 26 for assumptions). These efforts have culminated in the outcome depicted in Figure 25, where the distinctions between Bribus and Chainable are clearly visible.

As can be observed in the Figure 24, Chainable incurs a continuous maintenance cost, reflective of its PaaS model. In contrast, the cost profile for Bribus exhibits a notable peak during the first life cycle, corresponding to the point at which kitchens are actually replaced, after which it transitions to a steady state where 2.5% of the total number of kitchens are replaced per year.

This comparison illustrates the fundamental differences in the cost structures associated with the two different procurement models: Chainable's Product as a Service (PaaS) model, which involves a consistent and predictable maintenance fee, and Bribus's traditional procurement model, which involves periodic peaks in cost due to the

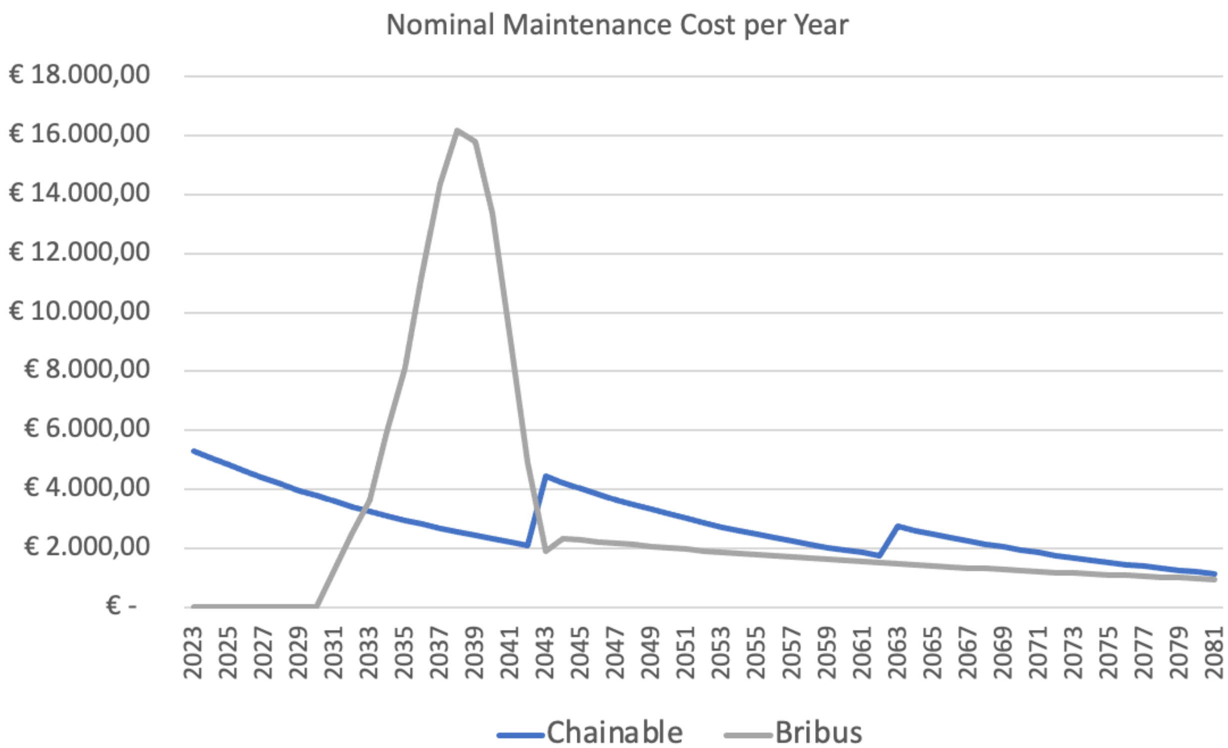


Figure 25 Illustrating the annual costs associated with Chainable and Bribus kitchen models. For Bribus, the costs are modeled using the Weibull distribution for kitchen renewals during the first life cycle, after which a 2.5% mutation rate is applied. For Chainable, the costs are structured according to the terms of the service/lease contract. (own source)

replacement of kitchens.

It is important to note that the resulting outcome of this LCC analysis is not the final step. This analysis will be further elaborated upon in the delivery phase of this project, where the operationalization and implementation of the tool will be explained in detail. In that phase, there will be delved into how this tool can be effectively integrated into Vesteda's operations, and how it can be used to inform and optimize decision-making processes.

In summary, this sub-chapter represent the development steps for the financial part of the LCC tool, ultimately accounting for environmental impact. Up until now it has provided a cost profile for both kitchens, highlighting the key differences in long-term costs between Chainable's PaaS model and Bribus's conventional model. These insights are critical input for Vesteda in making informed procurement decisions, which will be elaborated on in section [4.2.4].

Assumptions	
Chainable	**Bribus**
For this graph 100 kitchens were assumed	
years considered = 60 Within the tool also 20 years has been accounted for	
Discount rate = 5%	
No replacement of kitchens, only maintaintenance	First 20 years, use of Weibull distrubution function for replacement of kitchens. After 20 years the replacement rate follows the mutation rate of 2.5%.
Maintenance contract is €55,80 per kitchen per year	Renewal cost per kitchen is €1200
Contract lasted 20 years	Price per renewal of kitchen
New price for new contract after 20 years was account for inflation	Price increase in line with increasing construction costs

Figure 26 – Summarization of the assumptions for the development of the first part of the tool

4.2.3| Environmental Impact-LCC

The focus of this sub-chapter is the integration of environmental impact assessments, specifically for kitchens, into the existing LCC tool. This results in the hereafter named 'Environmental Impact (EI)-LCC' tool. The integration aims to facilitate investment decisions, which are both economically and environmentally substantiated. The integration is structured along the line of the following four components:

I. Environmental Impact Assessment: This section outlines the LCA process and its role in assessing the environmental impact of building elements.

II. Utilization of Environmental Product Declarations (EPDs): EPDs provide essential environmental data for the EI-LCC tool, supplementing financial data. This section discusses how this data is sourced and standardized.

III. Handling of Environmental Impact Data: This part explains the translation of environmental impact data into monetary terms using the Environmental Cost Indicator (MKI).

IV. Application of MKI: The final section elaborates on how the MKI is integrated into the LCC to offer a balanced investment assessment.

4.2.3.1 Environmental Impact Assessment - LCA and its Indicators

This section delves into the methodology of LCA to get a common understanding of how to interpret the data provided by the kitchens manufacturers, for correct usage of the environmental impact data.

To accurately assess and address the environmental impact of products, it is important to use a comprehensive environmental impact assessment (EIA) method that consider the full life cycle of the building and accounts for the environmental impacts associated with each phase of the life cycle. It was therefore that the LCA has been introduced and slowly being adopted in the building sector since 90's (Fava, 2006) and it is this methodology that has been recognized as a standard assessment method to analyze the building industry's environmental impact (Ortiz et al., 2009).

LCA is considered the most appropriate scientific methodology that evaluates the environmental impacts of products and processes throughout their entire life cycles and is seen as efficient tool for calculating the impacts in building design (Palumbo et al., 2020). This iterative approach is standardized in ISO 14040:2006 and is divided into four steps as presented in Figure 27:

i) Defining the study's goal and scope
ii) Data collection and inventory analysis
iii) Environmental impact assessment
iv) Result interpretation.

For the building sector in Europe, the LCA method is further governed by the standards EN 15804 for products and components and EN15978 for entire buildings. These standards propose a modular approach that encompasses the entire life cycle, dividing it into modules that belong to the following four phases as presented in Figure 28:

- Production Phase [Module A1-A5]
- Use Phase [Module B1-B7]
- End-of-life (EoL) stages [Module C1-C4]
- Beyond the life cycle [module D].

The modules included or excluded in the LCA are determined by the manufacturer during the goal and scope phase. Given the scope of this research, the available data from kitchen manufacturers, and the development of a MVP for the EI-LCC tool, specific to kitchens as building elements, EN15804 (products) will be further elaborated for the implementation of environmental impact. EN15978 (buildings) will not be discussed further.

The flexibility in defining the goal and scope of the LCA allows manufacturers of building elements to tailor the assessment to fit their specific business models and context. However, this flexibility can also

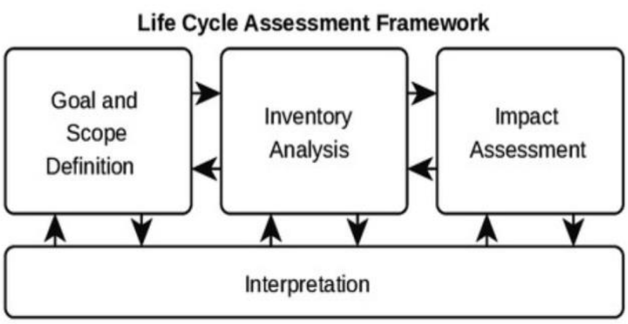


Figure 27 – Steps of LCA in line with ISO14040 (Tornaghi et al., 2018)

lead to discrepancies in data, making it challenging to compare different LCAs (Takano et al., 2015).

During the development of the LCC, and the implementation of the LCA results, careful consideration is given to the these discrepancies data. The approach of handling these discrepancies will be explained in the subsequent section.

4.2.3.2 EPD's

In this section, first the background of Environmental Product Declarations will be explained. Secondly, there will be elaborated on the obtained kitchen EPDs from manufacturers. Lastly the discrepancy following from the analysis of the EPDs will be uncovered, leading to the necessary assumption for a correct implementation in the LCC-tool.

4.2.3.2.1 Background

In the pursuit of developing an EI-LCC tool, which will be instrumental in the decision-making process during the design phase, makes the need for detailed data such as Environmental Product Declarations (EPDs) paramount (Palumbo et al., 2020).

EPDs are documents that offer precise and accurate analyses rooted in Life Cycle Assessments (LCA) and provides reliable and verifiable LCA-based information on specific products. Since 2012, the construction sector has been utilizing EPDs based on the European standard EN 15804+A1 (Durão et al., 2020), which is standardized by ISO 14025:2006. However, as of July 2022, reporting according to EN15804+A2, an updated version, has become mandatory in the Netherlands (Quist, 2022). This will be further elaborated later.

The EPDs are primarily designed to communicate environmental performance and facilitate comparisons between products within the same category, especially in business-to-business procurement. However, despite the possibility to compare different products, ISO 14025 asserts that comparative assertions based on this information are not applicable (Moré et al., 2022).

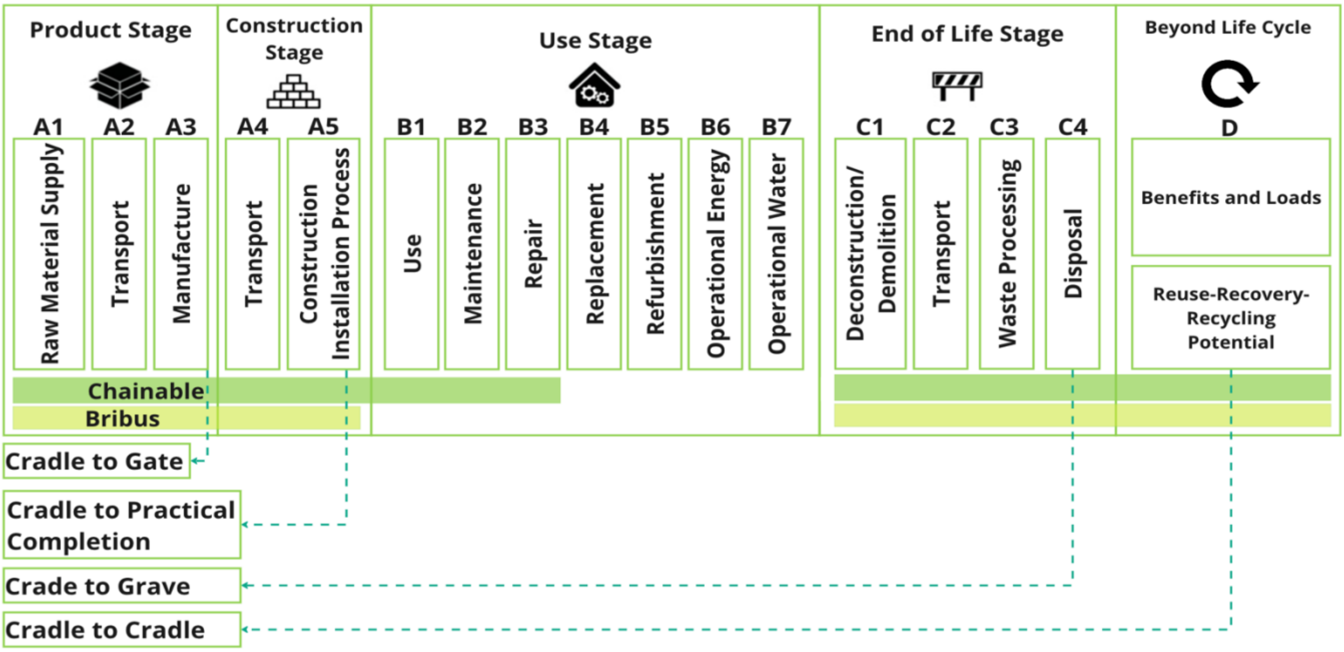


Figure 28 – Life Cycle Modules according the EN 15804 + A2:2019. Displaying the considered modules in the LCA of both Chainable and Bribus kitchens (Own source).

The EN 15804:2012(A1) standard lays the groundwork for EPDs, delineating parameters, life cycle stages, and offering directives for scenario development, inventory calculation, and impact assessment. This culminates in a set of eleven indicators, illustrated in Figure 29.

Building on this foundation, the EN 15804:2012(A2) emerges as an advanced iteration of the A1 standard. While it upholds the core tenets of the A1 version, the A2 adaptation integrates advancements based on fresh insights, technological strides, and feedback from its practical application, leading to a comprehensive set of nineteen indicators (See Figure 29) .

In the current landscape, EPDs are primarily aligned with the eleven indicators of EN 15804:2012(A1). Yet, a paradigm shift is in motion, transitioning from the A1 framework to the more expansive A2. This phase equips manufacturers with the opportunity to acquaint themselves with the broader set of nineteen indicators and recalibrate their LCA processes to align with the updated requirements.

It is worth noting that while the EPD from Bribus aligns with the original eleven indicators, whereas Chainable's EPDs encompass both the eleven and the nineteen indicators. For the sake of consistency in comparison, the EI-LCC tool currently employs the original eleven indicators. Nevertheless, the tool has been designed with the foresight to seamlessly integrate the full set of nineteen indicators once their adoption becomes standard practice.

As previously mentioned, the EN 15804:2012(A1+A2) standard outlines a procedure for calculating the environmental impact of construction products and categorizes EPDs into four types based on the chosen LCA system boundaries which are also represented in Figure 28 :

- Cradle to gate [Modules A1–A3]
- Cradle to practical completion [A1-A5]
- Cradle to Grave [A–C]
- Cradle to Cradle [A-D]

Utilizing the data from the manufacturer for one's own analysis raises the question: "Who should bear the responsibility for the environmental impact at each phase of an LCC?". For an IREIF like Vesteda, the lack of control over the environmental emissions during the production of the kitchen presents an ethical dilemma: Should Vesteda internalize this environmental impact or not? While this research does not further address ethical dilemmas, the EI-LCC tool is developed with these concerns in mind,

	Abreviation	Category	Unit
Core Environmental Impact indicators EN15804+A1	GWP	GWP=Global warming	kg CO_2-eq
	ODP	ODP=Ozone layer depletion	kg CFC-11-EQ
	AP	AP=Acidification of soil and water	kg SO_2-eq
	EP	EP=Eutrophication	kg PO_4^{3-}-eq
	ADPE	ADPE=Depletion of abiotic resources-elements	kg SB-eq
	ADPf	ADPF=Depletion of abiotic resources-fossil fuels	kg SB-eq
National Annex NMD	HTTP	HTP=Human toxicity	kg 1,4 DB-eq
	FAETP	FAETP=Ecotoxicity. fresh water	kg 1,4 DB-eq
	MAETP	MAETP=Ecotoxicity. marine water (MAETP)	kg 1,4 DB-eq
	TETP	TETP=Ecotoxicity. terrestric	Kg 1,4 DB-eq
	POCP	POCP=Photochemical oxidants creation	kg C2H4
Core Environmental Impact indicators EN15804+A2	AP	AP=Acidification (AP)	mol H+ eqv.
	GWP-total	GWP-total=Global warming potential (GWP-total)	kg CO_2-eq
	GWP-b	GWP-b=Global warming potential - Biogenic (GWP-b)	x
	GWP-f	GWP-f=Global warming potential -Fossil (GWP-f)	x
	GWP-luluc	GWP-luluc=Global warming potential - Land use and land use change	x
	EP-m	EP-m=Eutrophication marine (EP-m)	kg N eqv.
	EP-fw	EP-fw=Eutrophication,freshwater (EP-fw)	kg P eqv.
	EP-T	EP-T=Eutrophication, terrestrial (EP-T)	mol N eqv.
	ODP	ODP=Ozone depletion (ODP)	kg CFC-11-EQ
	POCP	POCP=Photochemical ozone formation - human health (POCP)	kg NMVOC eqv.
	ADP-f	ADPf=Resource use, fossils (ADP-f)	MJ
	ADP-mm	ADP-mm=Resource use, minerals and metals (ADP-mm)	kg SB-eq
	WDP	WDP=Water use (WDP)	m3 world eqv.
	ETP-fw	ETP-fw=Ecotoxicity, freshwater (ETP-fw)	CTUe
	PM	PM=Particulate Matter (PM)	disease incidence
	HTP-c	HTP-c=Human toxicity, cancer (HTP-c)	CTUh
	HTP-nc	HTP-nc=Human toxicity, non-cancer (HTP-nc)	CTUh
	IR	IR=Ionising radiation, human health (IR)	kBq U235 eqv.
	SQP	SQP=Land use (SQP)	m2a crop-eq.

Figure 29 - Environmental Impact Indicators for both EN15804+A1 and EN15804-A2. The prices are the environmental prices, metrics which compute the social damage of environmental pollution and is expressed it in euros per kilogram of pollutant. Environmental prices reflect the welfare losses that occur if one additional kilogram of a substance is released into the environment (De Bruyn et al., 2023). Figure own source

ensuring it can be adapted if it becomes a point of contention among stakeholders.

With this perspective, the decision was made to internalize the entire environmental impact, spanning from phases A1 to D. This approach is rooted in the desire to understand the complete lifecycle. It not only illuminates the entire process but also paves the way for constructive discussions with manufacturers and developers. Such dialogues can uncover ways to mitigate the environmental footprint, as desired by Vesteda (ADM1 [161-163])

4.2.3.2.2 The obtained kitchen EPDs

During the development process of the EI-LCC tool, three kitchen manufacturers as previously mentioned, were approached: Bribus[17], Chainables[18] and Bruynzeel.

Firstly, Chainables, who provided two EPDs, for both a wall cabinet and for a base cabinet as illustrated in Figure 30. The EPD data corresponding

[17] **Bribus** is a Dutch company specializing in kitchen design and manufacturing. They provide kitchen solutions primarily for the project market, including social housing, private sector rentals, owner-occupied homes, and utility construction. They manage the entire process from design and production to delivery and aftercare, ensuring a seamless experience for their clients.

[18] **Chainable** is a company that produces modular, circular, and sustainable kitchens as a service for the professional market. (Circular X, 2021)

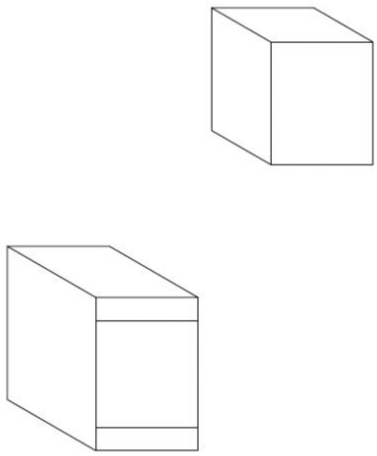


Figure 31 – Illustrative picture of the wall cabinet (top one), and bottom cabinet (bottom one) of Chainable (Goedkoop. A., 2023).

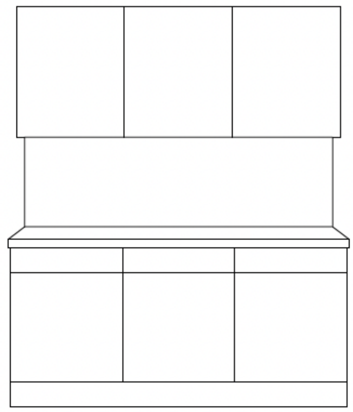


Figure 30- Illustrative picture of the three wall cabinets, two base cabinets and one sink cabinet of Bribus (Goedkoop. A., 2023)

to the bottom cabinet is depicted in Figure 32. For the EPD data of wall cabinet of Chainable, there is referred to the LCA excel file.

Secondly, Bribus provided one EPD which represents three wall cabinets, two base cabinets and one sink cabinet which is illustrated in 31. The results from the LCA of each component has been summed to present the total environmental impact. The EPD data corresponding to the Bribus kitchen is depicted in Figure 33.

Bruynzeel I[19] has no EPD available yet. However, Bruynzeel is currently in the process of conducting their LCA to establish their EPD, which underscores the growing awareness and importance of EPDs among manufacturers. Although Bruynzeel's EPD will not be completed within the timeframe of this research, it will be shared upon completion. Therefore, the tool is designed with flexibility in mind, allowing for the easy addition of data from this and other future EPDs.

While both the EPDs of Bribus and Chainable provide necessary input for the EI-LCC tool, it is important to note that neither fully represents a complete kitchen as precedingly mentioned. A comprehensive kitchen includes more than just the cabinets covered in these EPDs; elements like countertops and appliances are also integral components. Consequently, the EPDs do not capture the total environmental impact of kitchens, leading to a potential skew in the results generated by the EI-LCC tool. The environmental impact data for both kitchens are imported in the “LCA” excel file.

[19] **Bruynzeel** is a renowned large Dutch company, manufacturing kitchens since last century.

Besides, even with this incomplete data, the provided EPDs offer essential information that has facilitated the development of the MVP and its analytical framework. This foundation can be further refined in the future to assess the environmental impact of a kitchen in its entirety. Besides the environmental impact data, contains more essential information regarding the LCA and the kitchen itself.

4.2.3.2.2 The (dis)similarities of kitchen EPDs

As just stated, the EPD contains more information besides the environmental impact data. Therefore, analyzing the EPDs, preliminary to the implementation of the environmental impact data in the EI-LCC tool, is essential to establish the right assumptions. The analysis of the EPD brought to light four differences:

1) Difference in the LCA framework resulting in varying in-/exclusions of LCA modules.
2) Disparity in life cycle duration
3) The required made assumptions.

Firstly, the differences in the LCA framework, for both Chainable and Bribus can be explained from their differing business model. Every resulting difference in environmental impact data can be traced back in data shown in both Figure 32 as Figure 33. Starting with Chainable, on the one hand, with their PaaS business model, stating that they remain responsible for the maintenance and that it will preserve the quality of the kitchen through their service contract. This line of thought about maintenance results in the inclusion of the 'Use module' [B1-B3] and the exclusion of the 'Deconstruction/demolition module [C1]. While on the other hand, Bribus assumes that they produce a kitchen (module A), no environmental impact during the use phase, after which the kitchen will be completely deconstruction/demolished.

For both kitchen manufacturers applies that, B4- (Replacement) and B5 (Refurbishment) are not taken into account. For Chainable this originates from their idea of circularity and that all materials will be reused, whereas for Bribus, the exclusion originates from the idea that each kitchen will only be renewed after the technical life span. For both kitchens, the B6 module (operational use), and B7 module (Water use) are not included because, according to their defined LCA framework this does not apply, and no data is available.

Secondly, the life cycle duration where, on the one hand, Chainables implies and employs a 60 year life span in their LCA resulting from their PaaS business model as underlying rationale. While, Bribus on the other hand, maintains a 15 year life cycle, not include the 'Use module', since they assume that a kitchen will be replaced with a new kitchen when the end of the life is reached (20 years). These differences are carefully considered, resulting in a different allocation of the modules in time.

An overview of the differences between the EPDs from Chainables and Bribus are illustrated in Figure 34 (next page), showcasing what need to be considered during the configuration of the tool.

The dissimilarities identified from the EPD analysis led to additional assumptions. It is vital to approach these assumptions judiciously to ensure kitchen comparability. The following requirements of the EI-LCC tool have been established to ensure consistent results:

Life Cycle:

- The life cycle of Chainable remains 60 years.
- The life cycle of Bribus is 20 years resulting in the same renewal cycle as established in the financial part of the EI-LCC tool.

Environmental Impact Modules – Life Cycle Phases

- For both kitchens the already used modules are incorporated in tool.

Bribus whole Kitchen	Abbrev.	Unit	A1	A2	A3	A4	A5	B1	B2	B3	C1	C2	C3	C4	D	Total
Core Environmental Impact indicators EN15804+A1	ADPE	kg SB-eq	5,33E-02	7,67E-05	1,64E-04	5,53E-06	5,00E-08				6,29E-08	3,56E-05	1,55E-05	1,24E-06	-1,03E-01	-4,94E-2
	GWP	kg CO_2-eq	1,16E+02	7,65E-01	6,67E+00	2,52E-01	2,28E-01				1,54E-02	1,39E+00	7,66E+00	8,43E-01	-2,18E+01	1,12E+2
	ODP	kg CFC-11-EQ	1,07E-05	5,83E-08	1,18E-06	4,53E-08	-3,30E-08				7,60E-10	2,47E-07	1,25E-07	2,87E-08	-2,57E-06	9,78E-6
	POCP	kg C_2H_4	1,65E-01	9,98E-04	4,31E-03	1,59E-04	-4,67E-05				2,29E-06	8,40E-04	3,93E-03	2,59E-04	-3,55E-02	1,40E-1
	AP	kg SO_2-eq	7,25E-01	5,21E-03	3,77E-02	9,58E-04	-1,35E-04				2,88E-05	6,12E-03	2,18E-02	7,65E-04	-1,80E-01	6,17E-1
	EP	kg PO_4^{3-}-eq	8,80E-02	8,81E-04	6,54E-03	1,89E-04	-2,35E-06				5,93E-06	1,20E-03	5,51E-03	3,16E-04	-4,56E-02	5,70E-2
National Annex NMD	ADPf	kg SB-eq	9,84E-01	5,08E-03	4,86E-02	1,85E-03	-2,77E-03				1,16E-04	1,02E-02	6,02E-03	1,33E-03	-1,47E-01	9,07E-1
	HTP	kg 1,4 DB-eq	1,14E+02	1,83E+00	2,86E+00	9,18E-02	2,82E-03				1,73E-03	5,86E-01	2,75E+00	7,26E-02	-1,93E+01	1,03E+2
	FAETP	kg 1,4 DB-eq	2,11E+00	2,05E-02	8,08E-02	6,12E-03	5,97E-03				4,78E-05	1,71E-02	1,74E-01	4,52E-03	-4,02E-01	2,02E+0
	MAETP	kg 1,4 DB-eq	5,83E+03	3,95E+01	2,95E+02	1,02E+01	8,29E+00				2,02E-01	6,16E+01	1,74E+02	7,99E+00	-7,40E+02	5,69E+3
	TETP	kg 1,4 DB-eq	3,82E-01	7,02E-03	9,99E-03	1,71E-03	5,09E-05				7,85E-05	2,07E-03	3,16E-03	2,32E-04	2,82E-01	6,88E-1

Figure 32 - Overview of the environmental impact indicators of Bribus' kitchen arrangement and their respective values, retrieved from the EPD. (Own source)

Chainable Bottom Cabinet	Abbrev.	Unit	A1	A2	A3	A4	A5	B1	B2	B3	C1	C2	C3	C4	D	Total
Core Environmental Impact indicators EN15804+A1	ADPE	kg SB-eq	1,60E-03	1,39E-05	3,55E-05	1,37E-05	5,18E-05	9,54E-05	0,00E+00	3,39E-04	0,00E+00	9,65E-06	3,80E-06	1,43E-08	-9,87E-04	1,18E-3
	GWP	kg CO_2-eq	2,93E+01	5,44E-01	1,56E+00	5,34E-01	1,18E+00	3,73E+00	0,00E+00	1,67E+01	0,00E+00	3,78E-01	1,64E+00	6,34E-02	-1,46E+01	4,10E+1
	ODP	kg CFC-11-EQ	1,81E-06	9,64E-08	1,42E-07	9,48E-08	8,21E-08	6,62E-07	0,00E+00	2,12E-06	0,00E+00	6,70E-08	3,68E-08	2,76E-09	-1,05E-06	4,06E-6
	POCP	kg C2H4	2,37E-02	3,28E-04	2,37E-03	3,22E-04	9,93E-04	2,25E-03	0,00E+00	3,22E-02	0,00E+00	2,28E-04	7,61E-04	2,13E-05	-1,54E-02	4,78E-2
	AP	kg SO_2-eq	1,05E-01	2,39E-03	7,39E-03	2,35E-03	4,61E-03	1,64E-02	0,00E+00	8,94E-02	0,00E+00	1,66E-03	4,76E-03	7,16E-05	-8,67E-02	1,47E-1
	EP	kg PO_4^{3-}-eq	1,63E-02	4,70E-04	1,29E-03	4,61E-04	8,20E-04	3,23E-03	0,00E+00	1,59E-02	0,00E+00	3,26E-04	1,19E-03	2,59E-05	-2,41E-02	1,59E-2
National Annex NMD	ADPf	kg SB-eq	2,14E-01	4,00E-03	1,42E-02	3,93E-03	7,81E-03	2,75E-02	0,00E+00	1,47E-01	0,00E+00	2,78E-03	1,89E-03	1,25E-04	-8,16E-02	3,42E-1
	HTP	kg 1,4 DB-eq	8,54E+00	2,29E-01	1,78E+00	2,25E-01	4,47E-01	1,57E+00	0,00E+00	8,07E+00	0,00E+00	1,59E-01	5,94E-01	5,18E-03	-7,00E+00	1,46E+1
	FAETP	kg 1,4 DB-eq	2,84E-01	6,68E-03	6,63E-02	6,57E-03	1,32E-02	4,59E-02	0,00E+00	3,10E-01	0,00E+00	4,64E-03	2,36E-02	1,13E-04	-1,29E-01	6,32E-1
	MAETP	kg 1,4 DB-eq	7,99E+02	2,40E+01	5,61E+01	2,36E+01	3,32E+01	1,65E+02	0,00E+00	7,76E+02	0,00E+00	1,67E+01	3,78E+01	4,07E-01	-2,04E+02	1,73E+3
	TETP	kg 1,4 DB-eq	6,81E-02	8,09E-04	1,55E-02	7,95E-04	2,78E-03	5,56E-03	0,00E+00	4,06E-02	0,00E+00	5,62E-04	1,26E-03	1,86E-05	9,73E-02	2,33E-1

Figure 33 – Overview of the environmental impact indicators of Chainable's Bottom Cabinet and their respective values, retrieved from the EPD. (Own source)

- The environmental impact data of the Chainable kitchen will allocate the Production module [A] at the begin of the life cycle. The Use Module [B1-B3] will be divided by the years the LCC accounts for, thus 20 year and 60 years. Allocating it differently would result in an exaggerated use phase. For Chainable the modules [C and D] will only occur at the End of the life cycle, in year 20 and 60 respectively.
- Whereas, for the Bribus kitchen, the modules considered in certain year when a kitchen is replaced is by allocating the phase [C] and [D] in the year of renewal. Because a kitchen is renewed phase [A] must be allocated to.

Composition of the kitchens

For comparability, Chainable's kitchen comprises three base and three wall cabinets. This decision multiplies the environmental impact data of each cabinet by three. Bribus's kitchen data remains unchanged, representing the components in Figure 27.

The assumptions made for comparison are debatable and warrant refinement. However, the EPDs' Environmental Impact data is instrumental for the development phase, guiding data incorporation. The subsequent section [4.2.3.3] delves deeper into data handling.

	Chainables	Bribus
LCA System Boundaries	Complete life-cycle Exluding B4-B7	Complete life-cycle Excluding B1-B7 (use phase)
Life Cycle Duration	60 years	20 years
Included Kitchen Elements	Two EPDs: - one wall cabinet - one base cabinet	One EPD: - three wall cabinets - Two base cabinet - one sink cabinet
Companies Business Model	Kitchen as a Service. Ensuring Circularity	Replaced when quality is insufficient

Figure 34 – Overview of the differences between the EPDs of both companies (own source)

4.2.3.3 Utilization of the environmental indicators of LCA in LCC

The handling of this Environmental Impact data resulting from LCA within the EI-LCC-tool is a critical aspect. It involves the collection, processing, and interpretation of the data, ensuring its accuracy, relevance, and usability. This process must be handled with diligence and precision, as the quality of the data handling directly influences the reliability of the EI-LCC tool's output and, consequently, the sustainability of the investment decisions made based on this output.

The task of effectively integrating the indicators used in an LCA in an LCC, to aid investment decisions is challenging. As previously outlined in section [4.2.3.2] and demonstrated in Figure 29, the environmental impact categories have a high degree of complexity, as their interpretation is not straightforward. Furthermore, the inherent difficulty in clearly communicating these indicators to stakeholders in terms KPIs within the PMS of Vesteda poses significant issues. The large and complex data associated with these environmental impact categories can be overwhelming for individual actors in the construction and real estate sectors, a point emphasized by Ströbele & Lützkendorf (2018).

Numerous attempts have been made in *academic literature* to devise methods and frameworks for the integration LCC and LCA. According to Miah et al. (2017) several approaches of integrating LCC and LCA into frameworks, including independent LCA and LCC as part of a comprehensive framework, independent LCC and LCA analysis integrated by Multi-Criteria Decision Analysis (MCDA), optimization of LCC and LCA analysis, environmental LCC, and eco-efficiency. The most common strategies for this integration include mathematical modelling, optimization programming, and multi-criteria decision-making.

França et al. (2021) found that a variety of frameworks have been proposed in several studies offering a comprehensive guidance on how to connect environmental and economic analyses. These frameworks are generally favored over other approaches, such as the aforementioned methods and models, due to their broader applicability and ease of transferability. They typically provide instructions and insights on how to conduct a specific assessment or process, rather than focusing on specific variables and mappings that may require significant effort to apply in different contexts. One notable study by Kouloumpis and Azapagic (2018) proposed a fuzzy inference framework that integrates LCA, LCC, and Social Life Cycle Assessment (SLCA). In this framework, the results are converted into linguistic variables, and a sustainability assessment is conducted on the same basis.

However, França et al. (2021) states that monetization of environmental impacts has been widely used in existing frameworks, trying to translate environmental impacts into economic ones. This seems to have been the main path for LCA-LCC integration. The advantage of monetary valuation, as noted by Swarr et al. (2011), is that it provide clear information to stakeholders and policymakers when assessing the overall environmental quality of projects, products, or services, a feature that other methods lack. Schneider-Marin and Lang (2020) argue that a monetary valuation approach in the construction industry has two main benefits: it aggregates numerous environmental indicators into a single, easy-to-understand measure, and it allows for the comparison of alternative solutions in terms of economic and ecological aspects.

However, the monetization of environmental impact has been subject to criticism. Critics argue that it is problematic from a sustainability accounting perspective: assigning monetary values to environmental problems may imply that the impact of pollution can be compensated for by paying for its "cost" (Vogtländer and Bijma 2000). It is therefore criticized as a tool of "weak" sustainability, suggesting that monetary resources can compensate for the loss of ecological quality (Rennings and Wiggering 1997).

Another important factor that must be considered when deciding on the most suitable method for integration of LCC and LCA, is the context of how is dealt with LCAs in practice. In the Netherlands, a monetary valuation system for the environmental impact of buildings and civil engineering works has been well established and governed. The already well-established method is the MPG and MKI which has already been mentioned in section [2.4.3.2]. The methodology of monetizing the environmental impact has been well documented by De Bruyn et al. (2023) and is substantiated with elaborate research.

Therefore, despite the ethical concerns raised in academic literature about assigning monetary values to environmental impact, the monetization approach is deemed the most suitable for this tool compared to other methods and frameworks. It meets the requirements of being easy to understand, use, and communicate among a diverse range of stakeholders, which was one of the requirements mentioned during the interviews with Vesteda (PMS, [231-233]).

While other frameworks and methods have their value, they are not the best fit for integrating LCA and LCC in this context. The choice to use the Environmental Cost Indicator (MKI), which is already widely used and regulated in the Dutch building sector, further substantiates this decision. However, it is crucial to remember the limitations of this method. Therefore, users of this tool must be reminded to consider these limitations when using the tool and sharing the results.

In conclusion, the choice to utilize the MKI methodology to monetize LCA results, enables the use of a single-score indicator. The MKI, as a singular monetary value, fits the criteria for inclusion in the LCC tool and aligns with the method already in use in practice. Its monetary form eases its integration into the LCC tool. Moreover, process of monetizing environmental impact as advocated by França et al. (2021) and Schneider-Marin and Lang (2020), improves its understandability, making it a valuable method for benchmarking and effectively communicating environmental impact within the company and to a diverse group of stakeholders. Thus, the best choice for utilizing the MKI in the tool for the decision-making process. The underlying calculations will be explained in the subsequent section.

4.2.3.4 Explaining, Calculating, and Application of the MKI and CO2 costs, in EI-LCC

In the preceding sections, the use of EPDs representing the environmental impact data derived from a LCA was discussed. The approach of assigning monetary value to the environmental impact data for integration into the EI-LCC tool was selected as the best approach. This section will delve deeper into this process. The following three key topics will be covered:

I. The concept of *environmental impact pricing*
II. The methodology behind environmental Impact pricing
III. The incorporation and utilization of the resulting Monetary Environmental Cost Indicator (MKI) within the tool.
IV. CO_2 emissions (GWP) and ETS costs

4.2.3.4.1 Environmental Impact Pricing

Environmental Impact Pricing involves assigning a monetary value to the societal damage caused by environmental pollution. This value, referred to as the Environmental Cost (EC) or shadow cost, serves as a key figure that calculates and expresses the societal damage in unit cost (€) per environmental impact category (Bruyn et al., 2023). The shadow cost reflects the welfare losses that occur when an additional kilogram of the substance enters the environment (Bruyn et al., 2023). It can also be visualized as the highest acceptable cost level that the government and/or society is willing to spend on mitigating 1 unit of emissions (Schwarz et al., 2020). The shadow costs for each impact category are periodically determined independently by CE Delft, an independent research and consultancy foundation in the Netherlands.

4.2.3.4.2 Methodology of Environmental Impact Pricing

The shadow costs for each impact category function as respective weighting factors. In the Netherlands, eleven weighting factors (Environmental impact categories with their costs) are used to calculate the environmental burden of building products. These eleven impact categories are in line with the LCA analysis as standardized in the EN-15804-A1 (mentioned in section [4.2.1.2]). By combining them, a single value, known as the MKI or Environmental Cost Indicator (ECI), is derived (Moretti et al., 2022). An overview of these eleven impact categories and their corresponding costs to calculate the MKI is provided in Figure 35.

As stated in section [4.2.3.2], there is a transition towards EN-15804-A2, which requires additional Environmental Impact Indicators to be reported. However, the associated costs are not yet complete and could therefore not be retrieved. Nonetheless, these nineteen indicators will eventually have implications for the calculation of the Dutch MKI (Quist, 2022). Therefore, within the EI-LCC tool, these nineteen indicators are to be incorporated too, but will not be used for the current calculations of the MKI. The rationale behind including these nineteen indicators is to provide flexibility when the calculation method changes.

	Abreviation	Unit	Euro's
Core Environmental Impact indicators EN15804+A1	GWP	kg CO_2-eq	€ 0,05
	ODP	kg CFC-11-EQ	€ 30,00
	AP	kg SO_2-eq	€ 4,00
	EP	kg PO_4^{3-}-eq	€ 9,00
	ADPE	kg SB-eq	€ 0,15
	ADPf	kg SB-eq	€ 0,15
National Annex NMD	HTTP	kg 1,4 DB-eq	€ 0,09
	FAETP	kg 1,4 DB-eq	€ 0,03
	MAETP	kg 1,4 DB-eq	€ 0,00
	TETP	Kg 1,4 DB-eq	€ 0,06
	POCP	kg C2H4	€ 2,00
Core Environmental Impact indicators EN15804+A2	AP	mol H+ eqv.	€ 2,01
	GWP-total	kg CO_2-eq	€ 0,13
	GWP-b	x	x
	GWP-f	x	x
	GWP-luluc	x	x
	EP-m	kg N eqv.	€ 14,25
	EP-fw	kg P eqv.	€ 5,53
	EP-T	mol N eqv.	€ 0,34
	ODP	kg CFC-11-EQ	€ 29,10
	POCP	kg NMVOC eqv.	€ 1,40
	ADP-f	MJ	€ 0,01
	ADP-mm	kg SB-eq	€ 0,02
	WDP	m3 world eqv.	€ 0,14
	ETP-fw	CTUe	€ 0,03
	PM	Disease incidence	€ 1.937,05
	HTP-c	CTUh	€ 919.000,00
	HTP-nc	CTUh	€ 166.000,00
	IR	kBq U235 eqv.	€ 0,00
	SQP	m2a crop-eq.	€ 0,15

Figure 35 – Overview of the environmental cost per category, as retrieved from Bruyn et al. (2023). Figure is own source.

4.2.3.4.3 Utilizing the MKI of a building element during the life cycle of a building

The goal of incorporating the MKI in the EI-LCC tool is to assess the environmental impact of building elements throughout a building's life cycle. Firstly, this development is achieved by crafting a minimum viable product version of the EI-LCC tool that assesses a single building element, a kitchen.

The EPDs for two different kitchens vary in lifetime due to the business models of the company's manufacturing these elements. This variation leads to different environmental impacts each year of the life cycle. The integration has been carried out in two steps, using a separate Excel file: 1) Computing the total MKI for each module, and 2) Integrating it into the building life cycle, allocating the modules correctly. Exemplary figures containing the results of the Bribus kitchen are provided for clarification.

Firstly, summing the MKI of each Category per Module: This results in the total MKI per module. An example of category [A1] is depicted (See number. 1 in Figure 36). The total of the sum of [A1] till [A5], next to the sum of [B], [C] and [D] phases, serves as input for the LCC, in the next step of the integration. The sum of the MKI per module represents one kitchen as depicted in the rightest column (See Figure 36 number 2), which corresponds to the MKI value in the EPD, and thereby proving that the calculation is correct.

Secondly, the total calculated MKI of each four overarching phases in the previous step allows for insertion in the EI-LCC tool. From this result follows the next step of integrating the total MKI for each phase. This is done according to the assumptions established in section [4.2.3.2.2]. The task is to allocate these totals by year, using the number of kitchen renewals determined in section [4.2.2]. As example year 14 is highlighted, where in that year four kitchens were renewed (Figure 37, number 1, next page), resulting in the allocation of the MKI of each phase in that year. To view an overview year 3-13, please refer to the Excel file (LCA).

For Chainable kitchens, the allocation differs from Bribus due to their unique business models. For Chainable, the production phase [A] is allocated in year 0, and the total MKI of the use phase [B] is spread over 20 years for one kitchen (See Figure 38, next page). Calculating the MKI per year for phase [B] is done by multiplying the total amount of Kitchens with the total MKI for phase [B] for one kitchen, divided by the number of years. This division was necessary to avoid unrealistically high environmental impacts.

Furthermore, careful consideration was given to the allocation of phase [D]. Since maintenance occurs throughout the life cycle and there is no phase [C], it logically follows that phase [D] should also be distributed over the life cycle's duration. This distribution was essential to prevent excessive results and enable a fair comparison between the two kitchens.

The resulting MKI per year for each phase, which occurs in that specific year, takes inflation into account. This is justified because the Environmental Cost, as provided by De Bruyn et al. (2023), undergoes periodic revisions to ensure its currency and accuracy, reflecting real-world costs. Consequently, these costs are not static and inherently account for inflation, which is a ubiquitous

			A1	A2	A3	A4	A5	B1	B2	B3	C1	C2	C3	C4	D	Total	
Total phases EN15804+A1			€ 20,91	€ 0,24	€ 0,85	€ 0,03	€ 0,01	€ -	€ -	€ -	€ 0,00	€ 0,17	€ 0,80	€ 0,06	€ [illegible]	€ 18,92	
Bribus whole Kitchen	Abbrev.	Unit	A1	A2	A3	A4	A5	B1	B2	B3	C1	C2	C3	C4	D	Total	MKI
Core Environmental Impact indicators EN15804+A1	ADPE	kg SB-eq	[illegible],33E-02	7,6[illegible]E-05	1,64E-04	5,53E-06	5,00E-08				6,29E-08	3,56E-05	1,55E-05	1,24E-06	-1,03E-01	-4,94E-2	€ (0,01)
	GWP	kg CO_2-eq	1,16E+02	7,6[illegible]E-01	6,67E+00	2,52E-01	2,28E-01				1,54E-02	1,39E+00	7,66E+00	8,43E-01	-2,18E+01	1,12E+2	€ 5,60
	ODP	kg CFC-11 EQ	1,07E-05	[illegible],8[illegible]E-08	1,18E-06	4,53E-08	-3,30E-08				7,60E-10	2,47E-07	1,25E-07	2,87E-08	-2,57E-06	9,78E-6	€ 0,00
	POCP	kg C2H4	1,65E-01	9,9[illegible]E-04	4,31E-03	1,59E-04	-4,67E-05				2,29E-06	8,40E-04	3,93E-03	2,59E-04	-3,55E-02	1,40E-1	€ 0,28
	AP	kg SO_2-eq	7,25E-01	5,2[illegible]E-03	3,77E-02	9,58E-04	-1,35E-04				2,88E-05	6,12E-03	2,18E-02	7,65E-04	-1,80E-01	6,17E-1	€ 2,47
	EP	kg PO_4^{3-}-eq	8,80E-02	8,[illegible]1E-04	6,54E-03	1,89E-04	-2,35E-06				5,93E-06	1,20E-03	5,51E-03	3,16E-04	-4,56E-02	5,70E-2	€ 0,51
National Annex NMD	ADPf	kg SB-eq	9,84E-01	5,[illegible]8E-03	4,86E-02	1,85E-03	-2,77E-03				1,16E-04	1,02E-02	6,02E-03	1,33E-03	-1,47E-01	9,07E-1	€ 0,14
	HTP	kg 1,4 DB-eq	1,14E+02	[illegible],33E+00	2,86E+00	9,18E-02	2,82E-03				1,73E-03	5,86E-01	2,75E+00	7,26E-02	-1,93E+01	1,03E+2	€ 9,26
	FAETP	kg 1,4 DB-eq	2,11E+00	[illegible],05E-02	8,08E-02	6,12E-03	5,97E-03				4,78E-05	1,71E-02	1,74E-01	4,52E-03	-4,02E-01	2,02E+0	€ 0,06
	MAETP	kg 1,4 DB-eq	5,83E+03	[illegible],95E+01	2,95E+02	1,02E+01	8,29E+00				2,02E-01	6,16E+01	1,74E+02	7,99E+00	-7,40E+02	5,69E+3	€ 0,57
	TETP	kg 1,4 DB-eq	[illegible],82E-01	7,02E-03	9,99E-03	1,71E-03	5,09E-05				7,85E-05	2,07E-03	3,16E-03	2,32E-04	2,82E-01	6,88E-1	€ 0,04

Figure 36 – Summing up the MKI for each Modules as shown in the top rows Bribus (Own: Source)

Bribus	0	1	2	3	14	15	16	17	18	19	Totaal
Phase A-totaal	€ 2.203,56	€ -	€ -	€ -	€ 177,69	€ 253,74	€ 369,73	€ 452,56	€ 500,07	€ 510,08	€ 4.841,3
Phase B-totaal											€ -
Phase C-totaal	€ -	€ -	€ -	€ -	€ 8,26	€ [illegible]	€ 17,18	€ 21,03	€ 23,23	€ 23,70	€ 122,6
Phase D-totaal	€ -	€ -	€ -	€ -	€ (33,34)	€ [illegible]	€ (69,38)	€ (84,93)	€ (93,84)	€ (95,72)	€ (494,98)
Reële MKI flow	€ 2.203,56	€ -	€ -	€ -	€ 152,60	€ [illegible]	€ 317,53	€ 388,66	€ 429,47	€ 438,06	€ 4.468,83

Figure 37 – Overview of Bribus kitchen and the allocation of the MKI per phase per year the allocated MKI per module per year, accounting for their business-as-usual business model. Where kitchens are completely renewed, and no environmental impact is caused in the use phase [B]. In year 14 as highlighted four kitchens are renewed resulting in the production (phase [A]) of the kitchens and additional Phase [C] and [D] for the removal of the kitchens.

Chainable	0	1	2	3	14	15	16	17	18	19	TOTAL
Phase A-totaal	€ 3.296,53										€ 3.296,53
Phase B-totaal	102,10	€ 126,66	€ 129,83	€ 132,43	€ 164,66	€ 167,95	€ 171,31	€ 174,73	€ 178,23	€ 401,41	€ 3.228,34
Phase C-totaal	€ -									€ 646,98	€ 646,98
Phase D-totaal		€ (243,96)	€ (248,84)	€ (253,82)	€ (315,59)	€ (321,90)	€ (328,34)	€ (334,91)	€ (341,61)	€ (348,44)	€ (5.572,26)
Reële MKI flow	€ 3.398,62	€ (117,30)	€ (119,01)	€ (121,39)	€ (150,94)	€ (153,96)	€ (157,03)	€ (160,18)	€ (163,38)	€ 699,95	€ 1.599,58

Figure 38 – Overview of Chainable kitchen and the allocation of the MKI per phase per year accounting for their PaaS business model. To fit the image, year 4 till 13 is not shown, please refer to the LCA excel file. MKI phase [A] is attributed in T[year]=0. The MKI shown for phase [B] is the MKI for one kitchen is multiplied by the number of kitchens (100) and has been divided by the life span of this model (20 years). The accounts for phase [D]. Phase [C] has been allocated at the end of the life span in year 20. The upper arrow shows the allocation of the Use phase[A] during the whole cycle, whereas the bottom arrow shows the start of the Beyond Life phase [D].

factor in our current monetary economy. However, it is worth noting that discounting the monetary value of environmental impact remains a subject of debate. While monetizing environmental impact serves to make it more tangible, the intrinsic value of such impact remains constant over time, as it continues to harm the environment irrespective of its monetary valuation.

4.2.3.4.4 Additional Feature - CO_2 emissions (GWP) and ETS costs

Interviews conducted prior to the development of the EI-LCC tool revealed that Vesteda has an established CO_2 reduction pathway (PM2 [174-177]). In alignment with this pathway, Vesteda requested an overview focused solely on CO_2 emissions. Since the Global Warming Potential (GWP) is one of the environmental impact indicators within a LCA and an EPD used to calculate the MKI, it was possible to fulfill this request.

GWP is a widely accepted metric for comparing the potential impacts of different greenhouse gases, with CO_2 included in the indicator. However, specific CO_2 is not provided in the EPD, so the CO_2 equivalent (CO_2 -eq.) used within the GWP will be utilized for this calculation. Despite the uncertainty arising from not solely accounting for CO_2, this approach provides an indication of the market costs.

Monetizing CO_2 -eq. is achieved by utilizing the amount of CO2. Monetization can be done in several ways: 1) True costs, 2) market costs, 3) or using the cost price in the MKI calculation. For this additional feature of the tool, the market price derived from the Emissions Trading System (ETS) is chosen, as shown in Figure 39. True Costs is a study in itself, and the price used for GWP from De Bruyn et al. (2023) is already within the MKI price. Furthermore, in the context of Vesteda, the market price offers a clear and comprehensible cost price, leading to the choice of ETS costs, which will be

2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
30,48	41,75	55,94	67,49	79,04	90,59	102,14	113,69	125,24	136,79

Figure 39 - – CO2 prices in the Netherlands up until 2030(Nederlandse Emissieautoriteit, 2023)

CO2 emission (CO2 eq.)	A1	A2	A3	A4	A5	B1	B2	B3	C1	C2	C3	C4	D	Total Kg CO2 eq.
	1,16E+02	0,765	6,67E+00	2,52E-01	2,28E-01	0,00E+00	0,00E+00	0,00E+00	1,54E-02	1,39E+00	7,66E+00	8,43E-01	-2,18E+01	112,02
	Tot fase A					Totaal Fase B			Totaal Fase C				Totaal Face D	
	123,915					0			9,91				-21,8	

Figure 40 – Step 1 of calculating the carbon cost for Bribus. The amount of GWP is summed per module. This is shown in the bottom row. CO_2 per phase.

called *Carbon Costs*.

Combining GWP with ETS creates a monetary indicator reflecting both the environmental impact of emissions, as measured by GWP, and the economic cost, as reflected in the ETS price. This combination serves as a valuable tool for decision-makers, enabling consideration of both environmental and economic factors.

Prices up until 2030 are provided (Figure 39) and will be used until then. After 2030, Vesteda's indexation will be applied. The resulting prices are integrated into the EI-LCC tool and are exemplified in for Bribus and Chainable respectively.

Calculating the amount of CO_2 follows the same methodology as for the MKI but differs slightly. The calculation of carbon costs is explained in two steps: First, the utilization and allocation of Carbon emissions to the correct year, and second, monetization. Firstly, to calculate the carbon cost, the EPD data containing the GWP is used, resulting in the import of GWP from the example of Bribus in Figure 40. The amount of CO_2 (GWP) for each module is imported into the LCC Excel file. Similar to the MKI, the amount of CO_2 per module within a phase is summed, resulting in the total amount of CO2 for the four overarching phases [A], [B], [C], and [D]. The same process has been applied to the Chainable kitchen.

The second step involves calculating the carbon costs. This is done by allocating the overarching amounts of CO_2 per phase to the correct year, in the same manner as for the MKI, for both Bribus and Chainable kitchens. Subsequently, the total GWP per year is multiplied with the respective price for each year, as illustrated in Figure 41 for Bribus and Figure 42 for Chainable. This calculation leads to the total carbon cost for each kitchen throughout their respective life cycles.

Prijs per ton CO2	55,94	67,49	79,04	90,59	102,14	113,69	125,24	136,79	139,53	142,32	145,16	148,07	151,03	154,05	157,13	160,27	163,48	166,75	170,08	173,48	Totaal!
BRIBUS	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	
Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	
Phase A-totaal	12391,50	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	123,92	123,92	247,83	371,75	495,66	619,58	867,41	1239,15	1486,98	1610,90	1610,90	21189,47
Phase B-totaal	Not accounted for because of the business model																				0,00
Phase C-totaal	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	9,91	9,91	19,82	29,73	39,63	49,54	69,36	99,08	118,90	128,81	990,84	1565,53
Phase D-totaal	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	-21,80	-21,80	-43,60	-65,40	-87,20	-109,00	-152,60	-218,00	-261,60	-283,40	-2180,00	-3444,40
Total GWP [Kg CO2 eq.]	12391,50	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	112,02	112,02	224,05	336,07	448,09	560,12	784,16	1120,23	1344,28	1456,30	421,74	19310,59
Total Euro's/ ton CO2 Eq.	€ 693,18	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ 15,94	€ 16,26	€ 33,17	€ 50,76	€ 69,03	€ 88,01	€ 125,68	€ 183,13	€ 224,15	€ 247,69	€ 73,16	€ 1.820,17

Figure 41 – Implementation of the GWP indicator in the LCC and calculating the CO2 price for Bribus

Price per ton CO2	€ 55,94	€ 67,49	€ 79,04	€ 90,59	€ 102,14	€ 113,69	€ 125,24	€ 136,79	€ 139,53	€ 142,32	€ 145,16	€ 148,07	€ 151,03	€ 154,05	€ 157,13	€ 160,27	€ 163,48	€ 166,75	€ 170,08	€ 173,48	
Chainable	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	
Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Total
Phase A-totaal	26760,30	Because the kitchens are not replaced with a new one during the 60 years but only maintenance will be performmed, results in that this row is empty except in year 0.																			26760,30
Phase B-totaal		329,45	329,45	329,45	329,45	329,45	329,45	329,45	329,45	329,45	329,45	329,45	329,45	329,45	329,45	329,45	329,45	329,45	329,45	329,45	6259,55
Phase C-totaal	Only accounted for in the last year.																			1471,14	1471,14
Phase D-totaal		-739,50	-739,50	-739,50	-739,50	-739,50	-739,50	-739,50	-739,50	-739,50	-739,50	-739,50	-739,50	-739,50	-739,50	-739,50	-739,50	-739,50	-739,50	-739,50	-14050,50
Total GWP [Kg CO2 eq.]	26760,30	-410,05	-410,05	-410,05	-410,05	-410,05	-410,05	-410,05	-410,05	-410,05	-410,05	-410,05	-410,05	-410,05	-410,05	-410,05	-410,05	-410,05	-410,05	1061,09	20440,49
Total Euro's/ton	€ 1.496,97	€ (27,67)	€ (32,41)	€ (37,15)	€ (41,88)	€ (46,62)	€ (51,35)	€ (56,09)	€ (57,21)	€ (58,36)	€ (59,52)	€ (60,71)	€ (61,93)	€ (63,17)	€ (64,43)	€ (65,72)	€ (67,03)	€ (68,37)	€ (69,74)	€ 184,08	€ 691,67

Figure 42 – Implementation of the GWP indicator in the LCC and calculating the CO2 price for Chainable

4.2.4| Delivery of the EI-LCC-tool

The last step of the double diamond method is the *delivery* phase, which encompasses the required steps taken towards delivery of the tool. In this phase, results and insights obtained, are providing the answers Sub-RQ 4 and 5 in the following two topics respectively.

I. *Operationalizing* the tool's financial and environmental parts within the Investment Decision-Making Process of IREIFs for more enhance evaluation of sustainable decision-making.
II. Exploration of *how* the results from the tool could be utilized to include sustainability in the real estate investment decisions of IREIFs.

4.2.4.1 Operationalization of the tool

The initial idea of developing the EI-LCC was to provide insights into each shearing layer of Brand as a larger whole, regarding environmental impact and cost, to support the real estate investment decision-making process. However, due to aforementioned reasons, such as data handling intensity, the time frame of the research, and market players not yet reaching the required maturity in terms of environmental impact assessment (see Bruynzeel, who does not have an EPD available), it was decided to focus the development on one building element, resulting in an MVP of the EI-LCC tool. This focus led to the evaluation of kitchens, which impact Vesteda's budgeted maintenance cost the most (results from internal research).

This MVP aimed to exemplify the usability of the EI-LCC tool and its potential and demonstrating the insights the tool can provide and how these results can contribute to a sustainable investment decision process when the tool is further evolved and market parties mature.

IREIFs already have an investment Decision-Making process in place and the question remains of where in this process an EI-LCC tool could be utilized. This resulted in the fourth sub-research question:

"Where in the investment decision-making process of IREIFs can the LCC be utilized for more enhanced evaluation of sustainable decision-making?"

4.2.4.1.1 Utilization of the tool within the investment decision-making process

The positioning the MVP version of the EI-LCC tool

The current version of the EI-LCC tool provides insights into two kitchens, showcasing the possibilities for further implementation and utilization of the tool in the investment decision-making process.

The current analysis with the EI-LCC tool regarding the choice of kitchens was made possible with static data provided by the kitchen manufacturers. As such, the current version of the EI-LCC-tool does not position itself directly in the *Operational* level of the investment decision-making process (refer to theoretical framework) of a real estate investment proposal, as was initially preferred, but positions itself as *strategic* analysis tool, allowing the possibility to predetermine specific choices of building element, in this case the kitchens. This is also in line with the results obtained from the interviews with the employees of Vesteda. The interviews revealed that operationalization in such a way could be done and is mainly due to the serial production and uniformity of the kitchens, and that the kitchens could be decided on late in the investment decision process (ADM2, [105-108]; TADM2 [154-162]). The finish of the kitchens and bathrooms are, stipulated in the Program of Requirements, which Is already determined (TADM2 [154-162]). Therefore, insights from this version of the EI-LCC tool, could provide a better substantiation of the choices made within the program of requirements, which affects every investment decision-making process.

Strategic decisions are made possible with the current version of the EI-LCC tool in terms of predetermination of building element choices, which can be included in the Program of Requirements, could be further built upon by implementing more types of serial-produced elements. The tool could eventually allow for analysis and benchmarking purposes. It must be noted that not all manufacturers of building elements are matured regarding their LCAs.

Positioning the future version of the EI-LCC tool

The initial idea of the tool was to add and incorporate more building elements within the framework of the Shearing Layers of Brand (such as façade, flooring, and roof) to provide more in-depth insights into the costs and environmental impact during the investment decision-making process.

It is apparent that a lot of data and information is needed for the tool to be used to make strategic decisions for serial produced building elements. To actually be able to use the tool on an operational level, this is primarily related to the information requirements for populating the EI-LCC tool. As such the information supply within the Investment Decision Making Process is decisive for when the tool could be used. To find out when in the investment decision process the right information would be present, interviews were conducted. The following findings surfaced:

For the initial idea, interviews were conducted with Vesteda's (Technical) Acquisition and Development managers (T)ADM, when the required data for the tool would be available. The (T)ADMs provided details on when and how the required information is available to populate an EI-LCC tool, thereby determining when it could best be employed. These interviews revealed that the tool could be populated and utilized between the Technical Due Diligence (TDD) 1 and Technical Due Diligence (TDD) 2 phases, before the turnkey contract is signed, as shown in Figure 43 (ADM1 [175-179]; (TADM2 [318-324]). This was seen as a potential phase for the utilization of the tool since the TDD1, encompasses a general assessment regarding functional and qualitative requirements, and the legal framework (ADM2 [*70-77]; ADM1* [34-37]*)* providing overarching information useful for the tool. During this phase it is, furthermore, still possible to negotiate possible required changes to the design, in order to meet both financial and sustainable objectives of Vesteda as stipulated in the program of requirements (ADM1 [*65-71])*. Within the TDD2 phase, the design is almost as good as fixed resulting that the required data for the tool will definitely be available. However, the downside of waiting until this phase is that only minimal changes to the design can be made in which the tool can no longer be used as a

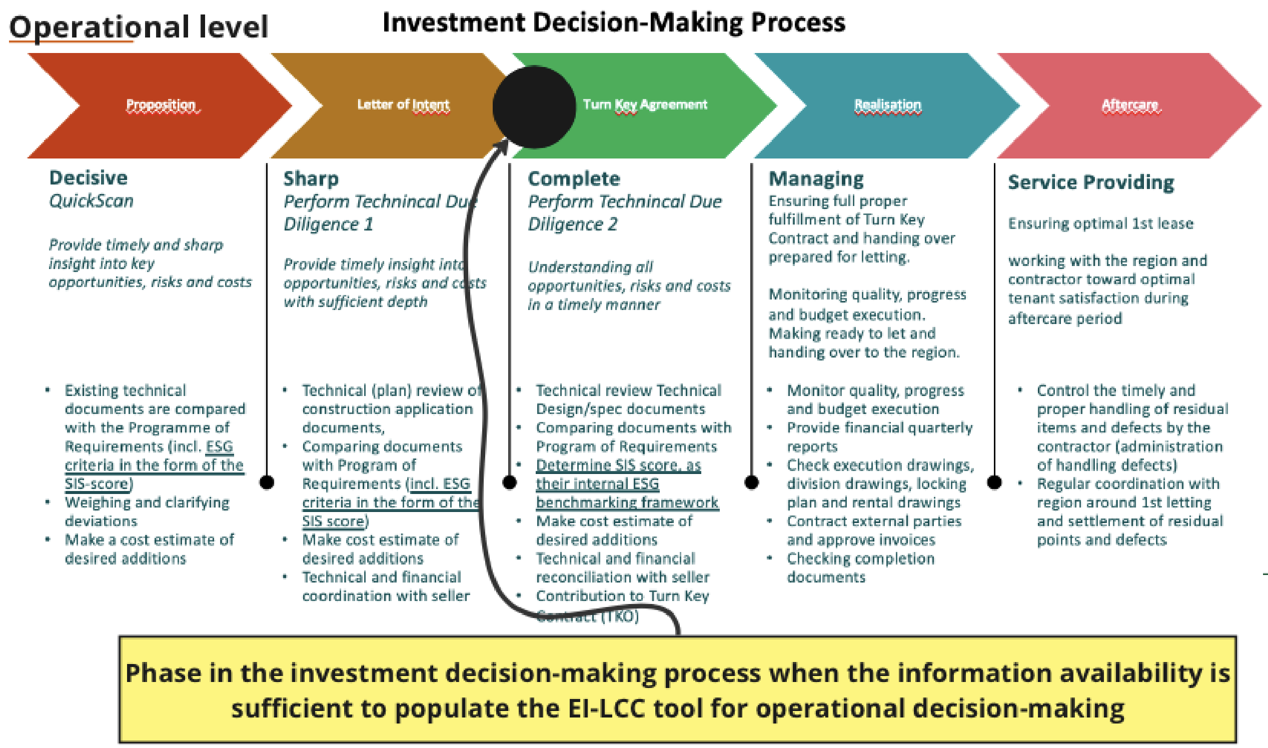


Figure 43 Allocation of the EI-LCC tool within the investment decision-making process based on the information and data availability in the Investment Decision-making process. The operational decision-making process positions itself at the micro-level (Source: Adapted from internal to document of Vesteda).

guidance instrument but more as a control tool.

However, despite the shown possibilities and opportunities, the current EI-LCC tool does not possess the required features and capabilities to conduct such an analysis, and thus cannot be employed within the investment decision-making process on an operational level as currently is. Nonetheless, the data and information availability would position the utilization of as shown in Figure 43.

4.2.4.1.2 Answer to Sub Research Question 4

In answering sub-research question 4, *"Where in the investment decision-making process of IREIFs can the LCC be utilized for more enhanced evaluation of sustainable decision-making?"* the tool can be utilized in decision making in two distinct ways:

Firstly, the tool can be utilized for building elements of a more static nature, like kitchens and bathrooms. Predetermined and substantiated decisions regarding such building elements could result in the inclusion in the program of requirements. This results in criteria to which building elements of potential real estate investment must adhere to. As such to tool becomes a more strategic tool with which strategic investment decisions are being made. These decisions must be made integral in a department transcending way. This ensures quality assurance across the real estate portfolio, allowing the EI-LCC tool to decide the best option in terms of environmental impact and life cycle cost. The results also enable dialogue with manufacturers to realize more sustainable building products.

Secondly, when the EI-LCC tool is further improved, and utilization within the *operational* level, wherein the Investment Decision-Making Process resides in, is possible, the tool could be utilized as shown in Figure 43, due to the data information availability. The results could guide and substantiate investment decisions, shaping real estate design for environmental impact reduction and cost efficiency. Utilizing the tool in this way, within the investment decision-making process, necessitates defining KPIs and establishing benchmarks.

In conclusion, consolidating the insights of both the operationalization of the tool and the utilization of the tool within the investment decision-making process, provides the answer that at the strategic and operational levels, the EI-LCC tool clearly demonstrate how it can support the investment decision process, thereby providing an answer to the fourth sub-question.

4.2.4.2| Integration of the results of the EI-LCC tool the investment decision making process of IREIFs.

This section focuses on how the EI-LCC tool and the results obtained with the EI-LCC tool could be utilized to in Real Estate Investment Decision-Making to include sustainability. Therefore, this section will be structured around the following two topics:

I. Interpretation of the EI-LCC tool results
II. Utilization of the EI-LCC tool's results for enhanced decision-making
II. Implementation of the results in the investment decision-making process

These three topics aim to collectively address sub-research question 5: *"How can the results obtained from an LCC-tool be utilized in real estate investment decision-making to include sustainability?"*

4.2.4.2.1 Interpretation of the results

The EI-LCC tool has been employed to analyze both the financial cost and the environmental impact, in monetary terms, of two specific kitchens.. The tool provided insights into both the 20 and 60-year life span of a building, but within this text, only the 60-year life span will be elaborated on, as these insights are already sufficient.

Firstly, results obtained from the financial part of the tool are in the realm of present values of maintenance and renewal costs, plus the investment cost, and additionally, the Real Costs during the lifecycle. These results are the outcome of the tool as developed in section [4.2.2]. For both Chainable and Bribus, this resulted in the representation of the costs over 60-year life span, displayed in Figure 43.

The analysis of the 60-year life span brought to light that the present value of Bribus is significantly higher due to the investment cost of the kitchen. However, looking at the real cost during the 60-year life span cycle, it shows the costs are much alike. Therefore, it completely depends on the preference and strategy of Vesteda if the real costs or the present value is chosen to substantiate the investment decision. However, from the valuation model of Vesteda, it was derived that the Present Value is used as well. In line with this thought, based on the financial analysis and no other investment criteria, the Chainable kitchen is the most favorable. The obtained result could be utilized in such a way that enables comparison between the kitchens.

Secondly, the results obtained from the environmental impact analysis of the EI-LCC tool regarding the kitchens provided insights into both kitchens, in terms of the MKI. This resulted in an overview of the MKI per phase during the 60-year and 20-year life span. In this text, the results from the 60-year time span are elaborated on.
As can be seen in Figure 44, the total MKI of the Bribus kitchen is substantially higher than the Chainable kitchen. This is attributed to the production phase of Bribus, where kitchens are completely renewed, and more environmental impact in the production phase occurs. While Chainable does account for the use phase and Bribus does not, this does not outweigh the renewal of entire kitchens. If the lowest MKI would solely be used as criteria, the Chainable kitchen would be favorable.

In conclusion, the obtained insights of both the financial part and the environmental impact in terms of the MKI could function as additional criteria in the investment decision-making process. It would be interesting to consolidate both insights of the EI-LCC tool into a single criterion. However, due to the differing business models of both kitchens, and the premature stage of the tool, a single, well-representative criterion could not be derived.

4.2.4.2.2 Utilization of the EI-LCC tool's results for an enhanced investment decision-making process

The resulting MVP version of the EI-LCC tool, along with its computed results, provides the numbers regarding the environmental impact (See figure 44) in terms of the MKI and the Present Value of the costs of a Kitchen (See Figure 45), however these results must be utilized in such a way that it substantiates investment decisions.

To do so, there is referred to the theoretical framework, where internal benchmarking was identified as a component of the PMS. Through desk research, it was discovered that Vesteda utilizes their SIS-framework as their internal *sustainable* benchmark as integral part of the investment proposal resulting from the investment decision-making process (see Figure 43).

During the interviews held with Vesteda employees it was unveil how the resulting outcomes of the EI-LCC tool could be integrated within the SIS-framework of Vesteda's internal benchmark framework to enhance sustainable investment decision-making:

Every decision of Vesteda revolves around return versus risk (PM2 [356]). According to ADM1

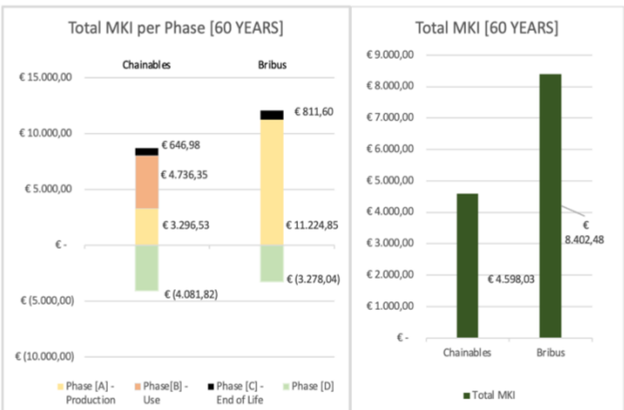


Figure 44 -Graphs representing the MKI. On the left: The total MKI for each phase during the life span of the kitchens. On the right: The sum of the MKI of each phase (Own source, screenshot EI-LCC tool)

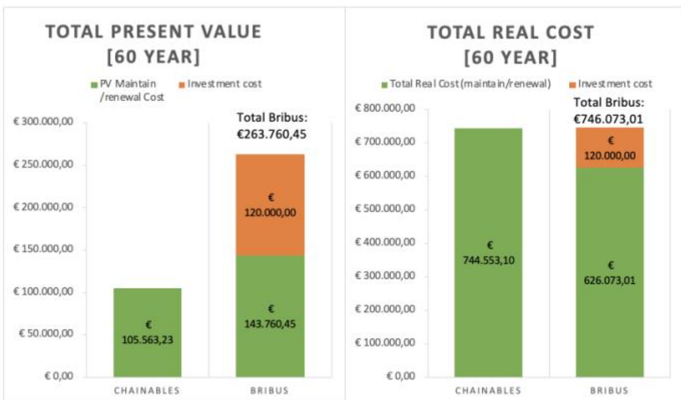


Figure 45 – Graph regarding the kitchens as building component, from Bribus and Chainable. On the left: showing the present value of the cost, over a life span of 60 years. On the right: The total real cost of both kitchens during its life cycle (Own source, screenshot EI-LCC tool)

(350-352), an EI-LCC tool could contribute to the investment decision-making process by offering transparent insights into environmental impact, initiating internal and external conversations. ADM1 (350-352) also suggests that integrating the LCC-tool into Vesteda's valuation model as a sustainable LCC-score would be beneficial.

The value of the EI-LCC tool lies in its ability to make building-specific cost assessments. Unlike current standard methods, it allows for detailed considerations that are often overlooked, thereby enabling more informed and intelligent investment decisions (ADM1 [304-315]); ADM2 [263-273]).

To employ the tool and enhance the decision process, it must be viewed as a management tool that ensures greater transparency, like an expectation management tool. It enhances predictability, thereby reducing risk perception, and provides insight into future possibilities, offering the means to manage them (PM2 [297-301]).

Currently, Vesteda's strategy of balancing environmental impact and cost by the incorporation as a KPI into the ESG framework. While still in its infancy, Vesteda acknowledges that policy regarding the utilization of assessment tools, like the EI-LCC, has not been defined. Consequently, they are uncertain about how to assess a proposed building, determining if a proposed projects strategically aligns with Vesteda's goals in terms of environmental impact and costs (PM1 [514-516]).

It has been said that the environmental impact results of the tool, should be implemented and manifested in the SIS-framework (PMS [48-50]), what confirms the initial thought of implementation.

In conclusion, interviews reveal that the EI-LCC tool can enhance investment decision-making when integrated into Vesteda's SIS-framework, a key component of their valuation model. For effective utilization, the EI-LCC tool's results should be incorporated as SPIs within this internal benchmark. The next section outlines preliminary steps for this integration in the investment decision-making process.

4.2.4.2.3 Implementation of the results of the EI-LCC tool in the investment decision-making process

The results of the EI-LCC tool, encompassing both cost and the MKI, will be integrated into two distinct areas within Vesteda's investment decision-making process. Specifically, the MKI will be incorporated into the SIS-framework, while the cost of a building element will have its own place in the investment proposal.

Firstly, the SIS-framework, integrated into the valuation model positions itself within the PMS of IREIFs as seen in Figure 46. The SIS-framework serves as a comprehensive ESG assessment tool. It covers various sustainability metrics, including GPR and MPG, allowing for a holistic evaluation of potential investments (See Figure 46) . Consequently, Vesteda can set sustainability standards that exceed legal requirements and aim for enhanced sustainability impact with each project (ADM1 [120-125]).

The interviewee noted that within the SIS-framework, different factors are weighed and considered. Each factor requires a minimum score, a target score, and contributes to an overall score. This sustainability score is then equated to future readiness. A higher sustainability score is indicative of lower risk, thus potentially allowing for a lower return on investment. However, this concept requires further clarification and definition (PMS [85-89]).

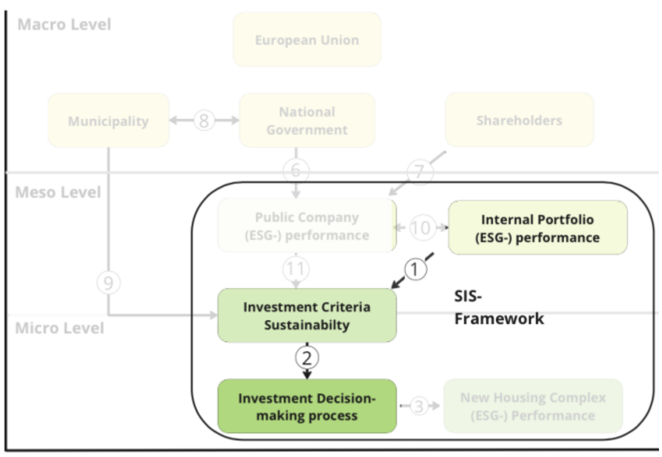


Figure 46 – Positioning of the SIS-framework and how it is manifested within the IREIFs

ESG FRAMEWORK	SiS									ESG score per comopnent	Totale ESG score (project)	Average ESG score
	Sustainability risk / impact on sustainability factor	Strategy (due diligence)	Sustainability Impact Score	Assessment	Potential mitigation	Reporting and monitoring	Score	%	WEGING		62%	66%
	Water use and water retention	Sustainable use and protection of water resources	# of water saving measures	2	Water saving measures and water retantion measures	Water saving measures	2			64%	62%	66%
			Projected average water consumption per unit	Average		% of expected water saved per unit per year	1					
	Durability and maintainability	Sustainable usage of materials and pollution prevention control	MPG score	1-0,7	Stimulate environmental friendly materials, apply testing on emmisions on formaldehyde concentration	MPG score	1					
Material and resources			GPR score environment and future value	7,5 environment 8 future value		GPR score	2	64%	3			
	Reduce environment unfriendly materials	Transition to circulair economy	Exclude environment unfriendly materials, 75% FSC certifate wood and 70% reuse of waste materials	Yes			1					
		Sustainable operating and maintenance costs	Average % of yearly maintenance costs per sqm in comparison to 5 year average of recent acquisitions (SFM and MFH)	Average	Adjust materials or design	Yearly maintenance below 5 year average of recent acquisitions	2					

Figure 47 – It shows a part of the SIS-framework utilized as Vesteda's ESG-performance Framework. This part focuses on the 'Material and Resource' component, one of six components in the ESG framework used as a performance measurement tool within Vesteda's PMS. This framework is integral to the valuation model within investment decision-making process, wherein it assesses and evaluates proposed projects. Specifically, it contributes to calculating the SIS. Within this single component, three sustainability risk are assessed, each containing two Sustainable Performance Indicators (SPIs). (Vesteda internal document)

Enhancing the investment decision-making process, it is possible by incorporating the MKI results from the EI-LCC tool into the SIS-framework. According to ADM1, this inclusion provides an opportunity to define clearer sustainability targets and ambitions, enabling Vesteda to set higher standards for new projects and meet established targets and compliance requirements (ADM1 [129-135]).

An employee of Vesteda elaborated on how various sustainability indicators, including the CO2 roadmap, have been implemented as performance measurements within Vesteda's Performance Management System. This example serves as a basis for understanding how to implement the EI-LCC tool and its results effectively.

Regarding the balance between financial returns and sustainability impact, the rationale behind measuring the performance of the CO2 roadmap is based on the assumption that investing in sustainability leads to an improved SIS score. This improved score is correlated with a lower risk perception and could permit a slight reduction in returns (e.g., 0.1%) (PMS [50-55])

In line with the previous, the utilization of the environmental impact results (the MKI), obtained from the EI-LCC tool could be used as an extra criteria within in the SIS-framework in a similar approach as is done with the Carbon Roadmap of Vesteda (PMS [457-471]). It thereby, enriches the Sustainable Impact Score by accounting for the environmental impact of specific building elements.

In line with the idea obtained from the interviews, a starting point must be established for each building element (in this version of the EI-LCC tool, a kitchen), resulting in the defining the ambition and goal to realize a reduction each year of the MKI. This is done by adjusting the requirements stipulated in the tool making them more stringent each year in order to achieve the goals. These stricter requirements each year, are reflected in the SIS through an improved score.

An example is shown in Figure 48 of how the MKI results could be implemented in the SIS[20]. The baseline MKI of each Building Elements need to be established and will function as the benchmark during a new investment decision process. The deviation from the baseline results in a possible score that could look like this:

5-10% above average of last 5 year → -1 Point
0-5% above average of last 5 year → 0 Point
Average → 1 point
0-5%Below average of last 5 year → 2 points
5-10% Below average of last 5 year → 3 Points

A total score of 17 point could be obtained with each indicator in the "Material and Resource" component.

ESG FRAMEWORK	SiS											ESG score per comopnent	Totale ESG score (project)	Average ESG score
	Sustainability risk / impact on sustainability factor	Strategy (due diligence)	Sustainability Impact Score	Assessment	Potential mitigation	Reporting and monitoring	Score	Comply to Green Finance Framework criteria	DNSH criteria	%	WEGING		63%	66%
Material and resources	Reduce environment unfriendly materials	Transition to circulair economy	Exclude environment unfriendly materials, 75% FSC certifate wood and 70% reuse of waste materials	Yes			1		Yes	71%	3	71%	63%	66%
		Sustainable operating and maintenance costs	Average % of yearly maintenance costs per sqm in comparison to 5 year average of recent acquisitions (SFM and MFH)	Average	Adjust materials or design	Yearly maintenance below 5 year average of recent acquisitions	2							
		Choiec of "building element" with lower MKI	MKI of "building element" in comparison to the 5 year average MKI of "building elements" chosen in recent acquisitions	5-10% Below 5 yr average	Dialogue with manufacturers of buildings elements ot procure building elements with less MKI	The building elements' MKI below average of recent Acquisitions	3							

Deviation of the average
5-10% above 5 yr average; 0-5% above 5 year average; Average; 0-5%Below 5 yr average ; 5-10% Below 5 yr average

5-10% above 5 yr average
0-5% above 5 year average
Average
0-5%Below 5 yr average
5-10% Below 5 yr average

Figure 48 Introduction of the MKI in the 'Material and Resource' component of the SIS-framework utilized by Vesteda. The indicator contributed a maximum of 3 points to a total of 17 point that could be obtained within this component.

The newly introduced indicator "Choice of building element with lower MKI" accounts for a maximum of 3 points. This scoring system is in line with insights obtained during the interviews, where it was proposed that when scoring above the requirement, a lower return could be considered within the investment decision process, while when scoring below the requirement, a higher return is expected (PMS [479-481]. Which resonates the mentioned risk versus return in interview with PM2 (PM2 [356]). and allows to opportunity to assess the risk versus return more (PMS [479-481]).

This leads to the final 'cost' part of this section, which focuses on the insights into the costs of building elements and how to utilize it. For instance, certain building elements like kitchens with lower MKI, may incur higher life cycle costs, leading to a present value that exceeds the five-year average. Such higher costs could then be justified by a higher SIS score, a factor that could be incorporated into the investment proposal. This in turn can provide the rationale on the ratio between the SIS score/return requirements. As such, the MKI then ratifies Real Cost or PV Cost.

However, while additional in-depth insights of how to link the SIS-score with the 'costs' of buildings elements is required for further implementation, they fall outside the scope of this study. Nonetheless, the case study of the kitchen as a building element, providing the opportunity to implement the results in the SIS-framework employed by Vesteda, illustrates the potential of the EI-LCC tool to enhance investment decision-making.

4.2.4.2.4 Answer to Sub Research Question 5

In conclusion and in addressing the fifth research question: *"How can the results obtained from an LCC-tool be utilized in real estate investment decision-making to include sustainability?":*

The results obtained from the EI-LCC tool could be utilized by enhancing Vesteda's investment decision-making process through the integration of the results within Vesteda's existing SIS-framework, thereby enriching investment evaluations by taking into account both environmental impact and life cycle costs.

Enriching the SIS-framework with the integration of the MKI allows for better substantiation. The relation between the SIS-score and investment decision-making, demonstrates itself on the cutting edge of a lower perceived risk perception when the SIS-score increases.

This has been illustrated in Figure 48, where tool's MKI can be effectively utilized by incorporating the results as additional criteria into the SIS-framework. This allows for more transparent way of considering the environmental impact. This integration allows for a more nuanced risk-return assessment that aligns well with insights distilled from interviews. The scoring system, based on MKI deviations, suggests that higher SIS scores could potentially justify lower returns on investment. Which in turn will be presented in the valuation model, for the substantiation of more expected expenses. These expected expenses could than again be derived from the financial part of the EI-LCC.

While the tool shows considerable promise for improving the sustainability of investment decisions, it is important to note that further in-depth research is required for its full-scale implementation. Especially with regards to the cost component of the EI-LCC tool. In summary, the EI-LCC tool, while still in its infancy, represents a valuable MVP showcasing the possibilities as future performance measurement tool for making more informed and sustainable investment decisions within Vesteda, as part of their PMS.

5| Discussion

In the previous chapter, the results and analysis of each phase of the double diamond process of the EI-LCC tool was presented in the quest to enhance sustainable investment decision-making in the real estate sector. This study introduced, developed and evaluated an EI-LCC tool. The tool was specifically designed to integrate with Vesteda's existing SIS framework, thereby opting for a more comprehensive approach to investment decision-making. Within this discussion the following topics are be touched upon:

I. The research approach and contextualization of the research findings obtained during the process
II. Evaluation of the tool

5.1| Contextualization of the research findings

This section delves into the research approach and the contextualization of the research findings obtained during the entire process. This section will be divided into two topics, 1) the obtained findings during the development phase of the tool and, 2) The findings during the delivery phase of how the tool could be utilized in terms of the context of an IREIF. Both the topics will be linked to the findings in from the Discover and Define phase, resulting in the contextualization of the research findings within the broader academic discourse (the theoretical framework), aiming to delve deeper for a more comprehensive understanding of the tool.

5.1.1| Obtained findings during development phase

As Manewa et al. (2021) noted, LCC is only slowly gaining traction in the building sector, despite its potential benefits and growing academic recognition. This study sought to overcome this slow adoption, through the integration of LCC and LCA within a tool, and implementing the tool into Vesteda's PMS to enhance investment decision-making. França et al. (2021) argued that integrating LCC with LCA presents both opportunities and challenges, a sentiment echoed in this study. While still in its infant stage, the EI-LCC tool shows promise for overcoming these challenges, which will be discussed subsequently.

5.1.1.1 The encounter challenges in line with the literature

The encountered challenges during the entire process align with the four challenges stated by França et al. (2021), who argued that an LCC is a data-, resource-, knowledge-, and time intensive cost management tool.

Firstly, the scarcity of requisite data concerning the environmental impact of building elements was evident. Dependency on manufacturers for EPDs is a critical factor. For instance, among the three kitchen manufacturers discussed in section [4.1.2.2], only Bribus and Chainable provided EPDs. These are only recently available, may 2023 and March 2023 respectively. This underscores the nascent stage of environmental impact consideration in the building sector, both for manufacturers and buyers.

Secondly, the development of a substantiated EI-LCC tool either requires in-house expertise or outsourced knowledge, both of which are scarce and costly. Investment in the development of such a tool is necessary, yet the value it contributes is neither quantified nor understood in terms of practical utility. This lack of clarity fosters a hesitant attitude toward adopting the EI-LCC tool, an obstacle that needs to be overcome.

Thirdly, the time-intensive nature of LCC poses a significant challenge, a characteristic that the current iteration of the EI-LCC tool also exhibits. As it stands, the tool provides insights into only two kitchen variants. Expanding its scope to include additional kitchens or other building elements would necessitate a complex, multi-step process, as it resonates on every excel sheet. Adding extra types of kitchens or other building elements in general, must be incorporated within each Excel-sheet. To mitigate this issue, future versions could benefit from automation, thereby reducing the need for manual adjustments to formulas and fixed input data in each excel sheet within the Excel file, a practice that is prone to errors.

In addition to the limited availability of data, discrepancies within the data itself present another challenge. These inconsistencies arise from the individual LCAs conducted for each kitchen variant, each having its own defined goal and scope. Such variability introduces a degree of uncertainty to the outcomes and affects the environmental impact calculations for each phase. This issue necessitated the assumptions detailed in section [4.2.3]. For instance, the EPD from Bribus pertains to three wall cabinets and 3 bottom cabinets, whereas the two EPDs from Chainable cover one wall cabinet and one bottom cabinet. To ensure comparability, the EPDs from Chainable were each multiplied by three, a method that has not been previously employed and thus raises questions about data accuracy. These assumptions were essential for the correct allocation and incorporation of the environmental impact (MKI) for each year. Despite the substantiation of these assumptions, a certain level of uncertainty remains and should be considered when using the EI-LCC tool. Nonetheless, the development of the EI-LCC tool holds the potential to initiate dialogues with manufacturers, even those who are not as advanced in this domain as Chainable and Bribus.

5.1.1.2 Monetizing the environmental impact

This leads to the issue of monetizing environmental impact data. In the EI-LCC tool, environmental impact is quantified as MKI. According to Gluch & Baumann (2004), the accuracy and completeness of input data significantly influence the final outcome of an LCC, a point that is corroborated in this study. The environmental cost assigned to each impact category carries a certain margin of error. This is because the utilization of MKI to monetize environmental impact relies on external assessments, in this case, those provided by Bruyn et al. (2021). Such assessments are subject to fluctuations in economic value and market conditions, adding an additional layer of unpredictability.

Moreover, the use of MKI as a metric is ethically contentious. Critics in scholarly literature argue that assigning monetary values to environmental issues may create the false impression that the detrimental impacts of pollution can be offset through financial compensation, an assumption that is fundamentally flawed (Vogtländer and Bijma., 2000). To elaborate on this critique, the inclusion of MKI in investment decision-making processes does not necessarily indicate that these environmental costs will be directly compensated. Instead, it suggests that the investment decision is predicated on a broader set of considerations. This raises important questions about how the monetization of environmental impact can be meaningfully applied to effect substantive change. Despite these ethical reservations, the clarity and ease of interpretation afforded by MKI make it a necessary component within the tool.

5.1.1.3 Reliance on other input variables

Lastly, the tool's reliance on various input parameters—such as inflation rates, discount rates, and annual renewal rates for kitchens—introduces a layer of uncertainty. While these inputs align with long-term sustainability objectives, their variability over extended time frames, such as 60 years, exacerbates financial uncertainty. This uncertainty is further compounded by fluctuating costs and potential policy changes, as noted by Ilg et al. (2016). Regarding the renewal rate of kitchens, the Weibull function is used to predict how many kitchens will be renewed in one year, within the first life cycle of the Bribus kitchen. The inputs variables within the Weibull function in excel, should have been derived from actual data of Vesteda, to fit the graph to real renewals within the first year. Unfortunately, such data could not (yet) be retrieved from their software systems.

In conclusion, despite the challenges encountered in the development of the EI-LCC tool—ranging from data availability to resource constraints, expertise requirements, time intensity, and ethical considerations—the tool offers significant opportunities. A dialogue with Bribus' sustainability manager highlighted the potential for Institutional Real Estate Investment Funds (IREIFs) to leverage their size and demand the necessary documentation

LCAs for more informed decision-making. This could act as a catalyst, akin to the previously mentioned 'flywheel effect.' If further refined, implemented, and utilized effectively, the tool has the potential to enhance transparency in investment decisions. This, in turn, could accelerate the transition toward reducing the environmental impact of the built environment.

5.1.2| Obtained findings during delivery phase

The development of the MVP of the EI-LCC tool has enabled the evaluation of kitchens, however, the results present the opportunities for assessing other building elements as well. This is in line with what Abouhamad & Abu-Hamd (2019) argued, who states that an LCC is a beneficial cost management tool which could evaluate alternative design options regarding building elements to determine the most economical option with the lowest life cycle cost. With the implementation of the MKI the evaluation is even broader. In the delivery phase, the focus was on elaborating *how* the results can be utilized and how these results could *enhance* the investment decision-making process. This section will subsequently discuss the tool's usefulness within the PMS of an IREIF to enhance the investment decision-making process.

Firstly, the results of the EI-LCC tool provides tangible metrics regarding the lifecycle of both Chainable and Bribus kitchens, specifically focusing on their Present Value and MKI. The tool effectively distinguishes between Chainable kitchens, offered as PaaS, and Bribus kitchens, which operate under a conventional business model. As elaborated in section [4.2.4.1.1], the tool's application has the potential to substantiate decisions within the program of requirements, especially for serially produced building elements such as kitchens and bathrooms. The evaluation as such, allows for the proactive evaluation of building elements, however this is more a strategic way of evaluation. It is important to note that the tool is not a standalone decision-making tool; the program of requirements encompasses a variety of factors including quality, aesthetics, brand familiarity, maintenance requirements, and manufacturer services, which are currently beyond the tool's evaluative scope. To enhance its strategic applicability, the tool would benefit from the inclusion of a broader range of kitchen brands and types, as well as other building elements.

Additionally, to fully leverage the EI-LCC tool's strategic capabilities within Vesteda's PMS, establishing a baseline for each building element—starting with kitchens—is imperative for effective benchmarking. Currently, the absence of such a baseline is attributed to Vesteda's data management system, which is not yet configured to extract the requisite data.

Lastly, while the existing version of the EI-LCC tool demonstrates its potential utility, further refinement remains essential. This encompasses not only improvements within the tool itself but also enhancements in data availability from both Vesteda and building element manufacturers.

Secondly, in order to utilize and *enhance* the investment decision-making process, besides further developing the tool, the results should be implemented in the SIS-framework, in which it emerged that in order to enhance the investment decision-making process, the tool should be positioned later in the process, than when the tool is utilized to evaluate buildings elements that are within the program of requirements.

Rodriguez et al. (2009) argued that a PMS and an ESG-framework provide a structured methodology to evaluate future investments against predefined objectives and KPIs. To employ the EI-LCC tool in the desired position in the investment decision-making process, as mentioned in [4.2.4.1.2] and in line with the conducted interviews, it must be integrated in the SIS-framework as proposed. This proposal of including the MKI in the SIS-framework, is still at an infant stage. The mentioned baseline must be derived from the current portfolio, in order to compare and evaluate a proposed building project.

Adding MKI as criteria in the SIS-framework followed from the interviews conducted. It is a possible way of how the results from EI-LCC tool could be integrated within the investment decision-making process. Besides, it outlined the preliminary steps which are required to be taken to actually add it to the SIS framework. Nonetheless, the actual implementation of the results of the EI-LCC tool within the SIS-framework as Performance indicator, is beyond the scope of this study.

Furthermore, the main focus has been on the kitchens' MKI results and how they can be integrated into the SIS framework, internal benchmarking as part of the PMS. In this, the results of over cost the cost of building element have been underexposed. Although it has been mentioned that with a higher SIS score a lower risk perception is experienced, and thus the return could be adjusted downwards, how this should be done is not sufficiently enough discussed.

In conclusion, the EI-LCC tool represents a suitable approach to sustainable investment decision-making, providing insights into both the environmental impact and financial costs of investment decisions. However, to utilize the tool to its full potential, additional steps must be taken, including the collection of more data and the conduction of more extensive analyses. Another required step is the linkage of the costs with the MKI. This will enable the results from the tool to be translated into solid KPIs that can be used within the PMS and ESG framework, thereby enhancing the effectiveness of sustainable investment decision-making.

5.2| Evaluation of the Tool

The EI-LCC tool was developed based on the design brief which was established after the discover and define phase, aiming to provide a solution to the specified problem. In this last section, it will be checked whether the tool provides a solution to the identified problem. In addition, the tool is evaluated for compliance with the established design requirements, both in order to validate the tool.

5.2.1| EI-LCC tool as Solution to the problem

Firstly, regarding the identified problem during the discover and define phase, is about the lack of considerations, in the investment decision-making process, regarding environmental impact and costs during the whole life cycle of buildings elements. Within literature there is consensus that this could be overcome by incorporating LCT tools into IREIFs' PMS, however due to the slow adoption rate caused by the lack of reliable data, lack of knowledge, the labor intensity and context specificity this implementation is rarely seen.

The EI-LCC tool was developed to address the aforementioned issue. Its MVP can evaluate two different types of kitchens, showcasing its ability to provide insights into both costs and environmental impacts of building elements. Although still in its early stages, the tool's output, specifically MKI and cost data, could serve as additional criteria in investment decision-making, thereby enhancing the decision's justification. However, before the tool can be broadly adopted, it needs further refinement, including the addition of more kitchen types and other building elements. Additional refinements are needed on how to utilize the results obtained from the tool. A solid benchmarking framework is essential to be set-up, ensuring that with minimal effort, large environmental impact reduction could be achieved.

The aforementioned barriers addressed in literature regarding the adoption of LCT in the sector, were indeed present during the development process. This is the development focused on the MVP of the EI-LCC tool, focusing on kitchens rather than a broader range of building elements. Nonetheless, the tool's development and its initial results demonstrate that it can enhance investment justification. However, this study only scratches the surface of the tool's full potential.

Lastly, to conclude, it is possible to develop an LCC tool integrated with LCA. The resulting EI-LCC tool is able evaluate and provide insights in the costs and MKI of building elements with the example of kitchens. The results from the tool must however be incorporated in the internal benchmarking framework of an IREIF to be utilized to its full potential.

5.2.2 Evaluation of Design Requirements

To ensure the efficacy and applicability of the EI-LCC tool, it is imperative to evaluate its alignment with the pre-established design requirements. These requirements were categorized into two main groups: Mandatory and Highly Desirable. The following sections provide a brief assessment of how the tool meets each of these criteria, thereby offering insights into its strengths and areas for improvement.

Mandatory requirements

- *The tool must employ life cycle costing as its underlying method*.

The development of the tool started with the LCC and succeeded. However, many assumptions had to be taken in the tool to be functioning. All assumptions are well substantiated but are still prone to things that may have been overlooked.

- *The tool must be able to assess building elements.*

The tool can assess kitchens as a first building element. While it is possible to incorporate more buildings elements, no additional building element has been incorporated. Incorporate more buildings elements is however labor intensive and requires expertise in excel and the underlying rationale of both the financial part as the environmental impact part.

- The tool must assess environmental impact by implementing and utilizing a corresponding SPI.

This has been successfully done, through the employment of MKI.

- *The model must assess the costs throughout a building elements' life cycle.*

This has been successfully done. The tool assesses costs throughout the life cycle. For Bribus a renewal rate has been established to gain insights in how many kitchens are renewed each year, during a life span of both 20 and 60-years. For the Chainable kitchen a small deviation has been introduced, because the costs consists of a constant maintain cost, which is recurring each year.

- *LCC-tool must consider the time value of money.*

The EI-LCC tool considers the time value of money by accounting for the inflation- and discount rate in the cost component. For the MKI, only the inflation rate is used because discounting would be ethically wrong.

- *The tool must enable a better substantiation for investment decisions in building elements in which an IREIF has influence, for a better trade-off between cost and environmental impact.*

The tool enables an improved substantiation within investment decisions by incorporating the MKI within the SIS-framework as an additional parameter. However, incorporating the results in the internal benchmarking, the SIS-framework, needs further refinement for the tool to be able adequately decide on what is the most desirable tradeoff between the (extra) cost and the environmental impact.

Highly Desirable

- *The development of the life cycle costing tool should adhere to the ISO 15686 standard.*

During the development the EI-LCC tool, the overarching framework has been adapted to fit the context of an IREIF. Since the development of this tool entails an MVP, ISO15686 has not been substantively addressed. If, however, multiple building elements are to be added then this would be highly recommended.

- *The duration of the life cycle considered in LCC-model should be aligned with the duration of the already utilized life cycle duration by IREIFs.*

Two lifespans are incorporated in the tool, both 20 and 60 years. The 20 year life span is aligning with the valuation model used by Vesteda. While the 60 years life span provide a better outlook for the environmental impact and the resulting MKI.

- *The tool should have the functionality to assess and compare more than one type of a specific building element.*

This succeeded through the examination of both Chainable and Bribus

- *The LCC-tool should be easy to operate.*

The tool is user-friendly for adjusting existing parameters like discount rate and tenant mutation rate. However, adding new building elements or kitchens is labor and time intensive, due to the multiple steps required to take throughout the whole Excel file in each sheet for the tool to be properly functioning. Furthermore, gathering the required input data regarding environmental impact and the cost for each building element and implementing it within the tool extra steps and adaptations to the model must be taken.

- *The tool should include a certain degree of flexibility from the beginning, allowing for future adaption.*

As mentioned during the development of both the environmental impact (MKI) as the LCC part, there has been accounted for a certain degree of flexibility allowing for the integration of new buildings elements. As mentioned above, this is however complex.

In conclusion of the assessment of the requirements, most of them have been covered. Certain requirements have been partially met because it was not possible due to missing data from Vesteda or from manufacturers. Furthermore, an attempt was made to implement the tool in the SIS framework within Vesteda's PMS. Although not elaborated on, this is an extra step taken that was not included as a requirement in the design brief.

6| Conclusions

In this study, the primary focus has been on the development and application of an LCC-tool that incorporates environmental impact, as measured by the MKI. The objective was to explore how IREIFs can integrate sustainability into their investment decision-making process through the use of this LCC-tool. The study's conclusions drawn from the answers to five sub-research questions, which collectively aim to address the main research question.

6.1 Conclusion sub-research questions

Within this section a summary of the answers is given to each sub-research questions. The collective insights derived from these answers will consolidate in addressing the main research question.

1) How is sustainability currently incorporated in the real estate investment decision-making process, and what challenges do Institutional Real Estate Investment Funds (IREIFs) face when implementing Life Cycle Costing within this process?

To explore the integration of sustainability into the investment decision-making processes of IREIFs, as well as the challenges associated with implementing LCC, a multi-level theoretical framework has been developed. This framework is structured around the Macro, Meso, and Micro levels, as illustrated in Figure 49.

Firstly, in terms of how sustainability is incorporated in IREIFs investment decision-making process, there will be started at the Macro level, where governing bodies exert influences by enforcing laws and regulations for the building sector and financial institutions. One such law is the compliance with the SFDR, mandating ESG reporting in line with the EU-taxonomy and thereby ensuring transparent reporting which indirectly the investment criteria. Additionally, Initiatives like the MRA's 20% bio-based materials target for 2025 also shape investment strategies.

The Meso level focuses on internal benchmarking and public (ESG) performance benchmarking. On the one hand, various public benchmarking frameworks have been highlighted, like the GRESB, MCSI and BREEAM. These ESG performance framework are each influencing the investment criteria to ensure high ratings in comparison with other IREIFs to remain attractive for future investors.

On the other hand, IREIFs are developing their internal benchmarking frameworks due to the rigidity of the public benchmarking framework (Newell et al., 2020). The flexibility of the internal benchmarking framework enables the possibility to shape the investment decision-making process,

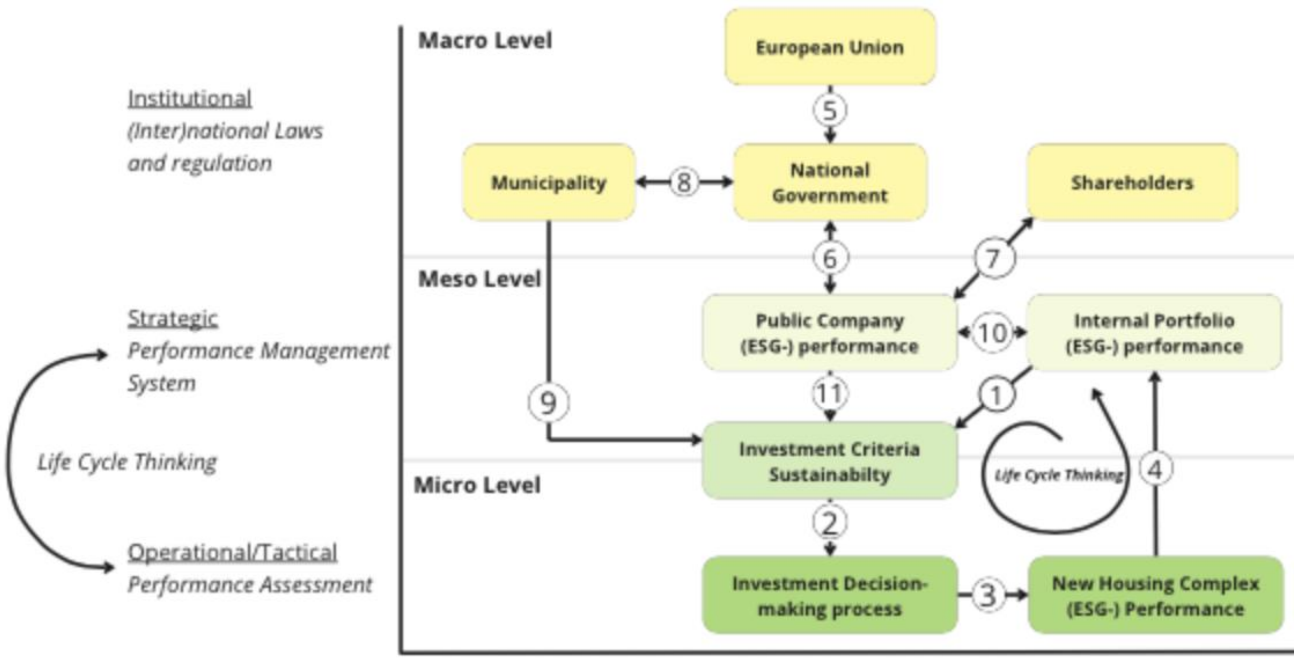


Figure 49 – Overview of the resulting theoretical framework, illustrating how each topic and stakeholders influences one and another. (Own source)

tailored to the ambitions and vision of an IREIF.

The Micro level involves the investment decision-making process to evaluate whether investment criteria are met. IREIFs use valuation models that assess various indicators, but often overlook cost and environmental impact. Literature suggests that LCT, specifically LCC, offers metrics for such assessments, although challenges in integration hinder adoption caused by a complex interplay of stakeholders and processes as shown in Figure 49. Each interplay is aimed at influencing the investment criteria, either directly or indirectly, and thereby shaping how sustainability is incorporated within the investment decision-making process.

Secondly, the challenges observed of implementing an LCC in the investment decision-making process include the need for substantial changes in existing PMS and KPMs, resulting in the required establishment of new benchmarks and strategies to revise the investment criteria. Furthermore, challenges observed of utilizing an LCC tool (Micro level) are regarding the vast amount of environmental impact and cost data, and its accuracy. A last observed challenge is the lack of specialized knowledge within companies.

2) What opportunities provide the implementation of the LCC tool for IREIFs?

The implementation of the LCC tool offers IREIF's opportunities across different levels of the complex landscape. At the micro-level, the adoption of the integrated LCC/LCA approach will allows for a comprehensive evaluation of both environmental and economic aspects of building elements within investment opportunities. These insights will ensure a more comprehensive assessment of the valuation model used within the investment decision-making process. This dual assessment enables more informed trade-offs between environmental impact and cost.

Lastly at the Meso-level, LCA/LCC tool could be utilized to gain a deeper insight in the performance of the current portfolio for internal benchmarking purposes. These benchmarks could serve as criteria for future investments, aiding IREIFs in achieving their ESG goals. These results obtained, from adding the tool to the broader PMS of IREIFs will result in better substantiated investment criteria. Thereby closing the cycle.

3) What methodology can be applied to develop an LCC-model for buildings, accounting for environmental impact, for implementation in the decision-making process of an Institutional Real Estate Investor?

Considering the research aim to develop an LCC tool accounting for the environmental impact of building elements, the Double Diamond Research Through Design method was deemed well-suited. This approach serves as an overarching framework, offering the flexibility essential for crafting a complex tool like the LCC model. The first diamond focuses on defining the problem space to 'design the right thing,' while the second diamond targets the solution space for 'designing the thing right.' A range of research methods are employed within each diamond to ensure progress. The Double Diamond's architecture, divided into the Discover, Define, Develop, and Deliver phases, provides a comprehensive understanding of both problem and solution spaces. This methodology not only permits but also mandates the documentation of each developmental step, ensuring that no information is lost throughout the process.

4) Where in the investment decision-making process of IREIFs can the LCC be utilized for more enhanced evaluation of sustainable decision-making?

The EI-LCC tool can support the sustainable investment decision-making process of IREIFs in two ways. Firstly, the current EI-LCC tool, as MVP, could be best employed on a strategic level, assessing building elements that are relatively static in nature, such as kitchens and bathrooms. Such building elements are included in the program of requirements, to ensure quality assurance across the real estate portfolio. The tool's output not only identifies the most cost-effective and environmentally friendly options but also facilitates meaningful dialogues with manufacturers to encourage the production of more sustainable building materials and finetune how the environmental impact is measured. The resulting MKI and the PV of the costs of both kitchens, could complement the current criteria to evaluate what kitchen should be bought.

Secondly, the interviews with the employees of Vesteda brought to lights that the EI-LCC tool could be utilized within the investment decision-making process (operational level), *if* it incorporates a broader range of building elements. The results of tool can then serve as a robust guide for investment decisions, helping to shape the design of real estate projects, while accounting for both environmental sustainability and cost-efficiency. The interviews conducted with employees of Vesteda, elucidated that the information availability to populate the improved tool, would be at between the TDD1 and TDD2 phase (See Figure 43).

5) How can the results obtained from an LCC-tool be utilized in real estate investment decision-making to include sustainability?

In answering the question, firstly, a reference is made to the theoretical framework where internal benchmarking is identified as a component of the PMS. The desk research has revealed the existence of the SIS-framework utilized by Vesteda as part of their valuation assessment of potential real estate investment to enable informed decision-making. Additionally, during this phase the insights distilled from the interviews underpinned that the SIS-framework is the right allocation where the resulting MKI of the EI-LCC tool could be integrated, in the form of an additional component. The SIS-framework functions as benchmark against which the potential real estate investment is evaluated. This results in a score for each component within their SIS-framework. Adding the MKI as an additional component result in a more comprehensive assessment and providing more transparency, as mentioned in the interviews. This more comprehensive assessment influences the risk perception, when a higher SIS score is obtained, this could substantiate in a lower expected return and vice versa. The insights obtained in the cost part of buildings elements could thereby be substantiated and will function as additional layer within the investment proposal.

Secondly, a proposal has been drawn up, to integrate the MKI result in the SIS-framework, under the name “Choice of building element with lower MKI”, which was elaborated on in section [4.2.4.2.3] and shown in Figure 48. The insights distilled from the interviews and the allocation of the environmental impact (MKI) within Vesteda’s internal benchmarking framework - the SIS framework - shows how the resulting tool could be used to enhance the sustainable investment decision. However, to be able utilize the tool to its full potential, besides adding more buildings elements, next to more kitchen types, for a more comprehensive evaluation, a baseline and benchmarks must be established to facilitate the use of the tool. Furthermore, next to the valuable obtained insights, the cost component remained underexposed in this research, which is mainly due to the missing data and the incomplete kitchens within the EPDs.

6.2 Conclusion main research questions

The entire graduation research revolved around the development of an LCC tool accounting for environmental impact, with the overarching aim of answering the main research question:

'How can an Institutional Real Estate Investor incorporate sustainability into the decision-making process by the implementation of life cycle costing?'

Addressing the main research question is best done through the findings obtained during the entire Research Through Design approach, the double diamond, which was utilized for the development of the LCC tool.

Firstly, during this development process it was determined that Vesteda can integrate sustainability into their decision-making process through the implementation of an integrated LCC and LCA approach, what resulted in the development of the *Environmental Impact* (EI)-LCC tool. The EI-LCC tool adopted the concept of monetizing environmental impact. This resulted in the environmental cost indicator (MKI) to be implemented and employed. The MKI enabled the EI-LCC tool the opportunity to evaluate both the costs and the MKI of building elements within bigger real estate project.

Secondly, the utilization of the results brought forward that it should be incorporated within the internal benchmarking framework, in line with the insights obtained from the theoretical framework. Within the context of Vesteda this resulted in the implementation within the SIS-framework. This SIS-framework was discovered during the internal research step. This SIS-framework functions as internal ESG-performance framework and is part of the valuation model in the decision-making process.

The established theoretical framework showed the complex landscape of IREIFs. It furthermore showed how sustainability is incorporated and is influenced directly and indirectly by both stakeholders as well as other process, and thereby influencing the investment decision-making process. Introducing a new performance measurement tool, like the EI-LCC tool within this landscape, has a significant effect on each stakeholder and process mentioned and should be thoughtfully implemented.

Thirdly, the monetization of environmental impact (MKI), facilitated by this approach, enables clear communication regarding investment decisions to stakeholders, both internally and external. To operationalize the EI-LCC tool, it is necessary to establish KPIs that allow for internal performance benchmarking in the SIS-framework. Furthermore, regarding external reporting, and substantiation of investment decisions, additional policy must be written.

Fourthly, the EI-LCC tool offers the opportunity to gain an understanding into costs and environmental impacts, thereby providing a basis for more informed investment decisions. Initially, the tool was intended for operational level use within the investment decision-making process of potential real estate investments, but the insights gained suggest its potential for strategic level application as well.

Fifthly, the obtained understanding regarding Environmental Product Declarations (EPDs) and LCAs, and how environmental impact is measured, opens the door for dialogue with chain partners. This conversation could lead to more sustainable practices within the manufacturing sector, further contributing to the overall sustainability of real estate investments.

In conclusion, the outlines have been sketched regarding how the resulting EI-LCC tool could enhance the sustainable investment decision-making process. It must be noted that the market, nor the tool is currently ready to be fully implemented and assist the investment decision-making process. This is mainly due to the infant stage IREIFs and the rest of the chain partners are in. This resulted in the unavailability data which is imperative for populating the tool and its further refinement and development. Nonetheless, the insights obtained with the development of the tool further provides the opportunity to spark the dialogue with relevant chain partners. Which is necessary to obtain the data regarding these building elements. The development process of the EI-LCC tool showed, in answer to the main research question, how IREIFs could incorporate sustainability into the decision-making process by the implementation of life cycle costing. With the development and proposed implementation of the EI-LCC tool, an effort has been made in bridging the gap between literature and practice. Despite still in an infant stage, the implementation of the EI-LCC tool, if further refined, could become a valuable tool for performance measurement regarding environmental impact and cost of building elements during a buildings life cycle for the substantiation of sustainable investment.

6.3 Limitations

This subsection will highlight the limitations of both this research and the development of the EI-LCC tool. A critical evaluation is essential for assessing the robustness, credibility, and transparency of the research. Identifying these limitations also serves as a guide for future research. The discussion will focus on the following topics:

I. Research methodology
II. The theoretical framework
III. Choice of building element
IV. The assumptions and decisions during the development of the tool.

By addressing these topics, this section aims to demonstrate academic integrity, thereby contributing a well-rounded, credible, and valuable perspective to the field of LCC and LCA implementation in practice.

Firstly, the Double Diamond approach is rarely employed for researching and designing performance tool within the realm of the built environment. While commonly used for designing tangible products, this approach is never being utilized for the design and development of a financial and environmental tool. This scarcity of application means there are no comparable studies, making it challenging to verify the methodology's validity and interpretation.

Secondly, the theoretical framework developed to understand the sustainability context of IREIFs and the potential implementation of an EI-LCC tool covers a wide range of topics and stakeholders. The framework's structure became clearer later in the research process, and a more detailed rationale for its design would have been beneficial. Additionally, given the framework's broad scope, further consideration should have been given to the selection of topics and stakeholders included. This limitation arose from the minimalistic research methodology employed for the literature review, chosen due to the complex and infant nature of the subject matter.

Lastly, the assumptions and decisions made during the tool's development introduce a layer of uncertainty, despite being well-substantiated. The resulting metrics e.g., MKI, Present Value, and Real Costs are approximations subject to a high degree of uncertainty. Furthermore, the data used for the kitchen element is not comprehensive; it omits key components such as kitchen appliances and countertops. While the study successfully demonstrates how an LCC tool can be integrated into the investment decision-making process of an IREIF, the tool's completeness, and consequently the reliability of its outcomes, remains a subject for further scrutiny.

6.4 Recommendations

6.4.1 recommendations for future development of the tool in practice.

The current iteration of the tool is not yet equipped for the comprehensive assessment of kitchens or any other building elements due to the limited availability of Environmental Product Declarations (EPDs) with the necessary data. For further development, multiple steps are advised to be taken to empower the scalability of the tool for both the strategic as well as the operational employment of the tool.

Firstly, for the upscaling of the tool and mitigate the dependency on chain partners, it is advisable to initiate dialogues with supply chain partners to encourage the provision of EPDs or alternative environmental impact data that can serve as essential input for the tool, besides the cost component within the tool.

Secondly, the tool would benefit from further refinements to enhance its user-friendliness and feature set. Specifically, the tool should be designed to allow for the easy addition of new building elements, thereby creating a more versatile and comprehensive assessment platform. This could be done along the line of the initial idea of the Shearing Layers of Brand. Alongside these technical enhancements, there is a need to contextualize the tool within a broader strategic framework. To establish its value in internal performance benchmarking, a baseline metric must be defined. This could be sourced either from the existing real estate portfolio or through market comparisons with currently available building elements. In either case, a well-articulated strategy is essential, for the employment on both the operational level as well as the strategic level.

Thirdly, the present version of the EI-LCC tool is designed to evaluate future investments in prospective building complexes. Extending the tool's applicability to Vesteda's existing housing stock could offer significant benefits. Specifically, it would provide a more robust framework for making informed decisions regarding redevelopments and renovations.

Fourthly, a strategy must be devised on how to deal with the results obtained from the EI-LCC tool, for it to be employed as *strategic* tool to decide on predetermined building elements. For the *operational* employment of the tool during the investment decision-making process, an additional strategy must be established.

Lastly, to ensure future development and upscaling of the tools' capability, it is recommended to automate the input where possible. The resulting outcomes and results obtained from an upscaled tool are in turn crucial to be investigated on how it would impact the investment decision-making. The upscaled LCC tool must be adapted to suit larger and more complex real estate projects. This includes examining its compatibility with existing project management software to facilitate seamless integration.

These recommendations aim to guide the tool's future development, ensuring it evolves into a robust, versatile, and widely applicable instrument for sustainable investment decision-making in real estate.

6.4.2 Recommendations for future research

While this study serves as an initial step toward integrating both LCC and LCA into sustainable investment decision-making, it merely scratches the surface of these complex underlying concepts.

Within the theoretical framework, three distinct levels were identified, each of which warrants further exploration to fully comprehend how a tool like the EI-LCC can be optimally utilized in this expansive landscape.

The research was conducted in collaboration with an IREIF in the Netherlands. To broaden the scope and applicability of the findings, future research should consider including multiple countries for comparative analysis. Such an approach could offer insights into cross-country variations in sustainable investment practices.

From a financial standpoint, longitudinal research could provide invaluable data on the long-term value creation associated with real estate investments. Specifically, it would be recommended to examine whether design choices based on LCA and LCC metrics contribute to a greater increase in real estate value over time, compared to projects that do not employ such a comprehensive approach.

A final recommendation for future research pertains to the inclusion of the social dimension, one of the three integral pillars of sustainability. Although the decision was made early in this study to omit the social aspect, the EI-LCC tool's efficacy could be significantly enhanced by its inclusion. Future research should explore methodologies for integrating this social component into the tool.

These recommendations aim to guide future research endeavors, enriching our understanding of how LCC and LCA can be effectively integrated into sustainable real estate investment decision-making.

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Appendix A – Explanation of Life Cycle Analysis (LCA)

In this appendix the underlying method of environmental impact analysis will be Discovered..

Life Cycle Assessment to Quantify the environmental impact of buildings

Buildings are long-lived structures that have a significant environmental impact throughout their entire life cycle. Typically, LCA studies adopt a building lifespan of either fifty or one hundred years, which varies based on the type of building construction (Andersen & Negendahl, 2022). From the extraction and processing of raw materials, through the construction and operational use with its heating and cooling, to the demolition and disposal of the building, buildings consume vast amounts of energy and resources, and generate significant greenhouse gas emissions, waste, and pollution (Islam et al., 2015). The environmental impact of buildings is complex and multifaceted, with important interdependencies and trade-offs between design choices in different phasess of the life cycle. For example, the energy consumption associated with building operation has a direct impact on greenhouse gas emissions and air quality, while the selection of building materials and construction methods can have indirect but significant environmental impacts, such as embodied carbon emissions and pollution associated with material manufacturing and transportation. To accurately assess and address the environmental impact of buildings, it is important to use a comprehensive environmental impact assessment (EIA) method that consider the full life cycle of the building and accounts for the environmental impacts associated with each phase of the life cycle.

It was therefore that the LCA has been introduced and slowly being adopted in the building sector since 90's (Fava, 2006) and it is this methodology that has been recognized as a standard assessment method to analyze the building industry's environmental impact (Ortiz et al., 2009). Conventional LCA consists of four main steps: shown in figure 47 in line with the International Standards of series ISO 14040 and ISO14044 (ISO, 2006).

Additionally, a LCA of a building conventionally considers five life cycle phases, i.e. design and production, transportation of materials, construction, use (operation and maintenance), and end-of-life (demolition, recycling and reuse, disassembly, and final disposal). These phasess encompass the entire life cycle of the building and are essential in assessing the environmental impact of the building over its entire life cycle (Apostolopoulos et al., 2023). Along with the building-specific EN 15978 and building-product-specific EN 15804, these four standards and norms are commonly referenced as the basis for LCA in studies in Europe (Schneider-Marin et al., 2022).

The goal of an LCA is to provide a quantitative measure of the environmental impact of a product or system, in this case a building, to identify opportunities for reducing this impact. The assessment typically involves a detailed inventory of resource flows associated with each phase of the life cycle, and the application of an environmental impact assessment (EIA) methods to calculate the environmental impact of each phase. Specifically, an LCA can measures a wide range of environmental impact categories. De Oliveira Fernandes et al. (2021) considered the following eleven categories:

1. Depletion of abiotic raw materials (excluding fossil energy carriers) ADP
2. Depletion of fossil fuels (ADP)
3. Climate change

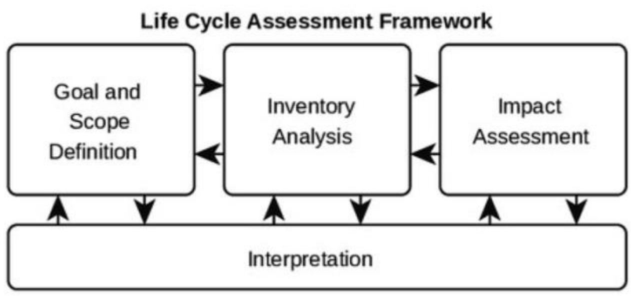

Figure 50 – Steps of LCA in line with ISO14040 (Tornaghi et al., 2018)

4. Ozone layer depletion (ODP)
5. Photochemical oxidation (POCP)
6. Acidification (AP)
7. Eutrophication (EP)
8. Human toxicity (HTP)
9. Freshwater aquatic ecotoxicity (FAETP)
10. Marine aquatic ecotoxicity (MAETP)
11. Terrestrial ecotoxicity (TETP)

However, according to Dong et al. (2021) there is a substantial discrepancy of the observed impact categories that are considered within the building LCA studies published in the past decade. The use of different categories not only arise from the differences between buildings but arises from the way of LCA modeling. Within these studies there is a focus on climate change and energy depletion, while there is a lack of information about other impact categories.

Over the past three decades, numerous building LCA software tools have been developed, each tailored to specific regions and designed to address particular impact categories of interest, while defining the boundaries of the analysis and accounting for necessary assumptions. These assumptions are a requisite as building typologies differ significantly across regions, due factors such as availability of materials, differing climates and building traditions and so on (Islam et al., 2015). However, LCA has its limitations since conducting a LCA for a specific building requires a customized approach that considers the unique characteristics of that building and, making it challenging to obtain accurate data for all life cycle phasess This comprehensive understanding of the building's design, construction, and materials is required. In practice, building LCAs are often simplified by using aggregated product data instead of detailed LCA calculations of individual processes. This is due to the time and resources required to conduct detailed LCA calculations for each building, which can be prohibitively high, may introduce errors and reduce comparability of results. Consequently, the use of aggregated data is a common practice in building LCA studies (Schneider-Marin et al., 2022).

Appendix B – The Interview Strategy (Dutch version)

Semi-gestructureerde interview set-up

**Opmerking: Interviewvragen kunnen variëren van persoon tot persoon en het kan voorkomen dat de vragen niet volgordelijk gesteld worden.*

Het afnemen van de interviews is gedaan bij drie verschillende afdelingen binnen Vesteda om meerdere perspectieven te krijgen voor het ontwikkelen van de LCC-tool. Dit resulteerde in drie verschillende vragensets.

Het interview bestaat uit drie delen.

A. Introductie
B. Interview vragen
C. Afsluiting

A.1 - Introductie onderzoek

Ik (Jesse Frackers) voer dit onderzoek uit als afstudeerder van de masteropleiding Construction Management & Engineering aan de TU Delft tijdens mijn afstudeerstage bij en in samenwerking met Vesteda. Het doel van dit onderzoek is om inzichten te vergaren voor het ontwikkelen en implementeren van een LCC-model als aanvulling op het investeringsbeslissingsproces van institutionele vastgoedbeleggers.

Het doel van dit gesprek is om te bespreken hoe het LCC-model past binnen het investeringsbeslissingsproces van Vesteda en hoe dit model kan bijdragen aan het verduurzamen van het vastgoedportfolio van Vesteda door te sturen op CO2 en materiaal gebonden emissies. Het model drukt de (extra) investeringskosten uit die nodig zijn voor duurzame ontwerpopties m.b.t. materiaal en biedt ook inzicht in de onderhouds- en exploitatiekosten die hiermee gepaard gaan. Bovendien kan het model inzicht geven in de milieu-impact van deze ontwerpopties waarmee dus een mogelijke milieu impact reductie gerealiseerd kan worden.

Verschillende vormen van Sustainable Investments zijn de afgelopen jaren snel gegroeid, nu een groeiend aantal institutionele beleggers en fondsen verschillende Environmental-, Social and Governance (ESG) factoren in hun beleggingsstrategieën opnemen. Hoewel er merkbare vooruitgang is geboekt, staan aanzienlijke uitdagingen een efficiënte mobilisatie van kapitaal ter ondersteuning van ESG- en klimaatgerelateerde doelstellingen in de weg. Er is dringend behoefte aan een betere vergelijkbaarheid van de methodologieën voor klimaattransitie, alsook aan transparantie en interpretatie van klimaatfinanciering en ESG-metriek voor verbeterde investeringsbeslissingen.

Met het LCC-model wordt er getracht helderheid te scheppen. Het LCC-model dient hier als kostenberekeningstool die rekening houdt met alle kosten die gepaard gaan met de hele levenscyclus van een vastgoedobject, vanaf de bouw tot en met de sloop. Door het gebruik van het LCC-model kunnen institutionele beleggers inzicht krijgen in de totale kosten van een investering, inclusief de kosten die verband houden met de impact op het milieu en duurzaamheid. Het ontwikkelen van een gestandaardiseerd LCC-model en het integreren van milieu-impactindicatoren moet hiermee een bijdrage leveren voor duurzame investeringsbeslissingen.

Het interview duurt +\- 1 uur en data zal gebruikt worden voor het ontwikkelen en implementeren van het LCC-tool dat geschikt is voor investeringsbeslissingen. U wordt gevraagd om tijdens het interview meerdere open vragen te beantwoorden en ik moedig u graag aan hierbij zoveel mogelijk te vertellen.

A.2 – Privacy en gegevens

Zoals bij elke onlineactiviteit is het risico van een databreuk aanwezig. Wij doen ons best om uw antwoorden vertrouwelijk te houden. Het interview zal tijdens de teamsvergadering worden opgenomen en getranscribeerd. Na afloop wordt aan de hand van deze opname de transcriptie verbeterd. De up-to-date transcriptie zal met u gedeeld worden ter controle, om het uitlekken van bedrijfsgevoelige informatie te voorkomen. Wanneer hier geen opmerkingen op zijn dan wordt de opname verwijderd en het transcript dusdanig gepseudonomiseerd wordt dat alleen de functie en het bedrijf wordt getoont. De niet anonieme data zal opgeslagen worden in aparte mappen in mijn persoonlijke OneDrive en zal zo snel mogelijk verwijderd worden. Vanuit de transcripten zullen quotes worden opgenomen in het rapport met functie en bedrijf, alleen wanneer dit van meerwaarde is. De transcripten worden als een bijlage bij mijn thesis opgeslagen bij de TU Delft voor visitatie doeleinden. Deze worden niet openbaar toegankelijk gemaakt, omdat ze geen onderdeel uitmaken van mijn publiek beschikbare thesis.

Uw deelname aan dit onderzoek is volledig vrijwillig, en u kunt zich elk moment terugtrekken zonder reden op te geven. U bent vrij om vragen niet te beantwoorden. *De data en informatie verzameld tijdens het interview, wordt verwijderd op de bewaartermijn zoals aangegeven in de wet AVG.*

<<start opname>>

Kunt u aangeven of u akkoord bent met het volgende:

- De dataverwerking.
- Dat het interview wordt opgenomen.

B. Interview vragen

Zoals eerder vermeld zijn de onderzoeksvragen afgestemd op de verschillende afdelingen. Dit resulteerde in een tweetal vragen lijsten.

B.1 Interviewvragen - Afdeling Acquisitie & Development

Deze interviewvragen refereren naar figuur 50.

1. Hoe bekend ben jij met duurzaamheid en de impact van de gebouwde omgeving op het milieu?

2. Zou je kunnen uitleggen hoe het investeringsbeslissingsproces stap voor stap werkt?

3. Hoe worden de duurzaamheidseisen gehandhaafd die er gesteld zijn in het ESG-framework en hoe gaan deze onderhandeling in zijn werk?

4. Hoe zou jij ervoor kunnen zorgen dat er zo vroeg mogelijk in het proces de juiste informatie omtrent duurzaamheid bemachtigt kan worden?

5. We denken dat het LCC model gedurende TDD2 fase ingevuld kan worden. Is dit de juiste fase van het Acquisitie proces? Kun je dit in het kort toelichten?

6. Wie dient het LCC model in te (kunnen) vullen? ADM of TADM? Kun je dit in het kort toelichten?

7. Tijdens het investeringsproces moet er slagvaardig gehandeld worden. Dat wil zeggen, dat de juist informatie op het juiste moment aanwezig moet zijn om beslissingen te kunnen nemen. Voorzie jij dat er genoeg tijd, en ruimte is om een LCC-model op te nemen in het investeringsbeslissingsproces?

8. Hoe kan het milieutechnische inzichtelijk maken van duurzaamheidsmaatregelen een bijdrage leveren aan betere investeringsbeslissingen?

9. Naast dat het LCC model inzicht biedt in de onderhoudskosten gedurende de levensduur, laat het ook zien welke potentiële milieu impact reductie het kan opleveren. Hoe zou deze milieu impact reductie gewaardeerd kunnen worden?

10. Het investeringsbeslissingsproces bestaat uit onderhandelingen met de partij die de proposities voorlegt, in welke mate houden zij zich bezig met duurzaamheid en dan specifiek milieu impact en valt hierover te onderhandelen?

11. Zou de milieu-impactreductie die voortvloeit uit duurzamere ontwerpopties (het gebruik van andere materialen) kunnen worden toegevoegd aan het programma van eisen en zouden zulke eisen dan gesteld kunnen worden aan ontwikkelaars?

12. Welke barrières voorzie jij, om duurzaamheid/milieu impact mee te nemen in investeringsbeslissingen?

13. Zie je de noodzaak van het creëren van een LCC-model? Zo ja/nee, waarom?

14. Wat hoop je uit het LCC model te kunnen halen?

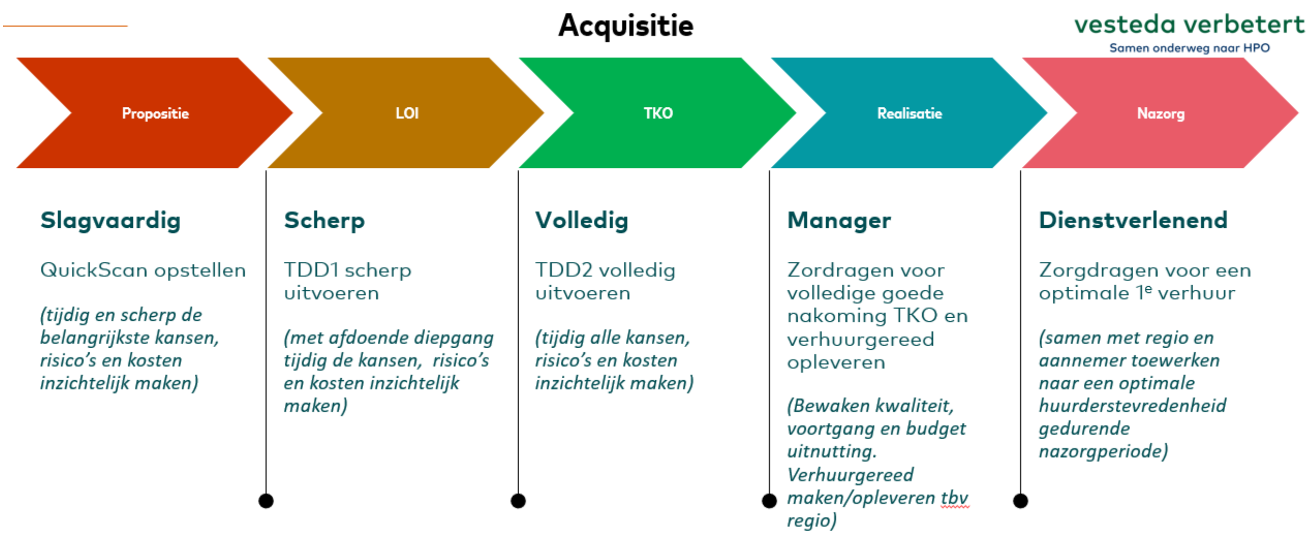

Figure 51 - Investeringsbeslissings -proces

B.2 Interviewvragen afdeling – Afdeling Portfolio strategy

1. Wat zijn de specifieke taken en verantwoordelijkheden van het Portfolio Strategy-team binnen Vesteda. En op gebied van duurzaamheid binnen Vesteda?

2. Wat is de ambitie van Vesteda met betrekking tot het inzichtelijk maken van duurzaamheidsmaatregelen voor het vastgoedportfolio?

3. Op welke manier heeft het Portfolio Strategy-team invloed op de investeringsbeslissingen binnen Vesteda?

4. Het businessplan van Vesteda stelt dat er wordt gestreefd naar out performance op lange termijn op zowel de inkomsten- als de kostenratio's en dat maatschappelijke waarde creatie, het ter beschikking stellen van betaalbare en duurzame huisvesting aan huishoudens met een middeninkomen betreft. Hoe kan volgens jou een LCC-model een bijdragen leveren aan deze maatschappelijke en economische waarde creatie?

5. Het doel van het LCC model is naast het inzichtelijk krijgen van mogelijke extra investeringen voor duurzamere ontwerp opties, ook inzicht te krijgen in het onderhoud en de exploitatie kosten gedurende de levensduur. Daarnaast moet het model het mogelijk maken om inzicht te krijgen in de milieu impact van verschillende ontwerpen opties van een gebouw. Hoe zou jij de afwegingsbeslissing maken tussen de milieu-impactreductie dat voortvloeit uit duurzamere ontwerpopties en mogelijke extra investeringen die ervoor nodig zijn?

6. Hoe zou deze afweging kunnen worden toegevoegd als KPI binnen het ESG-framework waaraan Vesteda zich houdt en heb je hier ideeën over?

7. Hoe gaan concurrerende bedrijven om met duurzaamheid en wordt er samengewerkt om duurzame doelen te behalen?

8. Momenteel worden de onderhoudskosten gebaseerd op kengetallen, 5,5%, 8%, 11% van de bruto huur inkomsten, weet jij waar deze getallen op gebaseerd zijn?

9. Zou het LCC-model kunnen worden gebruikt om gerichter te sturen op onderhouds- en exploitatiekosten? En zo ja, hoe zie je de mogelijke toepassing hiervan?

10. Kun je meer vertellen over hoe voorgaande duurzaamheidsmaatregelen zijn geïmplementeerd binnen Vesteda en of dit vanuit de eigen ambitie van Vesteda was of juist om te voldoen aan wet- en regelgeving?

11. Het volgende diagram beschrijft de begrote onderhoudskosten voor de aankomende tien jaar. Deze zijn nu onderverdeeld in deze categorieën. 'Overig' en 'duurzaamheid' zijn samen goed voor

47%. Zijn deze twee onderhoudsposten nog verder onder te verdelen en is dit inzichtelijk?

12. Hoe zou volgens jou het LCC model een bijdrage kunnen leveren in de onderhoudskeuzes die er gemaakt moeten?

13. Wat voor kansen maar ook barrières voorzie jij met de implementatie van een model als dit binnen Vesteda?

15. (Zou je mij meer kunnen vertellen over GRESB?)[21]

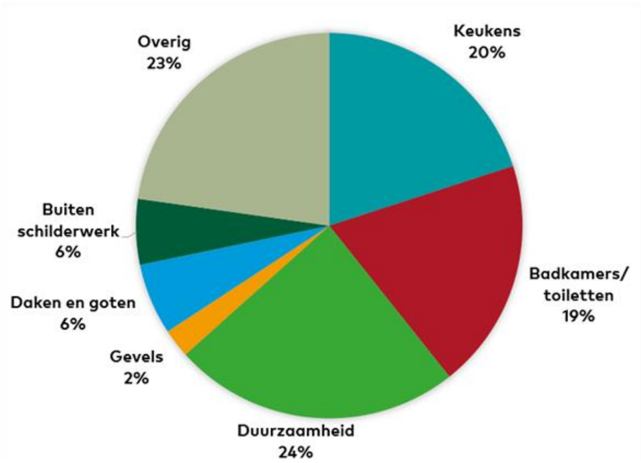

Figure 52 – Onderverdeling van begrote onderhoudskosten

C. Afsluiting

Na het stellen van alle interview vragen is er ruimte voor een open gesprek waarin de gelegenheid geboden wordt om op- of aanmerkingen te bespreken over het onderzoeksonderwerp/interviewinhoud.

"Bedankt voor uw tijd en mogelijkheid om het interview af te nemen bij u. Zoals ik in het begin heb aan gegeven zal ik de opnames transcriberen en met u delen. Met uw toestemming zal ik de opgedane inzichten verder verwerken in mijn onderzoek."

[21] Binnen de afdeling Portfolio Strategy zijn er verschillende rollen waaronder Portfolio Managers en de Programma Manager Duurzaamheid. De laatste vraag is specifiek voor de programma manager duurzaamheid.

Appendix C – ESG-framework Vesteda - SIS

ESG FRAMEWORK	Sustainability risk indicator	Strategy and due diligence	Sustainability Impact Score (SIS)	Potential mitigation	Reporting and monitoring
Climate	• Climate adaptivity • Biodiversity	• Resilience against physical climate risks (flooding, heat stress, groundwater flooding, wildfire and wooden pile rot) • Improve climate adaptivity • Increase biodiversity	• Climate Risk Score • Temperature exceeding and water retention measures • Biodiversity score • Green space per unit (green on roof or façade)	• Adjust positioning/orientation or design of the building • Apply a green roof for heat reduction and water retention • Green inner-courtyards and gardens to improve biodiversity	• Net climate adaptivity risk score • Tenant engagement/satisfaction • Biodiversity and ecosystem practices • Total sqm green surface per unit
Energy	• Energy emission and performance • Energy sources	• Reduce energy consumption • Stimulate sustainable energy • Reduce carbon footprint	• BENG 1 Energy need • BENG 2 Total energy use in KwH/sqm • BENG 3 production of renewable energy in % of total KwH	• Reduce energy use with extra (isolation) measures • Increase sustainable energy (for instance adding solar panels, LED) • Increase the use of renewable energy sources and exclude the use of natural gas	• Measure yearly energy use in KwH per sqm • % of sustainable energy of total KwH • GRESB score
Material and resources	• Water use • Durability and maintainability	• Minimise fresh water consumption • Sustainable usage of materials • Limit operate and maintenance costs	• # of water saving measures • Projected water consumption per unit per year • MPG score • GPR score environment and future value • Average % of yearly maintenance costs per sqm	• Water saving measures • Stimulate environmental friendly materials	• Water saving measures • % of expected water saving per unit per year • MPG score • GPR score • % of yearly maintenance costs in relation to 5 year average of recent acquisitions
Social	• Affordability • Social cohesion • Accessability	• Realise residential units for mid income households • Contribution to social cohesion and social wellbeing of tenants and liveable communities • Well accessible homes	• % of mid rental housing from total units • Of which regulated mid rental in % • # of social cohesion improving measures • Vesteda mobility score • GPR usage quality	• Allocate units for mid income households • Create high quality communal areas and entrances • Design barrier free access and apply ramps and electric doors	• Percentage of mid rental units on total portfolio • Tenant engagement/ satisfaction • Tenant turnover • GRESB
Health and wellbeing	• Temperature exceeding • Indoor air quality	• Comply with technical standard of Vesteda and building codes/ legislation/ planning permits	• Temperature exceedance score • Additional air quality measures	• Apply additional measures if necessary, such as extra air filters in ventilation systems or screens at the façade	• Tenant complaints/ satisfaction • WELL score • GRESB
	• Health and wellbeing employees and tenants		• Private or semi-private outdoor space in sqm per unit	• Design improvements or installation adjustments	
Governance	• Reputation • Compliance • Quality	• Screening of counterparty risks • KYC and customer due diligence • Internal and external audits • Contribution to ESG and social return of counterparties	• Satisfactory outcome CDD • Satisfactory outcome KYC • Audit score • ESG contribution and social return	• Exclude parties with reputational risks • Liaise with companies that have similar ESG standards • Responsible and well balanced decision making	• UN PRI benchmark • GRESB • Audit • Social return

Appendix D – Results of Building

Building element	
Vaste sanitaire voorzieningen	**31,8%**
Vaste keukenvoorzieningen	**21,3%**
Diversen	**14,1%**
Schilderwerk	**6,8%**
Dak	**6,2%**
Gevel	**5,9%**
Warmte-opwekking	**3,0%**
Transport; liften	**2,6%**
Binnenwand	**1,9%**
Luchtbehandeling	**1,3%**
Elektrotechnische Voorzieningen	**1,2%**
Terrein	**0,7%**
Beveiliging; brand	**0,6%**
Vloer binnen	**0,5%**
Drinkwater	**0,4%**
Communicatie; geluiden	**0,4%**
Algemene ruimten	**0,4%**
Verlichting	**0,3%**
Vloer buiten	**0,1%**
Plafondafwerking	**0,1%**
Afvoeren	**0,1%**
Storingsonderhoud	**0,1%**
Dienstverlening afnemers algemeen	**0,1%**
Interieur woning	**0,0%**
Koude-opwekking	**0,0%**
Trap en helling	**0,0%**
Losse keukeninventaris	**0,0%**
Technishe installaties	**0,0%**
Beveiliging; braak	**0,0%**
Beveiliging; overlast	**0,0%**
Regeling Klimaat en sanitair	**0,0%**
Gassen	**0,0%**
Vaste gebruikersvoorzieningen	**0,0%**
Wettelijke verplichtingen	**0,0%**
Klein planmatig onderhoud	**0,0%**

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