# Towards Sustainable Investments

**Integrating Embodied Carbon Reduction in Investment Decision-Making by Using a Discounted Cash Flow Model**

# Colophon

## Personal information

**Name:** Ruben Schmitz

**Student number:** 5470587

## Education

**Institution:** Delft University of Technology

**Faculty:** Architecture and the Built Environment

**Master:** Architecture, Urbanism & Building Sciences

**Master track:** Management in the Built Environment

**Scientific domains:** Housing quality and process innovation and Building Economics

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## Thesis supervisors

**1st mentor:** Prof.dr.ir. H.J. (Henk) Visscher
Professor Housing quality and process innovation

**2nd mentor:** Ir. E.H.M. (Ellen) Geurts
Course coordinator Building Economics

**Delegate of the board of examiners** Dr. A.J. (Aart) Oxenaar

## Graduation organization

**Company:** a.s.r real estate

**Supervisor:** MSc. P.J.C. (Patrick) de Baat

# Preface

In 2016, I started studying Built Environment at Avans University of Applied Sciences. During this bachelor's program, I learned the basics of the various facets of the Built Environment. It soon became clear that I wanted to learn more and continue my studies in management, which led me to apply for a master's program in Delft. After obtaining my pre-master's, I enthusiastically began the Master's in Management in the Built Environment at Delft University of Technology.

During my master's program and the internship I completed, I discovered a passion for two areas: real estate finance and engaging with new concepts. While searching for a topic, I was determined to combine these elements. After an inspiring lecture at Provada about the challenges of sustainability in the building and construction industry, specifically regarding embodied carbon and the associated uncertainties, my interest was piqued. It became immediately clear to me that I wanted to explore this from an investor's perspective. I realized how rewarding it would be to investigate this problem and how wonderful it would be to shed more light on it from the investors' perspective.

This research contributes to our understanding of how embodied carbon factors into the investment decision-making process. By studying how investment decisions have been made in projects with reduced embodied carbon, this should provide insight into the financial barriers and impacts of incorporating embodied carbon reduction strategies into the real estate investment decision-making process, ultimately stimulating large-scale reduction of embodied carbon in the building and construction industry.

I would like to extend my gratitude to my teachers, Henk Visscher and Ellen Geurts, for their invaluable guidance throughout the writing of my thesis. They were always ready and happy to answer my questions and offer helpful feedback. I am really thankful for their great guidance and support during this journey.

My thanks also go to my colleagues at a.s.r real estate, especially my thesis supervisor Patrick de Baat, for their guidance in the last six months. I appreciate everyone's willingness to engage in discussions about my topic and their critical insights on my presentation.

I would also like to thank the interviewees for their involvement in the interviews. Their valuable contributions were crucial in producing innovative outcomes for my research.

I hope you find pleasure in reading.

Ruben Schmitz

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# Abstract

To combat global warming, it is crucial to eliminate $CO_2$ emissions by 2050, especially since a third of global emissions are attributed to the building and construction industry. This sector's carbon footprint comprises operational emissions from daily activities and embodied carbon throughout a building's lifecycle. However, as buildings become more energy-efficient, embodied carbon increasingly dominates total emissions. In the Netherlands, few residential projects align with the Dutch Climate Agreement's. This is due to various challenges hindering large-scale carbon reduction efforts, with financial barriers being a prominent issue. However, limited research focuses on financial barriers from the perspective of investors, often lacking in-depth analysis and offering few practical solutions for these challenges. Recognizing the need for carbon reduction, the industry must adopt a new approach to investment decisions, prioritizing embodied carbon considerations. This study delves into these financial barriers and how strategies to reduce embodied carbon impact real estate investment decision-making, focusing on the traditional Discounted Cash Flow (DCF) model. Therefore the main research question is:

***"In what way does reducing embodied carbon in residential building projects impact the investment decision-making process from an investor's perspective?"***

To explore this, the study first conducts a literature review and exploratory interviews, followed by three case studies with semi-structured interviews. The findings reveals that the integration of embodied carbon in the investment decision-making process is still in its early stages. Although there is growing awareness and interest, embodied carbon is not yet a standard consideration in investment decisions. This integration depends on the flexibility of investors and the specific sustainability goals of projects. Traditional financial models and evaluation methods have largely remained unchanged. The study concludes that there is a need for further standardization and integration of carbon reduction in all aspects of investment practices to encourage the construction sector to achieve the goal of carbon net-zero by 2050.



**Key words:** Embodied carbon, Reduction strategies, Real estate investment decision-making, Investors, Discounted Cash Flow (DCF) model, Investment risks

# Executive summary

## Introduction

With global warming accelerating due to high $CO_2$ emissions worldwide, the urgency to eliminate $CO_2$ emissions by 2050. This target is not just critical but also mandated by the European Green Deal and the Dutch Climate Agreement. This is particularly relevant given that a third of global emissions are attributed to the building and construction industry. In this sector, carbon emissions comprise both operational emissions from daily activities and embodied carbon throughout the lifecycle of a building. As buildings become more energy-efficient, the significance of embodied carbon in total emissions grows. Despite this, in the Netherlands, few residential projects fully align with the Dutch Climate Agreement, largely due to various challenges that impede large-scale carbon reduction, including significant financial barriers. Yet, research into these financial barriers, especially from the investors' perspective, remains limited, often lacking depth and practical solutions.

Recognizing the vital need for carbon reduction, the industry must pivot towards a new approach in investment decision-making, one that gives higher priority to embodied carbon considerations. This study aims to explore these financial barriers and examine how strategies to reduce embodied carbon influence real estate investment decision-making, with a particular focus on the traditional discounted cash flow (DCF) model. Consequently, the primary research question of this study is:

***"In what way does reducing embodied carbon in residential building projects impact the investment decision-making process from an investor's perspective?"***

To answer the main question, five sub-questions have been formulated:

1. What is embodied carbon and how can this be quantified?
2. What are the current and expected future regulations regarding embodied carbon in building projects and which regulations could have impact on investment decision-making?
3. What strategies can be used to reduce the embodied carbon within a building project and how are these applied in current practice?
4. To what extent is (the reduction of) embodied carbon part of the investment decision-making process in the current practice?
5. What adjustments do investors make to the Discounted Cash Flow (DCF) parameters to reflect embodied carbon reduction strategies?

## Research method

This research followed an empirical research methodology and was conducted through qualitative research, which can be divided into three parts.

In the first part, a literature study was conducted on four concepts: embodied carbon and how to reduce it, regulations around embodied carbon, the investment decision-making process, and the DCF model. This led to an initial literature framework. Additionally, in part 1, exploratory interviews were conducted. These interviews tested, validated, and enhanced the findings from the literature with practical insights concerning reduction strategies and parameters influencing the DCF, resulting in an improved literature framework.

Subsequently, in part 2, empirical research was conducted, which included three case studies where embodied carbon reduction was a focus. These case studies were "Jonas" with investor Amvest, "Timberhouse" with investor Coltavast, and "SAWA" with investor Focus on Impact. Information was collected through semi-structured interviews to understand how investors typically navigate their investment decision-making process, how they adapted this process in the case studies, whether embodied carbon is still a consideration in their current investment decisions, which reduction strategies were applied, and the impact of these strategies on the DCF parameters. Additionally, the findings from these case studies were compared in a multiple case analysis to identify any common patterns.

Finally, in part 3, a discussion was formed by comparing all the results obtained from the literature study, exploratory interviews, and case studies. After that, a conclusion was drawn.

## Literature findings and validating it by a practical approach

### Embodied carbon

In this thesis, the concept of embodied carbon can be described as all the emissions of a carbon footprint of building's over its whole life, which are emissions that occurring during various phases of a building's life cycle, including raw material extraction, transportation, manufacturing, construction, maintenance and repair demolish, and beyond the buildings life cycle. Whereby embodied carbon van be quantified by the use of a life-cycle assessment (LCA). LCA is a tool to evaluate the environmental impacts associated with a product throughout its entire life cycle, including various stages

### Regulations

Then there are regulations regarding embodied carbon, which are divided into two main categories: environmental and sustainable finance regulations. Beginning with environmental regulations, initiatives like the European Green Deal and Dutch Climate Agreements have established future targets for reducing embodied carbon. Integral to this effort is the Environmental Performance Building (MPG) calculation, which promotes the use of sustainable materials by incorporating a Life Cycle Assessment (LCA) calculation. The upcoming Energy Performance of Buildings Directive IV (EPBD IV) will mandate a Global Warming Potential (GWP) calculation, further emphasizing the importance of sustainable building practices. On the sustainable finance front, the current SFDR (Sustainable Finance Disclosure Regulation) and the forthcoming CSRD (Corporate Sustainability Reporting Directive) establish guidelines for integrating sustainability into investors' reporting. Lastly, the EU taxonomy plays a crucial role in defining what is considered sustainable, providing a clear framework for both environmental and financial regulatory efforts.

### Embodied carbon reduction strategies

Based on the literature, 13 operational measures have been identified for reducing embodied carbon. Additionally, two more operational measures were identified from exploratory interviews. These 15 operational measures led to the development of the following five embodied carbon reduction strategies: the use of low-carbon materials, material reduction, materials reuse and recycling, local sourcing of materials and components, and construction optimization.

### Investment decision-making

Farragher & Kleiman (1996) and Farragher and Savage (2008) have identified seven key steps in an investor's decision-making process during investment. This process begins with setting a strategy, followed by establishing return and risk objectives. After calculating, the next step involves evaluating the cash flow. This is followed by an assessment of the risks involved with the investment. Based on these identified risks, adjustments are made to the cash flow. Once these adjustments are in place, the accepted proposals are implemented. The final step involves monitoring the assumptions made in the early stages during the use phase.

### Discounted Cash Flow model

Within the investment process, conducting an evaluation of the investment is crucial to determine what an investor can pay or the expected return. One of the most commonly used methods in investment decision-making is the DCF model.

The DCF approach calculates the present value of a property, primarily based on the holding period (HP), cash flow (CF), terminal value (TV), and the required internal rate of return (Req IRR). The holding period is the time investors expect to retain the investment. The parameters for the holding period mainly depend on the country where the investment is located, market conditions, and the type of investment. Investors then calculate future cash flows over the holding period by deducting expenses-related parameters from income revenue-related parameters. Whereby the used parameters differ if a loan is involved. Subsequently, the terminal value is determined, which represents the estimated value of the building at the end of the holding period. This can be done in two ways: either by using a predetermined yield percentage or based on the building's vacancy value.

These figures are then discounted back to their present value using a suitable discount rate or the required IRR. This rate is a reflection of the relationship between the investment's risk profile and the required return to mitigate that risk. It is determined by parameters based on market conditions, tenant-related aspects, and building-specific features like accessibility or sustainability.

After discounting the future cash flows to their present value, the sum is calculated. This leads to the valuation of the investment at a certain required IRR, indicating the initial investment value (IIV) of the building and land. This represents what an investor can pay at the present, denoted as t=0, where 't' stands for time.

## Investment decision-making in embodied carbon reduction projects

### Impact and incorporation of embodied carbon in investment decision making process

In the Jonas case study, all steps were utilized. However, the reduction of embodied carbon has had almost no impact on the execution of these steps. Nevertheless, there is growing interest in embodied carbon within Amvest. Completing an ESG (Environmental, Social, and Governance) impact framework for each new project is mandatory, where embodied carbon is taken into account. Additionally, ongoing discussions about adjustments needed to incorporate embodied carbon suggest that it might become a standard consideration in the future. In Timberhouse, the reduction of embodied carbon negatively impacted several steps. Beside that embodied carbon will not be included in future projects unless mandated by regulations. Lastly, in the SAWA, the impacts of reducing embodied carbon were mixed, both positive and negative. However, it is noticeable that efforts to reduce embodied carbon, especially with an aim to build more timber projects, are almost always or semi-consistently included.

### Applied reduction strategies

As demonstrated in the case studies, all cases show a pattern of using wood as a low-carbon material. In each study, there was a preference to incorporate wood as much as possible from the project's initial phase to reduce $CO_2$ emissions, with a focus on construction as the most important aspect. All the wood used is FSC-certified and sourced from Europe, resulting in relatively low transport distances compared to sourcing from outside Europe.

Furthermore, a trend in material minimization and reduction strategies is observed, where both Jonas and SAWA use the operational measure of minimal installations, employing natural ventilation systems such as type C. At Jonas, the structural and façade designs are optimized. Additionally, more sustainable alternative materials are utilized within Jonas and SAWA. Waste reduction in Jonas and transport optimization in both Jonas and Timberhouse are also addressed during construction. This is achieved by monitoring and minimizing energy and water use, reducing packaging materials, and using a construction hub and ticket systems to coordinate transport movements.

Finally, off-site manufacturing, including the use of prefabricated elements and modular units, is implemented in all case studies, with Timberhouse using modular units made in a fully automated factory.

### Impact of applied reduction strategies on the DCF parameters

In Jonas's, all the applied reduction strategies had no noticeable impact on the DCF parameters, either due to minimal effects or because of a turn-key agreement placing responsibility on the developer or contractor. For Timberhouse, the use of wood and modular units influenced cash flow both positively and negatively. However, the use of modular units also negatively impacted the terminal value. SAWA saw a more significant effect from the applied reduction strategies on DCF parameters. Similar to Timberhouse, wood usage had mixed effects on cash flow. Yet, in SAWA's case, wood positively influenced both the terminal value and the required IRR. Additionally, the use of prefabricated elements in SAWA positively impacted construction time.

## Discussion & Limitations

### Discussion

In discussing the new findings, it becomes clear that findings both support and contradict existing literature. One key finding that aligns with current knowledge in literature is the observation of higher initial property values for buildings that incorporate wood in their main structures and façades.

However, the findings contradict also some things from the existing literature. Notably, when wood is utilized within the main structure and façade, operational expenses tend to be higher. This increase in costs is primarily attributed to investors applying a higher risk premium, driven by a lack of experience and uncertainty regarding the long-term use of wood. Furthermore, contrary to some expectations, the research indicates that reducing embodied carbon does not necessarily lead to a higher vacancy rate. This trend is attributed to current market dynamics, where there is strong demand for rental properties.

Additionally, rental prices do not increase when embodied carbon is reduced in a building, mainly because tenants are not willing to pay more if they do not directly benefit financially from the reduction of embodied carbon.

Another surprising revelation from the findings is that buildings with reduced embodied carbon do not necessarily achieve a higher terminal value. This is because the market has yet to reflect a 'brown discount' or a 'green premium', and as such, appraisers do not currently take embodied carbon into account during valuation. Lastly, it's noted that the reduction of embodied carbon does not often lower the required IRR, suggesting that it does not significantly impact investment decisions.

In terms of new insights, it's concluded that the majority of strategies aimed at reducing embodied carbon have minimal impact on the parameters of the DCF model. This minimal impact is mainly because these strategies are often more relevant to contractors or developers rather than investors, especially in projects carried out through turnkey agreements. Additionally, the associated costs and risks of these strategies might be so small that they do not significantly influence the decision-making process of investors and are therefore often overlooked. However, this generalization does not apply to all strategies. Notable exceptions to the general trend include reduction strategies that involve the use of low-carbon materials, such as biobased materials, and construction optimization through off-site manufacturing. These strategies have both negative and positive impacts on the DCF parameters.

Starting with the negative impacts, the use of modular units results in a lower Gross Leasable Area (GLA)/Net Leasable Area (NLA) ratio, which means less NLA is available. This reduction in leasable space can subsequently lead to lower cash flow and terminal value when compared to a traditional project.

On the positive side, the use of wood in construction has several beneficial impacts. One of these is the potential sale of carbon credits, which can help offset the higher initial property value. However, it remains unclear who holds the responsibility for these carbon credits and is therefore entitled to the resultant additional income. Additionally, utilizing wood can lead to discounted interest rates on loans, providing a financial incentive for its use. Furthermore, employing modular units or prefabricated materials can significantly reduce construction time. This not only leads to a lower initial property value but could also imply a reduction in risk. Although this particular benefit was not observed in the study.

**Limitations**

The research under consideration is subject to a few potential limitations that might have impacted its findings. The first limitation pertains to the number of case studies analyzed and the number of investors interviewed. The limited scope in both these areas could have influenced the outcomes of the research. The second limitation involves the context of the case studies. Notably, the DCF calculations were conducted 4 to 7 years ago, a period during which market conditions, including interest rates and material costs, were significantly different from the present. Additionally, the case studies were not confined to a single city, introducing geographic variability into the data. Another point of consideration is the diversity of investors involved in the case studies. The research did not focus on a uniform type of investor; instead, it included one institutional investor and two private investors, each with considerable differences in their operations. Lastly, it is crucial to recognize that the research was conducted within the Dutch context, which might limit the applicability of its findings to other regions or markets.

## Conclusion & Recommendations

In summary, this research explored the financial barriers and the integration of embodied carbon into real estate investment decision-making using the traditional DCF model. It seeks to guide and promote a carbon net-zero built environment by 2050. This is done by giving an answer to the main research question:

*"In what way does reducing embodied carbon in residential building projects impact the investment decision-making process from an investor's perspective?"*

While awareness is increasing, the consideration of embodied carbon in the investment decision-making process is not yet a standard. The influence of reducing embodied carbon differs across various stages, and as of now, it tends to be predominantly negative. The degree to which it is integrated and its impact vary based on the investor's profile. Institutional investors face more direct effects from financial mandates and extensive regulations, potentially restricting their ability to reduce embodied carbon in projects. On the other hand, private investors may demonstrate greater flexibility, allowing for more embodied carbon reduction on an individual project level.

Regarding the impact of reducing embodied carbon on the DCF parameters, it's found that the reduction of embodied carbon doesn't significantly impact or factor into these parameters. Although various strategies with operational measures to reduce embodied carbon are applied, they almost have no effect on the DCF model's parameters. The adjustments made to the DCF parameters when implementing these reduction strategies are minimal. However, the use of bio-based materials and off-site manufacturing does lead to changes in the DCF parameters, both positive and negative.

In summary, incorporating embodied carbon reduction into investment decision-making is still in its early stages. The real impact of this integration depends on how flexible investors are, the specific sustainability objectives of the projects, and the degree to which investors can adapt existing models and create new ones. This effort is supported by regulations and an increasing demand for sustainable investments. However, it still needs more standardization and broader incorporation into every facet of investment practices.

### Recommendation for practice

To accelerate the reduction of embodied carbon in the building industry, investors and stakeholders need to improve knowledge sharing on its impact in investment decisions. Transparent communication about uncertainties, including costs, returns, and risks, is essential for mutual learning and avoiding redundant risk premiums.

Secondly, Institutional investors should engage in dialogues with shareholders to balance sustainability progress with fund return requirements. This may include reevaluating DCF parameters, such as lowering the required IRR or adopting different approaches to terminal value and benchmarks.

Another important aspect involves appraisers, who need to integrate sustainability more comprehensively into their real estate valuations, moving beyond reliance solely on historical data.

Additionally, the way embodied carbon is quantified requires refinement. The MPG calculation should differentiate between materials like concrete and wood. Moreover, direct steering with the PPm should be implemented. Therefore, Dutch regulations should not only use MPG but also incorporate PPm to effectively reduce $CO_2$ emissions.

The final recommendation is to increase incentives for reducing embodied carbon. While private investors currently have the flexibility to modify traditional models, but there are not enough incentives for them to standardize this practice. Enhanced government and market incentives, like subsidies, loan discounts, or carbon credit simulations, are crucial. However, to truly achieve large-scale reduction, government action are important, possibly through stricter regulations or the implementation of $CO_2$ pricing such as a carbon tax.

### Recommendations for further research

Firstly, since this research is primarily based on three case studies that do not reflect current market conditions, follow-up research is necessary to assess the impact of these insights on the current market. This could involve conducting case studies in the present market context, using a larger sample size, and potentially focusing on retail or office markets, or even extending the research to different countries. Additionally, further in-depth research could focus on how reducing embodied carbon affects specific themes of the DCF model.

Secondly, research could be conducted on how appraisers can incorporate sustainability into their evaluations. This includes exploring how appraisers can adopt a more future-oriented approach, rather than solely looking backward.

Thirdly, research should be conducted on how the process of reducing embodied carbon can be accelerated. This can involves examining what is needed from both the government and market parties.

Fourthly, research could be undertaken on the influence of carbon tax, carbon credits and carbon pricing on the investment decision-making process.

Lastly, research could be conducted on the relationship between a Paris Proof certificate and investment decision-making. Whereby it is also important to establish a standard definition of what constitutes a “Paris Proof” building.

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# List of abbreviations

| | |
|---|---|
| BREEAM | Building Research Establishment Environmental Assessment Methodology |
| CAPEX | Capital expenditures |
| CBS | Central Bureau for Statistics - Centraal Bureau voor de Statistiek |
| CF | Cashflow |
| CLT | Cross-Laminated Timber |
| $CO_2$ | Carbon dioxide |
| COP21 | the 21st Conference of the Paris |
| CSRD | Corporate Sustainability Reporting Directive |
| DCF | Discounted Cash Flow |
| DGBC | Dutch Green Building Council |
| ECI | Environmental Cost Indicator |
| EGI | Effective gross income |
| EPBD IV | Energy Performance of Buildings Directive IV |
| ESG | Environmental, Social and Governance |
| ETS | Emission Trading Systems |
| EU | European Union |
| FSC Certified | The Forest Stewardship Council Certified |
| G5 | The 5 Metropolitan cities of the Netherlands |
| GEY | Gross Exit Yield |
| GFA | Gross Floor Area |
| GHG | Greenhouse Gas |
| GIY | Gross Initial Yield |
| GWP | Global Warming Potential |
| HP | Holding Period |
| IRR | Required Internal Rate of Return |
| LCA | Life-Cycle Assessment |
| LTV | Loan To Value ratio |
| MIM | Environmental Impact Monitor |
| MPG | Environmental Performance of Buildings - Milieu Prestatie Gebouw |
| NFRD | Non-Financial Reporting Directive |
| NLA | Net Lettable Area |
| NOI | Net Operating Income |
| NPV | Net Present Value |
| PGI | Potential gross income |
| PPm | Paris Proof embodied carbon indicator - Paris Proof Materiaalgebonden indicator |
| PvE | Program of Requirements - Programma van Eisen |
| SFDR | Sustainable Finance Disclosure Regulation |
| SQ | Sub-questions |
| t=0 | Time at present |
| t=n | A specific time in the future |
| TV | Terminal Value |

# Chapter 1

## Introduction

Research context

Problem statement

Research aim and questions

Research relevance

Research guide

# 1 Introduction

## 1.1 Research context

### 1.1.1 Embodied carbon

According to the Intergovernmental Panel on Climate Change (IPCC, 2019), the climate change's current and projected impacts have spurred a critical need to reduce carbon emissions. The increase in the average global temperature must be kept below 2°C and, ideally, restricted to 1.5°C above pre-industrial levels to prevent catastrophic climate consequences. In order to achieve this goal, binding agreements were made at the COP21 conference in Paris to guarantee that in 2030, a 45% reduction in $CO_2$ emissions is expected and that all carbon emissions worldwide will be zeroed out by the year 2050 (IPCC, 2019). Also, the Dutch government has looked at COP21 and established ambitions for reducing carbon emissions, primarily outlined in the Dutch Climate Agreement (Klimaatakkoord). The main objective of the Dutch Climate Agreement is to reduce $CO_2$ emissions by 55% by 2030 compared to 1990 levels. By 2050, the goal is to be completely climate-neutral (Rijksoverheid, 2023).

To gain a comprehensive understanding of how to reduce $CO_2$ emissions, it is important to understand a building's carbon footprint over its lifespan. The carbon footprint of a building, which is also called the whole-life carbon emission of a building, consists of two categories (Röck et al., 2020). Firstly, the operational emissions, which result from the energy consumed during the day-to-day operations of a building (e.g., heating, cooling, and powering a building). The second aspect pertains to the embodied carbon that arises during various phases of a building's lifecycle, including raw material extraction, transportation, manufacturing, construction, maintenance, and end-of-life phase (Keyhani et al., 2023).

Numerous researchers have concluded that it is already possible to realize net zero buildings or even zero operational carbon buildings (Salem et al., 2020; Salem et al., 2020b; Construction Leadership Council, 2019). However, different studies show that embodied carbon will become more important in the built environment in the future. Firstly, in 2020, operational carbon accounts for up to 67% of emissions from a typical residential building, while embodied carbon accounts for 33% of emissions. However, in the case of highly energy-efficient buildings, operational carbon can be as low as 23%, with embodied carbon accounting for 77% of emissions (Keyhani et al. 2023). Heisel et al. (2022) reached a similar conclusion, stating that over the next decade, the majority, 70%, of carbon emissions related to new building construction will stem from embodied carbon. This is primarily due to technological advancements and innovations in energy efficiency, resulting in embodied carbon in buildings making a growing and more substantial contribution to carbon emissions (Ibn-Mohammed et al., 2013; Röck et al., 2020).

### 1.1.2 Investment decision-making

Investment decision-making is a critical process where individuals, financial managers, or investors choose how and where to allocate resources for the medium or long term. The primary objective is to cover investment costs and achieve significant profits (Avram et al., 2009). Making well-informed investment decisions can lead to increased returns and reduced risks, while poor choices may result in financial losses. Therefore, a solid understanding of the fundamental principles of the investment decision-making process and its execution is crucial for maximizing the value derived from the evaluation process, as emphasized by Virlics (2013). To explain this process, Farragher & Kleiman (1996) and Farragher and Savage (2008) identified 7 key steps that an investor follows, starting from strategy setting to the final stage of post-auditing the performance of the operating investment. This comprehensive journey, capturing the essence of effective investment decision-making, is detailed in these steps, which is illustrated in Figure 1.

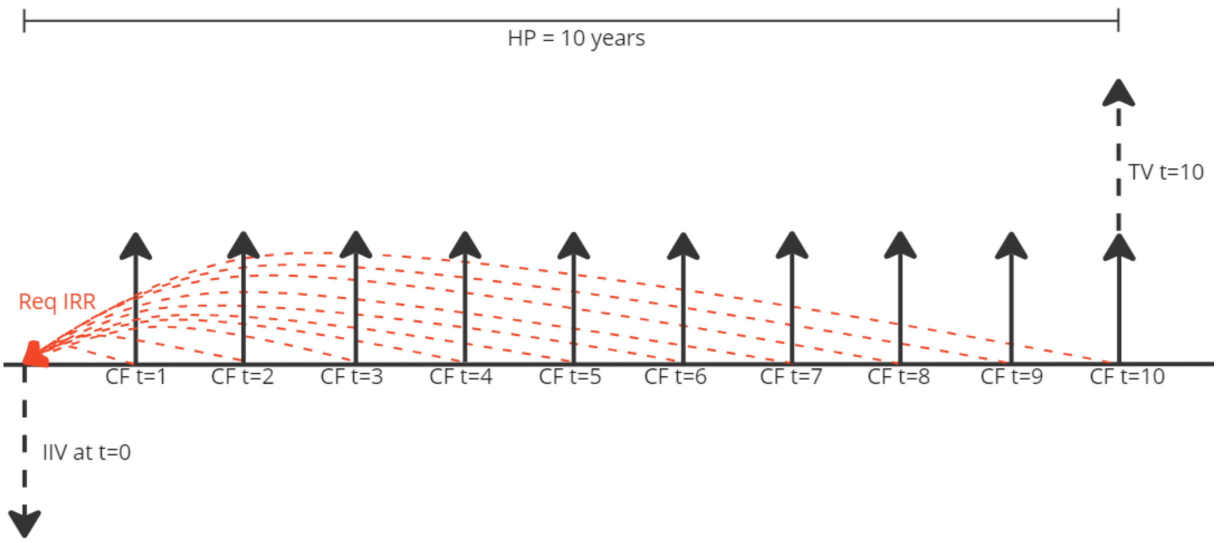

*Figure 1 - Investment decision-making process (Farragher & Kleiman, 1996; Farragher & Savage, 2008)*

Expanding on this framework, the investment valuation process necessitates that the chosen indicators must align with the specific characteristics of the project and the information available to the decision-maker (Avram et al., 2009). Such an approach demands an in-depth analysis of the investment project, which aligns with the three primary valuation methods in property investment: the comparison, income, and cost approaches (Archer & Ling, 2017). The most widely favored approach in investment decision-making is the Discounted Cash Flow (DCF) model, which falls under the income approach (Archer & Ling, 2017; Jones & Trevillion, 2022). Farragher et al. (1994) concluded that in 1993, 70% of all investors were using the DFC model to some extent, and Liapis et al. (2011) projected that this number has likely increased since then. This preference for the DCF model is rooted in financial theory, which suggests that forecasted cash flows should be assessed using methodologies that consider their amount, timing, profitability, and investment recovery potential - elements comprehensively incorporated within the DCF techniques (Farragher & Savage, 2008).

At the same time, the DCF method is also suitable for adjusting it to sustainability measures. The Royal Institution of Chartered Surveyors (2011) suggests that the DCF method may reflect sustainability issues in property valuation quicker such as for example other methods. Furthermore, it is the only approach that considers value attributes that are not yet evident in the market but may become significant in the future. Additionally, adjusting individual valuation parameters directly is the most transparent way to incorporate sustainability considerations into property valuation (Lorenz & Lützkendorf, 2011).

The DCF method is a widely accepted approach for valuing securities, projects, firms, or assets by considering the time value of money. It is considered robust and compatible with the traditional two-dimensional risk-return structure of investment appraisal, making it suitable for various valuations (Moro-Visconti, 2020). The DCF method involves determining the present value of an asset, primarily influenced by factors like the holding period (HP), cashflow (CF), terminal value (TV), and the required internal rate of return (Req IRR). The approach is based on the holding period, which is the period of time investors expect to hold the investment. The sum of its future cash flows (income revenue minus expenses) and determining the terminal value, which represents the calculated value of the building at the end of the holding period. These values are then discounted back to their present value using an appropriate required IRR (RICD, 2018).

The required IRR signifies the relationship between an investment's risk profile and the expected return. The applied required IRR is the return the investor seeks on their invested capital, adjusted according to the specific risk profile of the investment, which means a higher-risk investment demands a correspondingly higher IRR to mitigate that risk. Once the future cash flows are discounted to present value, the total is computed, resulting in the valuation of the investment at a specific required IRR. This valuation represents the initial investment value (IIV) at the present moment (t=0), accounting for future cash flows, risk profile, and desired returns. By customizing the parameters to match a project's characteristics, the project's value is determined (Leskinen et al., 2020).




**Legend**:
Holding Period (HP) = period of time investors expect to hold the investment.
Cashflow (CF) = income revenue minus expenses.
Terminal Value (TV) = value of the building at the end of the holding period.
Required Internal Rate of Return (Req IRR) = discount rate to calculate the future cash flows to the present value.
Initial Investment Value (IIV) = sum of the total discounted cash flows and terminal value.

*Figure 2 - Explanation of Discounted Cash Flow (DCF) model (own illustration)*

### 1.1.3 Financial Mechanisms regarding embodied carbon

Recently, various means, incentives, or methods have been developed to reduce embodied carbon within a project. One such method is carbon pricing, which can be done through selling carbon (carbon credits) or setting a price on carbon (carbon tax). Additionally, it is possible to purchase carbon offsets through carbon offsetting.

Carbon pricing

Carbon pricing serves as a pivotal policy instrument employed by both governments and corporations to advance their climate aspirations (The World Bank, 2022a). By imposing a price on greenhouse gas (GHG) emissions, this approach introduces a financial incentive to curtail emissions or enhance their removal from the atmosphere. The realm of carbon pricing mechanisms can be done by the use of direct pricing mechanisms such as carbon credits based on the Emission Trading Systems (ETSs) and carbon taxes.

Carbon credits function as follows: when certain materials are used within a building, such as biobased materials, biological carbon sequestration can occur, meaning that $CO_2$ is captured and stored, and thus is not emitted. At present, for every ton of $CO_2$ sequestered, one can receive a carbon credit. These credits can then be traded on the ETS (Climate Clean Up, 2021). Within the framework of an ETS, entities involved in emissions-intensive activities trade emission units to meet their allocated emission targets (The World Bank, 2022b). Achieving emission targets within an ETS is possible through cost-effective internal emissions reduction measures or by buying emission units in the carbon market, depending on their relative costs (The World Bank, 2022b). The ETS thus establishes a market-driven price for greenhouse gas emissions by creating a market for these emission units. This is illustrated in Figure 3.

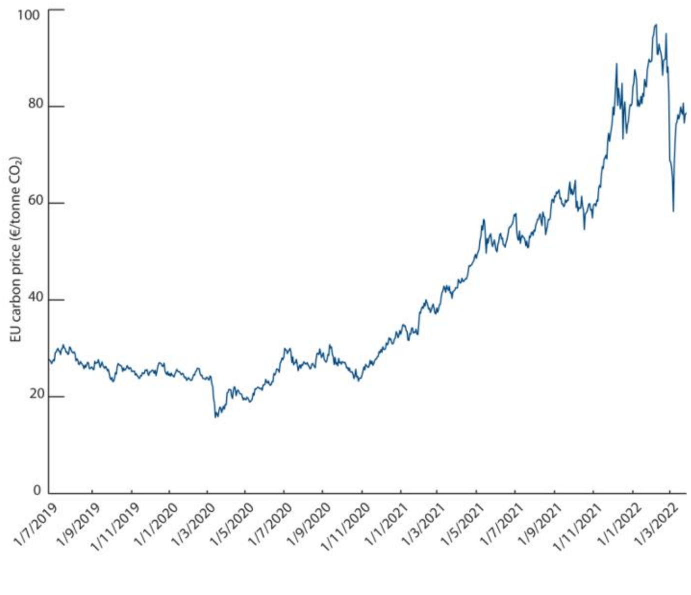



*Figure 3 - Carbon price development within Emissions Trading System (The World Bank, 2022)*

In contrast, a carbon tax represents a policy tool through which governments levy a fee on greenhouse gas (GHG) emissions, offering a financial incentive to reduce emissions (The World Bank, 2022). Under this mechanism, the market determines whether it is more economical to reduce emissions or pay the tax, depending on the government-defined price (The World Bank, 2022).

Carbon offsetting

Carbon offsetting, as explained by Marinucci (2023), is a method for balancing an organization's GHG emissions by initiating activities that reduce or remove an equivalent amount of GHG emissions elsewhere. This approach is often used when emissions cannot be feasibly or cost-effectively eliminated with current technologies. Offsetting typically involves a carbon credit exchange system or a carbon market, as explain above. (UKDGB, 2021). These credits are transferred from entities that achieve emission reductions to those who retire them to offset their own emissions (UKDGB, 2021; Broekhoff et al., 2019). After emission reductions are validated, the associated carbon credits are retired and removed from circulation (Broekhoff et al., 2019).

### 1.1.4 Dutch housing market

In recent years, the Dutch housing market has undergone significant changes. After hitting a low point in house prices in 2013, there was a remarkable surge in 2022, with January 2023 prices 93% higher than in 2013, averaging €424,681. This price increase is partly due to a supply-demand mismatch, resulting in a housing shortage since 2021. With 307,000 home seekers and 98,000 first-time buyers, the total demand reached 402,000 houses, expected to grow until 2024. However, the available housing stock fell short at only 90,000 homes, resulting in a shortage of 315,000 homes (Ministry of the Interior and Kingdom Relations, 2021).

To address this shortage, Dutch Minister of Housing and Spatial Planning, Hugo de Jonge, initiated an ambitious plan to construct 900,000 new dwellings by 2030, requiring an annual construction rate of around 128,000 new homes (RVO, 2022). Unfortunately, the actual number of dwellings constructed in 2021 and 2022 fell significantly short, with 71,000 and 73,000 homes built, respectively. Additionally, the total construction of residential real estate is projected to decrease by 1.5% in 2023 and 2% in 2024, primarily due to increased construction costs and sustainability challenges (EIB, 2023; Raad van State, 2022).

The Dutch housing market can be broadly categorized into three ownership groups. In 2022, 57.1% of houses were owner-occupied, 28.6% were owned by housing corporations with regulated rents, and 14.1% were owned by private landlords or real estate investors (CBS, 2023b). Over the past decade, private rental houses increased by 2.6%. The trend of developing more houses for the private rental sector is evident in the number of licensed building permits in 2022, with 47% allocated to rental houses and 53% to owner-occupied houses (CBS, 2023c).

As the rate of price increase in owner-occupied housing slows down (CBS, 2023a), investors seek to sell their properties to capitalize on surplus value. New regulations affecting mid-rental properties are expected to reduce profitability from 2024 onwards, leading private investors to show interest in selling rental properties on the owner-occupied market. This, coupled with rising interest rates and high construction costs, has increased the supply of houses to the market. However, a significant demand-supply gap is anticipated in the owner-occupied sector from 2023 to 2027.

## 1.2 Problem statement

The construction and building industry worldwide accounts for 37% all $CO_2$ emissions, as shown in Figure 4 (UNEP, 2022). Which is almost equivalent to the Netherlands, where the construction and building industries account for 38% of total $CO_2$ emissions of which 27% are operational emissions, and 11% are material-related emissions (DGBC, 2021). This finding highlights the crucial role that the building and construction sector plays in contributing to global carbon emissions and underscores the urgent need for mitigation efforts in this sector (Nadoushani & Akbarnezhad, 2015).

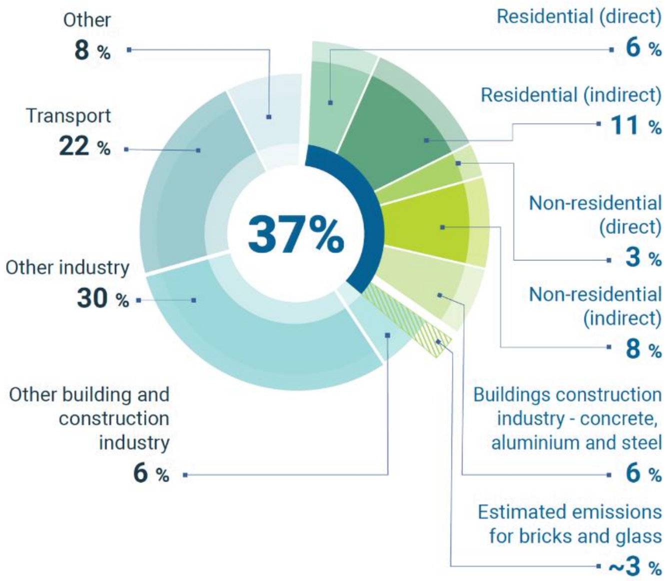



*Figure 4 - Global buildings and construction $CO_2$ emissions in 2021 (UNEP, 2022)*

Currently, in the Netherlands, there are hardly any residential projects that meet the embodied carbon emissions requirements to fulfill the goals set by the Dutch Climate Agreement. This is because there are problems related to this. Several studies have investigated the barriers and challenges preventing large-scale carbon reduction in the construction and building industry (Ohene et al., 2022; Rootzén et al., 2020; Heffernan et al., 2015; Pan & Pan, 2021; Godin et al., 2021). These studies have identified multiple barriers, with the most frequently mentioned ones being legislative, cultural, technical, market-related, geographical, and financial barriers. According to Ohene et al. (2022), financial barriers are the most commonly cited obstacles to reducing carbon emissions in new buildings. They define these financial barriers as those related to the investments required for adopting and implementing net-zero building strategies.

One of the limitations with existing research on carbon reduction and its financial barriers is that it is primarily done from the construction or architectural perspective (Davies & Osmani, 2011; Pan & Pan, 2021; Heffernan et al., 2015; Singh et al., 2019). Nevertheless, only limited research focuses on financial barriers from the perspective of an developer/investor. When such studies are conducted, they often lack depth and fail to provide sufficient solutions about the financial barriers (Glass et al., 2008; Ohene et al., 2022; Shurrab et al., 2019). Simultaneously, there is still market misunderstanding over what short-term actions to take, how to build mid- to long-term decarbonisation routes, and how to demonstrate progress toward specified objectives from the perspective of an investor (WorldGBC, 2023).

In the realm of real estate investment, decision-making processes have remained largely unaltered since 1996, with investors prioritizing financial gains such as return on investment, internal rate of return, or cash-on-cash rate of return (Farragher & Savage, 2008). While this traditional approach has served the industry well for decades, the emergent need for carbon reduction in the construction and building sector calls for a renewed perspective on investment decisions, particularly regarding embodied carbon. There is however a lack of understanding on how to assess also these renewed perspectives into risk assessment and financial modelling such as the traditional DCF method (or model). And lastly different studies have been conducted to understand the impact of sustainable improvements on the DCF model. Studies have examined the effects of green building certification (Leskinen et al., 2020), sustainability in general (Meins & Sager, 2015), and the impact of circular and sharing economies (Moro-Visconti, 2020). However, no research has been conducted concerning the impact of reducing embodied carbon on the investment decision-making process and therefore the financial implications on the DCF model.

## 1.3 Research aim and questions

Following this problem statement, the aim of this research is to understand and address the challenges and implications of reducing embodied carbon emissions in the construction and building industry, from the perspective of financial and investment decision-making processes. The research seeks to explore the financial barriers and impacts of incorporating embodied carbon reduction strategies into real estate investment decision-making process by using the traditional DCF model. This includes examining how considerations of embodied carbon can be integrated into the DCF model and understanding the potential financial implications of these considerations on the overall investment decision-making process. Ultimately, it seeks to contribute to guidance and stimulate the built environment towards achieving carbon net-zero by 2050, by aligning financial models and the investment decision-making process with this goal. Therefore, the main research question that will be addressed in this research is:

***"In what way does reducing embodied carbon in residential building projects impact the investment decision-making process from an investor's perspective?"***

Several sub-questions have been developed to address the main question. These will enhance our understanding of the subject, allowing for a comprehensive answer to the main question by integrating the insights obtained from these sub-questions, as depicted in Figure 5.

1. What is embodied carbon and how can this be quantified?
2. What are the current and expected future regulations regarding embodied carbon in building projects and which regulations could have impact on investment decision-making?
3. What strategies can be used to reduce the embodied carbon within a building project and how are these applied in current practice?
4. To what extent is (the reduction of) embodied carbon part of the investment decision-making process in the current practice?
5. What adjustments do investors make to the Discounted Cash Flow (DCF) parameters to reflect embodied carbon reduction strategies?

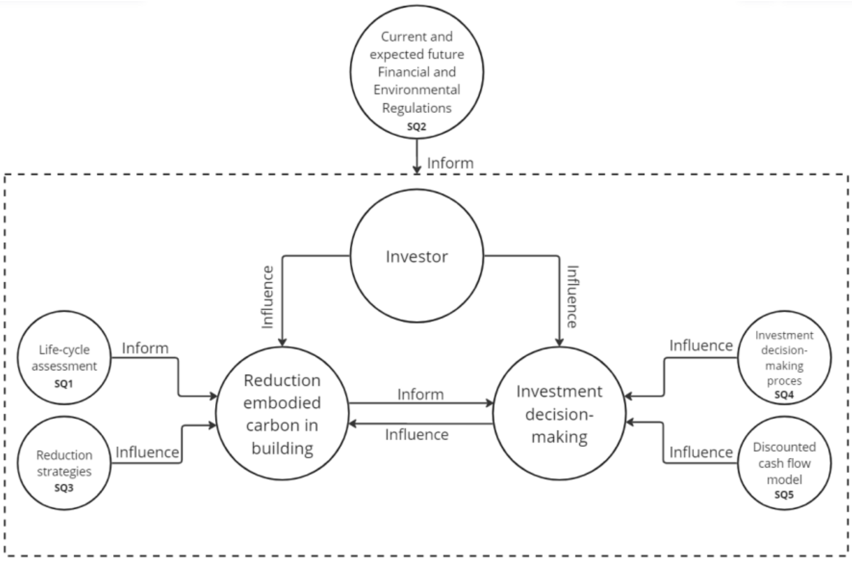



*Figure 5 - Conceptual framework (own illustration)*

## 1.4 Research relevance

### 1.4.1 Scientific relevance

This research addresses a critical aspect of climate change mitigation in the construction and building industry, which is a major contributor to global carbon emissions. With a shift in focus from operational to embodied carbon emissions, due to advancements in energy efficiency, there is a growing need to understand the financial implications of this shift. This study bridges the knowledge gap by exploring how reducing embodied carbon affects investment decision-making process of in investor, specifically through the lens of the DCF model. It examines the evolving Dutch housing market and the challenges posed by current and future regulations on embodied carbon. The research aims to provide insights into sustainable investment strategies and influence the approaches of investors. The ultimate goal is to align the strategies within the investment decision-making process with public sustainability goals, thereby steering the built environment towards net-zero carbon emissions by 2050.

### 1.4.2 Societal relevance

Building on the scientific insights presented in Section 1.4.1: Scientific relevance, the societal significance of this research lies in its potential to guide the reduction of carbon emissions in the building and construction sector. Lucky, there is a growing trend in the financial markets to invest in projects and companies that ensure the achievement of environmental goals (GFANZ, 2021; WorldGBC, 2023). However, to meet the COP21 goals, Europe is expected to need between €175 to €290 billion in additional annual investment over the coming decades, requiring both private capital and public funding (European Commission, 2019). This highlights the need for a comprehensive business case for sustainability in the real estate market to achieve net-zero emissions at the sectoral and global levels by 2050 (GFANZ, 2021; WorldGBC, 2022). As Adams et al. (2017) have noted, the most critical enabler of implementing sustainability in the real estate industry is a clear business case. Therefore, the primary objective of this research is to provide clear, actionable insights into the integration of embodied carbon considerations into investment decision-making processes, offering transparency and guidance to empower investors to make more informed, environmentally-conscious decisions.

## 1.5 Reading guide

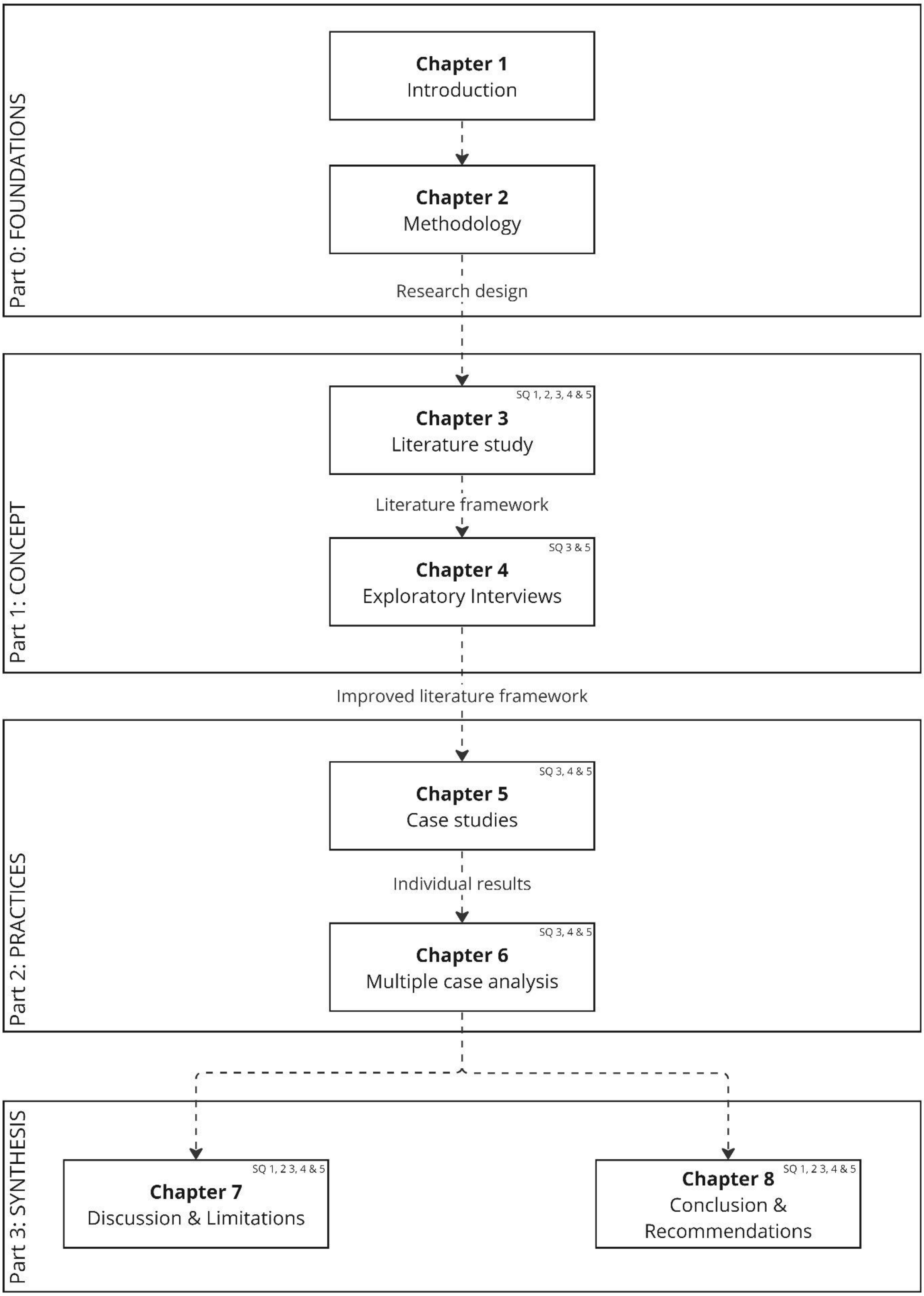



*Figure 6 - Research guide (own illustration)*

# Chapter 2

## Research method

Type of study

Research design

Data collection & selection criteria

Data analysis

Data management plan

Ethical considerations

# 2 Research method

In this chapter, the research methodology utilized in this study is presented and justified. Initially, an explanation is provided regarding the type of study conducted. Subsequently, the research design and the methods employed for data collection and analysis are discussed. The chapter concludes with a description of the data plan and ethical considerations that were taken into account during the research process

## 2.1 Type of study

In this research, both deductive and inductive approaches were used. Within part 1, the deductive approach was initially used to establish a literature framework (Figure 18) based on existing theories and concepts related to embodied carbon's influence on investment decision-making, as outlined in Chapter 3: Literature study. Exploratory interviews then validated and enhanced this framework with data from the practice. Following this deductive phase, an inductive approach was employed in part 2 to explore emerging insights and patterns from the case study data, generating new concepts to improve the understanding of how reducing embodied carbon affects investment decisions. In part 3, all the information from the literature study, exploratory interviews, and case studies were combined to develop new insights.

Additionally, in this research, qualitative methods were applied to answer the research question and sub-questions. The aim is to explore and gain initial insights into the impact of incorporating embodied carbon reduction into the real estate investment decision-making process using the traditional DCF model. Given the exploratory nature of the study, stemming from the aim of this research, qualitative methods were chosen.

## 2.2 Research design

This section outlines the research design, which is depicted in Figure 7. The figure illustrates the relationships between the sub-questions, research methods, and techniques to be employed.

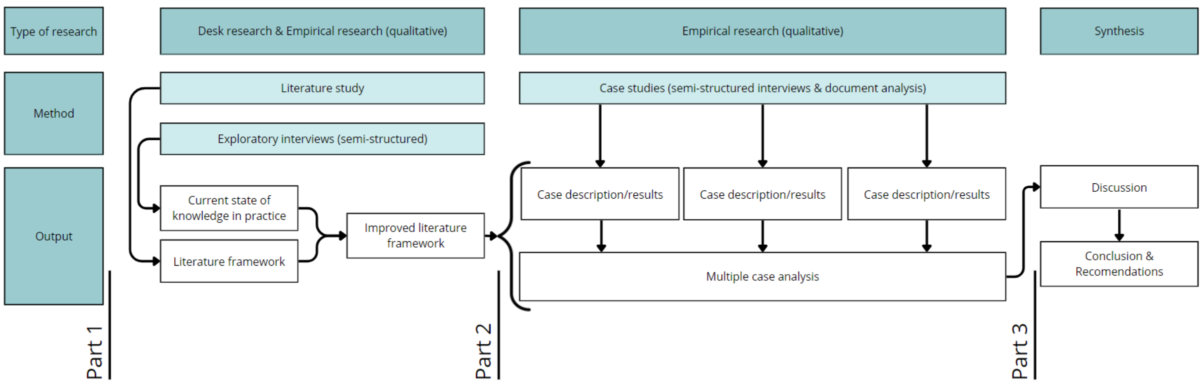



*Figure 7 - Research design (own illustration)*

### 2.2.1 Part 1: Desk research & Empirical research

Desk research: Literature study

In this part of the study, research was conducted on existing literature aimed at answering, sub-question 1: *"What is embodied carbon and how can it be quantified?"* and sub-question 2: *" What are the current and expected future regulations regarding embodied carbon in building projects and which regulations could have impact on investment decision-making?"*

Additionally, the literature study ensured the establishment of a foundational understanding of the current state of knowledge in these areas. To address sub-question 3, a self-constructed framework based on various literature sources was utilized. This framework encompasses five reduction strategies and their corresponding operational measures (Figure 12). Additionally, the frameworks by Farragher & Kleiman (1996) and Farragher and Savage (2008), which outline the investment decision-making process in seven steps, were employed to answer sub-question 4. Lastly, through an analysis of diverse literature, parameters that are used in the DCF model were identified and subsequently organized into an overview, which can be seen in Table 5. These frameworks and models were instrumental in examining case studies and in the development of interview designs. This entire process culminated in the creation of a literature framework, forming the bedrock of this research. Which resulted in the identification of four key concepts: embodied carbon, regulations around embodied carbon, the investment decision-making process, and the DFC model, which are all detailed in Chapter 3: Literature study.

Empirical research: Exploratory interviews

The second part of part 1 consisted of exploratory interviews conducted through semi-structured methods. Building upon the information gathered from the literature study, architects, appraisers, and investment acquisition manager were interviewed. These exploratory interviews aimed to lay the groundwork for subsequent research phases, focusing primarily on investment decision-making in the Netherlands. They intended to establish initial insights and bridge the gap between theory and practice.

Within this context, the initial literature framework underwent scrutiny and evaluation to identify any potential gaps. This process involved testing the framework of the embodied carbon reduction strategies (as illustrated in Figure 12) and reviewing all parameters in the DCF model (shown in Table 5), which helped in addressing sub-questions 3 and 5. It included examining the reduction strategies by exploring additional potential design strategies and devising methods to make them operationally measurable. Regarding the DCF model's framework, the process involved examining whether the identified parameters are utilized in practice and identifying any that were missing. This resulted in an updated version of the literature framework.

### 2.2.2 Part 2: Empirical research: Case studies

The second part of the research was conducted using case studies. Case studies are a research method that involves in-depth investigation of a specific phenomenon or individual unit, focusing on understanding developmental factors in relation to the environment. According to Yin (2009), the emphasis is on using existing theory as a foundation for case study research, which enables the exploration of potential deviations. This design entails the individual analysis of multiple cases and the implementation of a multiple case analysis to identify mechanisms, enhance causal relationships, and generate generalizable statements, thereby enhancing the validity of the research.

By employing a multiple-case study design, differences and similarities between cases can be understood, providing insights within specific situations and across different contexts. Based on the information obtained from part 1, the information can be tested on case studies.

The first aim of the case studies was to provide in-depth information primarily to answer sub-question 3: *"What strategies can be used to reduce the embodied carbon within a building project and how are these applied in current practice?”*. By utilizing the self-developed framework mentioned in the 'Empirical research: Exploratory interviews' section, semi-structured interviews were conducted with the architects and developers involved in these case studies. This approach enabled the identification and mapping of the reduction strategies and operational measures employed within them.

Subsequently, semi-structured interviews were conducted with the acquisition managers involved in the case studies to answer sub-question 4: *"To what extent is (the reduction of) embodied carbon part of the investment decision-making process in current practice?"* and sub-question 5: *“What adjustments do investors make to the Discounted Cash Flow (DCF) parameters to reflect embodied carbon reduction strategies?”.* Regarding sub-question 5, this approach utilized the framework of the 7 steps outlined by Farragher & Kleiman (1996) and Farragher and Savage (2008). The process began by first mapping the general investment decision-making process that investors go through, followed by an analysis of how this process was executed in the case studies to investigate differences when embodied carbon is reduced. Finally, inquiries were made about how embodied carbon is currently considered within the investment decision-making process.

Additionally, once it was established which reduction strategies and operational measures had been used within the case study, research was conducted to assess the impact of the implemented embodied carbon reduction strategies on the DCF parameters. This was anticipated to influence investment decision-making, providing answers to sub-question 5.

### 2.2.3 Part 3: Synthesis

The final part of the research is the synthesis, in which all the information obtained from the literature study, exploratory interviews, and case study was combined. In this section, the results of the empirical research were compared with the current literature study, with the aim of gaining new insights and providing answers to the main question of this research: *“In what way does reducing embodied carbon in residential building projects impact the investment decision-making process from an investor's perspective?”*

## 2.3 Data collection & selection criteria

The data collection process in both exploratory interviews and case studies was guided by the literature framework. Semi-structured interviews were employed for all types of interviews, allowing for a focused exploration of specific topics within qualitative research. In addition to interviews, documentation played a crucial role in the case studies, serving as primary sources of evidence for the case study database. This combination of interviews and documentation enhanced the comprehensiveness and reliability of the research findings.

### 2.3.1 Part 1: Desk research & Empirical research

The exploratory interviews were selected using purposive sampling. As mentioned above, the purpose of these interviews was to gain initial insights and understanding of current practices regarding reduction strategies for sub-question 3 and DCF parameters for sub-question 5, and to test the literature framework by examining various factors. Regarding the reduction strategies, interviews were conducted with individuals who had direct experience with reducing embodied carbon in a project. Concerning the DCF parameters, the aim was to determine whether the parameters were generally complete; therefore, these exploratory interviews sought to engage with individuals actively involved with the DCF model in practice. A sufficient number of interviews were conducted until confirmation was received that the coverage was complete. The number of interviews held can be seen in Table 1. Additionally, general exploratory interviews were conducted concerning regulations carbon pricing for sub-question 1 and around regulations around embodied carbon for sub-question 2.

*Table 1 - Data collection and selection criteria for desk research & exploratory interviews*

| Method | Sampling | Criteria Interviewees | Who | Amount | Referred as | Questions |
|---|---|---|---|---|---|---|
| Literature study | - | - | - | - | - | SQ-1<br>SQ-2<br>SQ-3<br>SQ-4<br>SQ-5 |
| Exploratory interviews (semi-structured) | Purposive sampling | Experience: With carbon pricing | Researcher from an investment company | 1 person | Interview E-1 | SQ-1 |
| Exploratory interviews (semi-structured) | Purposive sampling | Experience: With regulations around embodied carbon | Law experts | 2 persons | Interview E-2<br>Interview E-3 | SQ-2 |
| Exploratory interviews (semi-structured) | Purposive sampling | Experience: Experience lowering embodied carbon | Architects<br>Sustainable advisor | 1 person<br>1 person | Interview E-4<br>Interview E-5 | SQ-3 |
| Exploratory interviews (semi-structured) | Purposive sampling | Company: Related to real estate investment decision-making<br>Sector: Residential<br>Expertise: Market specialist investment management, finance modelling | Acquisition manager<br>Appraisers | 1 person<br>2 persons | Interview E-6<br>Interview E-7<br>Interview E-8 | SQ-5 |

### 2.3.2 Part 2: Empirical research (case studies)

Regarding the data collection and selection criteria within the case studies, given the exploratory nature of the research, the limited existing knowledge in the market, and the scarcity of projects with low embodied carbon, the focus of the criteria for the case studies was primarily on the availability of projects. Consequently, it was less crucial for all the case studies to be exactly the same, which led to the establishment of both hard and soft selection criteria that the case studies had to meet. These criteria can be found in Table 2.

*Table 2 - Data collection and selection criteria for case studies*

| Method | Amount | Sampling | Selection criteria case studies | Questions |
|---|---|---|---|---|
| Empirical research (case studies) | 3 | Purposive sampling | **Hard Selection criteria**<br>General: Early involvement of an Investors<br>General: finance modelling and risk assessment have been conducted<br>Building specifications: Residential building<br>(4 to 10 layers)<br>Design: multiple reduction strategies have been applied<br>**Soft Selection criteria**<br>Location: Randstad<br>Purchased: Same year | SQ-3<br>SQ-4<br>SQ-5 |

Due to the aforementioned factors, a purposive sampling method was used, through which three different case studies were identified: Jonas, Timberhouse, and SAWA. All these case studies met the hard selection criteria, were located in the Randstad area, and two of the case studies were purchased in the same year. Within these case studies, all interviews were conducted using semi-structured interviews. Details about who was interviewed in each case study can be found in Table 3.

*Table 3 - Data collection and selection criteria for interviews case studies*

| Case studies | Method | Sampling | Who or what | Referred as | Questions |
|---|---|---|---|---|---|
| Jonas | Semi-structured interviews | Purposive sampling | Architects<br>Developer<br>Acquisition managers | Interview J-A<br>Interview J-D<br>Interview J-AM | SQ-3<br>SQ-4<br>SQ-5 |
| Timberhouse | Semi-structured interviews | Purposive sampling | Architects/Developer<br>Acquisition managers | Interview T-A & D<br>Interview T-AM | SQ-3<br>SQ-4<br>SQ-5 |
| SAWA | Semi-structured interviews | Purposive sampling | Architects/Developer<br>Acquisition managers | Interview S-A & D<br>Interview S-AM | SQ-3<br>SQ-4<br>SQ-5 |

## 2.4 Data analysis

Regarding all interviews in the research, both exploratory and those from the case studies, ATLAS.TI was used. Coding was mainly developed based on the framework. For sub-question 3, the coding was constructed based on the five embodied carbon reduction strategies; for sub-question 4, the 7 steps; and for sub-question 5, the four main themes of the DCF model: holding period, cash flow, terminal value, and required IRR.

After all interviews were analyzed and the results were clear, a multiple case analysis was conducted. The results of the three case studies were compared side by side using two main techniques for analysis. The first technique was pattern matching, which involved comparing an empirically based pattern with a predicted one. The second technique was explanation building, aimed at providing insights and explanations for the investigated phenomenon.

Due to the lack of a sophisticated decision-making framework, explanation building served as an appropriate approach to analyze this concept. Thematic coding, utilizing a combination of inductive and deductive codes, was applied to code all the interviews. A detailed protocol outlining the coding process can be found.

## 2.5 Data management plan

The data management plan (DMP) for this research project is developed using the TU Delft DMPonline platform, which can be found Appendix I. The DMP outlines the procedures for data collection, documentation, and storage throughout the research, as well as the plans for data sharing after the completion of the project. Furthermore, the document outlines the plan for sharing the data after the research. While developing the DMP, it became evident that there was a significant likelihood of using confidential data. To address this, data under embargo were securely stored in the project storage at TU Delft.

## 2.6 Ethical considerations

All participants in the research were invited to participate voluntarily, and their informed consent was obtained before recording any information. See Appendix II for the informed consent form that is used. They received comprehensive information about the research's purpose and objectives. Since the study involved the examination of internal financial documents containing confidential and sensitive information, utmost care was taken in handling these documents. The information was used anonymously. The researcher maintained independence, honesty, and criticality throughout the study. Despite the research being conducted within a graduation company, the outcomes were not influenced or biased by this affiliation.

# Chapter 3
## Literature study

Embodied carbon

Regulation

Investment decision-making

DCF-model

# 3. Literature study

In this chapter, the literature review is discussed. Its aim is to provide answers to sub-questions 1 and 2 while establishing a theoretical background for sub-questions 3, 4 and 5. The literature study is divided into four concepts: embodied carbon in Subchapter 3.1 addressing sub-questions 1 and 3, regulations in Subchapter 3.2 covering sub-question 2, investment decision-making in Subchapter 3.3 related to sub-question 4, and the DCF model in Subchapter 3.4 pertinent to sub-question 5. These concepts have been examined with the goal of establishing a foundation for the research. This leads to the development of a literature framework for use in empirical research, detailed in Subchapter 3.5.

## 3.1 Embodied carbon

### 3.1.1 Quantifying the embodied carbon values

Embodied carbon ($kgCO_2e$) refers to the carbon emissions that arises during various phases of a building's lifecycle, including raw material extraction, transportation, manufacturing, construction, maintenance, replacement and end-of-life phase (Keyhani et al., 2023). Which can be calculated by:

$$\textit{Material Quantity (kg)} \times \textit{Carbon Factor } (kgCO_2e/kg) = \textit{Embodied Carbon } (kgCO_2e)$$

To measure the emissions a life-cycle assessment (LCA) is a tool that can be used to evaluate the environmental impacts associated with a product throughout its entire life cycle, which includes both indirect and direct carbon emissions of the associated activities (Trovato et al., 2020; Mohebbi et al., 2021; Weinfeld et al., 2023). The LCA is defined by the International Organization for Standardization in ISO14040 'as the compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle' (European Commision, n.d.). At this moment, according to Amiri et al. (2021) and Weinfeld et al., (2023), the LCA is the most sophisticated and well-established method that can be used to evaluate buildings' environmental implications.

During the LCA process, various stages and modules are defined by EN 15978, which helps in describing its environmental impact. The life cycle of a building is divided into five different stages: product stage [A1-A3], construction stage [A4-A5], use stage [B1-B5], and end-of-life stage [C1-C3] (Gibbons & Orr, 2020). These stages are visually represented in Figure 8.

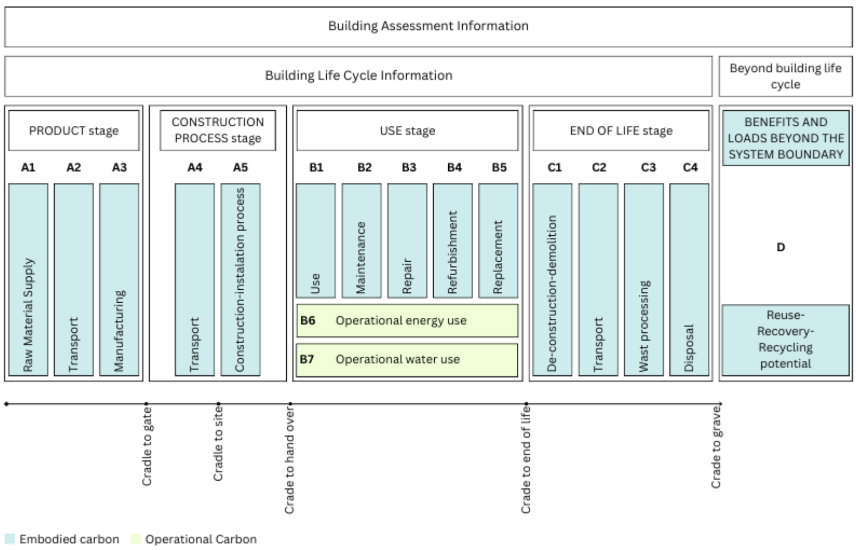



*Figure 8 - Life-cycle stages from BS EN 15978:2011 (Gibbons & Orr, 2020; NEN, 2011)*

Which modules should be incorporated within the LCA is determined by the system boundary, which is also stated in the ISO 14044 (2006). An important aspect within the system boundary is that it should stay consistent with the goal of the study (Rashid & Yusoff, 2015). Within calculating the LCA, there are many possible ways set the system boundary. However, Gibbons & Orr (2020) identified two primary system boundaries: embodied carbon over the building's life cycle, encompassing carbon emissions associated with modules A1–A5, B1–B5, and C1–C4; and upfront embodied carbon, also known as embodied carbon to practical completion, which refers to modules A1–A5.

However, each phase of a building's life cycle has a different magnitude of environmental impacts. Rasmussen et al. (2018) investigated a large body of LCA studied, but concentrated on the allocation of embodied carbon throughout the different phases. The authors concluded that the majority of the embodied carbon emissions come from the product stage [A1-A3], which is around 64%. Röck et al. (2020), concluded the same, but added that the maintenance and replacement [B2 & B5] and end-of-life stages [C3+C4] are also important, but their share in the overall environmental impact is considerably lower than the product stage.

### 3.1.2 Embodied carbon over the building layers

Before discussing the reduction strategies, it is important to understand the different layers of a building and how much embodied carbon is produced over the layers. Brand (1994) conceptualizes a building as a composite of elements referred to as S-layers, which collectively form the structure. His principles are underpinned by the varying lifespans of these construction elements and products. The carbon footprint of these building layers is intrinsically linked to their anticipated durability. Figure 9 provides a visual representation illustrating the five distinct layers as outlined by Brand (1994).

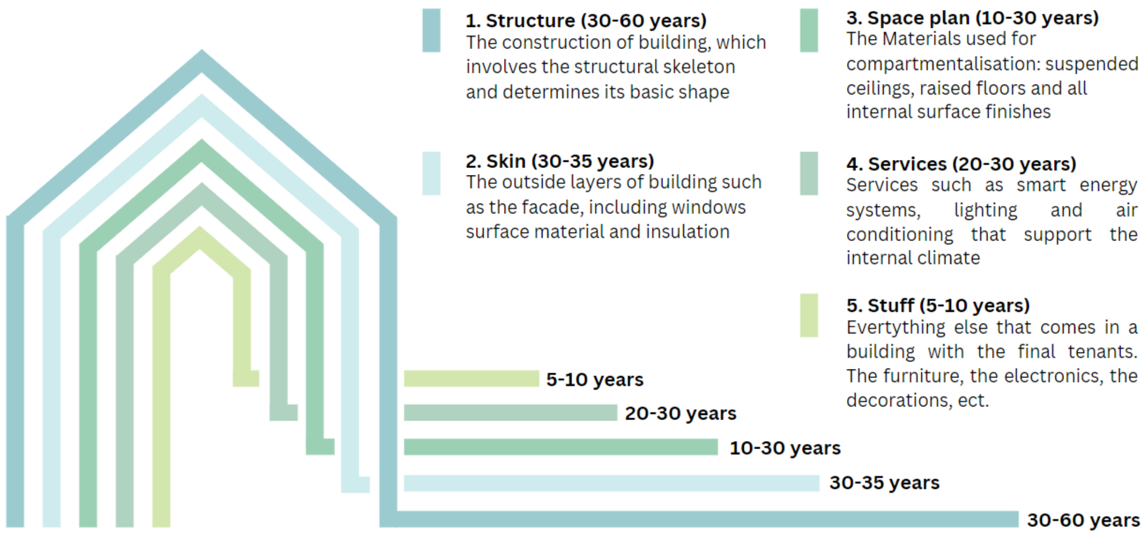



*Figure 9 - Distribution of the S-layers by Brand (1994) (Arup & wbcsd (2023)*

Arup & wbcsd (2023) conducted research on the amount of embodied carbon emissions using S-layers of Brand (1994). They distinguished between upfront carbon [A1-A5] and the use and end-of-life phases [B1-C4]. The results of this study are presented in Figure 10. From the data presented, it becomes evident that during the upfront phase, the structural aspects hold the utmost significance. However, during the use and end-of-life phases, the focus shifts towards services, encompassing both structural components and the services sectr in an integrated approach.

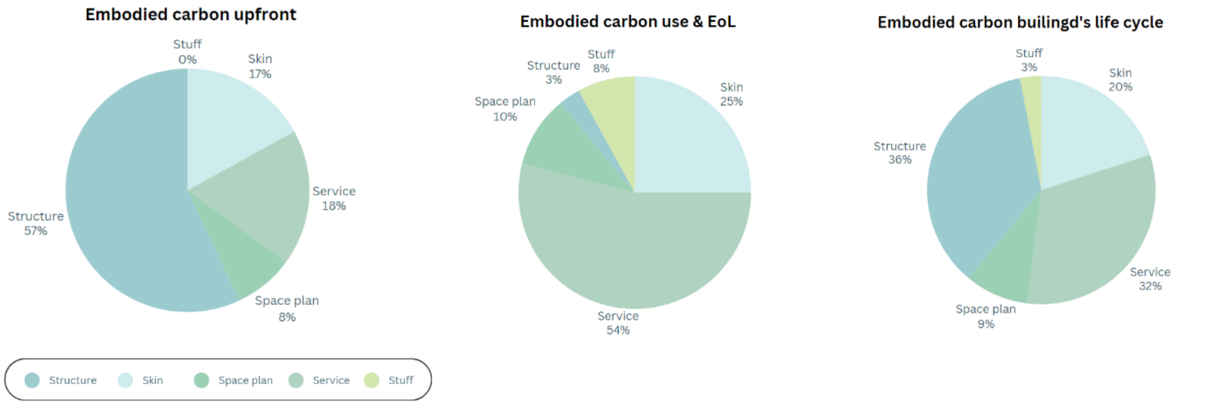



*Figure 10 - Percentage of embodied carbon emissions within the S-layers by Brand (1994) (Arup & wbcsd (2023)*

### 3.1.3 Embodied carbon in Dutch practice

Environmental Performance Building (MPG)

The first method for quantifying embodied carbon is through the use of the Environmental Performance of Buildings (Milieuprestatie Gebouw, MPG). The MPG is a crucial indicator of a building's sustainability and its environmental impact across the lifecycle of a building unit, with a focus on material composition. To promote the use of sustainable materials in construction, the Dutch government implemented the MPG, which will be further elaborated in Section 3.2.1: Environmental regulations. It is calculated by summing up the environmental impact of all materials used throughout the building's lifespan and then dividing this total by the gross floor area (GFA) allocated for residential and office purposes. The GFA is measured in square meters according to NEN2580 standards (Stichting Nationale Milieudatabase, 2020a).

$$MPG = (ECI \times amount) / (GFA \times lifespan) \quad [1]$$

$$€ / m^2 / year = (€ / (m^2, m \text{ or } \#) \times (m^2, m \text{ or } \#)) / (m^2 \times year) \quad [2]$$

When calculating the MPG, the environmental impact of a specific material is determined using the Environmental Cost Indicator (ECI), known as the 'Milieukostenindicator' (MKI) in Dutch. The ECI measures the overall environmental costs associated with a material's complete lifecycle, encompassing production, transportation, usage, and disposal (Quist, 2023). Sustainable materials, such as recycled, renewable, and biobased resources, generally exhibit lower environmental costs due to reduced energy consumption, decreased emissions, and minimized waste generation (Stichting Nationale Milieudatabase, 2020b). For each environmental impact, these estimates encompass the expected social costs that society would bear if the impact were to be prevented, in addition to the existing conventional solutions. Considering all environmental effects, the ECI is calculated as the shadow cost of that material, expressed in € per unit (commonly measured in square meters, meters, or quantities). A lower ECI value indicates that the material has a lesser environmental impact.

Paris Proof Material-related Indicator (PPm)

The MPG not only considers embodied carbon emissions but also includes other types of emissions in its calculation. Therefore, numerous market parties in the Netherlands have already been looking at how to measure embodied carbon emissions within a building project. Among these stakeholders, The Dutch Green Building Council (DGBC) stands out. They have developed a method for calculating embodied carbon emissions per square meter. Additionally, the DGBC has established specific target values for various building types (see Table 4), known as the Paris Proof embodied carbon indicator (Paris Proof Materiaalgebonden indicator, PPm). These target values aim to limit the total carbon emissions allowed in the construction sector to align with the 1.5°C global warming target outlined in the Paris Agreement (NIBE & DGBC, 2021).

*Table 4 - Paris Proof embodied carbon target values (NIBE & DCGB, 2021)*

| Paris Proof Target Values | Embodied carbon kg $CO_2$-eq. per $m^2$ | | | |
|---|---|---|---|---|
| | 2021 | 2030 | 2040 | 2050 |
| Residence (single-family home | 200 | 126 | 75 | 45 |
| Residence (mutli-family home) | 220 | 139 | 83 | 50 |
| Office | 250 | 158 | 94 | 56 |
| Retail Real estate | 260 | 164 | 98 | 59 |
| Industry | 240 | 151 | 91 | 54 |

Besides, currently, there is no official certification or calculation method approved by the Dutch government for determining when a building is 'Paris Proof'. Various certification bodies, like BREEAM and LEED, offer green certifications when a building meets certain criteria, which now include embodied carbon requirements. However, since this is only one specific aspect, obtaining these certifications does not necessarily reflect the status of embodied carbon (BREEAM, 2021).

### 3.1.4 Embodied carbon reduction strategies

Numerous research studies have explored different approaches to decrease the embodied carbon of buildings (Akbarnezhad & Xiao, 2017; Pomponi & Moncaster, 2016). These approaches can be broadly categorized into five main categories: (1) low-carbon materials, (2) material minimization and material reduction strategies, (3) material reuse and recycling strategies, (4) local sourcing and transport minimization, and (5) construction optimization strategies.

Low-carbon materials

To mitigate embodied carbon through material use, employing low-carbon materials is a key strategy (Akbarnezhad & Xiao, 2017). Dimoudi & Tompa (2008) found that structural materials like concrete and steel contribute the most to a building's embodied carbon, accounting for 59.57–66.73% of its total embodied carbon emissions. The specific types of concrete and steel used can significantly impact embodied carbon, with variations of up to 40%. Therefore, it's important to replace traditional materials with low-carbon building materials. Studies by González and Navarro (2006), and Sham et al., (2011) showed that using low-carbon materials could reduce $CO_2$ emissions by approximately 30% and 34.8% respectively. Choices include materials such as biobased ones like timber, bamboo, and hemp-lime composites (Yu et al., 2011; Ng et al., 2012).

Material minimization and material reduction

The total embodied carbon in a building depends on the quantity of material used (Akbarnezhad & Xiao, 2017). Therefore, to reduce embodied carbon, it is important to minimize material usage. One key method for this is through design optimization. Yeo & Gabba (2011) and Pomponi & Moncaster (2016) found that optimal design and avoiding overdesign ca n significantly reduce the quantity of materials and consequently embodied carbon. Their research indicated that optimizing structural design can reduce embodied carbon emissions by 10%. Additionally, Sobota et al. (2022) concluded that a building's compactness greatly influences material usage. Building compactness refers to the ratio between the building's envelope (facade, roof, and lower floor) and its usable floor area; a more compact building requires less facade per square meter of usable area. As illustrated in Figure 10, services also play a crucial role, with Sobota et al. (2022) noting that extending replacement intervals of service components can significantly impact $CO_2$ emissions. Finally, the quantity of materials used is also influenced by waste generated during component manufacturing, the installation process, and on-site construction (Poon et al., 2004).

Material Reuse and Recycling

Another strategy related to material selection is the use of recycling or reusing materials (Akbarnezhad & Xiao, 2017). Recycling reduces emissions by substituting environmentally intensive primary production with lower-impact secondary production. Additionally, this practice contributes to preserving non-renewable resources, reducing waste, and minimizing land use (Wiik et al., 2018). Reusing materials and components during building retrofits or demolitions is an effective way to reduce embodied carbon (Akbarnezhad & Xiao, 2017; Tingley et al., 2018). Research by Akbarnezhad & Xiao (2017) suggests that many building elements, such as doors, floorboards, structural elements like steel or timber beams, modular systems, facades, and window frames, can be in good enough condition at the end of a building's service life for reuse in similar or different applications. Tingley et al. (2018) also emphasize that materials with high embodied carbon should be prioritized for reuse, as replacing new materials of such types can result in substantial environmental benefits. Figure 11 illustrates the stages of the LCA where recycling or reusing can be applied.

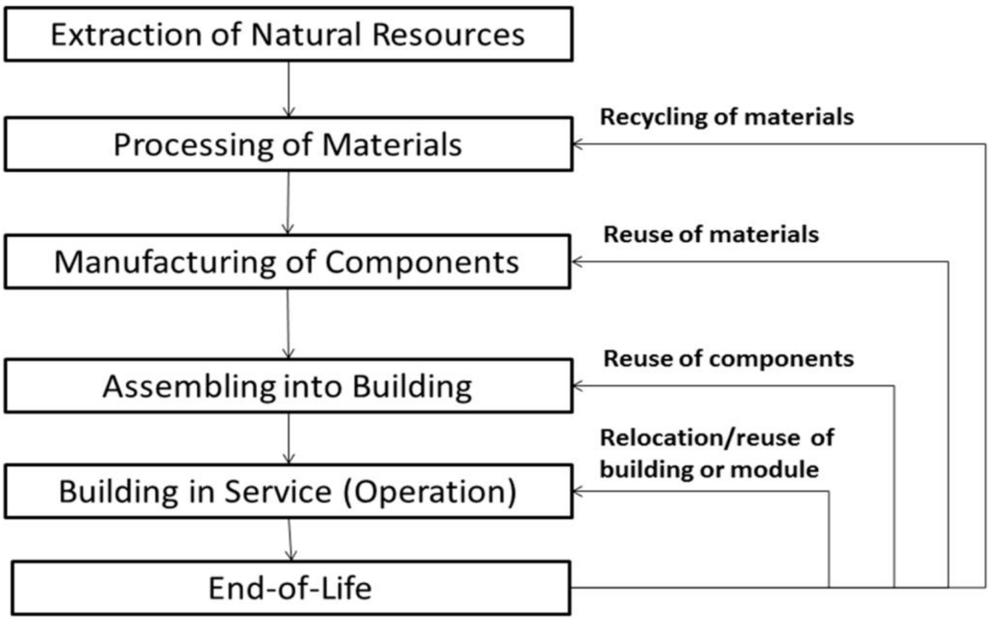



*Figure 11 - The use of reused and recycled materials in building life cycle (Akbarnezhad & Xiao, 2017)*

Local Sourcing of Materials and Components

The impact of transportation is an important contributor to the embodied carbon of building (Akbarnezhad & Xiao, 2017). Within transportation different aspects can have an influence on realizing a low carbon building. The main factors affecting transport emissions include the quantity of material to be transported, the size of the material, the transportation distance, and the mode of transport (Akbarnezhad & Xiao, 2017). Whereby the use of local materials would reduce the transportation impacts (Pomponi & Moncaster, 2016). Furthermore, when selecting materials for low-carbon buildings, it is essential to take into account the key factors that influence transport emissions, such as the frequency of trips, the transportation mode, and the distance requirements.

Construction Optimization

The last strategy to mitigate embodied carbon is construction optimization. The reduce of the embodied carbon of a building can be regulated by reducing the construction emissions, which are associated with temporary construction materials and the construction equipment (Akbarnezhad & Xiao, 2017). The mitigation of carbon emissions during the construction phase can be conducted through different approaches including optimizing the construction operations to reduce the idle time of equipment, selection of optimal equipment for a construction operation, optimizing the operation of equipment, and minimizing the on-site transport including both horizontal and vertical transport (Akbarnezhad & Xiao, 2017). The optimization of the construction can also be influenced by the use of innovative machinery and the reduction of delays (Pomponi & Moncaster, 2016). Beside that the use of prefabricated elements and off-site manufacturing can reduce the embodied carbon (Pomponi & Moncaster, 2016).

In Figure 12, the summary of all the reduction strategies, including the operational measures, is presented.

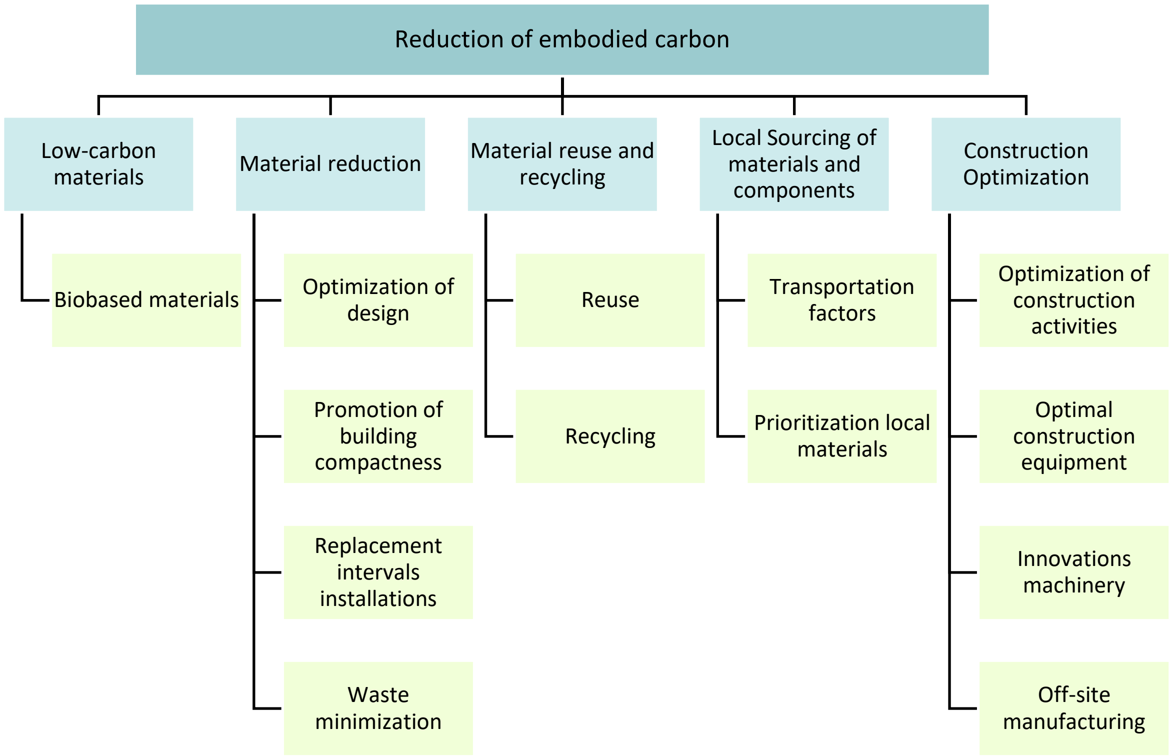



*Figure 12 - Summary of all the reduction strategies including the operational measures (own illustration)*

## 3.2 Regulations

### 3.2.1 Environmental regulations

Like mentioned above in the introduction, the agreements were made at the COP21 about the $CO_2$ reduction. Additionally, in December 2019, the European Commission introduced the 'European Green Deal.' The deal encompasses a wide range of objectives to combat climate change, including the heightened ambition to reduce $CO_2$ emissions within Europe by 55% by 2030 compared to 1990 levels. To achieve this goal, a package of measures has been proposed and has already been largely adopted by the European legislature and national governments, under the label 'fit for 55.' This means that the European Climate Law legally obligates compliance with this objective (EU Council, 2023).

In March 2020, the European Commission adopted the new Circular Economy Action Plan as part of the European Green Deal, legally binding the EU to achieve climate neutrality and zero net emissions by 2050. Among the plan's 35 objectives, some pertain to EU sustainable product standards. These objectives are expected to introduce new measures in the construction and building sector, potentially significantly reducing emissions. These measures encompass sustainability criteria for construction products, improved recycling practices, the promotion of durability, digital building logbooks, the integration of LCA for public procurement, and the establishment of an EU sustainable finance framework (European Commission, 2020).

However, on February 9th, 2023, the European Parliament voted for the Energy Performance of Buildings Directive IV (EPBD IV) (European Parliament, 2023). This means that the regulation concerning carbon emissions will maybe become even stricter. In the new directive, for the first time, the European Parliament considers it to be important to calculate $CO_2$ equivalents throughout the entire lifespan of a building. Starting from January 1, 2027, the calculation known as the Global Warming Potential (GWP), which assesses the impact of all greenhouse gases on the greenhouse effect, will be mandatory for buildings larger than 2,000 square meters. For all new constructions, this requirement will apply from January 1, 2030 onwards. Furthermore, additional reduction targets are slated to be implemented beyond 2030 (European Parliament, 2023).

Currently, the Netherlands lacks mandatory regulations for allowable embodied carbon $CO_2$-eq emissions per square meter (NMD, 2020). However as, mentioned in Section 3.1.1: Quantifying the embodied carbon values, the Dutch government introduced the Environmental Performance of Buildings (Milieuprestatie Gebouw, MPG) to promote sustainable materials in construction. According to RVO (2023), the MPG currently serves as the primary regulatory instrument for mitigating environmental impact. The MPG is obliged to be included in every building permit application for newly constructed houses or offices (larger than 100 $m^2$). Within the building regulations, a maximum MPG score of 0,8 is required for residential functions. Aligned with long-term objectives, the government is implementing a gradual reduction plan to achieve a 0.5 MPG requirement by 2030, with discussions underway to possibly expedite this target to 2025 (RVO, 2021). However, the MPG score does not only reflect the embodied carbon, as other emissions are also included in the calculations (NMD, 2020).

### 3.2.2 Sustainable finance regulations

The European Commission, recognizing the growing impact of climate change and resource depletion, has emphasized the need for more investment in eco-friendly companies and products. It acknowledges the vital role of the financial sector in driving the transition to sustainability in order to meet the objectives of the European Green Deal. Therefore, an action plan has been created that includes measures such as establishing an EU taxonomy for sustainable activities and requiring companies to report on a range of social, environmental, and governance (ESG) indicators under the Sustainable Finance Disclosure Regulation (SFDR) or Corporate Sustainability Reporting Directive (CSRD).

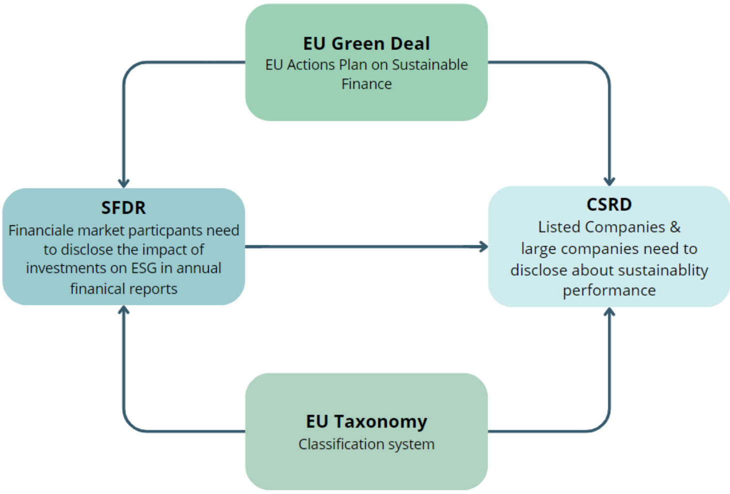



*Figure 13 - Relationship between EU Green Deal, CSRD, SFDR and EU Taxonomy (own illustration)*

<u>The EU Taxonomy</u>

Implemented on 12 July 2020, the EU Taxonomy is a key advancement in sustainable finance, influencing investors and issuers within and outside the EU. This system lists environmentally sustainable activities to boost the EU's sustainable investment and fulfil the European Green Deal objectives (European Commission, 2023a). It offers clear definitions for sustainable activities, supporting companies and policymakers in transitioning towards the EU's environmental goals, relevant to frameworks like the SFDR and CSRD. The Taxonomy mandates reporting on progress against specific criteria, promoting investment in low-carbon sectors and the decarbonization of high-carbon ones, thereby enhancing environmental performance and resilience economy-wide, including through green financing (EU TEG on Sustainable Finance, 2020). The European Commission (2021) has set six environmental objectives to guide these efforts, which can be seen in Figure 14.

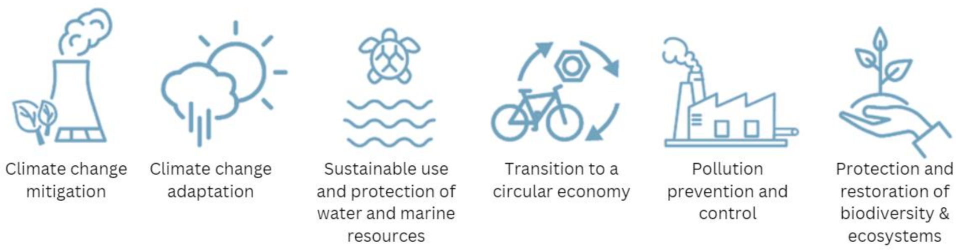



*Figure 14 - Six environmental objectives within EU taxonomy adopted from DGCB (2023)*

Within the EU taxonomy, embodied carbon within the built environment is described in the "Climate change mitigation" objective, which can be found in Chapters 7.1 and 7.2 of the EU taxonomy (European commission, 2021). However, for further details on the requirements that specific activities must meet to be classified as 'environmentally friendly activities' within the EU taxonomy and which chapters within the EU taxonomy address embodied carbon, please refer to Appendix III.

Sustainable Finance Disclosure Regulation

Once there is a shared understanding of ecological sustainability, the next crucial step is to ensure that financial intermediaries incorporate sustainability considerations into their investment policies and advice, while providing transparency to the investing public regarding the extent to which these considerations are implemented. Notably, European regulations previously lacked transparency concerning the foundation of sustainable investments. However, this changed significantly with the enactment of the Sustainable Finance Disclosure Regulation (SFDR) on March 10, 2021 (Busch, 2023). This regulation mandates that financial market participants and advisors disclose, in their annual financial reports, the extent to which investments have had adverse impacts on both people and the environment. The SFDR's primary objective is to include non-financial, sustainable aspects in annual reporting alongside financial metrics. This proactive approach serves as a powerful incentive for financial market participants to enhance the sustainability performance of their investments and funds while implementing their ESG policies (European Union, 2019). The ESG reporting under the SFDR must comply with the Regulatory Technical Standards (RTS). In this context, a financial product, such as an investment or fund, can be classified as Article 6, 8, or 9 (European Union, 2019):

- Article 6 (gray) signifies that the product is not (sufficiently) sustainable.
- Article 8 (light green) indicates that the product includes sustainability features.
- Article 9 (dark green) signifies that the product can be considered as sustainable.

More information about the SFDR can be found in Appendix IV.

Corporate Sustainability Reporting Directive

The Non-Financial Reporting Directive (NFRD) has been in effect since the financial year 2018 and has been transposed into Dutch law as the "Besluit Bekendmaking Niet-Financiële Informatie" (Disclosure of Non-Financial Information Decree). This directive requires organizations that meet certain criteria to report on their policies and performance related to the environment, social conditions, and governance. In order to enhance transparency and comparability of reporting, the EU has decided to replace the NFRD with a new directive, the Corporate Sustainability Reporting Directive (CSRD). The CSRD is expected to come into effect from the financial year 2024 and must be incorporated into Dutch law by no later than July 6, 2024. However, it is important to note that the CSRD will not immediately apply to all companies (European Commission, 2023b). Figure 15 shows in which year the CSRD becomes mandatory for different types of companies.

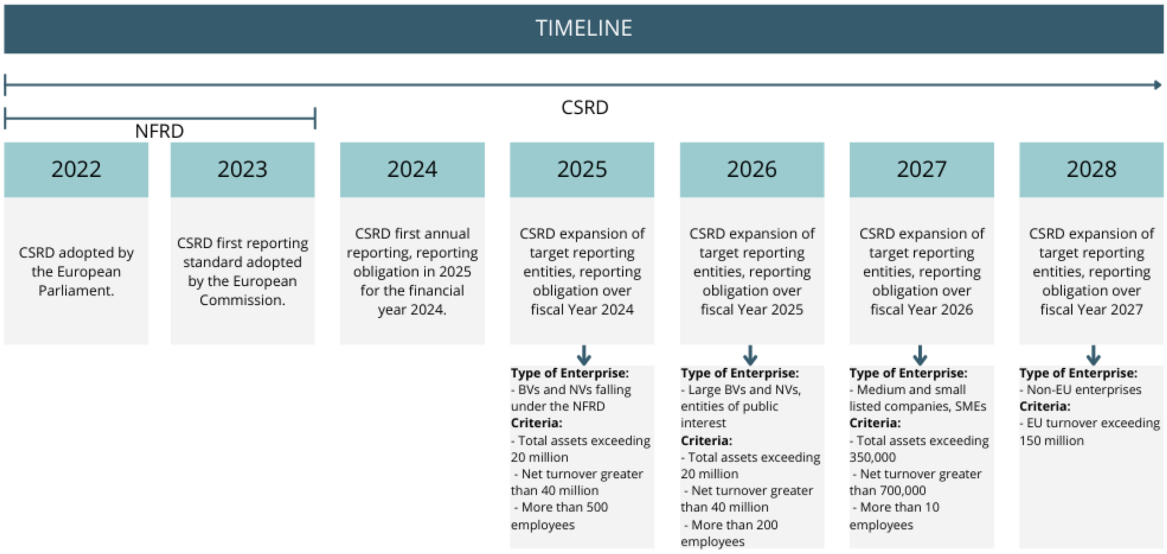



*Figure 15 - Time line of upcoming CSRD (own illustration, adopted from DGCB (2023)*

The CSRD aims to ensure that companies are transparent about their sustainability activities, risks, and performance related to people and the environment. Conversely, this provides customers and stakeholders with tools to make informed choices and guide the sustainability policies of these companies. The CSRD's sustainability reporting, covering all three ESG areas, is comprehensively overviewed in Figure 16. Regarding embodied carbon, ESRS E1 Climate change will play an important role, with climate change mitigation being applicable to this research. Specific paragraphs of relevance and more information can be found in Appendix V.

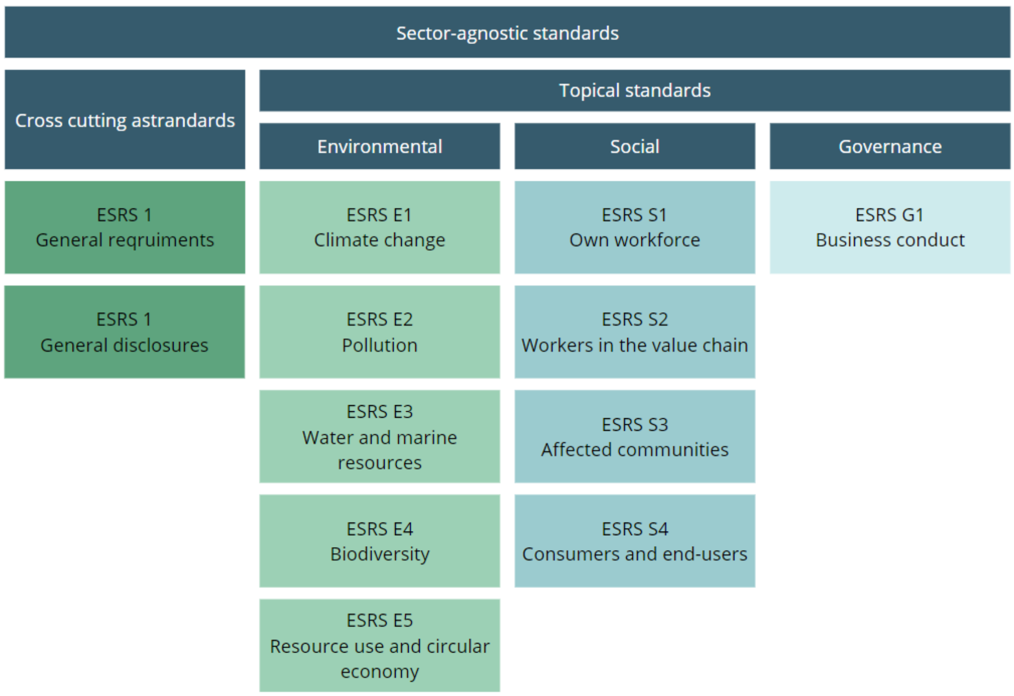



*Figure 16 - CSRD's topics (European Commission, 2023b)*

## 3.3 Investment decision making

### 3.3.1 Decision making in real estate

As explained in the introduction, real estate investment, which involves allocating resources for the medium to long term, aims to cover costs and yield high profits. In this context, effective decision-making is crucial for maximizing returns and minimizing risks, as poor decisions pose a risk of financial losses. The basis of investment decisions lies in comprehensive project analysis, where risk plays a key role due to uncertainties in recovering costs and earning profits (Virlics, 2013).

In real estate investment, the primary decision involves selecting the type of assets to purchase or build. This process requires quantifying future expectations, zoals bijvoorbeeld een DCF-model (Atherton et al., 2008; French, 2001; Keeney & Raiffa, 1976). These input variables, such as rental income, operating costs, and yields, are crucial for decision-making, acting as the driving force behind it. However, not all investment decision variables are controllable or predictable. Factors like risk, yield, and rent are largely dictated by market conditions, thus limiting investor control (Atheron et al., 2005). This, therefore, is the reason for the complexity in real estate investment, which arises from the sensitivity of outcomes to changes in input variables. A detailed explanation of these concepts using a DCF model will be provided in Subchapter 3.4: DCF-model.

Beside the financial criteria also non-financial criteria, such as sustainability criteria have impact on the decision making process (Warren-Myers, 2012; Mantogiannis & Katsigiannis, 2020). Sustainability criteria typically encompass three dimensions: environmental, social, and economic (Dobrovolskienė et al., 2021). Sustainability has become an integral part of reporting and governance for large companies, as evidenced by Directive 2014/95/EU, and is a fundamental component of various ESG standards (Jackson & Orr, 2021). In this research, the focus will be on environmental sustainability, where environmental criteria may include objectives such as achieving an MPG score of 0.5, as discussed in Subchapter 3.2: Regulations.

### 3.3.2 7 steps off investment decision-making

Since the 1970s, various researchers have emphasized the significance of investment decision-making within the real estate sector (French, 2001; Keeney & Raiffa, 1976; Atherton et al., 2005; Tang & Li 2009). Virlics (2013) later concluded that when making an investment decision, a solid understanding of the fundamental principles of the investment decision-making process and its execution is essential. As explained in the introduction the framework made by Farragher & Kleiman (1996) and Farragher and Savage (2008) will be used, they did a study about the real estate investment decision-making process within practice by looking at institutional investors (REITs, pension funds, life insurance companies) and private investment companies and developed a framework consisting of the following steps, as illustrated in Figure 1.

<u>Step 1: Setting a strategy</u>

Farragher & Kleiman (1996) state that strategic analysis is key for identifying a company's competitive advantages and recommending investment strategies for optimal resource use. Their research, along with Farragher and Savage (2008), indicates that 84% of investors use strategic analysis, though private investment firms are less likely to plan strategically. The approach's importance is underlined by data showing 93% of insurance companies, 86% of pension funds, and 63% of private investors recognizing competitive advantages. These figures, although outdated, show a growth in strategic implementation from 1996 to 2008.

Step 2: Establishing return/risk objectives.

Once a strategic plan has been devised, it is important for a company to set a maximum acceptable risk objectives (tolerance for uncertainty and potential losses) and a minimum required rate-of-return (desired financial outcomes) that align with its competitive advantages and targeted investments (Farragher & Kleiman, 1996). The balance between return and risk is crucial in determining the investment approach. The formulation of quantitative return and risk objectives not only facilitates the evaluation of prospective investments but also ensures effective communication within the organization, thereby maintaining organizational coherence (Farragher & Savage, 2008).

Step 3: Forecasting and evaluate expected costs returns.

The third step, forecasting and evaluate expected costs returns which can be conducted after the potential investment opportunity has been identified. This is done by forecasting the cash cost and return by looking at the expected amount, uncertainty, and timing (Farragher & Savage, 2008). Which can be divided into two parts: how to calculate the cost returns and the time period that is used to calculate the cost returns.

For the investors it is first important to know which method will be used to calculate the cash cost and return. However different ways can be used to calculate the cash cost and return, for example cash flows, cash return and income (earnings) returns (Farragher & Savage, 2008). Secondly important aspect is when using cash flows is which time frame will be used, this determines over what period of time the cash cost and return will be calculated (Farragher & Savage, 2008). Lastly after forecasting the amount and timing of expected returns, the forecast values should be translated into an evaluation measure. To evaluate the cash cost and return in general there are two ways; based on first years returns, which are for example cash-on-cash rate of return, equity dividend rate payback and gross income multiplier. Alternatively, other valuation methods such as real option valuation, net present value (NPV), and IRR take into account the returns expected to be generated over the intended holding period of the investment. Which means that those valuation methods evaluated the actual cash flows generated by the investment over the intended holding period, which will be further discussed in Subchapter 3.4: DCF-model.(Farragher & Savage, 2008; RICD, 2018; Jones & Trevillion, 2022). This also indicates why the DCF-model is a suitable method for calculating low embodied buildings investments, because one of the financial barriers is the high upfront investments.

Step 4: Assessing investment risk

The fourth step of the framework is assessing the investment risk. This needs to be done because the return within a real estate investment is uncertain. Therefore, an assessment of the uncertainty needs to be conducted, after that an calculation can be done to a risk-adjusted evaluation measure (Farragher & Kleiman, 1996).

There are two ways of assessing investment risk: qualitative risk assessment and quantitative risk assessment. Qualitative risk assessment involves verbal scenario analysis and aims to provide an understanding of the uncertainty surrounding an investment, without providing a quantitative measure. On the other hand, quantitative risk assessment is a more formal procedure that utilizes numerical calculations to provide a quantitative measure of uncertainty. It involves the use of computerized calculations and also includes verbal discussions to complement the quantitative analysis (Farragher & Savage, 2008).

Step 5: Making a risk-adjusted evaluation of the forecast costs and returns

Formal risk adjustment involves either adjusting the forecasted cash flows or increasing the required-rate-of-return to reflect an investor's unwillingness to bear the assessed risk. The forecasted returns can be adjusted subjectively or through the use of certainty equivalents. The desired rate-of-return can be adjusted subjectively or by use of the capital asset pricing model (Farragher & Kleiman, 1996).

Step 6: Implementing accepted proposals

After deciding to invest in a project, the success of the investment can be jeopardized if it's not implemented on time, within the budget, and with the desired quality. One effective method to ensure successful execution is to create an action plan and designate a project manager responsible for its execution (Farragher & Savage, 2008).

Step 7: Auditing operating performance

An audit is a review of the operational performance of implemented investments, expressed in terms of the initial assumptions. Audits are most effective when conducted regularly by independent audit staff not involved in forecasting, decision-making, or the operation of the investment (Farragher & Kleiman, 1996). Auditing promotes accurate and truthful predictions, as individuals understand they will be responsible for their projections. Additionally, it serves as a financial oversight tool, signaling when adjustments are necessary to maximize an investment's value.

### 3.3.3 The investment decision-makers

As previously mentioned, it is important to recognize the diversity among investors. Investors exhibit variations in their strategies, risk tolerance, asset management approaches, and more. However, academic literature often oversimplifies this diversity by treating investors as a homogeneous group. One way to differentiate among investors is by considering their legal status. Farragher and Kleiman (1996) have already made this distinction, categorizing investors into two main groups: private investors and institutional investors (REITs, pension funds, life insurance companies).

Institutional investors are defined as entities that have access to funds required for investment as a result of their operations (Jones & Trevillion, 2022). Each category of institutional investors operates within a specific risk profile that aligns with their investment strategy (Archer & Ling, 2017). Their primary activities typically revolve around managing and safeguarding pensions while facilitating private investors' access to investments tailored to their desired risk profiles. In the Netherlands, examples of institutional investors include pension funds, insurance funds, and investment funds, as documented by CBS (2016). The most significant disparity between institutional and private investors often lies in the scale of capital at their disposal. Institutional investors have access to substantial amounts of capital, often sourced from third parties. Consequently, they are subject to stringent regulatory frameworks designed to govern their operations.

## 3.4 DCF-model

### 3.4.1 The valuation of an investments

As explained in the previous chapter, within real estate investment, the primary decision-making involves selecting the type of assets to purchase, where the valuation of investments is an important component. Purchasing an asset requires an initial investment for future income over a potentially extended period. It is important that the investor determines the right price for this income or validates the proposed purchase price. It is also important to make a fundamental consideration regarding the balance of current expenditures against future income, taking into account the variable value of money over time due to factors such as inflation and risk. This is an important aspect of this process (Jones & Trevillion, 2022).

Additionally, in a DCF investment property valuation, future benefits, comprising cash flows and terminal value, are identified, timed, and evaluated for variability over a specified holding period (Riggs, 1988). The future benefits from real estate are realized as cash flows, derived from rental income, expenses, and property appreciation, which are not constant but can also vary over time (Jones & Trevillion, 2022). A schematic diagram of how the initial investment, cash flows, and terminal value can be spread over a certain holding period within the valuation of an investment using the DCF model is shown in Figure 17.

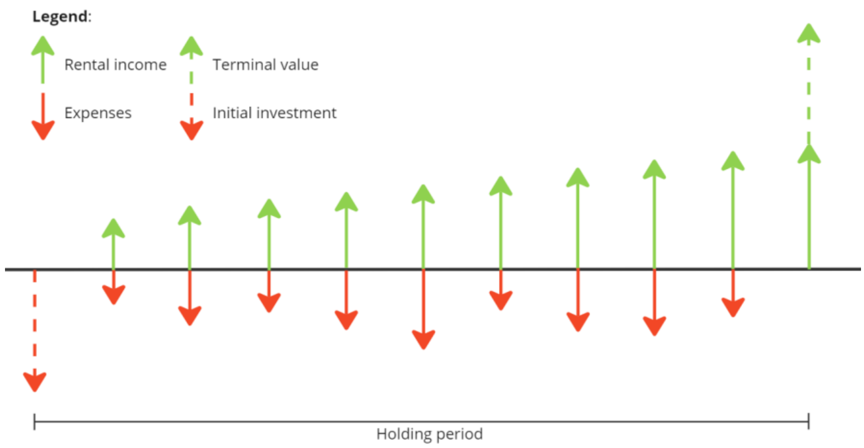



*Figure 17 - Schematic scheme of DCF model (own illustration)*

These future benefits are discounted to their present value, indicating the price a prospective investor should pay at the valuation date, also called initial investment (Jones & Trevillion, 2022; Ling & Archer, 2018). The discount factor applied in this process must encapsulate the total required IRR from the investment—both income and capital appreciation—while also considering the associated risk (Riggs, 1988). The term refers to the process and procedures for DCF analysis estimating (Ling & Archer, 2018).

The result of those discounted cashflows is being evaluated by using the net present value (NPV). The NPV of an investment is determined by summing the discounted cash flows (future cashflow and terminal value), calculated using the internal required rate of return/discount rate (r), and subtracting the initial investment (I) (Pšunder & Cirman, 2011).

$$NPV = \sum_{t=0}^{n} = -I_0 \frac{CF_t}{(1+r)^t}$$

**Legend:**
n = years of investment
I= initial investment
$CF_t$ = net cash flow for any year of the investment
r = required internal rate of return/discount rate

Based on the above information, it can be concluded that the valuation of a real estate investment based on a DCF model can be divided into the following four elements:

1. The holding period;
2. Future annual cash flows from property operations;
3. The terminal value of the property at the end of the assumed investment holding period and;
4. The required internal rate of return also called discount rate.

In the following subchapters, the discussion will cover the concepts of the holding period, cash flows, terminal value, and required internal rate of return, along with an explanation of the parameters that determine these four main themes.

Table 5 provides an overview of all parameters that can influence the main themes: holding period, cash flow, terminal value, and required internal rate of return, thereby playing a role in the valuation of an investment using the DCF model. Additionally, three new parameters have been added that are not yet present in the literature concerning the DCF model but could be significant when incorporated embodied carbon into the investment process. These are carbon credits, carbon offsetting, and carbon tax. For further explanation of these parameters and how this table was created, see Appendix VI.

*Table 5 - Overview of DCF parameters gathered from literature*

| Discounted Cash Flow Model | | | | |
|---|---|---|---|---|
| Holding period | Cashflow | | Terminal value | Required IRR |
| National tax law | Initial property value | Construction time | GEY (Gross exit yield) | Government bonds |
| National depreciation systems | Land value | Interest factor for construction | $Cashflow^{t+1}$ | Inflation |
| Market conditions | Rent/$m^2$ | Loan | Depreciation Factor | Property law |
| Initial investment | NLA (Net Lettable Area) | Amortization | | Demand and supply |
| Type of investment | GFA/NLA ratio | Interest rate on loan | | Local market |
| | Nominal annual rent increase | Depreciation factor | | Tenant credit worthiness |
| | Inflations | Tax rate | | Multi/single let |
| | Vacancy rate | GIY (Gross initial yield) | | Period to expire of leases |
| | Other income | Carbon pricing | | Accessibility |
| | Operation expenses | Carbon offsetting | | Sustainability |
| | Capital expenditures | Carbon taks | | Building obsolescence premium |

### 3.4.2 Impact of sustainability on DCF parameters

The influence of sustainability on the financial aspects of real estate has evolved over time. Initially, property investment professionals believed that sustainability had minimal impact on rents and yields, but this perception has shifted (Sayce et al., 2007). U.S. investors now see sustainability as an avenue for risk management, return potential, and gaining a competitive edge in Responsible Property Investment (RPI) (Pivo, 2008).

Sustainable properties offer financial advantages, such as higher occupancy rates, reduced operational costs, and lower depreciation rates and decreased regulatory obsolescence. These benefits can stimulate demand and potentially reduce the risk premium during the pricing process (Fuerst and McAllister, 2011a; Pivo and Fisher, 2010).

Studies have shown that investors and tenants are willing to pay premiums for sustainable buildings. Eichholtz et al. (2010), Miller et al. (2008) and Pivo and Fisher (2010) found capital value premiums ranging from 6% to 16% for green-rated properties in the U.S. tenants are also willing to pay more for energy-efficient structures, driven by various benefits, from reduced costs to improved reputation. For instance, BREEAM-rated buildings in the UK command higher rents than their non-rated counterparts (Fuerst and de Wetering, 2015). Lastly, Leskinen et al. (2020) concluded that a green certification increases rental income, occupancy rate, and sales price, but has a negative effect on the yields (risks).

In terms of risk reduction, sustainability is viewed as a means to mitigate investment risks, reducing depreciation rates, obsolescence, and capital expenditure, as defined by Ellison et al. (2007). Investor demand for sustainable properties may stem from lower operating costs, improved corporate image, and reduced risk associated with extended building life, as suggested by Eichholtz et al. (2010).

The integration of sustainability into decision-making processes still lacks comprehensive empirical investigation. While new buildings often incorporate higher sustainability standards, older structures might require significant retrofitting, termed as the 'brown discount' (GBCA,2008). Key financial aspects, such as capital expenditure, lifecycle, terminal value, and discount rates, are central to understanding the financial implications of sustainability in real estate. Green standards might lead to significant capital expenses, impacting property valuations. However, the perception of reduced risk can result in higher property values for sustainable buildings (GBCA, 2008).

## 3.5 Literature framework

To offer a comprehensive understanding of the research, it is crucial to establish the interconnections among the concepts previously introduced. Figure 18 visually depicts the relationships between these central concepts. This framework serves as a valuable tool in addressing the research questions and elucidating their interdependencies.

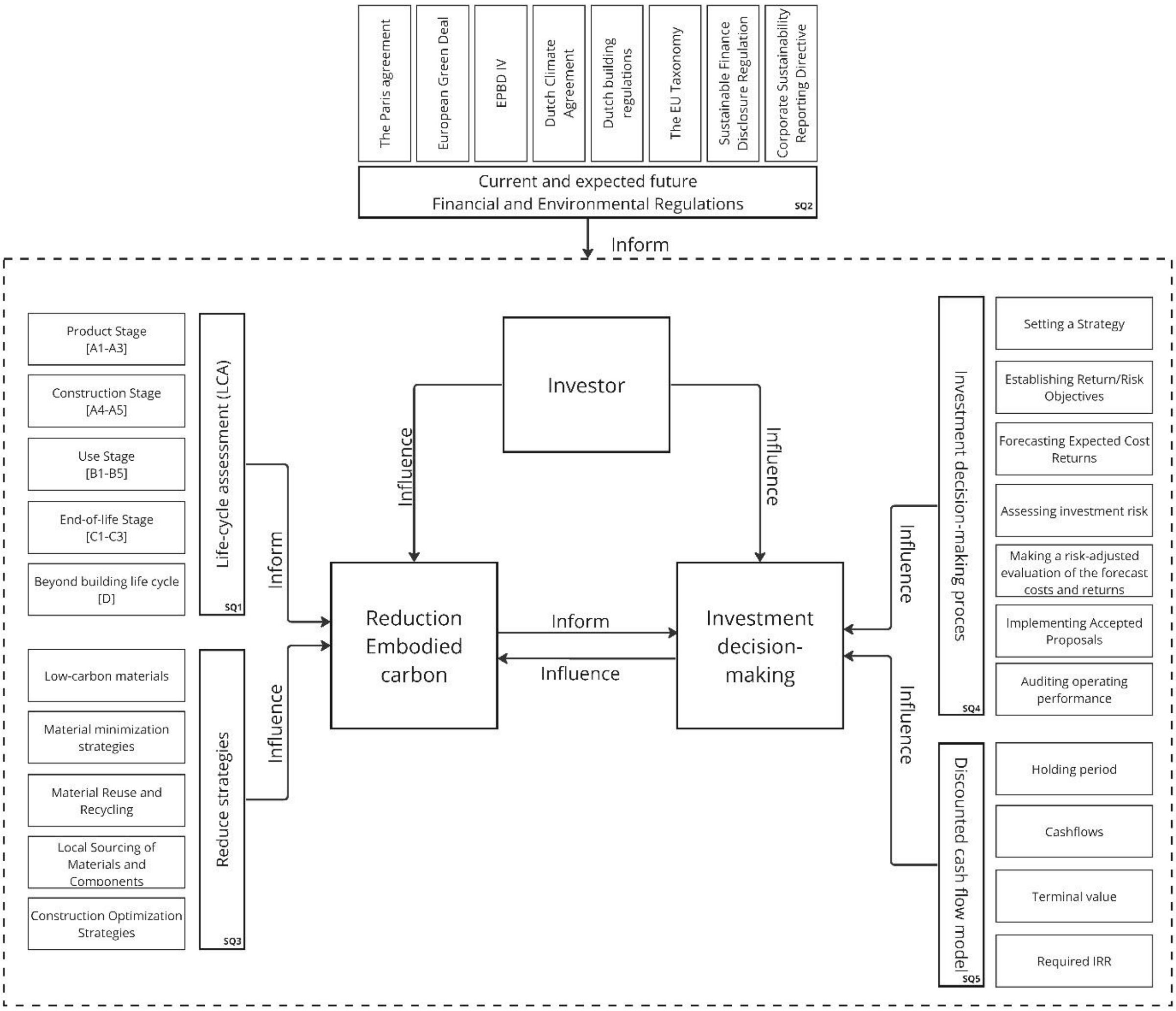



*Figure 18 - Literature framework (own illustration)*

# Chapter 4

## Validating the literature findings: Through explorative interviews

Embodied carbon reduction strategies

Parameters of the DCF-model

# 4. Validating the literature findings: Through explorative interviews

In this chapter, the self-developed embodied carbon reduction strategies and the DCF parameters that have arisen from the literature study are tested, validated, and supplemented when necessary through exploratory interviews. This helps ensure that there is a better-developed and comprehensive framework in place to provide answers to sub-question 3: *"What strategies can be used to reduce the embodied carbon within a building project and how are these applied in current practice?"* and sub-question 5: *"What adjustments do investors make to the Discounted Cash Flow (DCF) parameters to reflect embodied carbon reduction strategies?"*

## 4.1 Embodied carbon reduction strategies

From the interviews E-4 & E-5 (2023), it is concluded that the five identified reduction strategies were essentially complete, except for two missing operational measures. Firstly, concerning low-carbon materials, the following was stated:

> *"Well, I would say it's quite extensive and comprehensive. The only thing I think is that when you say "low carbon materials" and only list biobased materials there, I think it might be a bit simplistic. In the sense that there are more than just biobased materials that are also low carbon. " – Interview E-4*

An example was provided regarding $CO_2$-negative bricks produced using carbonation technology, where $CO_2$ is stored in the product, and residual streams from the steel industry are used for baking the bricks (Interview E-4, 2023). It was also mentioned that there are more products like this. Therefore, sustainable alternatives to existing materials are included as operational measures within the low-carbon material reduction strategies.

The second remark pertained to the measure related to the extension of the replacement intervals of service components. It was suggested that instead of extending the replacement intervals of service components, it is possible to design buildings more passively, resulting in structures with fewer or no installations (Interview E-4, 2023). This approach would lead to less or even no need for the replacement of service components. As a result, the operational measure 'Minimal use or no use of installations (passive design)' is incorporated into the material minimization and material reduction strategies.

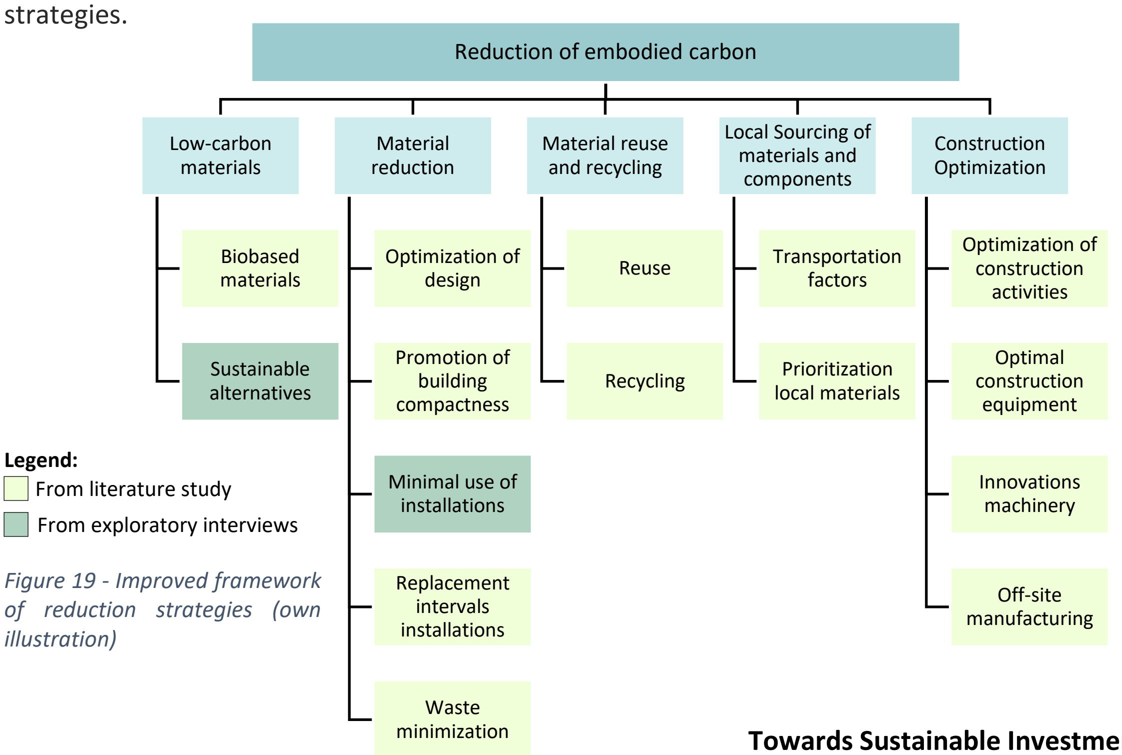



*Figure 19 - Improved framework of reduction strategies (own illustration)*

## 4.2 DCF parameters

Beside testing embodied carbon reduction strategies, the DCF parameters were also evaluated through exploratory interviews. The first column in the DCF table is the holding period. All the participants agreed that the holding period is typically fixed, allowing for benchmarking with the market. However, they were not entirely certain about how it is initially determined, and as a result, none of the parameters from the literature were explicitly mentioned. In summary, no specific feedback was provided on the parameters governing the holding period.

The second aspect that was discussed was the cashflow. To begin with, it is concluded that al the current parameters in place were accurate. However, one important parameter was missing according to all participants, which was the mutation rate. The mutation rate refers to the number of tenant relocations each year, which can be significant when the rent in the market rises or falls. This means that when a tenant leaves, and there is a difference between the current rent and the market rent, the rent can be increased or decreased. Additionally, participant of interview E-6 (2023) mentioned that the construction time, GFA/NLA ratio and interest factor for construction are parameters that were also missing. In addition, everything related to external financing has not been mentioned as parameters used by the interviewees; however, it was indicated that these could be used. Finally, the parameters related to $CO_2$ emissions have not been considered yet, but all the interviewees indicated that these could be relevant in the future.

The terminal value is the third column in the DCF table. From the interviews E-6, E-7, and E-8 (2023) is concluded that three parameters were still missing: the vacancy value (€/NLA), representing the vacancy value per square meter of NLA; the value growth of the vacancy value (%), indicating the percentage increase in the vacancy value per square meter of NLA; and, consequently, the total NLA itself. The vacancy value represents the market value of a property in a vacant state, while the value growth of vacancy value represents how much the vacancy value increased or decreased each year. During the interview, it actually emerged that there are two ways to calculate the terminal value. The first method is as described in Section 3.4.1: The valuation of an investments, using the GEY, while the second method calculates the terminal value using the formula below:

$$\textit{Terminal value at } t = (\textit{vacancy value } (€/m^2)) * \textit{total NLA } (m^2) * (1 + \textit{value growth of vacancy value } (\%))^t$$

Finally, regarding the required IRR, it can be concluded that there is variability in the use of the identified parameters from the literature among the interviewees. Interviewee E-6 (2023) noted that a standard required IRR is always utilized but was uncertain about its composition. In contrast, during the interviews with interviewees E-7 (2023) and E-8 (2023), almost all the parameters were discussed. The only exceptions were property law and the local market, which were not explicitly mentioned. However, upon reviewing the table, both interviewees concurred with the listed parameters and had no additional comments.

In Table 6, the adjusted parameters of the DCF model can be seen. The table below displays the parameters that have been added, highlighted in gray.

*Table 6 - Improved table of DCF parameters*

| Discounted Cash Flow Model | | | | |
|---|---|---|---|---|
| Holding period | Cashflow | | Terminal value | Required IRR |
| National tax law | Initial property value | Construction time | GEY (Gross exit yield) | Government bonds |
| National depreciation systems | Land value | Interest factor for construction | Cashflow$^{t+1}$ | Inflation |
| Market conditions | Rent/m$^2$ | Loan | Depreciation Factor | Property law |
| Initial investment | NLA (Net Lettable Area) | Amortization | Vacancy value (NFA) | Demand and supply |
| Type of investment | GFA/NLA ratio | Interest rate on loan | Value growth of vacancy value (NFA) | Local market |
| | Nominal annual rent increase | Depreciation factor | NLA (Net Lettable Area) | Tenant credit worthiness |
| | Inflations | Tax rate | | Multi/single let |
| | Vacancy rate | GIY (Gross initial yield) | | Period to expire of leases |
| | Mutation rate | Carbon pricing | | Accessibility |
| | Other income | Carbon offsetting | | Sustainability |
| | Operation expenses | Carbon taks | | Building obsolescence premium |
| | Capital expenditures | | | |

**Legend:** Operational measures from literature Operational measures added from exploratory interviews

# Chapter 5

## Investment decision-making in embodied carbon reduction case studies

Jonas
Timberhouse
SAWA

# 5. Investment decision-making in embodied carbon reduction case studies

This chapter presents results from three case studies: Jonas, Timberhouse, and SAWA, addressing sub-questions 3: *"What strategies can be used to reduce the embodied carbon within a building project and how are these applied in current practice?";* 4: *"To what extent is (the reduction of) embodied carbon part of the investment decision-making process in the current practice?"*; and 5: *"What adjustments do investors make to the Discounted Cash Flow (DCF) parameters to reflect embodied carbon reduction strategies?"*

The structure encompasses a project description, applied reduction strategies, an overview of the general investment decision-making process of the investor and its execution in the case study. It also examines whether the reduction of embodied carbon currently impacts daily practice and whether it is included in investment decision-making. This is followed by a discussion on the utilized DCF parameters and the impact of embodied carbon reduction strategies on these parameters in the case studies. For all investment decision-making processes, the framework of Farragher & Kleiman (1996) and Farragher and Savage (2008) was adhered to.

These three case studies were selected based on the following criteria: it must be a residential building, with early involvement of investors, where financial modeling and risk assessment have been conducted, and lastly, multiple reduction strategies have been applied. Figure 20 shows the locations of the three case studies in the Netherlands.


*Figure 20 - Location of the selected case studies in the Netherlands (own illustration)*

# Jonas

## 5.1 Jonas

### 5.1.1 Project description

Jonas is located at the harbor of Amsterdam IJburg and is a high-quality and sustainable apartment complex with eight floors, including a public base and a parking garage. The complex comprises 273 apartments, including 190 mid-market compact rental studios with a high level of finishing, and 83 owner-occupied apartments. In addition to the individual living spaces, Jonas features a communal living room and a rooftop beach (common outdoor space). The design references the legend of 'Jonas and the Whale.' The interior is characterized by a contrasting open courtyard known as the canyon in light wooden framing. The path through the building leads to a green courtyard with several trees. Furthermore, Jonas has received the highest possible sustainability certificate: BREEAM Outstanding (Orange Architects, 2023). The construction of the building was executed in the traditional manner through the use of poured 'green concrete'. Furthermore, the facade is finished with zinc panels, and a significant amount of wood has been used for the interior facade (canyon and roof) (Interview J-A, 2023).

*Figure 21 - The use of wood on the Canyon (left picture) and the roof (right picture) within Jonas (Amvest, 2023)*

The Jonas originated from a tender issued by the municipality of Amsterdam, where you could score 60 points on quality, 30 points on sustainability, and 10 points on the financial bid. Additionally, the municipality used BREEAM to measure sustainability, and it was mandatory to achieve an "excellent" or "outstanding" rating. Jonas ultimately received a full 90 points for quality and sustainability during the tender, thus winning the tender (Interview J-A, 2023). In Table 7, the specifications of the project can be seen.

*Table 7 - Specifications of Jonas*

| Specification | Jonas |
|---|---|
| Size (GFA) | 29.950 m² |
| Design | 2017 |
| Construction time | 3 years |
| Realisation | 2022 |
| Investor | Amvest |
| Architect | Orange Architects |
| Developer | Amvest |
| Contractor | Ballast Nedam |
| MPG score | 0,67 €/m² GFA |
| PPm | 300 kg $CO_2$-eq. per m² |
| Interest rate | between 1,4% & 1,7% |
| Material cost | 28% cheaper comparted to 2023 |

Sustainable concept

As mentioned above, the project was guided by BREEAM certification. Therefore, throughout the project, various categories were closely monitored, including transportation, materials, and waste. By steering the project in these categories, the embodied carbon in the project was reduced. This was achieved through the involvement of two experts, one during the design phase and one during the execution phase (Interview J-A, 2023). These experts continuously coordinated the entire BREEAM process. Additionally, sustainability in the design phase was monitored in the 3D model using the MIM tool (Environmental Impact Monitor). By utilizing the MIM tool, various materials were compared, allowing for the selection of the most sustainable materials. Furthermore, it enabled the direct determination of shadow prices and carbon footprints (Interview J-D, 2023).

Investor profile

Amvest is an institutional investor that operates three different funds, with Jonas being part of the Amvest Residential Core Fund. All funds are open-ended, meaning they have no end date. Additionally, each fund has various external shareholders who invest in that particular fund. With the capital from these shareholders, investments are made in new real estate projects, aiming to achieve a specific annual return. The focus of the Amvest Residential Core Fund is on Dutch rental properties that should provide stable returns over the long term. Furthermore, it is important to provide a sustainable and pleasant living environment, which is expected to have a positive impact on the world (Interview J-AM, 2023).

### 5.1.2 Applied embodied carbon reduction strategies

Table 8 provides a summary of the applied embodied carbon reduction strategies based on the interviews with the architect and the developer. Thereby also the possible benefits of the applied strategy is described.

*Table 8 - Applied embodied carbon reduction strategies within Jonas (Interview J-A & J-D, 2023)*

| Strategies & operational measures | | Application |
|---|---|---|
| Low-carbon materials | Biobased materials | A portion of the project has been executed in Douglas wood (FSC certified). This is a type of wood that, once treated, requires no further maintenance. This was used for the patios on the exterior of the project and the entire interior courtyard's facade finishing (wooden slats), see Figure 21. Additionally, 50% of the rear construction of the facade, inner wythes, and frames are made of wood. |
| | Sustainable alternatives | - |
| Material reduction strategies | Optimization of structural design | The construction has been fully optimized to reduce environmental impact. This included the optimization of reinforcement steel, resulting in more than a 30% reduction in the load on the concrete elements. It is designed in the way they only use what is truly necessary. This optimization also contributed to a lighter foundation. In addition, material has been saved through the optimization of the wooden slats in the courtyard. |
| | Building compactness | - |
| | Minimal use of installations | Consideration was given to the most sustainable method of ventilation, which led to the choice of type C (natural supply with mechanical exhaust). This resulted in material savings as fewer ducts needed to be installed, and no large installation units were required. |
| | Replacement intervals installations | - |
| | Waste minimization | The construction site management is organized in such a way as to minimize environmental impact. Objectives for energy and water usage during construction were established in advance. Throughout the construction process, energy and water consumption were monitored on a weekly basis, allowing for prompt identification of excessive consumption. Furthermore, subcontractors were asked to minimize packaging materials, and when used, to separate them. |
| Reuse and Recycling | Recycling | Within the project, the entire load-bearing structure is made from 'green concrete,' known as Blast Furnace Cement (CEMIII), where 25% of the coarse aggregate has been replaced with the coarse fraction of concrete aggregate from demolished concrete structures. |
| | Reuse | - |
| Local Sourcing of Materials | Transportation factors | During the construction process, efforts were made to reduce traffic movements to the construction site. This was done through the use of a construction hub, where trucks had to pre-request a ticket with a specific time slot. They could then enter the construction hub during that time slot and depart afterward. This led to fuller trucks and prevented them from driving around in circles when the construction site was full. This resulted in a more efficient setup. |
| | Prioritization local materials | Within the project, a specific choice was made to source Douglas wood from Europe (Czech Republic) rather than Canada. However, due to the highly optimized design of the wooden slats, the wood needs to be transported to the Netherlands for cutting and is then sent to Denmark or Sweden for treatment, before returning. |
| Construction Optimization | Optimization of construction activities | - |
| | Optimal construction equipment | - |
| | Innovations machinery | - |
| | Use of off-site manufacturing | Within the project, all facade elements, inner wythes, and stairs have been made from 2D prefab elements. In all other aspects, the project adheres to traditional construction methods, involving the on-site formwork and casting of walls and floors. |

**Legend:** Used / Partly used / Not used

### 5.1.3 Investment decision-making process

This paragraph outlines Amvest's general investment process. Additionally, it details how this process was conducted within Jonas, including whether reducing embodied carbon had an impact on the execution of the step compared to the general process. The results are presented in Table 9, with a detailed explanation in Appendix VII.

*Table 9 - Comparison of Investment decision-making process at Amvest and Jonas (Interview J-AM, 2023)*

| Steps | Amvest general | Jonas |
|---|---|---|
| Setting a strategy | - Portfolio plan (outlines strategy for next 3 years)<br>- Describes the overall fund strategy<br>- Reevaluated annually | - In line with portfolio plan, but more emphasis on sustainability through achieving a BREEAM Outstanding certificate. |
| Establishing return/risk objectives. | - Fixed Internal Rate of Return (IRR) requirement<br>- Regional index (vacancy rate, Value growth of vacancy value) to be more flexible to achieve the IRR. | - Same as general |
| Forecasting and evaluate expected costs returns | - IRR model<br>- Holding period of 10 year<br>- Terminal value based on Cashflow year 11 and GEY | - Same as general<br>- But final IRR got above the required IRR |
| Assessing investment risk | - Risk matrix<br>- Qualitative in nature and evaluates risk on fifteen different points<br>- Low, medium or high<br>- Reputation, collaboration with partners, technical risks, legal risks, location, vacancy, marketing, and the feasibility of the planned schedule | - 80% low risk<br>- High risk: solvency and reliability of the contractor and concept of Jonas (small units)<br>- Choice of sustainable materials of BREEAM outstanding not incorporated in the risk assessment |
| Making a risk-adjusted evaluation on cost | - Is always applied if it is necessary, mainly concerning cash flow and returns | - No specific adjustments were made to the cash flow concerning the identified risks in the risk matrix for Jonas.<br>- IRR also was above the requirement |
| Implementing Proposals | - Structured method and approach from the moment of purchase<br>- Clear division of roles and collaboration between the technical manager, the asset manager, and the supervisor | - Followed its usual process |
| Auditing performance | - Financial control department and real estate analysts oversee the buildings to verify if they meet the expectations outlined in the investment proposal. | - Not yet applicable, but they are going to do it |

**Legend:** No impact at all | Positive impact | Moderate impact | Negative impact

### 5.1.4 Incorporation of embodied carbon

This paragraph explains the extent to which the reduction of embodied carbon is included in Amvest's standard practice. The results are presented in Table 10.

*Table 10 - Incorporating embodied carbon in Amvest's investment decision-making (Interview J-AM, 2023)*

| Investment D-M steps | Incorporating of embodied carbon in standard practice |
|---|---|
| Setting a strategy | - Increased focus on sustainability and embodied carbon, leading to changes in the material choice within the Program of Requirements (PvE).<br>- Introduction of an ESG framework where embodied carbon becomes an integral part.<br>- The current focus is on mapping and analyzing new projects scores regarding the MPG and Paris Proof indicators. |
| Establishing return/risk objectives. | - Discussion on embodied carbon within return/risk objectives has been reignited among shareholders, with analysis on alignment with the fund's strategic direction, particularly 'Paris Proof' objectives, however not included yet. |
| Forecasting and evaluate expected costs returns | - Discussion about the holding period with the shareholder arises, primarily because rental prices are often capped for the next 15 years, meaning that mutations are not taken into account.<br>- Future sustainability requirements, such as the 'Paris Proof' standards, are considered. If a project does not meet these future standards, it may lead to additional investments. |
| Assessing investment risk | - Embodied carbon not direct included in the risk matrix yet, but potential future changes with the 'impact framework' especially regarding long-term risks from embodied carbon and material choices. |
| Making a risk-adjusted evaluation on cost | - |
| Implementing Proposals | - Sustainability is considered in implementing proposals, but embodied carbon not direct included. |
| Auditing performance | - No direct changes from reducing embodied carbon, but standard monitoring of maintenance costs for certain materials is conducted, influencing feedback on choice of materials the PvE. |

**Legend:** Included Semi included Not included

### 5.1.5 Used DCF parameters

Table 11 displays the parameters used by Amvest, which are also applicable to Jonas.

*Table 11 - Used DCF parameters within Amvest (Interview J-AM, 2023)*

| Holding period | Cashflow | | Terminal value | Required IRR |
|---|---|---|---|---|
| National tax law | Initial property value | Construction time | GEY (Gross exit yield) | Government bonds |
| National depreciation systems | Land value | Interest factor for construction | $Cashflow^{t+1}$ | Inflation |
| Market conditions | Rent/$m^2$ | Loan | Depreciation Factor | Property law |
| Initial investment | NLA (Net Lettable Area) | Amortization | Vacancy value (NFA) | Demand and supply |
| Type of investment | GFA/NLA ratio | Interest rate on loan | Value growth of vacancy value (NFA) | Local market |
| | Nominal annual rent increase | Depreciation factor | NLA (Net Lettable Area) | Tenant credit worthiness |
| | Inflations | Tax rate | | Multi/single let |
| | Vacancy rate | GIY (Gross initial yield) | | Period to expire of leases |
| | Mutation rate | Carbon pricing | | Accessibility |
| | Other income | Carbon offsetting | | Sustainability |
| | Operation expenses | Carbon taks | | Building obsolescence premium |
| | Capital expenditures | | | |

**Legend:**
Used
Not used

### 5.1.6 Adapted DCF parameters by applied the reduction strategies

This section addresses the impact of reduction strategy considerations on the parameters of the DCF-model, as shown in Table 12. However none of the applied reduction strategies had any impact on the DCF parameters. Additionally, where a reason has been provided by the investor for why the applied reduction strategies had no impact, this is also displayed in the table.

*Table 12 - Impact of used reduction strategies within Jonas on the DCF parameter (Interview J-A, J-D & J-AM, 2023)*

| Operational measures | | Impact on DCF | | Explanation of impact on DCF parameters |
|---|---|---|---|---|
| **Biobased materials** | Patios and the entire interior courtyard's facade finishing made of Douglas wood and 50% of the rear construction of the facade, inner wythes, and frames are made of wood. | HP | No impact | - |
| | | CF | No impact | **Initial property value:** are indirectly higher because wood is currently more expensive however not clear whether the use of wood has actually resulted in a higher initial property value. **Operation expenditures:** A standard maintenance cost percentage had been used. This choice was made because there isn't enough direct experience with the type of wood selected, and therefore, it is uncertain if it is truly maintenance-free. |
| | | TV | No impact | - |
| | | IRR | No impact | - |
| **Optimization of design** | 30% reduction concrete elements, lighter foundation, optimization of the wooden slats. | HP | No impact | - |
| | | CF | No impact | **Initial property value:** It is expected that the reduced use of concrete and increased use of wood will indirectly lead to lower costs, but it is not clear if it has had a significant impact. **Operation expenditures:** the reduced use of wooden slats would result in lower maintenance costs, although this benefit is considered small and has not been directly factored into the investment decision. |
| | | TV | No impact | - |
| | | IRR | No impact | - |
| **Minimal use of Installations** | Ventilation type C. | HP | No impact | - |
| | | CF | No impact | **Initial property value:** This aspect may have had an influence, but the investor emphasizes that its impact on the purchase decision is minimal. **Operation expenditures:** The potential cost savings from reduced maintenance are not directly visible within the DCF model for the investor but may be considered an indirect benefit in the long term and could possibly be taken into account in future projects. |
| | | TV | No impact | - |
| | | IRR | No impact | - |
| **Waste minimization** | Energy and water consumption were monitored and minimize packaging materials. | DCF | No impact | - |
| **Recycling** | Recycled concrete. | DCF | No impact | - |
| **Transportation factors** | Use of construction hub and ticket system. | DCF | No impact | - |
| **Prioritization of local materials** | Raw wood used from Czech Republic, | DCF | No impact | - |
| **Use of prefabricated elements** | 2D prefab elements (facade elements, inner wythes, and stair) | HP | No impact | - |
| | | CF | No impact | **Construction time:** Should have a positive impact. However, the interviewee did not specifically know if it had an impact because 2D prefab facade elements and internal spandrel panels were used within Jonas, as this was a small part of the construction. |
| | | | No impact | |
| | | TV | No impact | - |
| | | IRR | No impact | - |

**Legend:** Positive impact · No impact · Negative impact

# Timberhouse

## 5.2 Timberhouse

### 5.2.1 Project description

Timberhouse stands tall as a unique hybrid residential tower in the Buiksloterham area of Amsterdam North, offering a harmonious blend of stacked wooden prefab modules surrounding a central concrete elevator shaft. This innovative project consists of 22 rental apartments thoughtfully designed for young professionals, complemented by ground-floor commercial spaces.

The journey of Timberhouse began with a tender request from the municipality of Amsterdam. Responding to the call for a circular building, the type of rental housing was left entirely open. This challenge was won by the owner of Timber & Co and Finch Buildings. However, at that time, Timber & Co lacked the financial means to realize Timberhouse. Following a dialogue between Coltavast and the owner of the two companies, Timber & Co was acquired by Coltavast, securing the necessary funding. Consequently, Timber & Co and Finch Buildings took on the role of delegated developers, with the additional responsibility of providing architectural services for a fee. In Table 13, the specifications of the project can be seen.

*Table 13 - Specification of Timberhouse*

| Specification | Timberhouse |
|---|---|
| Size (GFA) | 1.974 $m^2$ |
| Design | 2019 |
| Construction time | 6 months |
| Realisation | 2022 |
| Investor | Coltavast |
| Architect | Finch buildings |
| Developer | Timber & Co |
| Contractor | Volkerwessels |
| MPG score | 0,56 €/$m^2$ GFA |
| PPm | unknown |
| Interest rate | between 1,5% & 1,8% |
| Material cost | 24% cheaper comparted to 2023 |

Sustainable concept

The initial vision of Finch Buildings was to design a circular building, prioritizing the use of biobased materials. The primary goal was to create a flexible building for the future, with the lowest possible $CO_2$ footprint. This ambition led to the development of a building made from wooden modular units. The project incorporated over 666 cubic meters of wood, which has resulted in the storage of approximately 414 tons of $CO_2$. Furthermore, an additional 562 tons of $CO_2$ emissions were avoided by foregoing a concrete and steel framework.

Investor profile

Coltavast is a private investor with approximately 15 employees, and they consider themselves a family office. The company is currently run by the two sons of the founder, who also have various other businesses. In addition, there is one more shareholder, which is the founder himself. The in current focus is on retail and residential real estate, with a focus on Utrecht and Amsterdam for residential properties. The primary goal of their investments is to achieve the highest possible returns by utilizing both equity and debt.

### 5.2.2 Applied embodied carbon reduction strategies.

Table 14 provides a summary of the applied embodied carbon reduction strategies based on the interviews with the architects and the developer. Thereby also the possible benefits of the applied strategy is described.

*Table 14 - Applied embodied carbon reduction strategies within Timberhouse (Interview T-A & D, 2023)*

| Strategies & operational measures | | Application |
|---|---|---|
| Low-carbon materials | Biobased materials | Within the project, laminated wood has been used for all the modular units. Additionally, the entire upper floor has been constructed using timber frame construction. |
| | Sustainable alternatives | - |
| Material reduction strategies | Optimization of structural design | - |
| | Building compactness | - |
| | Minimal use of installations | - |
| | Replacement intervals installations | - |
| | Waste minimization | - |
| Reuse and Recycling | Reuse | - |
| | Recycling | - |
| Local Sourcing of Materials | Transportation factors | The factories where the modular units are made are located in the Netherlands, so a large portion of the workforce commutes to the factory by bicycle. In this factory, everything related to the modular units is manufactured. This means that only one transportation movement was needed to transport the entire apartments to the construction site. Compared to 2D prefab elements, this saves at least half of the transportation movements. |
| | Prioritization local materials | The raw wood (FSC certified) used within the project originates from Central Europe, such as Austria, Germany, or Switzerland. However, the factories used for producing the modular units are located in the Netherlands. |
| Construction Optimization | Optimization of construction activities | - |
| | Optimal construction equipment | The modular units are manufactured in a factory where nearly everything is automated. |
| | Innovations machinery | The modular units are manufactured in a factory where nearly everything is automated. |
| | Use of off-site manufacturing | Within the project, Modular units were used. These were described as essentially a box that comes from the factory with the floor, walls, kitchens, and bathroom inside, but the exterior cladding and interior finishing are not yet applied. Because of this was the highest point was reaches within six months. |

**Legend:** Used | Partly used | Not used

### 5.2.3 Investment decision-making process

This paragraph outlines Coltavast's general investment process. Additionally, it details how this process was conducted within Timberhouse, including whether reducing embodied carbon had an impact on the execution of the step compared to the general process. The results are presented in Table 15, with a detailed explanation in Appendix VIII.

*Table 15 - Comparison of Investment decision-making process at Coltavast and Timberhouse (Interview T-AM, 2023)*

| Steps | Coltavast general | Timberhouse |
|---|---|---|
| Setting a strategy | - They approach investments opportunistically, identifying opportunities rather than actively pursuing a predefined strategy. But focused on financial results. | - Financial returns less important, the goal was to make the portfolio more sustainable so that they can obtain cheaper loans. |
| Establishing return/risk objectives. | - Minimum internal rate of return (IRR)<br>- The GIY must be higher than market standard | - The IRR and GIY were initially set lower at the beginning of the project. |
| Forecasting and evaluate expected costs returns | - Based on one year of cashflow<br>- Holding period of 1<br>- Terminal value based vacancy value (market conform) or a GEY | - Same as general<br>- Terminal value done by using: vacancy value (market conform)<br>- But final IRR was lower than required IRR |
| Assessing investment risk | - Risk assessments but employs a flexible and informal approach<br>- Qualitative in nature.<br>- Evaluates risk on their personal judgments of feasibility and project location. | - Wood carried a certain level of risk. This was because it was a new approach for them, and they were uncertain about its long-term implications.<br>- Investment risks were considered low because the property could always be used by the family, indicating a form of inherent value. |
| Making a risk-adjusted evaluation on cost | - Is always applied if it is necessary, mainly concerning cash flow and returns | - Wood was seen as a risk; therefore, they used a premium of 5% on the operational cost. Went from 10% to 15% |
| Implementing Proposals | - Structured method and approach from the moment of purchase, they used hire different people in to monitor the project. | - Same as general |
| Auditing performance | - The building's performance is monitored annually after completion (examining rental income and maintenance costs) | - Rent is higher, but because of the location and;<br>- No extra cost have been made so far regarding wood and operational cost |

**Legend:** No impact at all  Positive impact  Moderate impact  Negative impact

### 5.2.4 Incorporation of embodied carbon in the investment decision-making steps

This paragraph explains the extent to which the reduction of embodied carbon is included in Coltavast's standard practice. The results are presented in Table 16.

*Table 16 - Incorporating embodied carbon in Coltavast's investment decision-making (Interview T-AM, 2023)*

| Investment D-M steps | Incorporating of embodied carbon in standard practice |
| --- | --- |
| Setting a strategy | - Sustainability is incorporated as a necessity, with government regulations being the driving force.<br>- It has recently become a consideration in investment choices that if they ever intend to sell the project, it should align with the requirements of pension funds. |
| Establishing return/risk objectives. | - Sustainability aspects, including the reduction of embodied carbon, do not alter the aim for a minimum return of on equity.<br>- Financial goals remain the priority, and it's assumed that an investment not meeting this threshold is not worth pursuing. |
| Forecasting and evaluate expected costs returns | - |
| Assessing investment risk | - |
| Making a risk-adjusted evaluation on cost | - |
| Implementing Proposals | - |
| Auditing performance | - No directly included, however maintenance costs are always monitored. |

**Legend:** Included  Semi included  Not included

### 5.2.5 Used DCF parameters

Table 17 displays the parameters used by Coltavast, which are also applicable to Timberhouse.

*Table 17 - Used DCF parameters within Coltavast (Interview T-AM, 2023)*

| Holding period | Cashflow | | Terminal value | Required IRR |
| --- | --- | --- | --- | --- |
| National tax law | Initial property value | Construction time | GEY (Gross exit yield) | Government bonds |
| National depreciation systems | Land value | Interest factor for construction | Cashflow$^{t+1}$ | Inflation |
| Market conditions | Rent/m$^2$ | Loan | Depreciation Factor | Property law |
| Initial investment | NLA (Net Lettable Area) | Amortization | Vacancy value (NFA) | Demand and supply |
| Type of investment | GFA/NLA ratio | Interest rate on loan | Value growth of vacancy value (NFA) | Local market |
| | Nominal annual rent increase | Depreciation factor | NLA (Net Lettable Area) | Tenant credit worthiness |
| | Inflations | Tax rate | | Multi/single let |
| | Vacancy rate | GIY (Gross initial yield) | | Period to expire of leases |
| | Mutation rate | Carbon pricing | | Accessibility |
| | Other income | Carbon offsetting | | Sustainability |
| | Operation expenses | Carbon tax | | Building obsolescence premium |
| | Capital expenditures | | | |

**Legend:** Used  Not used

### 5.2.6 Adapted DCF parameters by the applied reduction strategies

This section addresses the impact of reduction strategy considerations on the parameters of the DCF-model, as shown in Table 18.

*Table 18 - Impact of used reduction strategies within Timberhouse on DCF parameter (Interview T- A&D & AM, 2023)*

| Operational measure | | Impact on DCF | | Explanation of impact on DCF parameters |
|---|---|---|---|---|
| **Biobased materials** | Laminated wood for all the modular units | HP | No impact | - |
| | | CF | ↑Initial property value | **Initial property value:** It was lower due to construction costs; it was €200 per square meter more expensive compared to traditional concrete. |
| | | | ↑Operation expenditures | **Operating expenditures:** Because it's not clear how wood performs in the long term, costs increased by 5%. |
| | | | ↓Interest rate on loan | **Interest rate on the loan:** Because of to green financing, they had to pay 0.3% less interest. |
| | | TV | No impact | - |
| | | IRR | No impact | - |
| **Transportation factors** | The modular unit factories are in the Netherlands, requiring only one transportation movement. | DCF | No impact | - |
| **Local materials** | Raw wood (FSC certified) used from mid Europe. | DCF | No impact | - |
| **Optimal construction equipment** | The modular units are produced in a highly automated factory. | DCF | No impact | - |
| **Innovations machinery** | The modular units are produced in a highly automated factory. | DCF | No impact | - |
| **Off-site manufacturing** | Modular units were used | HP | No impact | - |
| | | CF | ↓ Construction time | **Construction time**: By shortening the construction time to 6 months, a 4% reduction in the initial property value can be achieved. |
| | | | ↓ GLA/NLA ratio | **GLA/NLA ratio**: Through the use of double walls and floors. |
| | | | ↓ NLA (Net Lettable Area) | **NLA (Net Lettable Area)**: A poorer GLA/NLA ratio results in less NLA in a building. |
| | | TV | ↓ NLA (Net Lettable Area) | **NLA (Net Lettable Area):** Due to a poorer GLA/NLA ratio. |
| | | IRR | No impact | - |

**Legend:** Positive impact | No impact | Negative impact

# SAWA

## 5.3 SAWA

### 5.3.1 Project description

SAWA is the first wooden residential building in Rotterdam, standing at over 50 meters in height. The project's initial focus was on creating a unique and circular wooden residential building, aiming to add value to the neighborhood and the city in the broadest sense. SAWA comprises 39 owner-occupied homes, 20 private sector rental homes, 50 mid-rental homes (€700 - €1,000), a restaurant, and a community facility. The homes are modern, spacious, and each has an outdoor space. Additionally, various communal areas are designed to encourage interactions among neighbors (Mei Architects, 2023).

The project originated when the developer approached the municipality of Rotterdam with a vision to contribute to reducing $CO_2$ emissions and achieving (inter)national climate goals while simultaneously creating affordable housing. Following several discussions between the municipality and the developer, the plot of land was promptly awarded to the developer (Interview S-A&D, 2023). In Table 19, the specifications of the project can be seen.

*Table 19 - Specification of SAWA*

| Specification | SAWA |
|---|---|
| Size (GFA) | 12.000 $m^2$ |
| Design | 2019 |
| Construction time | 2 years |
| Realisation | not yet, in construction at this moment. |
| Investor | Focus On Impact |
| Architect | Mei architects |
| Developer | Nice Developers |
| Contractor | ERA Contour |
| MPG score | 0,60 €/$m^2$ GFA |
| PPm | unknown |
| Interest rate | between 1,5% & 1,8% |
| Material cost | 24% cheaper comparted to 2023 |

Sustainable concept

SAWA is the building that was ultimately designed with four key principles: $CO_2$ reduction, mid-rental housing, biodiversity, and communal spaces. In line with the Paris and Glasgow Climate Agreements, the European Green Deal and the goals of the municipality of Rotterdam, the decision was made to reduce $CO_2$ emissions significantly. This led to the creation of a building where the primary load-bearing structure is almost entirely constructed from CLT (cross-laminated timber), with the use of concrete minimized. Through the extensive use of CLT and other measures, the building not only avoids emitting $CO_2$ but also sequesters it. In fact, the construction of SAWA alone sequesters 5,000 tons of $CO_2$ (Interview S-A&D, 2023). Throughout the design process, there was a continuous focus on reducing embodied carbon, guided by the following one-liner:

*Figure 22 - Construction design SAWA (Mei Architects, 2023)*

*"Adaptability, is detachability, is assembly construction, is factory-based construction, is faster, is lower failure costs and is cheaper." - Interview S - A&D*

Investor profile

Focus on Impact presents itself as a developer and investor with a lean team of around 15 staff members. The firm, exhibiting the traits of a family office, is propelled by four shareholders. Focus on Impact consistently aims to maintain a loan-to-value (LTV) ratio of 45% for financing its new projects. Their investment portfolio is varied, covering sectors like Residential, Care & Cure, Urban Development, Industrial & Logistics, and Retail & Leisure real estate. The projects chosen by Focus on Impact are required to meet one of three key criteria: they should either support the development sector, provide returns better than the average market, or be extraordinarily unique (Interview S-AM, 2023).

### 5.3.2 Applied embodied carbon reduction strategies.

Table 20 provides a summary of the applied embodied carbon reduction strategies based on the interviews with the architects and the developer. Thereby also the possible benefits of the applied strategy is described.

*Table 20 - Applied embodied carbon reduction strategies within SAWA (Interview S-A & D, 2023)*

| Strategies & operational measures | | Application |
|---|---|---|
| Low-carbon materials | Biobased materials | The main structure consists of 90% CLT and laminated wood, with 50% of the facade finish being wood and wooden frames & inner cavity leaves. The intention was to construct the will structure of wood, but it was 20% more expensive, making it unfeasible. |
| | Sustainable alternatives | - |
| Material reduction strategies | Optimization of structural design | - |
| | Building compactness | - |
| | Minimal use of installations | Ventilation type C (natural supply with mechanical exhaust controlled by $CO_2$) has been used. This has resulted in a reduction of up to 60 to 70% in ventilation ducts. In addition, only small compact fans are possible. That resulted in a reduction of 5000 euros per dwelling in construction costs and lower maintenance costs, as it only involves small ventilation units costing around 500 euros. Furthermore, the installations are all detachable and mounted in an accessible manner, making them more cost-effective and easier to replace. |
| | Replacement intervals installations | - |
| | Waste minimization | - |
| Reuse and Recycling | Recycling | - |
| | Reuse | Recycled roof gravel is used. This is applied as dry ballast on the CLT floor. The roof gravel comes from flat roofs throughout the country. |
| Local Sourcing of Materials | Transportation factors | - |
| | Prioritization local materials | All the wood used is FSC certified wood. This wood all comes from forests in Germany. Additionally, the sawmill for the construction elements and the CLT factory were just across the border in Germany. This is not direct local sourcing, but it is relatively close. |
| Construction Optimization | Optimization of construction activities | - |
| | Optimal construction equipment | - |
| | Innovations machinery | - |
| | Use of off-site manufacturing | The main supporting structure and facade finishing are 2D prefab elements. With these, a time saving of three months to half a year has been achieved. |

**Legend:** Used | Partly used | Not used

### 5.3.3 Investment decision-making process

This paragraph outlines Focus on Impact's general investment process. Additionally, it details how this process was conducted within SAWA, including whether reducing embodied carbon had an impact on the execution of the step compared to the general process. The results are presented in Table 21, with a detailed explanation in Appendix IX.

*Table 21 - Comparison of Investment decision-making process at Focus on impact and SAWA (Interview S-AM, 2023)*

| Steps | Focus on Impact general | SAWA |
|---|---|---|
| Setting a strategy | - Not directly one standard strategy. | - Same as general. |
| Establishing return/risk objectives. | - No standard IRR or GIY; return is based on the market and is product-specific. Must be higher than the market. | - The required IRR and GIY were initially set lower. |
| Forecasting and evaluate expected costs returns | - IRR model<br>- Variable holding period (10-15 years), depending on the possible exit scenario imposed by the municipality.<br>- Terminal value calculated based on $CF^{t+1}$ & vacancy value | - Same as general, final IRR got below market.<br>- Holding period of 10 years was applied.<br>- Terminal value calculated by the use of vacancy value. |
| Assessing investment risk | - Qualitative assessment done for each project, sometimes involving external parties. Factors can include: rent, location, technique, quality, materialization, sound, fire safety, environment. | - Four major risks: building's fire safety, availability of wood, maintenance of wood, and whether they would secure the green financing and if it would be on time. |
| Making a risk-adjusted evaluation on cost | - Yes, conducted when necessary | - The operational percentage has been slightly increased. However, there are non-cash flow adjustments: sprinklers added, developer is going to do the asset management for the first 5 years. |
| Implementing Proposals | - Standard method with role-based responsibilities | - Followed its usual structured method, but with a slightly more controlled approach. |
| Auditing performance | - Yes every assumption will be measured | - Not yet applicable, but they are going to do it |

**Legend:** ☐ No impact at all ☐ Positive impact ☐ Moderate impact ☐ Negative impact

### 5.3.4 Incorporation of embodied carbon in the investment decision-making steps

This paragraph explains the extent to which the reduction of embodied carbon is included in Focus on Impact's standard practice. The results are presented in Table 22.

*Table 22 - Incorporating embodied carbon in Focus on Impacts' investment decision-making (Interview T-AM, 2023)*

| Investment D-M steps | Incorporating of embodied carbon in standard practice |
|---|---|
| Setting a strategy | - Embodied carbon, specifically timber construction, will now be more routinely considered, with an aim to assess the feasibility of timber for each project while maintaining a good risk-return balance. However, it will not become a strict requirement but rather an additional consideration. |
| Establishing return/risk objectives. | - There is a willingness to slightly lower return expectations for a "SAWA" type of product, which considers not just embodied carbon but also circularity, shared value, biodiversity, inclusivity, and energy neutrality. |
| Forecasting and evaluate expected costs returns | - No direct impact from considering embodied carbon, already possible to adjust things when necessary. |
| Assessing investment risk | - No impact, material choice has always been a consideration in risk assessment. |
| Making a risk-adjusted evaluation on cost | - |
| Implementing Proposals | - With embodied carbon considerations, there may be closer oversight in the initial stages of the project due to perceived higher risks. |
| Auditing performance | - No impact from considerations of embodied carbon; because, maintenance costs are always monitored |

**Legend:** ☐ Included ☐ Semi included ☐ Not included

### 5.3.5 Used DCF parameters

Table 23 displays the parameters used by Focus on impact, which are also applicable to SAWA.

*Table 23 - Applied DCF parameters within Focus on Impact (Interview T-AM, 2023)*

| Holding period | Cashflow | | Terminal value | Required IRR |
|---|---|---|---|---|
| National tax law | Initial property value | Construction time | GEY (Gross exit yield) | Government bonds |
| National depreciation systems | Land value | Interest factor for construction | Cashflow$^{t+1}$ | Inflation |
| Market conditions | Rent/$m^2$ | Loan | Depreciation Factor | Property law |
| Initial investment | NLA (Net Lettable Area) | Amortization | Vacancy value (NFA) | Demand and supply |
| Type of investment | GFA/NLA ratio | Interest rate on loan | Value growth of vacancy value (NFA) | Local market |
| Exit scenarios | Nominal annual rent increase | Depreciation factor | NLA (Net Lettable Area) | Tenant credit worthiness |
| | Inflations | Tax rate | | Multi/single let |
| | Vacancy rate | GIY (Gross initial yield) | | Period to expire of leases |
| | Mutation rate | Carbon pricing | | Accessibility |
| | Other income | Carbon offsetting | | Sustainability |
| | Operation expenses | Carbon taks | | Building obsolescence premium |
| | Capital expenditures | | | |

**Legend:** Used Not used

### 5.3.6 Adapted DCF parameters by the applied reduction strategies

This section addresses the impact of reduction strategy considerations on the parameters of the DCF-model, as shown in Table 24.

*Table 24 - Impact of used reduction strategies within SAWA on the DCF parameter (Interview S-A, S-D & S-AM, 2023)*

| Operational measures | | Impact on DCF | | Explanation of impact on DCF parameters |
|---|---|---|---|---|
| **Biobased materials** | The main structure is made 90% of CLT and laminated wood, 50% of the facade finish is wood and wooden frames & inner cavity leaves. | HP | No impact | - |
| | | CF | ↑Initial property value | **Initial property value:** was higher because of the use of wood. |
| | | | ↑Operational Expenses | **Operational Expenses**: they do not have any experience with wood. |
| | | | ↓ Interest on loan | **Interest on loan:** they used two types of green financing therefore it was 30% cheaper. |
| | | | ↑Carbon credits | **Carbon credits**: additional €500.000 which is put in operational fund for the building (5% of Initial property value) |
| | | TV | ↑ Value growth of vacancy value | **Value growth of vacancy value:** The project, currently based on capped mid-rent, offers low rates for its market segment. The investor believes that selling the apartments on the open market will yield higher values due to the building's quality. |
| | | | ↑ Vacancy value | **Vacancy value:** Increasing the value growth of the vacancy value results in a higher Vacancy value. |
| | | IRR | ↑Demand and supply | **Demand and supply:** The required IRR was set lower as the investor was confident that using wood and other applied concepts would boost demand for renting or selling the apartments, thereby reducing risk. |
| | | | ↑Sustainability | **Sustainability**: Because it is a sustainable building, this has had an impact on the quality of the building, reducing future risks. |
| **Minimal use of installations** | Ventilation type C | DCF | No impact | - |
| **Recycling** | Recycled roof gravel for dry ballast on floor. | DCF | No impact | - |
| **Prioritization of local materials** | Wood (FSC certified) from Germany and factory just across the border in Germany. | DCF | No impact | - |
| **Off-site manufacturing** | The main supporting structure and facade finishing are 2D prefab elements. | HP | No impact | - |
| | | CF | ↓ Construction time | **Construction time:** It had a minor impact; however, it wasn't clear what impact it exactly had on the cash flow. |
| | | TV | No impact | - |
| | | IRR | No impact | - |

**Legend:** Positive impact (green) · No impact (peach) · Negative impact (pink)

# Chapter 6

## Multiple case analysis

General information
Quantify embodied carbon values
Location and Timing
Investors profile
Applied embodied carbon reduction strategies
The general Investment decision-making process of the Investors
Investment decision-making process within the case studies
Incorporation of embodied carbon in investment decision-making
Adapted DCF parameters by applied reduction strategies

# 6 Multiple case analysis

In this chapter, the results of the three different case studies from Chapter 5: Investment decision-making in embodied carbon reduction case studies, are compared side by side. The results are examined to identify any patterns among them. This analysis will assist in answering sub-questions 3: Strategies for reducing embodied carbon in construction and their current application; 4: The role of embodied carbon reduction in current investment decision-making; and 5: Adjustments investors make to DCF parameters for embodied carbon reduction strategies.

## 6.1 General information

*Table 25 - Comparison of the general information across the different case studies*

| | Jonas | Timberhouse | SAWA |
|---|---|---|---|
| Size (GFA) | 29.950 $m^2$ | 1.974 $m^2$ | 12.000 |
| Apartments | 190 mid-market | 22 private sector | 50 mid-market |
| Size of Apartments (GFA) | 43 to 52 $m^2$ | 44 to 80 $m^2$ | 55 to 80 $m^2$ |
| Rent (per month) | €1.068 | €1.199 - €1.939 | €720 - €1.050 |
| Delivery method | Turn-key | Turn-key | Turn-key |

Differences in size are evident across the various case studies, as reflected in the quantity of apartments that have been rented. In both Jonas and SAWA, the municipality mandated the creation of mid-market rental housing, capping the rental rates at a maximum of €1.100 per month. For SAWA, there is also a stipulation that they must maintain these mid-range rents for a specified number of years before having the option to lease or sell the apartments on the open market. Furthermore, all case studies were delivered using a turn-key approach, where the development risk rests with the developer. In this arrangement, a predetermined price is agreed upon in advance, and it is the developer's responsibility to complete the project within that budget, often working with contractors. As a result, the investor is not responsible for the construction of the project, shifting the development burden to the developer.

## 6.2 Quantify embodied carbon values

*Table 26 - Comparison of embodied carbo scores across the different case studies*

| | Jonas | Timberhouse | SAWA |
|---|---|---|---|
| MPG score | 0,67 €/$m^2$ GFA | 0,56 €/$m^2$ GFA | 0,60 €/$m^2$ GFA |
| PPm | 300 $CO_2$-eq. per $m^2$ | Unknown | Unknown |
| Construction stored carbon | Not applied | 414 $kgCO_2$ | 5000 $kgCO_2$ |

**Patterns: Timber construction projects exhibit a slightly higher MPG score than concrete projects, although the distinction is not particularly pronounced**

In all three projects, embodied carbon has been quantified using the MPG. It is clear that both timber construction projects (Timberhouse and SAWA) have scored higher than the concrete project (Jonas), however, the difference is not very significant. Unfortunately, only Jonas has a PPm score available, so a comparison could not be made. Lastly, there are the financial mechanisms. Carbon offsetting or carbon tax was not used within the case studies; however, Timberhouse and SAWA did sequester $CO_2$ within their projects. In the case of SAWA, the construction stored carbon per GFA is higher due to the use of a massive wooden main supporting structure.

## 6.3 Location and Timing

**Pattern: All case studies are located in a G5 city, giving them similar characteristics. Additionally, there is little difference in the interest rates and material costs.**

To begin with, the analysis starts with some general information. As can be seen in Figure 20 , all three case studies are located in the Randstad region. Timberhouse and Jonas are both located in Amsterdam, while SAWA will be built in Rotterdam.

Furthermore, it's also important to outline the projects in a timeline, as shown in Figure 23. In this timeline, it is clear that the interest rates and material costs for all three case studies were considerably lower compared to now. During interviews, both the investors of Timberhouse and SAWA explicitly mentioned that the low interest rate has been crucial in making their projects feasible, and with the current interest rate and material costs, it would not have been possible to do so.

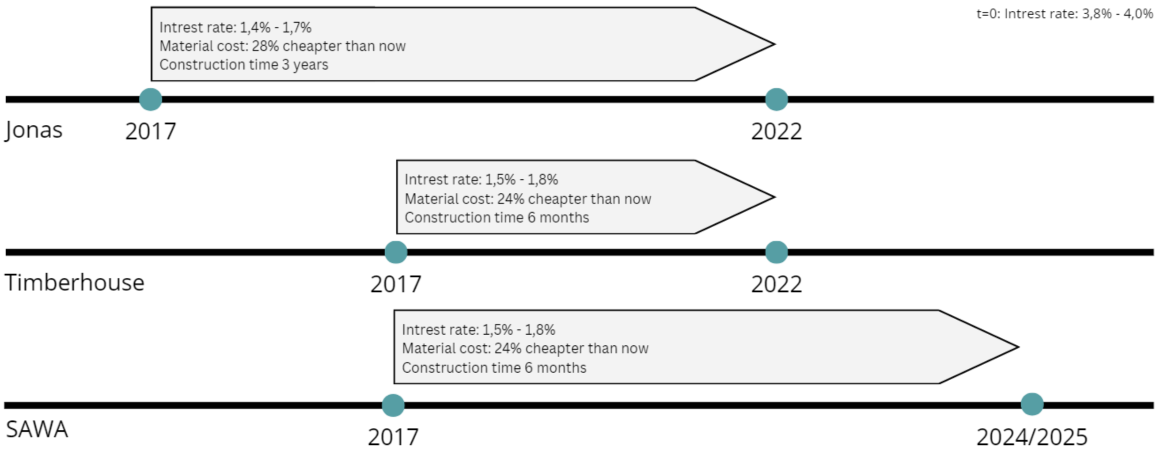



*Figure 23 - Comparing market data and construction time across a timeline (own illustration)*

## 6.4 Investors profile

*Table 27 - Comparison of the type of investors involved in the case studies*

| | Amvest | Coltavast | Focus on impact |
|---|---|---|---|
| Type | Institutional | Private investors | Private investors |
| Funding | Open-ended fund, shareholders (pension and insurers companies) | Family offices, both equity and debt. | Family offices, both equity and debt. |

**Pattern: Private investors tend to be more flexible and have a higher risk tolerance in their decision-making and often utilize leveraged equity financing.**

While Amvest operates as an institutional investor, Coltavast and Focus on Impact are private investors. The interviews have also revealed that there is some difference in the level of flexibility. What has been found is that Amvest must adhere to certain rules set within the fund. In Amvest, all funds are received from external shareholders. If they were to deviate from this, it would mean that a large part or all external shareholders must agree to it. In contrast, Coltavast and Focus on Impact can be more flexible in their decision-making because the lines are shorter, and there are fewer stakeholders involved. Furthermore, concerning funding, Amvest uses a more traditional institutional financing structure, while Coltavast and Focus on Impact rely on shareholder equity and bank debt for financing, indicating a more private and potentially more flexible financing approach.

## 6.5 Applied embodied carbon reduction strategies

*Table 28 - Comparison of the applied embodied carbon reduction strategies across the different case studies*

| Strategies & operational measures | | Jonas | Timberhouse | SAWA |
|---|---|---|---|---|
| Low-carbon materials | Biobased materials | Wood | Wood | Wood |
| | Sustainable alternatives | - | - | - |
| Material reduction strategies | Optimization of structural design | Construction & wooden slats | - | - |
| | Building compactness | - | - | - |
| | Minimal use of installations | Ventilation type C | - | Ventilation type C |
| | Replacement intervals installations | - | - | - |
| | Waste minimization | Energy and water monitor and minimize packaging materials | - | - |
| Reuse and Recycling | Recycling | Green concrete | - | Roof gravel for dry ballast |
| | Reuse | - | - | - |
| Local Sourcing | Transportation factors | Construction hub and ticket system | One movement to construction site | - |
| | Prioritization local materials | Europe | Europe | Europe |
| Construction Optimization | Optimization of construction activities | - | - | - |
| | Optimal construction equipment | - | Automated factory | - |
| | Innovations machinery | - | Automated factory | - |
| | Use of off-site manufacturing | Some prefab elements | Modular units | Prefab elements |

**Legend:** Used | Partly used | Not used

### 6.5.1 Biobased materials

**Pattern: All cases show a pattern of using wood as low-carbon material.**

Starting with biobased materials, in both Timberhouse and SAWA, the primary building structure, except for the core, is entirely made of wood, and this has been the goal from the outset in both projects. This was chosen because It was emphasized by the architects that when the construction is done in wood instead of concrete or steel, it has the most significant impact on reducing embodied carbon (interview S - A&D, 2023; interview T - A&D, 2023). In Timberhouse and SAWA, almost the entire facade finishing is made of wood, while in Jonas, wood is used in some parts of the building.

### 6.5.2 Material reduction

**Pattern: Optimizing structural design and implementing ventilation type C are effective ways to reduce material consumption.**

Regarding material reduction, Jonas has implemented the most operational measures. They optimized the entire construction process, leading to a 30% reduction in concrete and reinforcing steel usage, saving €100,000 to €150,000 on wooden slabs by design optimization. Additionally, they optimized all wood used in the canyon area, resulting in a cost savings of €100,000 to €150,000. During construction, they monitored energy and water usage and promoted minimal packaging.

Jonas and SAWA both chose to use ventilation Type C for significant material reduction. Interviews revealed that Type C required 60 to 70% fewer ventilation ducts and eliminated the need for large units, using only small, cost-effective ventilation units. This led to a cost reduction of €5000 per dwelling, with lower maintenance costs due to the replacement of only small, €500 ventilation units when needed.

### 6.5.3 Material Reuse and Recycling

**Pattern: Recycled materials are used to replace traditional concrete.**

In both Jonas and SAWA, recycled materials were used. Jonas used "green concrete" for the entire construction. At SAWA, recycled roof gravel was used as dry ballast on the CLT floor where the pipes are located. The use of recycled roof gravel as dry ballast made the project more flexible and demountable because it allows easy access to the pipes instead of being poured in place. Directly applying reused materials was not done in any of the case studies. However, SAWA and Timberhouse are both designed in a way that almost everything in the building can be reused as separate materials or components.

### 6.5.4 Local Sourcing of Materials

**Pattern: The use of FSC-certified wood is evident in all case studies, and $CO_2$ emissions are reduced by lowering transportation distance and movements.**

In all case studies, FSC-certified wood was used, signifying the use of sustainable wood from well-managed European forests. While this may not directly prioritize local materials, it is still a better practice than importing wood from another continent. Jonas stands out as the only case where efforts were made to minimize this by employing a construction hub and ticket system. Timberhouse also considered this but due to its use of factory-produced modular units, requiring only one transportation movement for the entire apartment construction, transportation distance was naturally reduced. Furthermore, Timberhouse aimed to avoid oversized units that would necessitate special transportation. Comparatively, SAWA had to source 2D prefab elements from Germany, even though the difference between having a factory in the Netherlands or Germany was considered negligible by SAWA's architect, as the majority of the environmental impact stems from the construction phase.

### 6.5.5 Construction Optimization

**Pattern: Using off-site manufacturing is a commonly employed method to reduce embodied carbon, with 2D prefab elements being less effective than modular units due to their longer construction times.**

To start, all three case studies utilize off-site manufacturing, but they exhibit differences. In Jonas, only the facade elements, inner wythes, and stairs are constructed using 2D prefab methods. In contrast, SAWA employs 2D prefab elements for both the primary support structure and facade finishing, resulting in a construction time reduction of approximately three to six months. Timberhouse achieves the most substantial reduction in embodied carbon, as the entire building, excluding the facade finishing and core, consists of modular units. The use of prefabricated modular units has reduced the construction time to just 6 months. These modular units are manufactured in a highly automated factory.

## 6.6 The general Investment decision-making process of the Investors

Table 29 shows the results of how the different investors within the research in general conduct their investment decision-making. It provides an overall description of how each investor goes through the 7 steps.

*Table 29 - Comparison of the investment decisions-making process of the different investors*

| Investment D-M steps | Amvest | Coltavast | Focus on impact |
|---|---|---|---|
| Setting a strategy | Yes, fund strategy based on portfolio plan (outlines strategy for next 3 years), yearly updated. | Not directly, approach to investments more opportunistically and focused on financial results. | Not directly one standard strategy, but projects must either serve the development arm, offer better than market returns, or be exceptionally unique |
| Establishing return/risk objectives. | Fixed IRR, based on market, GIY based on market, but vary on location | Semi fixed IRR, GIY higher than market standard. | No standard IRR or GIY; based on market conditions and are product-specific, but higher than market |
| Forecasting and evaluate expected costs returns | IRR model, fixed holding period (10 year), terminal value ($CF^{t+1}$ & vacancy value) | Forecasting operational cashflow, fixed holding period (1 year), terminal value (a set GEY & vacancy value) | IRR model, variable holding period (10-15 years), determined possible exit scenarios. Terminal value calculated based ($CF^{t+1}$ & vacancy value) |
| Assessing investment risk | Risk matrix of standard 15 points, Qualitative. | Yes, but employs a flexible and informal approach based on personal judgments of feasibility. | Qualitative risk assessment, product-specific. |
| Making a risk-adjusted evaluation on cost | Yes, if necessary | Yes, if necessary | Yes, if necessary |
| Implementing Proposals | Structured method, clear division with different tasks | Structured method, clear division with different tasks | Standard method with role-based responsibilities |
| Auditing performance | Yes | Yes | Yes |

### 6.6.1 Step 1: Setting a strategy

**Pattern: Private investors do not stick to a strategy, it is mainly about financial results.**

There is a correlation in that both private investors (Coltravast and Focus on Impact) do not have a direct strategy, but their main focus is on achieving financial returns. In contrast, Amvest, being an institutional investor, utilizes a portfolio plan that outlines the strategy for the upcoming three years.

### 6.6.2 Step 2: Establishing return/risk objectives.

**Pattern: A fixed required IRR leads to uncertainty about the origin and structure of the required IRR demand.**

Amvest and Coltavast both employ a fixed required IRR. With Coltavast's required IRR requirements, there is some flexibility, as it was clearly stated that if it does not exceed the required IRR , it is better to invest elsewhere, unless the owners have a particular preference, which was referred to as the 'sweetener of the week.' In contrast, at Amvest, the fixed required IRR applies to the entire portfolio, and all individual acquisitions must meet this criterion. Lastly, Focus on Impact did not have a specific standard required IRR but rather looked more at the current market. To conclude, the Amvest Which parameters were used to determine the required IRR by the investor can be seen in Table 30.

*Table 30 - Comparison of the used required IRR parameters across the different case studies*

| Jonas | Timerhouse | SAWA |
|---|---|---|
| Government bonds | Government bonds | Government bonds |
| Inflation | Inflation | Inflation |
| Property law | Property law | Property law |
| Demand and supply | Demand and supply | Demand and supply |
| Local market | Local market | Local market |
| Tenant credit worthiness | Tenant credit worthiness | Tenant credit worthiness |
| Multi/single let | Multi/single let | Multi/single let |
| Period to expire of leases | Period to expire of leases | Period to expire of leases |
| Accessibility | Accessibility | Accessibility |
| Sustainability | Sustainability | Sustainability |
| Building obsolescence premium | Building obsolescence premium | Building obsolescence premium |

**Legend:** Used Not used

### 6.6.3 Step 3: Forecasting and evaluate expected costs returns

Holding period

**Pattern: A fixed holding period leads to uncertainty about the parameters influencing it and results in reduced flexibility.**

To begin with the forecasting of the expected cost return, both Amvest and Coltavast use a standard holding period. However, Amvest's holding period is 10 years, while Coltavast's is only 1 year for new projects. Focus on Impact has a variable holding period, which often falls between 10 and 15 years. This is determined based on possible exit scenarios and is also project-specific. As a result, according to the interviews, they perform a more realistic calculation than when using a standard timeframe of 10 years because they adapt to scenarios. See Table 31 which parameters are employ within the different investors.

*Table 31 - Comparison of the used holding period parameters across the different case studies*

| Jonas | Timberhouse | SAWA |
|---|---|---|
| National tax law | National tax law | National tax law |
| National depreciation systems | National depreciation systems | National depreciation systems |
| Market conditions | Market conditions | Market conditions |
| Initial investment | Initial investment | Initial investment |
| Type of investment | Type of investment | Type of investment |
| | | Exit scenarios |

**Legend:** Used Not used

Cashflow

**Pattern: Using a longer holding period allows for more flexibility in dealing with future expectations and makes the investment more future-proof.**

With regard to the cashflow, both Amvest and Focus on Impact use a standard IRR model in which they spread the revenues and costs over a certain period, making various assumptions to determine future cash flows.

In the case of Timberhouse, this is not the case, and this is also reflected that they do not use parameters such as the nominal annual rent increase, vacancy rate, and mutation rate. To conclude, both Coltavast and SAWA use debt capital, which means they utilize additional parameters that are not used by Amvest.

*Table 32 - Comparison of the used cashflow parameters across the different case studies*

| Jonas | | Timberhouse | | SAWA | |
|---|---|---|---|---|---|
| Initial property value | Construction time | Initial property value | Construction time | Initial property value | Construction time |
| Land value | Interest factor for construction | Land value | Interest factor for construction | Land value | Interest factor for construction |
| Rent/m² | Loan | Rent/m² | Loan | Rent/m² | Loan |
| NLA (Net Lettable Area) | Amortization | NLA (Net Lettable Area) | Amortization | NLA (Net Lettable Area) | Amortization |
| GFA/NLA ratio | Interest rate on loan | GFA/NLA ratio | Interest rate on loan | GFA/NLA ratio | Interest rate on loan |
| Nominal annual rent increase | Depreciation factor | Nominal annual rent increase | Depreciation factor | Nominal annual rent increase | Depreciation factor |
| Inflations | Tax rate | Inflations | Tax rate | Inflations | Tax rate |
| Vacancy rate | GIY (Gross initial yield) | Vacancy rate | GIY (Gross initial yield) | Vacancy rate | GIY (Gross initial yield) |
| Mutation rate | Carbon pricing | Mutation rate | Carbon pricing | Mutation rate | Carbon pricing |
| Other income | Carbon offsetting | Other income | Carbon offsetting | Other income | Carbon offsetting |
| Operation expenses | Carbon tax | Operation expenses | Carbon tax | Operation expenses | Carbon tax |
| Capital expenditures | | Capital expenditures | | Capital expenditures | |

**Legend:** Used Not used

## Terminal value

**Pattern: Using a longer holding period takes into account future value increases or decreases in the terminal value.**

All three investors calculate the terminal value using either the GEY or the vacancy value. However, Timberhouse determines the terminal value based on the current market's vacancy value at present, while Focus on Impact and Amvest both make assumptions when determining the terminal value at the end of their cash flow by using the value growth of vacancy value and the vacancy value.

*Table 33 - Comparison of the used terminal value parameters across the different case studies*

| Jonas | Timberhouse | SAWA |
|---|---|---|
| GEY (Gross exit yield) | GEY (Gross exit yield) | GEY (Gross exit yield) |
| Cashflow$^{t+1}$ | Cashflow$^{t+1}$ | Cashflow$^{t+1}$ |
| Depreciation factor | Depreciation factor | Depreciation factor |
| Vacancy value (NFA) | Vacancy value (NFA) | Vacancy value (NFA) |
| Value growth of vacancy value (NFA) | Value growth of vacancy value (NFA) | Value growth of vacancy value (NFA) |
| NLA (Net Lettable Area) | NLA (Net Lettable Area) | NLA (Net Lettable Area) |

**Legend:** Used Not used

### 6.6.4 Step 4: Assessing investment risk

**Pattern: Qualitative method is used for assessing investment risk; however, private investors have a less structured approach.**

All three investors conduct an assessment of the investment risk, and they do this in a qualitative manner. However, Amvest is the only one with a standard checklist that is used for every project.

### 6.6.5 Step 5: Making a risk-adjusted evaluation of the forecast costs and returns

**Pattern: Risk-adjusted evaluation of costs is feasible for every investor.**

At all three investors, it has been concluded that after conducting the assessment regarding investment risk, certain elements can be adjusted within the financial model if necessary.

### 6.6.6 Step 6: Implementing accepted proposals

**Pattern: Implementing accepted proposals always done in structured manner**

All three investors have their own structured approach with a clear division of tasks and responsibilities to ensure that projects are completed within time, within budget, and with the desired quality.

### 6.6.7 Step 7: Auditing performance

**Pattern: Monitoring the assumptions made during the purchase is important for all investors.**

All three investors monitor the performance of a project after it is put into use. In the case of Coltavast, the focus is mainly on rental income and maintenance costs, while Focus on Impact and Amvest examine all assumptions.

## 6.7 Investment decision-making process within the case studies

In Table 34, a comparison is shown of how the 7 investment decision-making steps were executed in the different case studies. Simultaneously, it can be seen through various colors whether the reduction of embodied carbon had an impact on the execution of the step compared to the general process.

*Table 34 - Comparison of the investment decisions-making process across the different case studies*

| Investment D-M steps | Jonas | Timberhouse | SAWA |
|---|---|---|---|
| Setting a strategy | Similar to general, but with more emphasis on sustainability through achieving a BREEAM Outstanding certificate. | Financial returns less important. | Same as general, project was exceptionally unique. |
| Establishing return/risk objectives. | No specific adjustments were made. | The required IRR and GIY were initially set lower. | The required IRR and GIY were initially set lower. |
| Forecasting and evaluate expected costs returns | Same as general, final IRR got above the required IRR. | Same as general, but terminal value calculated by the use of vacancy value, final IRR got below required IRR. | Same as general, but terminal value calculated by the use of vacancy value, final IRR got below market. |
| Assessing investment risk | 80% low risk, high risk: solvency and reliability of the contractor and concept of Jonas (small units). | The use of wood was a risk because they did not know how it would perform in the long term. | Four major risks: fire safety, wood availability, maintenance, and whether they would secure the green financing and if it would be on time. |
| Making a risk-adjusted evaluation on cost | No specific adjustments were made, IRR was above the requirement. | A risk premium of 5% on operational costs due to uncertainty regarding wood. | The operational percentage has been slightly increased. However, there are non-cash flow adjustments: |
| Implementing Proposals | Followed its usual process structured method | Followed its usual process structured method | Followed its usual structured method, but with a slightly more controlled approach. |
| Auditing performance | Not yet applicable, but they are going to do it | Rent is higher, but because of the location, no extra operational cost regarding the use of wood. | Not yet applicable, but they are going to do it |

**Legend:** ☐ No impact at all ☐ Positive impact ☐ Moderate impact ☐ Negative impact

### 6.7.1 Step 1: Setting a strategy

**Pattern: Lowering embodied carbon has a little impact to the applied strategies of the investors.**

Within Jonas, the investors slightly adjust their strategies, the only thing they mentioned is that there was a slightly greater focus on sustainability. Additionally, to the extent that Focus on Impact has a standard strategy, it was not adjusted for SAWA either. However, for Coltavast, Timberhouse was certainly an adjustment to their strategy. Whereas their focus is normally solely on financial returns, for this project, it was agreed in advance that this was not of utmost importance. However, the project did serve a strategic purpose; Timberhouse was intended to make the portfolio more sustainable so that they could obtain cheaper loans from banks for future projects. Therefore, by accepting lower returns on this project, they indirectly worked on their strategy to achieve the highest possible financial returns.

### 6.7.2 Step 2: Establishing return/risk objectives.

**Patterns: Private investors can be more flexible with their required IRR when a project's focus is on sustainability compared to institutional investors.**

In both Timberhouse and SAWA, the required IRR was initially set lower at the beginning of the project. Additionally, both investors had a requirement that the GIY should always be higher than the market, but for these projects, this was not important. Both investors had discussed this in advance because they both wanted a project that would put their company in the spotlight. They also knew that this was necessary to make the project feasible. This was not the case for Jonas, where the requirement for their required IRR had to be met.

### 6.7.3 Step 3: Forecasting and evaluate expected costs returns

**Pattern: Lowering embodied carbon in the case studies did not impact the execution, although timber construction projects can result in lower final IRRs than market comfort.**

In all three projects, the method of determining the holding period, cash flow, and terminal value was done in the same way a described in Section 6.6.3: Step 3: Forecasting and evaluate expected costs returns. However, the final IRR for Jonas exceeded Amvest's required IRR, while for SAWA and Timberhouse, both final IRRs were below the required IRR or below market rates."

### 6.7.4 Step 4: Assessing investment risk

**Pattern: The use of non-traditional building materials like wood is perceived as an increased risk, particularly among investors with less experience in this area.**

With regard to reducing embodied carbon and the associated measures, there were no risks considered for Jonas. The choice of sustainable materials or the pursuit of BREEAM outstanding was not directly incorporated into the risk assessment. However, both investors of Timberhouse and SAWA identified various risks related to the use of wood. Both were new to this and unsure about the long-term implications, especially regarding maintenance. They assumed that wood, prone to discoloration, might need more upkeep than traditional concrete. For SAWA, additional major project risks included fire safety, wood availability, and concerns about securing timely green financing.

### 6.7.5 Step 5: Making a risk-adjusted evaluation of the forecast costs and returns

**Pattern: When using wood in the structure and facade finishing, adjustments are made in both financial modeling and operational strategies.**

The use of wood was seen as a risk at Timberhouse and SAWA, so both investors applied a risk adjustment to their cash flow. In addition, Focus on Impact took some other risk mitigation actions for SAWA that did not directly impact their cash flow. Firstly, the developer would handle the asset management of the building for the first 5 years, meaning that the investor would not be responsible for maintenance during that period. Furthermore, with regard to fire safety, they required sprinklers in the building, but these costs were borne by the developer. The interviewee emphasized that without these adjustments, the project would not have been feasible. Within Jonas, no specific adjustments were made because the final IRR was above the required IRR.

### 6.7.6 Step 6: Implementing accepted proposals

**Pattern: A standard implementation process has been followed, but extra attention to monitoring and coordination is possible.**

In all three projects, the normal process followed was similar to what is done in a traditional project. However, it was mentioned for SAWA that they proceeded with a slightly more controlled approach because the project was just feasible, and they couldn't afford any mistakes.

### 6.7.7 Step 7: Auditing performance

**Pattern: No difference in execution compared to the general process.**

The final step is auditing performance. For Jonas and SAWA, this was not immediately applicable because the projects have either just been completed or are not yet delivered. It was emphasized, however, that this would certainly be done. For Timberhouse, auditing performance has already been conducted, as the project has been in use for over a year now. During the performance audit, it was revealed that the rent was higher than estimated. It was emphasized that this increase was not due to it being a wooden project but because the location had become more popular, and the market had risen. Additionally, there are currently no additional operational costs regarding the use of wood.

## 6.8 Incorporation of embodied carbon in investment decision-making

Table 35 shows to what extent the reduction of embodied carbon is included within the standard practice of the investment decision-making within the different case studies.

*Table 35 - Comparing embodied carbon incorporation in investment decisions-making across the case studies*

| Investment D-M steps | Amvest | Coltavast | Focus on impact |
|---|---|---|---|
| Setting a strategy | Increased focus on sustainability and embodied carbon by new projects | Sustainability is incorporated as a necessity, with government regulations being the driving force. | Embodied carbon, especially timber construction, is now more routinely considered for feasibility while maintaining a good risk-return balance. It's an additional consideration, not a strict requirement. |
| Establishing return/risk objectives. | Discussion about return/risk objectives has been reignited among shareholders with the focus on 'Paris Proof' objectives | Financial goals remain a priority, with a minimum return of the required IRR (Internal Rate of Return) on equity, and sustainability aspects do not alter this. | Willingness to slightly lower return expectations for a "SAWA" type of product, which considers various sustainability factors. |
| Forecasting and evaluate expected costs returns | Discussions about holding period due to capped rental prices and future sustainability requirements. | - | No direct impact from considering embodied carbon, already possible to adjust things when necessary. |
| Assessing investment risk | Potential future changes with the use of the 'impact framework', particularly regarding long-term risks from embodied carbon and material choices. | - | Material choice is always a consideration. |
| Making a risk-adjusted evaluation on cost | - | - | - |
| Implementing Proposals | Sustainability considered, but embodied carbon not direct included. | - | Might be closer oversight in initial project stages due to perceived higher risks. |
| Auditing performance | Standard monitoring of maintenance costs for certain materials influences feedback on material choice in PvE. | Maintenance costs are always monitored | Maintenance costs are always monitored |

**Legend:** Included Semi included Not included

### 6.8.1 Step 1: Setting a strategy

**Pattern: Embodied carbon is increasingly focused on, but the approach and intensity of this focus vary and therefore it is not standard yet.**

Both Amvest and Focus on Impact demonstrate a proactive attitude with a strong emphasis on embodied carbon, which can lead to changes in material choices for both. However, it is not yet a strict requirement for either, and for Focus on Impact, it mainly revolves around wood and the associated carbon credits. In addition, Amvest is actively involved in mapping and analyzing new project scores regarding MPG and Paris Proof indicators using their new ESG framework. In contrast, Coltavast does not consider embodied carbon, as sustainability is incorporated as a necessity, with government regulations being the driving force.

### 6.8.2 Step 2: Establishing return/risk objectives.

**Pattern: Incorporating embodied carbon has little impact on establishing return/risk objectives.**

Regarding return and risk objectives, it can be observed that Amvest engages in discussions about embodied carbon, but this does not have a direct included within their financial goals. Coltavast continues to prioritize financial objectives, and sustainability does not alter this stance. In contrast, Focus on Impact demonstrates greater flexibility by being willing to slightly lower their return expectations for more sustainable projects.

### 6.8.3 Step 3: Forecasting and evaluate expected costs returns

**Pattern: Incorporating embodied carbon has no direct impact on the forecasting and evaluating expected cost returns.**

For all investors, it was clearly stated that incorporating embodied carbon does not affect how the holding period, cash flow, and terminal value are determined. However, there is now a discussion with the shareholders at Amvest regarding the fixed 10-year holding period. Because if a project does not meet these future standards, it may lead to additional investments that are not accounted for. This flexibility is already available at Focus on Impact due to their adaptable approach to the holding period.

### 6.8.4 Step 4: Assessing investment risk

**Pattern: There is a general tendency to adhere to traditional risk assessment methods, though there is room for future adjustments.**

In the assessment of investment risks, it can be observed that Amvest is considering potential future changes in its 'impact framework,' indicating an anticipation of long-term risks associated with embodied carbon and material choices. However, for both Coltavast and Focus on Impact, embodied carbon is currently not directly included in their risk assessments. However, for Focus on Impact, the choice of materials is always considered within the assessment.

### 6.8.5 Step 5: Making a risk-adjusted evaluation on forecast cost and returns

**Pattern: Incorporating embodied carbon has no direct impact on how risk-adjusted are done on forecasted cost and returns.**

Regarding the risk-adjusted evaluation of costs and returns, there is no noticeable impact of embodied carbon at all three companies.

### 6.8.6 Step 6: Implementing accepted proposals

**Pattern: Incorporating embodied carbon does not affect how the implementation or acceptance of proposals is carried out for the majority.**

When implementing proposals, Amvest considers sustainability, but embodied carbon does not have a direct impact on their decision-making processes. Coltavast also does not see any impact from embodied carbon, while Focus on Impact may apply stricter oversight in the early stages of projects due to perceived higher risks, just as they did for SAWA.

### 6.8.7 Step 7: Auditing performance

**Pattern: Incorporating embodied carbon does not affect the audit performance, as it is either already considered or deemed not important.**

Finally, when auditing operational performance, Amvest does not experience direct changes due to embodied carbon, although monitoring maintenance costs may influence future material choices in their projects. Coltavast and Focus on Impact do not observe any direct impact; however, they are always monitoring maintenance costs.

## 6.9 Adapted DCF parameters by applied reduction strategies

*Table 36 - Comparing the Impact of applied reduction strategies on the DCF parameters across the case studies*

| Strategies & operational measures | | DCF | Influence on DCF (Jonas) | Influence on DCF (Timberhouse) | Influence on DCF (SAWA) |
|---|---|---|---|---|---|
| Low-carbon materials | Biobased materials | Holding period | No impact | No impact | No impact |
| | | Cashflow | No impact | ↑Initial property value<br>↑Operation expenditures<br>↓Interest rate on loan | ↑Initial property value<br>↑Operational Expenses<br>↓ Interest on loan<br>↑Carbon credits |
| | | Terminal value | No impact | No impact | ↑ Value growth of vacancy value<br>↑ Vacancy value |
| | | Required IRR | No impact | No impact | ↑Demand and supply<br>↑Sustainability |
| | Sustainable alternatives | HP, CF, TV & IRR | - | - | - |
| Material reduction | Optimization of structural design | HP, CF, TV & IRR | No impact | - | - |
| | Building compactness | HP, CF, TV & IRR | - | - | - |
| | Minimal use of installations | HP, CF, TV & IRR | No impact | - | No impact |
| | Replacement intervals installations | HP, CF, TV & IRR | - | - | |
| | Waste minimization | HP, CF, TV & IRR | No impact | - | - |
| Reuse and Recycling | Reuse | HP, CF, TV & IRR | - | - | - |
| | Recycling | HP, CF, TV & IRR | No impact | - | No impact |
| Local Sourcing | Transportation factors | HP, CF, TV & IRR | No impact | No impact | - |
| | Prioritization local materials | HP, CF, TV & IRR | No impact | No impact | No impact |
| Construction Optimization | Optimization of construction activities | HP, CF, TV & IRR | - | - | - |
| | Optimal construction equipment | HP, CF, TV & IRR | - | No impact | - |
| | Innovations machinery | HP, CF, TV & IRR | - | No impact | - |
| | Off-site manufacturing | Holding period | No impact | No impact | No impact |
| | | Cashflow | No impact | ↓ Construction time<br>↓ GLA/NLA ratio<br>↓ NLA (Net Lettable Area) | ↓ Construction time |
| | | TV | No impact | ↓ NLA (Net Lettable Area) | No impact |
| | | Terminal value | No impact | No impact | No impact |

**Legend:** Not applied | Positive impact | No impact | Negative impact

### 6.9.1 Low carbon materials

Biobased-materials

**Cashflow**

**Pattern: Using wood in the construction and facade finishing leads to a higher initial property value and operation expenditures.**

When biobased materials like wood are utilized in a project, they typically enhance the initial property value, as seen in Timberhouse and SAWA. Coltavast compared Timberhouse in traditional concrete with wood, resulting in a €200 per square meter cost difference favoring wood. In SAWA, investors believed the cost difference to be significantly higher, though exact figures were unclear. In Jonas, the use of wood was expected to indirectly increase the initial property value due to its higher cost. However, the investor couldn't confirm if wood had indeed raised the property value. Jonas initially explored an all-wood construction but deemed it financially unfeasible due to the high initial property value. Furthermore, It's important to note that Timberhouse and SAWA constructed their entire structures with wood, while Jonas used wood primarily for specific finishes, explaining its lower visibility in the project's total construction costs.

Additionally, investors of both Timberhouse and SAWA imposed a risk premium on operational expenses because of their lack of experience with wood and uncertainty about its long-term performance. In Jonas, Douglas wood was used, and it had been treated to require minimal maintenance according to the developer. However, standard maintenance cost percentages were applied based on portfolio benchmarks due to limited direct experience with this wood type, as its long-term maintenance requirements were uncertain.

**Pattern: The use of wood leads to discounts on interest rates and an additional cash flow through the acquisition of carbon credits, which can result in better returns and, consequently, more opportunities for sustainable investments.**

Moreover, investors in both Timberhouse and SAWA received discounts on the interest rates of their loans. At Timberhouse, this resulted in a reduction of 0,3% on the interest rate, and at SAWA, it was even higher, with a difference of around 0,5%. Finally, at SAWA, carbon credits were sold from storing 5000 tons of $CO_2$, resulting in 5000 carbon credits sold via ETS with a credit value of €100 each, totaling an additional €500,000. These funds were allocated to the operational fund for the building, equivalent to 5% of the initial property value.

**Terminal value**

**Pattern: Institutional investors cannot flexibly deal with the parameter 'value growth of vacancy value' because they are tied to external parties operating based on current market conditions, whereas private investors can do so.**

In both Jonas and Timberhouse, the use of wood had no impact on the terminal value, as both projects retained their values based on prevailing market conditions at that time. Where the terminal value for Jonas is strongly influenced by external factors. Because Amvest is an institutional investor and they work with external shareholders, an appraisal report from an external appraiser is required for each purchase. This external appraiser calculates the investment, just like the investor, using a DCF model. They do this through benchmarking with similar projects in the market, which means they always look back in the past.

The problem is that they now only incorporate differences in variables, such as a 'brown discount' or 'green premium' on the vacancy value in the DCF model, when this is proven in the market. Because currently in the market, there is no 'brown discount' or 'green premium' visible for buildings or materials with lower embodied carbon, and this is also not taken into account by the appraisers, it is very difficult for Amvest to incorporate this. However, in the case of SAWA, a different approach was taken concerning the value growth of vacancy value. The project cashflow was calculated based on capped mid-rent rates for the foreseeable future, which were relatively low given the quality of the products offered in the market. The investor believed that when the apartments were sold on the open market, their value of the project would be higher due to the quality, influenced by the use of wood. Therefore, a higher percentage of value growth of vacancy value was applied, resulting in an increased vacancy value, which, in turn, contributed to a higher terminal value.

**IRR**

**Pattern: The use of wood can lead to a reduction in the required IRR, as it makes the building more sustainable and increases its demand.**

The Investor of Jonas stated that the IRR has not changed due to the use of wood. Initially, the investor concluded that the IRR may be slightly lower if initial property value is higher. However, according to the interviewee, the IRR should remain the same, and if there are any differences it would be balanced out by adjusting other parameters. The investor of Timberhouse reached the same conclusion. In a traditional project, the IRR should always remain the same, regardless of the initial property value. However, in the case of Timberhouse, it was set lower once. However, the investor in SAWA has set a lower required IRR because they were convinced that the use of wood and other applied concepts would result in an exceptionally sustainable building, leading to a high-quality building. Additionally, because the project is a unique building for which there are no comparable properties on the market, this leads to higher demand, which, in turn, makes it easier to rent or sell the apartments, reducing risk.

### 6.9.2 Material reduction strategies

Optimization of design

**Pattern: The use of fewer materials in the project, leading to cost savings and reduced maintenance, does not affect the DCF parameters.**

Jonas was the only project where optimization of the design was applied. During the interview with the developer, they mentioned that just by optimizing the wooden slats, savings of €100.000 to €150.000 were achieved. However, the same conclusion can be drawn as with the operational measure: biobased materials. Less material usage would reduce construction costs, leading directly to a lower initial property value. However, it was also unclear here whether this had any impact and what that might have been. Additionally, the reduced use of wooden slats would result in lower operational expenses, although this benefit is considered small and has not been directly included in the investment decision.

A building with minimal use of installations

**Pattern: The use of fewer materials in the project, leading to cost savings and reduced maintenance, does not affect the DCF parameters.**

In both Jonas and SAWA, ventilation type C was implemented to reduce embodied carbon. The implementation of a ventilation type C results in the use of less, smaller and cheaper installations, creating the expectation of reduced maintenance costs and construction cost according to the both of the developers.

The investor of Jonas concluded that this aspect may have had an influence on the initial property value, but the investor emphasizes that its impact on the purchase decision is minimal. The potential cost savings from reduced maintenance are not directly visible and taken into account within the DCF model for the investor but may be considered an indirect benefit in the long term and could possibly be taken into account in future projects. Additionally, the investor of SAWA concluded that the same that implementation of a ventilation type C had no impact on the DCF parameters.

Waste minimization during production and construction

**Pattern: Waste minimization during production and construction does not impact de DCF-parameters.**

Only in the Jonas this operational measure was utilized. However, it did not have a direct impact on the parameters of the DCF model. As mentioned above, these costs are also borne by the contractor, and furthermore, they will be truly minimal compared to the overall project costs.

### 6.9.3 Material reuse and recycling

Recycling

**Pattern: The use of recycled materials does not impact the DCF parameters.**

In both Jonas and SAWA, recycled materials were used. However, both investors concluded that this did not have a direct impact on the DCF parameters. This is also because these costs borne by the developer, and in proportion to the total costs, these expenses are low, which is why they didn't have a direct impact. Additionally, both investors see no risk in using recycled concrete.

### 6.9.4 Local Sourcing of Materials and Components

**Pattern: Local sourcing of materials and components does not impact the DCF parameters.**

Consideration of transportation factors

The costs and risks associated with this operational measure are also borne by the contractor. Therefore, it did not have a direct impact on the DCF parameters.

Prioritization of local materials

Prioritizing local materials did not have any impact on the DCF parameters in all the case studies. These costs and risks are also incurred by the contractor.

### Construction Optimization Strategies

**Pattern: Using optimal construction equipment and innovative machinery does not impact de DCF-parameters.**

Selection of optimal construction equipment

Although within Timberhouse, the modular units were manufactured in a factory where nearly everything is automated, this did not directly impact the parameters of the DCF model.

Promotion of innovations and energy-efficient machinery

While Timberhouse utilized modular units manufactured in a highly automated factory, this did not have a direct impact on the parameters of the DCF model.

Use of prefabricated elements and off-site manufacturing

**Pattern: The use of 2D prefab elements or modular units reduces construction time, leading to a lower initial property value.**

In all three case studies, either 2D prefab elements or modular units were employed, affecting the construction time of Timberhouse and SAWA. Timberhouse's use of modular units reduced construction time to 6 months, resulting in a 4% initial property value reduction. Similarly, SAWA's utilization of 2D prefab elements reduced construction time from 3 to 6 months. In contrast, Jonas, primarily constructed with cast-in-place concrete, determined the main construction time. Although 2D prefab elements were used for facade elements, inner wythes, and stairs in Jonas, constituting a smaller project portion, their specific impact on parameters remained unclear during the investor interview. However, it was recognized that 2D prefab elements could positively affect construction time.

**Pattern: Utilizing modular units leads to a lower GLA/NLA ratio, decreasing the total NLA.**

Finally, the use of modular units in Timberhouse had a negative impact on the GLA/NLA ratio. This is because each unit has its own walls, floors, and ceilings, and when these units are stacked, it means that everything is used double, resulting in less NLA relative to GLA. A poorer GLA/NLA ratio leads to a reduction in NLA. With the NLA being lower, the cash flow is also reduced. Additionally, since the terminal value in Timberhouse is calculated based on the vacancy value, and there is less NLA, this will also be lower in comparison to a traditional project.

# Chapter 7

## Discussion & Limitations

Discussion on research findings

Research limitations

# 7 Discussion & Limitations

This chapter of the thesis discusses the findings, aiming to explore financial barriers and the integration of embodied carbon into real estate investment decision-making using the traditional DCF model. It seeks to guide and promote a carbon net-zero built environment by 2050. Additionally, this chapter will discuss the study's limitations.

## 7.1 Discussion on research findings

### 7.1.1 Quantification of embodied carbon

Based on empirical findings, it has been confirmed that quantifying embodied carbon within Dutch practice is done through LCA (Life Cycle Assessment) calculations. This aligns with the statements by Amiri et al. (2021) and Weinfeld et al. (2023), who asserted that LCA is the most sophisticated and well-established method for evaluating the environmental impact of buildings. Furthermore, it can be concluded from the empirical research that in Dutch practice, embodied carbon is currently quantified using Environmental Performance Building (MPG), which means that the quantification of embodied carbon is carried out through LCA assessments.

However, the findings highlight some issues with quantifying embodied carbon using the MPG. It was found that the MPG may not be a suitable way to express embodied carbon for three reasons. Firstly, the MPG encompasses not only embodied carbon but also accounts for other emitted substances. Secondly, when comparing the MPG scores within the case studies, it was noticeable that there are almost similar MPG scores when using concrete or wood construction, even though wood is considered more sustainable. Contrary to this, according to The RVO (2023), the MPG currently serves as the primary instrument for mitigating environmental impact, with a focus on selecting the most sustainable building material composition. However, this is currently not done effectively within the current calculation of the MPG because wood is not adequately accounted for in module D. This is also been concluded by the interviews T-A&D and S-A&D (2023), they both concluded that the issue arises because wood in module D is not reused but incinerated, resulting in significant $CO_2$ emissions. Both interviewees believe that if wood were demountable, it could be reused, thus reducing its environmental impact. Consequently, this problem limits the effectiveness of environmental impact mitigation.

Lastly, there is an issue with expressing the MPG, as it is represented in €/$m^2$.GFA.year. This metric implies that for each environmental impact, the estimates encompass the expected social costs that society would incur if the impact were to be prevented, in addition to existing conventional solutions. When considering all environmental effects, the ECI is calculated as the shadow cost of that material, expressed in € per unit (commonly measured in square meters, meters, or quantities), as mentioned by NMD (2020). However this approach makes it unclear how much $CO_2$ is emitted per square meter, hindering effective management and communication within the industry.

Therefore, when the goal is to reduce embodied carbon within a building project, the PPm is a more suitable metric, as it directly relates to $CO_2$ emissions per GFA, providing a clearer and more relevant perspective. Consequently, it is also important that not only the MPG is utilized in Dutch regulations to reduce $CO_2$ emissions, but the PPm as well.

### 7.1.2 Reduction strategies of embodied carbon within current Dutch practice.

From the findings, it became clear that all applied embodied carbon reduction strategies within the case studies were also present in the literature framework. However, the findings did show a preference for certain strategies, as they have a greater impact on reducing $CO_2$ emissions.

Firstly, it was found that in all case studies there was a preference to incorporate wood as much as possible instead of traditional materials from the project's initial phase, with a focus on structure as the most important aspect because it would have the greatest impact on reducing $CO_2$ emissions. These findings align with the conclusions of González and Navarro (2006), and Sham et al. (2011), who demonstrated that replacing traditional materials with environmentally friendly building materials could reduce $CO_2$ emissions by approximately one third. This emphasizes the importance of material selection for carbon reduction. However, in order to promote the use of wood within the current practice, it is important that, as mentioned above, the calculation of module D is adjusted within the MPG calculation. Because concrete is currently cheaper than wood, and there is almost no difference in the scores that can be achieved, market parties are not encouraged to use wood. Nonetheless, the findings indicate that when concrete is used, recycled concrete is utilized. Additionally, it is observed that when wood is used, it is all FSC-certified and sourced from Europe, which leads to relatively low transport distances compared to sourcing from outside Europe, and new trees are planted for the wood used.

Furthermore, the findings show that limiting material use through measures such as minimal use of installations and optimization of design are also frequently chosen and efficient strategies for the reduction of embodied carbon. This aligns with Akbarnezhad & Xiao (2017) and Nadoushani & Akbarnezhad (2015), who confirm that the amount of embodied carbon is related to the quantity and type of materials used. Additionally, Yeo & Gabba (2011) and Pomponi & Moncaster (2016) emphasize that optimized design can lead to a reduction in the amount of materials and thus embodied carbon. The literature agrees with the findings, as the application of ventilation type C resulted in 60 to 70% fewer ventilation ducts being needed, with no need for large units; only small, cost-effective ventilation units were applied. Also, by optimizing the construction, a 30% reduction in concrete and reinforcing steel usage could be achieved.

Additionally, the findings show that in all case studies, off-site manufacturing, including the use of prefabricated elements or modular units, are applied. In the majority of the case studies, the facade elements were executed in prefab, and initially, the intention was to construct the structure in prefab in all cases because this would have the most impact on reducing embodied carbon. However the use of modular units, is more effective in reducing embodied carbon. This is due to various reasons. Firstly, almost the entire construction of the project can be completed in a factory, allowing for as much automation as possible. This results in a shorter construction time and fewer transportation movements of people. Additionally, only one transportation movement to the construction site is needed.

It is also immediately apparent that the three strategies most impactful in reducing embodied carbon, as identified in the findings, relate to the choice of materialization, structure, and services. This can be associated with the product stage [A1-A3] and replacement [B2 & B5] of the LCA. This aligns with the conclusions in the literature by Arup & wbcsd (2023); Rasmussen et al. (2018) and Röck et al. (2020).

### 7.1.3 Embodied carbon part of investment decision-making process

Step 1: Setting a strategy

In the practice of investment decision-making, the integration of embodied carbon reduction is clearly evolving within the "setting a strategy" step, but it has limited impact and is not yet fully standardized. This is partly because private investors lack a standard strategy for embodied carbon. The findings. Case studies further reveal that when embodied carbon is reduced, this actually has little impact on their strategy in the majority of cases. However, the majority of the involved parties currently adopt a proactive approach towards embodied carbon, but it is not yet a strict requirement in their decision-making process. This became evident as one investor is currently in the process of assessing the MPG and PPm scores of all projects, as this is included in their fund strategy through an ESG impact framework. Additionally, another investor is focusing on the use of wood due to new carbon credits. Finally, one investor slightly adjusted their strategy because they are normally financially driven, but this became less important in one instance.

So, while there is some attention to embodied carbon among investors, it has not yet led to significant strategic changes. Which means that if these investors, who are among the few frontrunners in the Netherlands investing in projects with low embodied carbon, lack a standardized focus on this, it can suggest that most market parties also have not standardized the reduction of embodied carbon within their strategy. This could hinder the objectives of the Dutch Climate Agreement.

Step 2: Establishing return/risk objectives.

When determining return and risk objectives, it appears that there is more flexibility in practice for private investors compared to institutional investors when it comes to projects emphasizing embodied carbon, as long as this is accompanied by an incentive. Within the case studies, both private investors exhibited more flexibility with their required IRR because they lowered it, which was necessary to make the projects feasible. However, this was not an issue because both of them wanted a project that would bring them into the spotlight or provide other financial benefits. It is important to note that one of the private investors is willing to do this more often, while the other has indicated that this was a one-time adjustment. This could mean that as long it is not mandatory, more incentives are needed in the market for investors to lower their required IRR

The problem, in contrast with the institutional investor, lies in the fact that on one hand, shareholders expect them to be progressive in terms of sustainability, while on the other hand, they must still strictly adhere to the fund's return requirements. This was evident in the case study involving the institutional investor; the project was initially conceived in wood. However, this approach resulted in a final IRR lower than the required IRR, thus not meeting the requirements and leading to a switch to concrete. These fund's return requirements can, therefore, hinder the process of reducing embodied carbon. Consequently, it is important for institutional investors to initiate a dialogue with shareholders about the required IRR in relation to sustainability. This is to determine whether agreements can be reached to lower the required IRR when purchasing highly sustainable projects.

Step 3: Forecasting and evaluate expected costs returns

In the case of forecasting and evaluating expected costs and returns, the findings revealed that involving or reducing embodied carbon had impact on certain DCF parameters, however it had no direct impact on the execution of the holding period, cash flow, or terminal value in practice. This consistency was observed across all case studies, irrespective of the investor, as it was executed in the same manner as their general investment decision-making process.

Step 4: Assessing investment risk

In current investment practice regarding investment risk assessment, firstly, the role of incorporating and reducing embodied carbon in risk assessment is variable and appears to depend on the materials used in the project and the specific experiences of investors. This was evident from the case studies, where, in cases where the structure and facade finishing were done in wood, this was considered a new and potentially increased risk due to the lack of experience and knowledge about long-term effects. In contrast to the case study where recycled concrete was used, there were no risks associated with embodied carbon and sustainable materials in this particular case. Therefore, it is important to stimulate transparent communication within the market regarding the use of wood during the building's use phase. If this is not done, it could mean that every investor working with wood for the first time will impose a risk premium, which will make it more challenging to finalize the business case.

Secondly, it can be argued that the majority of investors do not currently consider embodied carbon as a standard part investment risk assessment. Because currently, only one investor includes material as a standard part of the assessment. Nevertheless, it is evident from the findings that this may change in the future. This is once again highlighted by the fact that, as mentioned above, an investor is obligated to use the ESG impact framework for every new project, where long-term risks related to embodied carbon and material choices can become apparent.

Step 5: Making a risk-adjusted evaluation of the forecast costs and returns

In current practice, the consideration of embodied carbon has a limited impact on risk-adjustment for expected costs and returns, except when wood is used. This was evident in the case studies, where adjustments were made to cash flow when wood was used in the structure and facade finishing. However, it's important to note that there are other possibilities to mitigate risks that don't directly impact cash flow but focus on risk management throughout the construction, development, and use phase. Despite this, all investors emphasized that including embodied carbon doesn't affect this step, as adjustments based on identified risks are always included when needed.

Therefore, these findings suggest that, although embodied carbon has some influence through the use of wood, it is not yet considered a critical factor and is not systematically included in this step's execution. Therefore, these findings suggest that, although embodied carbon has some influence through the use of wood, it is not yet considered a critical factor and is not systematically included in the execution of this step. The same conclusion can be drawn as with Step 4: Assessing investment risk, namely that when adjustments have been made, transparent communication remains important. This is especially significant between the developer and the investor, so that if the investor identifies a risk, it may potentially be resolved already with the developer and no adjustment have to be made.

Step 6: Implementing accepted proposals

The findings indicate that the incorporation of embodied carbon has little influence on the standard execution of proposal implementation. It has been found that in all case studies, the usual structured method was followed, with the exception of one case study where a slightly different approach was taken, indicating that this will also be done in the future. However, the other two investors have indicated that there will be no change in approach in the future when embodied carbon is involved.

Step 7: Auditing performance

Based on the findings, it is expected that involving or reducing embodied carbon will not impact the execution of auditing performance. When embodied carbon is present, the investors emphasized during the interviews that all initial assumptions, such as operating expenses, value growth, rent, construction time, etc., which embodied carbon could potentially affect, are measured as standard practice. Furthermore, it can be concluded based on the findings that the use of wood currently does not entail additional operating costs, and therefore, the assumptions are incorrect. However, it is important to note that this conclusion is not yet valid since in the majority of the case studies, this step has not been carried out, and the case study in which it has been done and this observation was made has only been on the market for one year.

This means that, based on these findings, no conclusion can currently be drawn about the accuracy of assumptions made during investment decision-making regarding the impact of reducing embodied carbon on DCF parameters. However, the most important aspect at this stage is that if conclusions are drawn from the auditing performances, they should be communicated transparently within the market, as mentioned in Step 4: Assessing investment risk.

### 7.1.4 Impact of reduction strategies on the DCF-parameters

To begin with, based on the findings, it can be concluded that the majority of strategies for reducing embodied carbon have little to no impact on the parameters of the DCF model. This is primarily because these strategies mainly concern the contractor or developer, and since the projects are often carried out through a turnkey agreement, this subsequently does not affect the investor. Additionally, it may also be the case that the associated costs and risks are so small that they have minimal influence on the investor's choices and are therefore not taken into account. This was the case for all applied reduction strategies except for low-carbon materials (biobased materials) and construction optimization (off-site manufacturing).

Holding period

The empirical research has shown that none of the reduction strategies impact the determination of the holding period. This is because the majority of investors adhere to a standard holding period, meaning no parameters are used. However, one investor is flexible in determining the holding period through a parameter known as the exit sales scenario. Yet, the reduction of embodied carbon does not influence this parameter. This is because it relates to the duration for which the investor must keep the rental apartments before being allowed to sell them, a decision determined by the municipality.

The empirical research has shown that none of the reduction strategies impact the determination of the holding period. Most investors adhere to a standard holding period, meaning no parameters are used. One investor, however, is flexible in determining the holding period through a parameter known as the exit sales scenario.

Nevertheless, embodied carbon does not play a role in this, as this parameter relates to the duration for which the investor must keep the rental apartments before being allowed to sell them, a decision determined by the municipality.

Interestingly, a majority of investors are becoming increasingly aware of the importance of flexibility in determining the holding period. This is evident as an institutional investor engages in dialogue with shareholders about using a longer holding period. Moreover, both investors have indicated that such flexibility, sometimes implying a longer duration, could be advantageous for integrating future sustainability requirements. This consideration includes the potential need for additional capital expenditures if a building does not comply with future regulations, thereby preventing the building from becoming stranded (Interview J-AM, 2023; Interview S-AM, 2023).

The problem is that concerning embodied carbon, a building cannot become stranded in this aspect. Unlike operational emissions, where non-compliant buildings need to be made more sustainable, embodied carbon occurs during various phases of a building's lifecycle and primarily involves one-time emissions that cannot be undone. Once constructed, the embodied carbon has already been emitted. Therefore, replacing materials, such as concrete with wood, would only result in additional embodied carbon emissions.

This implies that a longer holding period does not directly lead to a more accurate calculation when it comes to future capital expenditure regarding sustainability requirements. However, a longer holding period may be more cost-effective for the additional investments needed to reduce embodied carbon during construction. Additionally, this means that if a building does not become stranded in the future, there is no immediate incentive for investors to invest extra now to prevent future additional investments. This results that current practice investors are not incentivized to reduce embodied carbon in a project, as it is not yet a mandatory requirement within the regulations.

Cashflow

The findings have revealed that using wood to reduce embodied carbon within projects negatively impacts operational expenditures or is not considered at all. This finding contrasts with conclusions drawn by Eichholtz et al. (2010) and Leskinen et al. (2020), who argued that sustainability reduces operational costs. This discrepancy can be attributed to the fact that both studies focus on green certified buildings, which encompass a broader sense of sustainability beyond just the use of wood. However, in this research, as demonstrated by the case studies, investors applied a higher risk premium due to inexperience and uncertainty regarding the long-term use of wood. Even when wood with maintenance-free features, which entails extra costs, was used, this factor was overlooked.

Furthermore, previous literature suggested that sustainability impacts vacancy rates (Fuerst and McAllister, 2011a; Pivo and Fisher, 2010; Leskinen et al., 2020). Contrary to this, the current findings indicate that reducing embodied carbon has no effect on the vacancy rates. Which is largely due to the high demand for middle-income rental apartments leading to rapid occupancy. Additionally, Leskinen et al. (2020) posited that sustainability could lead to increased rental prices. However, the research found no correlation between reducing embodied carbon and higher rents, partly due to the middle-income rent cap in most case studies and the perception that tenants are unwilling to pay more. This reluctance is because reducing embodied carbon does not offer financial benefits to tenants, unlike energy-neutral buildings.

The findings also provide insights that expand existing literature on sustainability's impact on investment decisions. Firstly, reducing embodied carbon can negatively affect the cash flow. The findings revealed that using modular units negatively impacts the GLA/NLA ratio, resulting in lower NLA, which in turn lowers the cash flow and terminal value compared to traditional projects. Furthermore, utilizing wood for construction and facade finishing to reduce embodied carbon significantly increases the initial property value. As a result of this high initial property value, the use of an all-wood construction was abandoned in a case study due to financial limitations, ultimately leading to the selection of other sustainable materials.

However, the findings also show that there are some counterbalances to positively influence cash flow. Firstly, in one case study in the Netherlands, carbon credits were sold for the first time, potentially offsetting the higher initial property value (Interview S-AM, 2023). However, within current practice it is not clear in who is responsible for these carbon credits and thus also entitled to the additional income (Interview S-A&D, 2023). Secondly, the use of prefabricated elements or modular units reduces construction time, which may results in a lower initial property value. This is because most projects are delivered turn-key, meaning the investor only pays upon completion. However, as developers do not want to bear the risk by investing solely their own money until completion, a loan with interest is often provided by the investor from the start of construction, which added to the initial property value (Interview E-6, 2023). Besides that, a shorter construction times also reduce investor risk by minimizing missed investment opportunities. However, none of the investors took this reduction into account. Finally, it is possible to receive a discount on loan interest rates, which can be essential under current market conditions to ensure the financial viability of projects. All these benefits lead to better returns and, consequently, more opportunities for reducing embodied carbon.

Terminal value

Empirical research has shown that in the majority of case studies, the application of most strategies for reducing embodied carbon did not affect the terminal value. Literature has drawn various conclusions about the parameters used to determine the terminal value. Firstly, Sayce et al. (2007) concluded that investing in sustainability has little impact on yields. Contrarily, Leskinen et al. (2020) concluded that it does have a positive impact on yields, and they also found that sustainable buildings have higher terminal value. This is also confirmed by GBCA (2008), indicating the existence of a 'brown discount' and a 'green premium' that lead to terminal value.

When examining the terminal value, it becomes clear that the effect of reducing embodied carbon on a higher terminal value depends on several factors. Most case studies did not consider terminal value growth in their calculations, except for one that involved the operational use of biobased materials. The first reason of the absence of terminal value growth in these studies can be attributed to the fixed holding period of one year maintained by an investor. This approach prevents the inclusion of potential future benefits, such as terminal value growth, associated with reducing embodied carbon in a project. Because the investor focuses solely on the present and, consequently, on current market conditions, there is a lack of consideration for potential value growth. This oversight can complicate the calculation of the business case and hinder the reduction of embodied carbon within the building and construction industry.

Another factor influencing terminal value is the varying flexibility in calculations between private and institutional investors. In a case study involving an institutional investor, the terminal value growth from reducing embodied carbon was not factored in. This omission stems from the vacancy value and its growth parameters being based on current market conditions and benchmarking with similar projects. These parameters are influenced by property type and how its value is affected by sustainability considerations, linked to the 'brown discount' and 'green premium'. Recent market changes have shown a value difference between buildings with different energy labels and offices with varying BREEAM certifications (Interview E-7, 2023; Interview E-8, 2023). However, embodied carbon's impact has not yet been observed in this context.

However interviews with investors from the case studies revealed different opinions on the terminal value of buildings with low embodied carbon. The institutional investor and one private investor anticipated the emergence of a 'brown discount' and 'green premium.' However, the issue is that the institutional investor currently cannot incorporate a higher vacancy value growth to reflect this in their calculations. This is because making an assumption like this involves significant risk, especially since the terminal value plays a crucial role in calculating the final IRR. They cannot take this risk due to agreements with external shareholders. Additionally, the institutional investor is also constrained by appraisers who currently operate based on current market conditions, without looking ahead.

Conversely, the private investor included a higher vacancy value growth in their calculations, resulting in a higher terminal value. This decision was made because the cash flow was calculated based on capped mid-rent rates, which seemed low for the quality of the products offered in the market. The investor believed that selling the apartments on the open market would fetch a higher value due to the quality, enhanced by the use of wood.

This indicates a growing attention to 'green premiums' and 'brown discounts,' highlighting an increasing awareness and appreciation of sustainability in the real estate market. However, institutional investors are still hindered by limitations in incorporating the reduction of embodied carbon into their calculations. Similar to the use of a fixed holding period of one year, this leads to difficulties in making the business case viable, consequently impeding the reduction of embodied carbon.

Required IRR

In terms of the required IRR, it can be concluded that the use of carbon reduction strategies generally does not impact it. Investors prioritize financial returns and focus on achieving specific returns, even in sustainable projects that may be less risky. Currently, there is not enough confidence among the majority of investors that reducing embodied carbon sufficiently decreases risk to justify a lower return. This leads that risk reduction is not a primary factor in investment decision-making, and that risk mitigation is not directly reflected in the required Internal IRR.

As outlined in Section 7.1.3: Step 2: Establishing return/risk objectives, in one case study, a private investor did lower the required IRR to make a project feasible, explicitly stating that this reduction was not a result of carbon reduction strategies. The other private investor also reduced the required IRR to ensure project feasibility, believing that the strategy of using low-carbon materials, particularly wood, could decrease project risk, thereby justifying a lower IRR. This investor's view is that the use of wood and other sustainable concepts would lead to an exceptionally sustainable, high-demand, high-quality building.

This aligns with the findings of Fuerst and McAllister (2011a) and Pivo and Fisher (2010), which suggest that sustainable buildings can stimulate demand and potentially reduce the risk premium during pricing. Lastly the institutional investors cannot lower the required IRR due to agreements with external stakeholders, which can hinder them to invest in the reduction of embodied carbon.

Despite the current lack of direct incentives for investors to reduce embodied carbon, what is not being considered by all investors is the future marketability of sustainable buildings. Buildings that meet future standards, such as being completely carbon-neutral or 'Paris Proof', may be more appealing to institutional investors. Such projects are likely to retain more value and carry less risk, especially with the forthcoming regulations of the CSRD. The CSRD mandates that institutional investors will soon need to report the $CO_2$eq emissions of their entire value chain, as stated in §44. This requirement includes the acquisition of real estate, details of which are explained in Appendix V. Therefore, it suggests that in the future, institutional investors might only be able to purchase buildings with a low embodied carbon score.

This means that currently, institutional investors may be limited in their capacity to accept lower IRRs and thus to invest in sustainability. However, there is potential among private investors to support sustainable construction practices. In addition, future market trends and regulations are likely to place a greater emphasis on sustainability. This could lead to a slow but steady shift in the real estate market towards a greater appreciation and integration of sustainability practices.

## 7.2 Research limitations

Despite the positive impact this research can have in an attempt to develop a more future-proof built environment, there are also some limitations to this research. The research is conducted in a limited timeframe. Therefore, some choices in the research were made with time in mind and not exclusively focused on what is best for the outcomes of the research.

Furthermore, a potential limitation in the case studies is related to the number of cases analyzed and the number of investors interviewed, which may have impacted the research outcomes. A larger number of case studies and interviews could have potentially resulted in more accurate results. However, the advantage of selecting a limited number of cases was the opportunity to conduct thorough examinations of each case and perform cross-case analyses. Despite the relatively small sample size of case studies, the interview findings uncovered significant similarities and differences, enhancing the overall validity of the research.

In addition, there are some content-related limitations regarding the context of the case studies and the interpretation of the results. Firstly, the investment decisions and DCF calculations were made 4-7 years ago under different market conditions, especially in terms of interest rates and material costs. Moreover, at that time, embodied carbon was a relatively new concept, resulting in limited experience with it. It is possible that new insights or regulations have emerged since then that could influence decision-making. Furthermore, all case studies are located in one of the G5 cities, with two in Amsterdam and one in Rotterdam. However, assumptions regarding the parameters of the DCF model can vary by city. Additionally, the case studies did not use a uniform type of investor; there was one institutional investor and two private investors, with considerable differences in how private investors operate. Appraisers played a significant role in the decisions made by certain investors. Lastly, it is important to note that the research was developed within the Dutch context.

# Chapter 8

## Conclusion & Recommendations

Answering the research questions

Recommendations for further research

# 8 Conclusion & Recommendations

This chapter serves as a conclusion to the research, summarizing the main findings pertaining to the research aim and questions. It also elucidates the research's contributions to both theory and practice, along with offering practical recommendations for practice and suggestions for future research.

## 8.1 Answering the research questions

The main aim of this research is to explore financial barriers and the integration of embodied carbon into real estate investment decision-making using the DCF model. It seeks to guide and promote a carbon net-zero built environment by 2050. This is done by giving an answer to the main research question: *"In what way does reducing embodied carbon in residential building projects impact the investment decision-making process from an investor's perspective?*". To thoroughly address the main research question, first answer is given to the five sub-questions in this study.

### 8.1.1 Sub-question one

**What is embodied carbon and how can this be quantified?**

Embodied carbon refers to the carbon emissions associated with a building throughout its entire life cycle, including raw material extraction, transportation, manufacturing, construction, maintenance, replacement, and end-of-life phases. It can be quantified using a life cycle assessment (LCA) methodology, which evaluates the environmental impacts associated with a product or building system throughout its life cycle. The quantification formula for embodied carbon is as follows:

$$\textit{Embodied Carbon } (kgCO_2e) = \textit{Material Quantity } (kg) \times \textit{Carbon Factor } (kgCO_2e/kg).$$

The LCA assesses both direct and indirect carbon emissions from associated activities. across a building's life, including production, construction, use, end-of-life, and beyond. Whereby the majority of embodied carbon emissions are associated in the product stage. However, the maintenance and replacement stages and end-of-life stages also contribute to the overall environmental impact, albeit to a lesser extent. Additionally, the building components, specifically structure and services during the building's total life cycle, are primarily responsible for embodied carbon emissions, at 36% and 32%, respectively. Whereby embodied carbon within the Dutch practice currently is quantified by using the Environmental Performance Building (MPG), however the Paris Proof Material-related Indicator (PPm) should more suitable metric for comparing embodied carbon within building projects. Both of these methods utilize an LCA assessment.

### 8.1.2 Sub-question two

**What are the current and expected future regulations regarding embodied carbon in building projects and which regulations could have impact on investment decision-making?**

The current and future regulations regarding embodied carbon in construction projects, especially in the European context, have significant implications for investment decisions. Within this regulation, a distinction is made between Environmental and Sustainable finance regulations. Firstly, the European environmental regulations, particularly the European Green Deal and the Dutch Climate Agreement, set reduction goals regarding embodied carbon. The Netherlands' Environmental Performance Building (MPG) metric encourages sustainable material use to decrease embodied carbon.

The upcoming Energy Performance of Buildings Directive IV (EPBD IV) and the amendments to the European Green Deal mandate further emissions reductions in construction. This includes sustainability criteria for building products and, finally, mandatory Global Warming Potential (GWP) calculations for new buildings starting from 2027. Financial regulations like the Sustainable Finance Disclosure Regulation (SFDR) and upcoming Corporate Sustainability Reporting Directive (CSRD) demand disclosure of investment impacts on environmental sustainability within their reports, aiming to foster transparency and informed decision-making. The EU Taxonomy, integral to these regulations, defines what constitutes sustainable economic activities, aiding in green financing and influencing investment choices.

### 8.1.3 Sub-question three

**What strategies can be used to reduce the embodied carbon within a building project and how are these applied in current practice?**

To reduce embodied carbon within a construction project, various operational strategies and measures can be applied, as evidenced by both theory and practice. These strategies include the use of low-carbon materials, material minimization and reduction, material reuse and recycling, local sourcing of materials and components, and construction optimization. Figure 25 illustrates which operational measures have been implemented and to what extent.

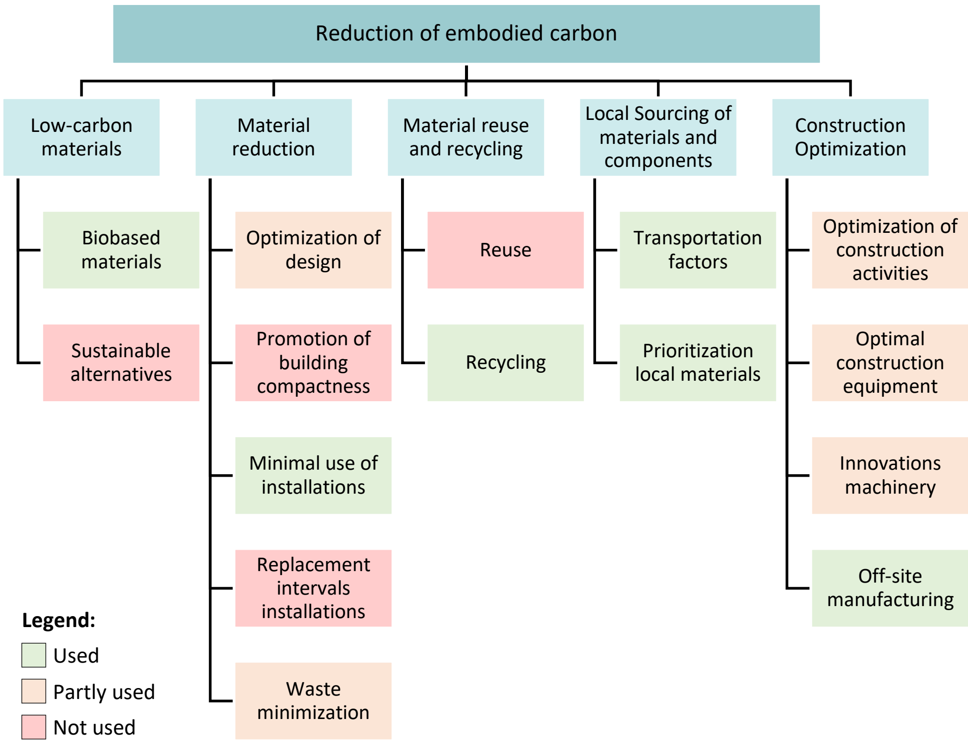



*Figure 24 - Conclusion of the applied reduction strategies across the case studies (own illustration)*

These strategies are implemented through specific choices in materials and construction methods. As demonstrated in the case studies, all cases exhibit a pattern of using wood as a low-carbon material. Were there was a preference in all case studies to incorporate wood as much as possible from the project's initial phase to reduce $CO_2$ emissions, with a focus on construction being the most important aspect. Where all the wood used is FSC-certified and sourced from Europe, which results in relatively low transport distances compared to sourcing from outside Europe.

Furthermore, a trend is observed within the strategy of material minimization and reduction, where if a project uses the operational measure of minimal use of installations, the use of natural ventilation systems, such as ventilation type C, is the most popular choice. In addition, one of the case study demonstrated that optimizing structural design and facade finishing is also an efficient way to reduces embodied carbon. More sustainable alternative materials, such as recycled roof gravel and concrete, are used as alternatives to traditional cast-in-place concrete. Waste reduction and transport optimization are also addressed during construction. This is achieved through monitoring and minimizing energy and water use, reducing packaging materials, and using a construction hub and ticket systems to coordinate transport movements.

Finally, off-site manufacturing, such as the use of prefabricated elements and modular units, is applied in all case studies. This has a significant impact on reducing embodied carbon because it shortens construction time, reduces the amount of transportation movements and reduces the $CO_2$ emissions associated with construction activities.

### 8.1.4 Sub-question four

**To what extent is (the reduction of) embodied carbon part of the investment decision-making process in the current practice?**

In current practices, the integration of embodied carbon reduction in the investment decision-making process of investors is still limited and evolving. Although there is a growing awareness, embodied carbon is not yet a standard consideration in investment decisions. The degree of integration varies significantly among different investors and depends on individual strategies and flexibility. The conclusion regarding the extent to which reducing embodied carbon is part of the investment decision-making process and whether it has an impact can be seen in Table 37.

*Table 37 - Conclusion of integration and impact of the reducing embodied carbon on the investment decision-making*

| Investment decision-making steps | Integration of embodied carbon | Impact of embodied carbon |
|---|---|---|
| Step 1: Setting a strategy | | |
| Step 2: Establishing return/risk objectives. | | |
| Step 3: Forecasting and evaluate expected costs returns | | |
| Step 4: Assessing investment risk | | |
| Step 5: Making a risk-adjusted evaluation on cost | | |
| Step 6: Implementing Proposals | | |
| Step 7: Auditing performance | | |

**Legend:** Included / Positive impact   Semi included / Moderate impact   Not included / Negative impact   No impact at all

When establishing return/risk objectives, private investors show more flexibility in projects that emphasize embodied carbon, whereas institutional investors are bound by stricter yield requirements. In forecasting and evaluating expected costs and returns, traditional financial models and evaluation methods largely remain unchanged, despite the increasing attention to embodied carbon.

The risk assessment for investments and the corresponding risk adjustments to the forecasted cash flows also vary, mainly depending on the materials used in projects and the specific experiences of investors. Lastly, in the actual implementation of proposals and the auditing of the operating performance, there is little to no influence from considerations regarding embodied carbon, although it is possible that slightly more attention may be given to projects where embodied carbon is reduced.

In conclusion, despite growing interest and awareness surrounding embodied carbon, its actual integration into the investment decision-making process remains limited and varies among investors, with traditional investment decision-making processes largely remaining unchanged.

### 8.1.5 Sub-question five

**What adjustments do investors make to the Discounted Cash Flow (DCF) parameters to reflect embodied carbon reduction strategies?**

Based on the results, it can be concluded that investors make minimal adjustments to their DCF parameters when certain embodied carbon reduction strategies are applied. Such adjustments were observed in only two of the strategies, as can be seen in Figure 26.

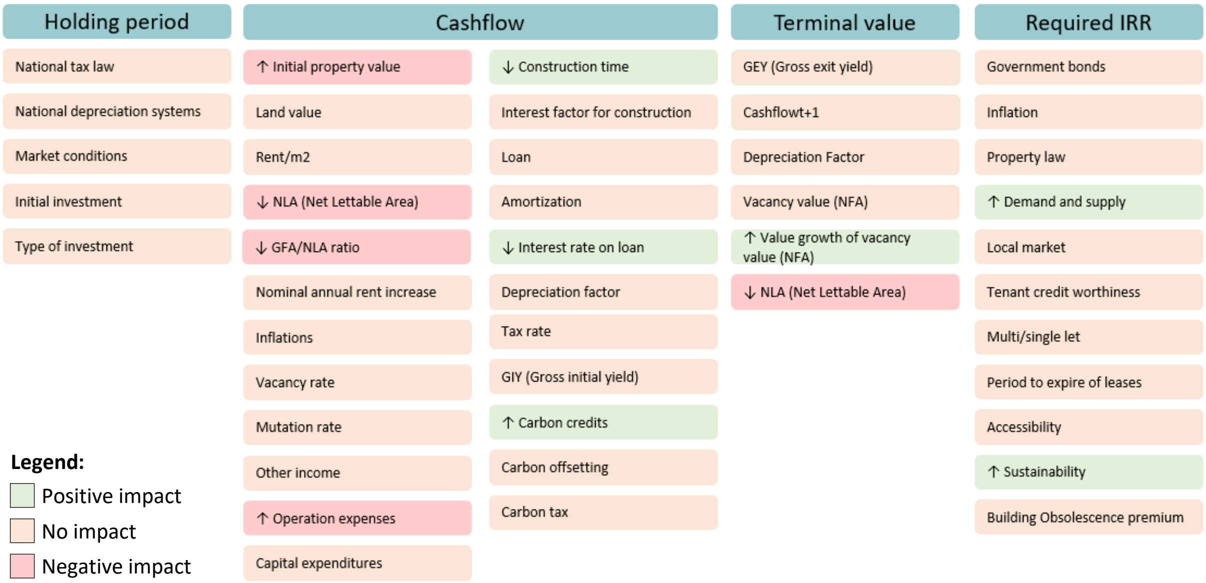



*Figure 25 - Conclusion of the impact of the applied reduction strategies on the DCF parameters (own illustration)*

The first strategy that directly impacted investment parameters is the use of low-carbon materials, particularly bio-based materials like wood. Incorporating wood in construction can increase the initial property value due to the added costs of materials and construction. However, the use of wood, both structurally and as facade finishing, has negatively impacted operational expenditures. This is largely due to inexperience and uncertainty associated with wood as a building material.

Another significant aspect of this strategy is the financial benefits, such as interest rate discounts on loans when using borrowed money, crucial for the projects' financial feasibility. Additionally, the option to sell carbon credits arises from the $CO_2$ storage capability of the building, adding another dimension to the financial benefits.

Regarding the terminal value, a higher vacancy value growth rate was used in one of the case studies, due to anticipated higher market values influenced by the building's quality and the use of wood, consequently increasing the terminal value. Which also results in a lower required IRR in the future, due to expectations that the building's sustainability features will enhance its quality and demand, thereby reducing investment risk.

The second strategy influencing the DCF parameters involves construction optimization, particularly through operational measures like using prefabricated elements and off-site manufacturing. In all three case studies, prefabricated elements or modular units were utilized, which positively impacted the construction time parameters of the cash flow. Additionally, the use of modular units negatively affected the GLA/NLA ratio, leading to lower cash flow and a reduced terminal value compared to traditional projects.

### 8.1.6 The main research question

**In what way does reducing embodied carbon in residential building projects impact the investment decision-making process from an investor's perspective?**

Investors' decision-making processes consist of various steps, and the integration of embodied carbon reduction varies within these. Although there is growing awareness, embodied carbon is not yet a standard consideration for investors and remains in its early stages, with traditional financial models and evaluation methods remaining unchanged. In some steps, such as setting a strategy, establishing return/risk objectives, or assessing investment risks and making adjustments to the cash flow, embodied carbon reduction is considered to some extent. However, the extent of integration and the willingness or ability to adjust traditional models and develop new ones depends on the nature of the investor.

Institutional investors must strictly adhere to the requirements of the fund to meet the needs of the shareholders and are more directly impacted by broader regulations. This can limit the reduction of embodied carbon in projects, whereas private investors might exhibit more flexibility on a project-by-project basis, enabling them to more easily make adjustments in traditional models based on their own will. Furthermore, the choice of materials plays a significant role, wherein the use of wood notably influences the investment decision-making process.

Additionally, the actual impact of reducing embodied carbon on the DCF model is minimal. While various strategies and operational measures to reduce embodied carbon are applied in construction projects, they have almost no impact on the parameters of the DCF model. However, the use of biobased materials and off-site manufacturing leads to both negative and positive adjustments in the DCF parameters. This includes an increase in the initial property value and operational expenditures due to the use of wood in projects, and a lowering of the GFA/NLA ratio when using modular units. But the use of wood also offers benefits such as interest rate discounts on loans, expected improved growth in vacancy value, an additional source of income through the sale of carbon credits, and a growing demand that reduces risk. Additionally, the use of modular units and prefabricated elements can also shorten construction time.

Although this process is supported by regulations, and there is a growing demand for sustainable investments, with investors open to adapting their traditional models, there remains a notable lack of incentives to standardize the reduction of embodied carbon in the current investment decision-making process. This situation is further complicated by the significant uncertainty among investors regarding future costs and returns associated with reducing embodied carbon.

In conclusion, significant steps must still be taken to achieve the objectives of the Dutch Climate Agreement and the European Green Deal for a carbon-neutral built environment by 2050. This requires further standardization and integration into all aspects of investment practice, firstly through more transparent communication between market parties. Secondly, institutional investors should engage in dialogues with shareholders, resulting in a more flexible approach regarding the determination of DCF parameters. Thirdly, it is necessary to revise the method appraisers use to evaluate buildings, focusing on the incorporation of sustainability. Additionally, adjustments need to be made to the way the MPG is calculated, and lastly, there should be an increase in incentives or an acceleration of regulations surrounding embodied carbon.

## 8.2 Recommendation for practice

The results of this research offer several important recommendations for investors and involved stakeholders to ensure that the large-scale reduction of embodied carbon in the building and construction industry is accelerated.

Since a lack of knowledge was observed about the impact of reducing embodied carbon within investment decision-making, it is important to continue sharing knowledge. It is crucial for investors to maintain transparent communication with each other about all uncertainties related to costs, returns, and potential risks, so they can learn from each other and avoid applying extra risk premiums repeatedly. Furthermore, clear communication between investors and developers is key. It enables developers to proactively make changes and allows for early resolution of risks identified by investors, potentially avoiding later adjustments. Also, if the developer undertakes certain actions to reduce risks, these should be acknowledged by the investor, rather than conservatively sticking to the traditional way of working.

The second recommendation is that institutional investors should engage in dialogues with shareholders. Due to emerging regulations, shareholders expect them to be progressive in terms of sustainability, while they must also strictly adhere to the fund's return requirements. However, it is important to discuss how this can be achieved, for example, by adopting a flexible approach regarding the determination of DCF parameters. This could involve lowering the required IRR, adopting a different approach to terminal value, or not always working based on benchmarks. Such discussions should lead to making it easier to complete the business case.

Additionally, appraisers play a significant role in determining the value of real estate, especially for institutional investors. It is important that appraisers incorporate sustainability more into their evaluations, instead of solely focusing on historical data.

The fifth recommendation relates to how embodied carbon is currently quantified. Firstly, the MPG calculation should be revised so that it's not possible to achieve the same MPG score with both concrete and wood. Additionally, there should be more direct steering with the PPm, considering that it directly relates to $CO_2$ emissions per GFA , providing a clearer and more relevant perspective. Consequently, it is also important that not only the MPG is utilized in Dutch regulations to reduce $CO_2$ emissions, but the PPm as well.

The final, and perhaps most crucial, recommendation is that there needs to be an increase in incentives to reduce embodied carbon. Currently, private investors have the flexibility to act and make adjustments in traditional models based on their own will, but there are not enough incentives for them to standardize this practice. Therefore, more incentives from the government and market parties are necessary, such as subsidies, discounts on loans, simulations of carbon credits, etc. However, this alone will not lead to a large-scale reduction of embodied carbon. Thus, it is important for the government to take action by tightening regulations or implementing $CO_2$ pricing, for example, through a carbon tax.

## 8.3 Recommendations for further research

Firstly, it is recommended to conduct follow-up research on the impact of the insights from this study on current market conditions. This could lead to different understandings as interest rates, regulations, and construction costs are currently different, influencing decision-making. This can be achieved through in-depth research focused on the impact of reducing embodied carbon within a building on one of the DCF model themes. Alternatively, similar research could be conducted on a larger scale, perhaps internationally, or within other types of real estate assets such as offices and retail.

Secondly, research could be conducted on how appraisers can incorporate sustainability into their evaluations. This includes exploring how appraisers can adopt a more future-oriented approach, rather than solely looking backward. This shift could enable market participants to consider sustainability earlier in their investment decision-making process.

Thirdly, research should be conducted on how the process of reducing embodied carbon can be accelerated. This involves examining what is needed from both the government and market parties. For instance, investigating the role of government policy and regulation in encouraging the integration of embodied carbon in investment decisions, and how investors can be more flexible in their decision-making regarding the reduction of embodied carbon, along with the necessary requirements and impacts.

Fourthly, research could be undertaken on the influence of carbon tax on the investment decision-making process, as is currently being explored in Germany (Achmea Real Estate, 2023; Interview E-1, 2023). Additionally, further research could be conducted on carbon credits, as it is currently unclear how Carbon Credits are allocated, who is responsible for compensation, and who ensures that the stored $CO_2$ remains sequestered. And lastly the impact of internal carbon pricing on the investment decision-making (Achmea Real Estate, 2023; Interview E-1, 2023).

Lastly, all investors and appraisers mentioned that a certificate indicating a building is “Paris Proof” would have a positive impact. Research could be conducted on the relationship between a Paris Proof certificate and investment decision-making. Whereby it is also important to establish a standard definition of what constitutes a “Paris Proof” building.

# Chapter 9

## Reflection

Relation with the academic field

Method

Process

# 9 Reflection

In this concluding chapter, a reflection is given on the research. It begins with the relation with the academic field. This is followed by an evaluation of the methodologies employed. The chapter concludes with a personal reflection on the research process.

## 9.1 Relation with the academic field

The thesis is written within the theme of Energy Transition, although embodied carbon does not fall directly under this theme. However, it is related to the sustainability transition currently taking place in the built environment. Within the Master's track Management in the Built Environment (MBE), investment decision-making by using a DCF model has always been a part of the curriculum. However, until now, there was no connection made between this topic and sustainability, particularly embodied carbon, and its impact on investment decisions. This research has established that connection and aligns with the research area of Real Estate Economics and Housing Quality and Process Innovation.

MBE focuses on solutions for building development and management, as well as making the built environment more sustainable. While the primary goal of the research was to provide clarity on the investment decision-making process and insights into the possible ways to reduce embodied carbon, the overarching objective is to make the built environment more sustainable. This research contributes to reducing the carbon footprint of the construction and building. Significant improvements can be made in the traditional investment process. This broader sustainability goal is also why the research fits within the broader Master's program MSc Architecture, Urbanism, and Building Sciences.

## 9.2 Method

This study used a qualitative empirical research method, beginning with a literature review in four areas: strategies and regulations for reducing embodied carbon, investment decision-making, and the DCF model.

In the literature study on embodied carbon and its reduction strategies, there was sufficient recent literature available. However, time constraints might have led to an incomplete model and overlooking new insights. Similar limitations applied to the review of regulations regarding embodied carbon, where a concise approach was necessary due to the study's limited scope. Additionally, the investment decision-making process was examined using the framework of Farragher & Kleiman (1996) and Farragher and Savage (2008), but the outdated sources affected the relevance of the results. However, the methods used in the literature study and framework development later provided support, facilitating communication with and explanations to interview participants.

The second part of the study, involving empirical research, focused on exploratory interviews due to the topic's novelty and limited data. Therefore, I chose to first conduct exploratory interviews. These interviews helped test and refine existing frameworks on embodied carbon reduction and DCF model parameters. Consequently, both frameworks were revised, with minor modifications made to the reduction strategies, likely due to the limited number of interviewees. However, significant changes were made to the parameters of the DCF model, which, as revealed in the case studies, are frequently used and have a substantial impact on the model.

To acknowledge the traditional investment sector, case studies were used to make the results more tangible and less speculative. Finding suitable case studies was difficult due to the scarcity of projects that involved multiple embodied carbon reduction strategies and investors. Eventually, out of five identified Dutch case studies, three were included in the study. These case studies were crucial for understanding the impact of reduction strategies and making findings more tangible, particularly in investor interviews. This was especially helpful as some investors had a traditional mindset, often unaware of the specific measures taken to reduce embodied carbon and their implications. This led some investors to reconsider why they hadn't implemented certain measures, despite the intentions of the developer and architect.

In the case studies, I primarily gathered data through semi-structured interviews and documents, effectively suiting my research needs. Interviews followed a systematic order, starting with architects, then developers, and finally acquisition managers. This approach facilitated better organization of information and allowed for more in-depth responses. Furthermore, A multiple-case study analysis was conducted, comparing the results side-by-side to identify clear patterns and draw conclusions. For all interviews, Atlas.TI was used, which helped with analyzing the interviews. Predefined codes ensured that the results were organized and easy to compare.

To conclude this part of the reflection, two reflective questions connected to the content of my study are posed. The first question is: What are the main barriers that currently prevent investors from investing in the reduction of embodied carbon? An appropriate second question to counter the answer from the first would be: What are the key insights gained from the findings that could encourage investors to invest in the reduction of embodied carbon?

## 9.3 Process

To start with, I thoroughly enjoyed the graduation process. I found it both enjoyable and enlightening to delve so deeply into a new subject that aligns with my passion – innovative engagement with the built environment, particularly the financial aspects. Personally, I find research and expanding my knowledge very rewarding, but bridging that connection with practical application makes it even more tangible and enjoyable. The process from P1 to P2 was a bit challenging due to the busyness in my personal life. However, the vacation period between P2 and the commencement of the research went well. It allowed me to rest and review everything anew. During the initial weeks, I noticed that some of the things I had done didn't make logical sense. Nevertheless, I found that the process from after my P2 until my P4 progressed much more smoothly. With my full focus on conducting my research, I could execute it more effectively, prepare better for meetings with supervisors, and didn't encounter major issues.

In hindsight, I should have perhaps involved more people in understanding the content and the process while being more thoughtful about what I communicated and how. This became evident when one of my supervisors, after three weeks into the research, still wasn't clear whether my research was quantitative or qualitative. Additionally, during my P3, I noticed that certain topics still weren't clearly understood. However, it might have been beneficial to validate the achieved results based on the current market. As mentioned earlier, the context of the case studies is significantly different from the present. Validating the results could have further enhanced their credibility by discussing them within an expert group.

Overall, it has been a successful year. It was a great experience to delve into the practical and theoretical aspects of graduation. Looking back, I consider it a highly educational, independent, and challenging period.

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## Appendix I - Data management plan

**Title:** Integrating Embodied Carbon Reduction in Investment Decisions-Making with a DCF Model.

**Creator:** Ruben Schmitz

**Affiliation:** Delft University of Technology

**Template:** TU Delft Data Management Plan template (2021)

**Project abstract:**

To combat global warming, it is crucial to eliminate $CO_2$ emissions by 2050, especially since a third of global emissions are attributed to the building and construction industry. This sector's carbon footprint comprises operational emissions from daily activities and embodied carbon throughout a building's lifecycle. However, as buildings become more energy-efficient, embodied carbon increasingly dominates total emissions. In the Netherlands, few residential projects align with the Dutch Climate Agreement's. This is due to various challenges hindering large-scale carbon reduction efforts, with financial barriers being a prominent issue. However, limited research focuses on financial barriers from the perspective of investors, often lacking in-depth analysis and offering few practical solutions for these challenges. Recognizing the need for carbon reduction, the industry must adopt a new approach to investment decisions, prioritizing embodied carbon considerations. This study delves into these financial barriers and how strategies to reduce embodied carbon impact real estate investment decision-making, focusing on the traditional DCF model. Therefore the main research question is: *"In what way does reducing embodied carbon in residential building projects impact the investment decision-making process from an investor's perspective?"*

To explore this, the study first conducts a literature review and exploratory interviews, followed by three case studies with semi-structured interviews. The findings reveals that the integration of embodied carbon in the investment decision-making process is still in its early stages. Although there is growing awareness and interest, embodied carbon is not yet a standard consideration in investment decisions. This integration depends on the flexibility of investors and the specific sustainability goals of projects. Traditional financial models and evaluation methods have largely remained unchanged. The study concludes that there is a need for further standardization and integration of carbon reduction in all aspects of investment practices to encourage the construction sector to achieve the goal of carbon net-zero by 2050.

**ID:** 133907

**Start date:** 01-09-2023

**End date:** 29-02-2024

**Last modified:** 05-10-2023

**1. Name of data management support staff consulted during the preparation of this plan.**

My faculty data steward, [Janine, Strandberg], has reviewed this DMP on [25-10-2023].

**2. Date of consultation with support staff.**

I. Data description and collection or re-use of existing data

**3. Provide a general description of the type of data you will be working with, including any re-used data:**

| Type of data | File format(s) | How will data be collected (for re-used data: source and terms of use)? | Purpose of processing | Storage location | Who will have access to the data |
|---|---|---|---|---|---|
| Recorded data | MP4. | Interviews with experts from investment firms and Interviews with experts from the case studies | To collect in-depth Explanatory data | TU Delft: Project Data (U:) | the supervisor (TU delft) and me |
| Transcript from the interviews | Text file (docx.) | From the interviews | So that the recorded interview can be analyzed | TU Delft: Project Data (U:) | the supervisor (TU delft) and me |
| Overview schemes of interviews | (CSV.) | From the transcript. | To make the results clear for the external parties | TU Delft: Project Data (U:) | the supervisor (TU delft) and me |

**4. How much data storage will you require during the project lifetime?**

< 250 GB

II. Documentation and data quality

**5. What documentation will accompany data?**

README file or other documentation explaining how data is organized

III. Storage and backup during research process

**6. Where will the data (and code, if applicable) be stored and backed-up during the project lifetime?**

Project Storage at TU Delft

IV. Legal and ethical requirements, codes of conduct

**7. Does your research involve human subjects or 3rd party datasets collected from human participants?**

Yes

**8A. Will you work with personal data? (information about an identified or identifiable natural person)**

***If you are not sure which option to select, first ask your Faculty Data Steward for advice. You can also check with the privacy website . If you would like to contact the privacy team: privacy-tud@tudelft.nl, please bring your DMP.***

Yes

8B. Will you work with any other types of confidential or classified data or code as listed below? (tick all that apply)

***If you are not sure which option to select, ask your Faculty Data Steward for advice.***

Yes, confidential data received from commercial, or other external partners

Yes, data related to competitive advantage (e.g. patent, IP)

9. How will ownership of the data and intellectual property rights to the data be managed?

***For projects involving commercially-sensitive research or research involving third parties, seek advice of* your Faculty Contract Manager when *answering this question. If this is not the case, you can use the example below.***

During the research, only me, the supervisor from the TU Delft and the companies have the right to the data. When the research is done it depends on whether the companies give permission to make it public.

**10. Which personal data will you process? Tick all that apply**

Email addresses and/or other addresses for digital communication

Data collected in Informed Consent form (names and email addresses)

Gender, date of birth and/or age

Function within company

Years of experience

**11. Please list the categories of data subjects**

Experts from investment firms and Interviews with people from the case studies; asset manager, fund managers, acquisition managers, developers, architects, contractors, sustainable advisors, cost advisors.

**12. Will you be sharing personal data with individuals/organisations outside of the EEA (European Economic Area)?**

No

**15. What is the legal ground for personal data processing?**

Informed consent

**16. Please describe the informed consent procedure you will follow:**

All the participants in the research study will be asked for their consent; this is first asked beforehand if they want to be part of the study and in the data process. Also, during the interview's, the participant will fill in a consent form.

**17. Where will you store the signed consent forms?**

Other - please explain below

Same storage solutions as explained in question 6

**18. Does the processing of the personal data result in a high risk to the data subjects?**

**If the processing of the personal data results in a high risk to the data subjects, it is required to perform a Data Protection Impact Assessment (DPIA). In order to determine if there is a high risk for the data subjects, please check if any of the options below that are applicable to the processing of the personal data during your research (check all that apply).**

**If two or more of the options listed below apply, you will have to complete the DPIA. Please get in touch with the privacy team: privacy-tud@tudelft.nl to receive support with DPIA.**

**If you have any additional comments, please add them in the box below.**

Evaluation or scoring

Systematic monitoring

**19. Did the privacy team advise you to perform a DPIA?**

No

**22. What will happen with personal research data after the end of the research project?**

Personal research data will be destroyed after the end of the research project

V. Data sharing and long-term preservation

**27. Apart from personal data mentioned in question 22, will any other data be publicly shared?**

All other non-personal data (and code) produced in the project

**29. How will you share research data (and code), including the one mentioned in question 22?**

All anonymized or aggregated data, and/or all other non-personal data will be uploaded to 4TU.ResearchData with public access

**30. How much of your data will be shared in a research data repository?**

100 GB - 1 TB

**31. When will the data (or code) be shared?**

Other - please explain

At the end of the research project

**32. Under what licence will be the data/code released?**

CC0

VI. Data management responsibilities and resources

**33. Is TU Delft the lead institution for this project?**

Yes, the only institution involved

**34. If you leave TU Delft (or are unavailable), who is going to be responsible for the data resulting from this project?**

The Head of the Department of the Best Experiments (hod-bestexperiments@tudelft.nl)

**35. What resources (for example financial and time) will be dedicated to data management and ensuring that data will be FAIR (Findable, Accessible, Interoperable, Re-usable)?**

4TU.ResearchData is able to archive 1TB of data per researcher per year free of charge for all TU Delft researchers. We do not expect to exceed this and therefore there are no additional costs of long term preservationa

# Appendix II - Informed consent form

Geachte heer/mevrouw,

U wordt uitgenodigd om deel te nemen aan een onderzoek genaamd **Towards Sustainable Investments - Integrating Embodied Carbon Reduction in Investment Decisions with a DCF Model**. Dit onderzoek wordt uitgevoerd door R**.Q (Ruben) Schmitz**, als afstudeeronderzoek voor de Mastertrack Management in the Built Environment aan de Faculteit van Bouwkunde aan de Technische Universiteit Delft. Met behulp van mentoren: **Prof.dr.ir. H.J. (Henk) Visscher** en **Ir. E.H.M. (Ellen) Geurts** vanuit de TU Delft en **Patrick de Baat** vanuit a.s.r. real estate.

Toelichting onderzoek

De bouw- en vastgoedsector draagt aanzienlijk bij aan $CO_2$-uitstoot, met een groeiende nadruk op het verminderen van materiaalgebonden $CO_2$ in de gebouwde omgeving. Er zijn echter verschillende uitdagingen die grootschalige koolstofreductie-inspanningen belemmeren, waarbij financiële barrières een prominent probleem vormen. Verrassend genoeg richt beperkt onderzoek zich op financiële barrières vanuit het perspectief van ontwikkelaars/beleggers, vaak zonder diepgaande analyse en oplossingen. Nu de industrie het belang van koolstofreductie erkent, is een vernieuwd perspectief op investeringsbeslissingen noodzakelijk, vooral met betrekking tot materiaalgebonden $CO_2$. Het blijft echter een uitdaging om te begrijpen hoe deze perspectieven kunnen worden opgenomen in risicobeoordeling en financiële modellering, zoals de traditionele DCF-methode. Het doel om kennis toe te voegen over de veranderingen in risicobeoordelingen en de financiële implicaties van het integreren van overwegingen voor het verminderen van materiaalgebonden $CO_2$ in investeringsbeslissingen met behulp van DCF-parameters vanuit een beleggersperspectief. Het verleggen van de focus van bouw naar investeringsperspectief om meer investeringen in initiatieven die materiaalgebonden $CO_2$ verminderen te bevorderen, uiteindelijk bijdragend aan de vermindering van de koolstofvoetafdruk van de bouw- en vastgoedsector en het toevoegen van nieuwe gebouwde woningen.

Toelichting Interview

Het interview zal ongeveer 60 minuten in beslag nemen. De data (interview opname) zal gebruikt worden voor het verwerken, transcriberen en coderen van het interview. De geanonimiseerde resultaten die uit de verschillende interviews verkregen wordt zal gepubliceerd worden in de openbare TU Delft Repository. De primaire data worden na afronding van het onderzoek verwijderd.

Zoals bij elke online activiteit is het risico van een databreuk aanwezig. Wij doen ons best om uw antwoorden vertrouwelijk te houden. We minimaliseren de risico's door data anoniem te verzamelen en in een, door de TU delft goedgekeurde en beveiligde omgeving te bewaren.

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 of om naderhand toegang te vragen tot het transcript en informatie te wijzigen/verwijderen. Als u vragen heeft over het onderzoek kunt u contact opnemen via e-mail (R.Q.Schmitz@student.tudelft.nl) of telefoon (**+31 (0)6 34 41 97 07).**

Bij akkoord, verzoek ik u vriendelijk om onderstaande verklaring in te vullen en te ondertekenen. Het invullen van de verklaring betekend dat u met bovenstaande akkoord gaat.

Met vriendelijke groet,

Ruben Schmitz

**Gelieve de toepasselijke box aan te vinken:**

| | | Ja | Nee |
|---|---|---|---|
| 1. | Ik heb de informatie over het onderzoek gedateerd **x** gelezen en begrepen, of deze is aan mij voorgelezen. Ik heb de mogelijkheid gehad om vragen te stellen over het onderzoek en mijn vragen zijn naar tevredenheid beantwoord. | ☐ | ☐ |
| 2. | Ik doe vrijwillig mee aan dit onderzoek, en ik begrijp dat ik kan weigeren vragen te beantwoorden en mij op elk moment kan terugtrekken uit de studie, zonder een reden op te hoeven geven. | ☐ | ☐ |
| 3. | Ik begrijp dat mijn deelname aan het onderzoek de volgende punten betekent:<br>a) Een geluidsopname van het interview (deze zal na voltooien van de transcriptie verwijderd worden).<br>b) Een uitgewerkt transcript van het interview. | ☐ | ☐ |
| 4. | Ik begrijp dat de studie **29-02-2024** eindigt. | ☐ | ☐ |
| 5. | Ik begrijp dat de persoonlijke informatie die over mij verzameld wordt en mij kan identificeren, zoals (***naam, contactgegevens, bedrijfsgevoelige informatie)***, niet gedeeld worden buiten het studieteam. | ☐ | ☐ |
| 6. | Ik begrijp dat de volgende stappen worden ondernomen om het risico van een databreuk te minimaliseren, en dat mijn identiteit op de volgende manieren wordt beschermd in het geval van een databreuk: anonimiseren van de transcripten: verwijdering van fragmenten zodra het (geannonimiseerde) transcript volledig verwerkt is, opslag in versleutelde drive, vernietiging van persoonlijke informatie na einde onderzoek | ☐ | ☐ |
| 7. | Ik begrijp dat mijn deelname betekent dat er persoonlijke identificeerbare informatie en onderzoeksdata worden verzameld, met het risico dat ik hieruit geïdentificeerd kan worden. | ☐ | ☐ |
| 8. | Ik begrijp dat na het onderzoek de geanonimiseerde informatie gebruikt zal worden voor het eind rapport. | ☐ | ☐ |
| 9. | Ik geef toestemming om mijn antwoorden, ideeën of andere bijdrages anoniem te quoten in resulterende producten. | ☐ | ☐ |
| 10. | Ik begrijp dat de persoonlijke data die over mij verzameld wordt, vernietigd wordt op **29-02-2024** | ☐ | ☐ |

**Handtekening**

_____________________________ _____________________________ _________

Naam deelnemer Handtekening Datum

Ik, de onderzoeker, verklaar dat ik de **informatie en het instemmingsformulier** correct met de potentiële deelnemer heb gedeeld, naar het beste van mijn vermogen, heb verzekerd dat de deelnemer begrijpt waar hij/zij vrijwillig mee instemt.

**Ruben Quinten Schmitz**

___________________________ ____________________ _________

Naam onderzoeker Handtekening Datum

## Appendix III - EU taxonomy regulations regarding embodied carbon

In January 2018, a high-level expert group on sustainable finance came up with the idea of the Taxonomy. A couple of months later, in March, the EU's financial regulations were reformed, and a European Commission's action plan for financing sustainable growth was made. Two years later, the Taxonomy regulation was published in the European Union's Official Journal in June 2020 and became operational a month later. The Taxonomy regulation was published in the Official Journal of the European Union on 22 June 2020 and entered into force on 12 July 2020 (European Commission, 2023). This means that all financial products marketed into or manufactured in the European Union, including pension products, will be required to refer to the Taxonomy, which also includes example real estate funds (EU TEG on sustainable finance, 2020).

An activity is deemed to be green only if it meets all these requirements. Currently, for construction and real estate activities, substantial contribution criteria have been established only for the first 3 environmental objectives. However, significant harm criteria have been defined for all climate objectives. Furthermore, uniform minimum safeguards apply to all activities. All criteria have been approved and definitively determined by the European Commission (DGCB, 2023).

Within the EU Taxonomy, the aim is to be both "taxonomy aligned" and "taxonomy-eligible." This means that under the EU Taxonomy, an activity is regarded as environmentally sustainable or "aligned" with the EU Taxonomy if it makes a substantial contribution to one of the six environmental objectives, does not cause significant harm to any of the others and meets the uniform minimum safeguards. However, any specific economic activity can be evaluated for alignment only if it is already included in the EU Taxonomy, meaning it is "taxonomy-eligible" (European Commission, 2023).

For investors within the EU Taxonomy, the substantial contribution criteria are outlined in Chapter 7, "Construction and Real Estate Activities." Specifically, for new building purchases, Chapters 7.1, "Construction of New Buildings," and 7.7, "Acquisition and Ownership of Buildings," are relevant. Concerning Climate Change Mitigation, there is only one Technical Screening Criterion related to embodied carbon. In Chapters 7.1 and 7.7, the requirement is stated as follows: "For buildings larger than 5000 $m^2$, the life-cycle Global Warming Potential (GWP) resulting from construction must be calculated for each stage in the life cycle and disclosed to investors and clients upon request". (European Commission, 2021).

Furthermore, in Chapter 7.1, there is an additional "do not harm" criterion related to $CO_2$ emissions. This criterion, under the "Transition to a Circular Economy," states: "At least 70% (by weight) of non-hazardous construction and demolition waste (excluding naturally occurring material referred to in category 17 05 04 in the European List of Waste established by Decision 2000/532/EC) generated on the construction site must be prepared for reuse, recycling, and other material recovery, including backfilling operations using waste to substitute other materials, in accordance with the waste hierarchy and the EU Construction and Demolition Waste Management Protocol." (European Commission, 2021).

## Appendix IV - SFDR regulations regarding embodied carbon

Recital (10) of the SFDR highlights that the legislation aims to rectify information asymmetries in principal-agent relationships by focusing on three critical areas: (i) the integration of sustainability risks, (ii) the consideration of adverse sustainability impacts, and (iii) the promotion of environmental or social characteristics, as well as sustainable investment (European Union, 2019). These objectives are accomplished through pre-contractual and ongoing disclosures made by financial market participants or financial advisers acting as agents on behalf of principals, thereby ensuring transparency and accountability to end investors (Chiu, 2022; Busch, 2023). Chiu (2022) emphasizes that the SFDR establishes a robust framework for the labelling of sustainable financial products, effectively setting a gold standard within the industry. This framework applies to two types of financial intermediaries: (i) financial market participants, such as asset managers, and (ii) financial advisers, including investment and insurance advisers (Busch, 2023).

There are no predefined criteria to determine whether a product falls under Article 6, 8, or 9. The reporting entity decides in which category to place the product, based on its characteristics and the relevant article. The more transparent the reporting on ESG indicators, the 'greener' the classification. For Article 9, a condition is that a product must consist entirely of sustainable investments. Entities classified as Article 8 or 9 are obligated to report against the EU Taxonomy. However, an Article 9 classification does not automatically satisfy the EU Taxonomy; this must be additionally demonstrated.

## Appendix V - CSRD regulations regarding embodied carbon

Within the CSRD standards, there is no table or list indicating which indicators are mandatory or optional. The distinction within the CSRD is made by means of wording, see Table 38.

*Table 38 - Information on when reporting should occur within the CSRD*

| Type of Indicator | Description |
|---|---|
| Shall disclose | Used for mandatory indicators or data points. |
| May disclose | Used for optional, voluntary indicators or data points. |
| Shall Consider | Used when the reporting entity is expected to include certain matters, sources, and/or methodologies in the reporting. |
| Phased-in | 'Phased-in Disclosure Requirements' include indicators that can be gradually incorporated over time. Entities may choose to exclude these indicators from their reports in the first year or years and incorporate them later on |

Regarding embodied carbon, ESRS E1 Climate change will play an important role, with climate change mitigation being applicable to this research. Which paragraphs are relevance regarding embodied are stated below:

### Disclosure Requirement E1-1 –Transition plan for climate change mitigation

- §14 - The undertaking shall disclose its *transition plan* for *climate change mitigation*
- §15 -The objective of this Disclosure Requirement is to enable an understanding of the undertaking's past, current, and future mitigation efforts to ensure that its strategy and *business model* are compatible with the transition to a sustainable economy, and with the limiting of global warming to 1.5°C in line with the Paris Agreement and with the objective of achieving climate neutrality by 2050 and, where relevant, the undertaking's exposure to coal, oil and gas-related activities.
- §16 - The information required by paragraph 14 shall include:
    - §16 (a) - by reference to *GHG emission reduction targets* (as required by Disclosure Requirement E1-4), an explanation of how the undertaking's targets are compatible with the limiting of global warming to 1.5°C in line with the Paris Agreement;
    - §16 (b) - by reference to GHG emission reduction targets (as required by Disclosure Requirement E1-4) and the *climate change mitigation actions* (as required by Disclosure Requirement E1-3), an explanation of the *decarbonisation levers* identified, and key actions planned, including changes in the undertaking's product and service portfolio and the adoption of new technologies in its own operations, or the upstream and/or downstream value chain;
    - §16 (c) - by reference to the *climate change mitigation actions* (as required by Disclosure Requirement E1-3), an explanation and quantification of the undertaking's investments and funding supporting the implementation of its *transition plan,* with a reference to the key performance indicators of taxonomy-aligned CapEx, and where relevant the CapEx plans, that the undertaking discloses in accordance with Commission Delegated Regulation (EU) 2021/2178;
    - §16 (d) - a qualitative assessment of the potential *locked-in GHG emissions* from the undertaking's key assets and products. This shall include an explanation of if and how these *emissions* may jeopardise the achievement of the undertaking's *GHG emission reduction targets* and drive *transition risk,* and if applicable, an explanation of the undertaking's plans to manage its GHG-intensive and energy-intensive assets and products;
    - §16 (e) - for undertakings with economic activities that are covered by delegated regulations on climate adaptation or mitigation under the Taxonomy Regulation, an explanation of any objective or plans (CapEX, CapEx plans, OpEX) that the undertaking

has for aligning its economic activities (revenues, CapEx, OpEx) with the criteria established in Commission Delegated Regulation 2021/213936;
    - §16 (f) - if applicable, a disclosure of significant CapEx amounts invested during the reporting period related to coal, oil and gas-related economic activities

## Disclosure Requirement E1-3 –Actions and resources in relation to climate change policies

- §29 In addition to ESRS 2 MDR-A, the undertaking shall:
    - §29 (a) when listing key *actions* taken in the reporting year and planned for the future, present the *climate change mitigation* actions by decarbonisation lever including the nature- based solutions;
    - §29 (b) when describing the outcome of the actions for climate change mitigation, include the achieved and expected *GHG emission reductions;* and
    - §29 (c) relate significant monetary amounts of CapEx and OpEx required to implement the actions taken or planned to:
        - i. the relevant line items or notes in the financial statements;
        - ii. the key performance indicators required under Commission Delegated Regulation (EU) 2021/2178; and
        - iii. if applicable, the CapEx plan required by Commission Delegated Regulation (EU) 2021/2178.

### Disclosure Requirement E1-4 –Targets related to climate change mitigation and adaptation

- §34 - If the undertaking has set *GHG emission reduction targets39,* ESRS 2 MDR-T and the following requirements shall apply:
    - §34 (a) - GHG emission reduction targets shall be disclosed in absolute value (either in tonnes of $CO_2$eq or as a percentage of the *emissions* of a base year) and, where relevant, in intensity value;
    - §34 (b) - GHG emission reduction targets shall be disclosed for *Scope 1, 2,* and *3 GHG emissions,* either separately or combined. The undertaking shall specify, in case of combined *GHG emission reduction targets,* which GHG emission Scopes (1, 2 and/or 3) are covered by the target, the share related to each respective GHG emission Scope and which GHGs are covered. The undertaking shall explain how the consistency of these targets with its GHG inventory boundaries is ensured (as required by Disclosure Requirement E1-6). The GHG emission reduction targets shall be gross targets, meaning that the undertaking shall not include GHG removals, *carbon credits* or avoided emissions as a means of achieving the GHG emission reduction targets;
- §44 - The undertaking shall disclose in metric tonnes of $CO_2$eq its:
    - §44 (a) - gross Scope 1 GHG emissions;
    - §44 (b) - gross Scope 2 GHG emissions;
    - §44 (c) - gross Scope 3 GHG emissions;
    - §44 (d) – total GHG emissions;
- §45. - The objective of the Disclosure Requirement in paragraph 44 in respect of:
    - §45 -(c) gross *Scope 3 GHG emissions* as required by paragraph 44 (c) is to provide an understanding of the GHG emissions that occur in the undertaking's upstream and downstream value chain beyond its Scope 1 and 2 GHG emissions. For many undertakings, Scope 3 GHG emissions may be the main component of their GHG inventory and are an important driver of the undertaking's *transition risks*
- §51 - The disclosure of gross *Scope 3 GHG emissions* required by paragraph 44 (c) shall include GHG emissions in metric tonnes of $CO_2$eq from each significant *Scope 3 category* (i.e. each Scope 3 category that is a priority for the undertaking) .

**Disclosure Requirement E1-7 – GHG removals and GHG mitigation projects financed through carbon credits**

- §56 - The undertaking shall disclose:
    - §56 (a) - GHG removals and storage in metric tonnes of $CO_2$eq resulting from projects it may have developed in its own operations, or contributed to in its upstream and downstream value chain; and
    - §56 (b) - the amount of GHG emission reductions or removals from climate change mitigation projects outside its value chain it has financed or intends to finance through any purchase of carbon credits.
- § 57 - The objective of this Disclosure Requirement is:
    - § 57 (a) - to provide an understanding of the undertaking's *actions* to permanently remove or actively support the removal of GHG from the atmosphere, potentially for achieving *net-zero targets* (as stated in paragraph 60).
    - § 57 (b) - to provide an understanding of the extent and quality of *carbon credits* the undertaking has purchased or intends to purchase from the voluntary market, potentially for supporting its GHG neutrality claims (as stated in paragraph 61).
- § 58. The disclosure on *GHG removals and storage* required by paragraph 56 (a) shall include, if applicable:
    - § 58 (a) - the total amount of GHG removals and storage in metric tonnes of $CO_2$eq disaggregated and separately disclosed for the amount related to the undertaking's own operations and its upstream and donwstream value chain, and broken down by removal activity; and
    - § 58 (b) - the calculation assumptions, methodologies and frameworks applied by the undertaking.
- § 59 - The disclosure on *carbon credits* required by paragraph 56 (b) shall include, if applicable:
    - § 59 (a) - the total amount of carbon credits outside the undertaking's *value chain* in metric tonnes of $CO_2$eq that are verified against recognised quality standards and cancelled in the reporting period; and
    - § 59 (b)- the total amount of carbon credits outside the undertaking's value chain in metric tonnes of $CO_2$eq planned to be cancelled in the future and whether they are based on existing contractual agreements or not.
- § 60 - In the case where the undertaking discloses a *net-zero target* in addition to the gross *GHG emission reduction targets* in accordance with Disclosure Requirement E1-4, paragraph 30, it shall explain the scope, methodologies and frameworks applied and how the residual GHG *emissions* (after approximately 90-95% of GHG emission reduction with the possibility for justified sectoral variations in line with a recognised sectoral decarbonisation pathway) are intended to be neutralised by, for example, GHG removals in its own operations and upstream and donwstream value chain.
- § 61 - In the case where the undertaking may have made public claims of GHG neutrality that involve the use of *carbon credits,* it shall explain:
    - § 61 (a) - whether and how these claims are accompanied by GHG *emission reduction targets* as required by Disclosure requirement ESRS E1-4;
    - § 61 (b) - whether and how these claims and the reliance on carbon credits neither impede nor reduce the achievement of its GHG emission reduction targets47, or, if applicable, its net zero target; and
    - § 61 (c) - the credibility and integrity of the carbon credits used, including by reference to recognised quality standards

## Disclosure Requirement E1-8 –Internal carbon pricing

- § 62 - The undertaking shall disclose whether it applies *internal carbon pricing schemes,* and if so, how they support its decision making and incentivise the implementation of climate-related *policies* and *targets.*
- § 63 - The information required in paragraph 62 shall include:
  - § 63 (a) - the type of internal carbon pricing scheme, for example, the shadow prices applied for CapEX or research and development (R&D) investment decision making, internal carbon fees or internal carbon funds;
  - § 63 (b) - the specific scope of application of the carbon pricing schemes (activities, geographies, entities, etc.);
  - § 63 (c) - the carbon prices applied according to the type of scheme and critical assumptions made to determine the prices, including the source of the applied carbon prices and why these are deemed relevant for their chosen application. The undertaking may disclose the calculation methodology of the carbon prices including the extent to which these have been set using scientific guidance and how their future development is related to science-based carbon pricing trajectories; and
  - § 63 (d) - the current year approximate gross GHG emission volumes by Scopes 1, 2 and, where applicable, Scope 3 in metric tonnes of $CO_2$eq covered by these schemes, as well as their share of the undertaking's overall GHG *emissions* for each respective Scope.

# Appendix VI - Determination of the DCF parameters

## Holding period

The initial phase of investment appraisal involves determining the expected duration of the holding period. Rowley et al. (1998) concluded in their research that Investors who are purchasing or developing new properties typically have a specific holding period in mind right from the beginning. Collett et al. (2003) emphasize the significance of understanding the holding period when making investment decisions in real estate. Investment appraisal involves determining an analysis period and making asset allocation decisions based on the variances and covariances of assets influenced by the specified time interval or analysis. However, determining the optimal holding period in real estate calculations is a complex task, as highlighted by Baroni et al. (2007) and Collett et al. (2003). But at a minimum, the analysis involves comparing the cost of acquisition with the potential gains from holding and subsequently selling the asset later.

As mentioned in the previous paragraph, determining the optimal holding is a complex task. This is because this decision involves considering various factors. Firstly, the holding period can be influenced by tax laws and depreciation systems in a given country, as these factors may incentivize investors to sell a property at a specific time (Baroni et al., 2007; Fisher and Young, 2000). Secondly, the duration of the holding period is heavily influenced by market conditions. During periods of higher market liquidity, holding periods tend to decline, while during periods of lower liquidity, holding periods tend to increase. Additionally, there is generally a negative correlation between market volatility and the duration of the holding period (Collett et al., 2003). Thirdly, the height of transaction costs associated with initial investment is an important consideration. It is necessary to factor in the minimum holding period required to cover the substantial transaction costs typically associated with real estate investments (Collett et al., 2003).

Lastly, the specific type of investment also influences the holding period decision. Rowley et al. (1996) concluded that for office properties, the decision is often driven by factors such as depreciation or obsolescence. On the other hand, the decision for retail properties is more empirical and may depend on active management and the state of the market. However, for residential properties, it has been observed that investors tend to sell sooner when property values rise at a faster rate compared to rents (Brown and Geurts, 2005).

## Cash Flows

To begin with the determination of cash flows, it is first necessary to calculate the Net Operating Income (NOI). This is done by estimating the rental income of the property, including vacancy and collection losses, and then deducting all expenses associated with maintaining and operating the property, as well as the capital expenditures related to it (Ling & Archer, 2018). Additionally, the calculation of cash flow varies depending on whether debt is used; in such cases, a distinction can be made between cash flows before and after tax. Furthermore, there are certain parameters within the cash flow that determine or influence it, such as Gross Initial Yield (GIY), nominal annual rent increase, inflation, etc. (Ling & Archer, 2018). Table 39 shows how the operating cash flow can be calculated.

*Table 39 - Operating cash flow adapted from Ling & Archer (2018)*

| | | |
|---|---|---|
| | **Operating cash flows at t=n** | |
| | Potential gross income (PGI) | = rent per NLA x number of NLA |
| - | Vacancy & collection loss | = for ex. natural vacancy rate |
| = | **Gross rent income** | |
| + | Miscellaneous income | = income from other sources |
| = | **Effective gross income (EGI)** | |
| - | Operation expenses | = fixed and variable expenses |
| - | Capital expenditures (CAPX) | = replacements and alterations to extend building life span |
| = | **Net operating income (NOI)** | |
| - | Investments | = Initial property value + land value |
| = | **Investment cashflow (before-tax)** | |
| - | Debt services (DS) | = loan + interest + amortization |
| = | **Net equity cashflow (before tax)** | |
| - | Tax liability | = taxable operating income x tax rate |
| = | **Net equity cashflow (after tax)** | |
| | | |
| | Net operating income | |
| - | Depreciation | = (property value-land value-residual value) x (100/lifespan) |
| - | Interest | = loan x Interest rate |
| = | **Taxable income** | |
| x | Corporate tax rate | |
| = | **Tax liability** | |

## Terminal value

Terminal value is the estimated value of an asset at the end of the specified analysis period. It allows the future cash flows generated by the asset beyond the forecasted period or the potential income that can be obtained from selling the valued asset at the end of the projected period (Żelazowski, 2014). Żelazowski (2014) and Hordijk & Van De Ridder (2003) concluded that the most impactful factor in the valuation process of the terminal value is the length of the analysis period. A ten-year period is considered optimal because longer durations, such as 15 years, introduce complexity and result in artificial scenarios instead of real market developments. Conversely, shorter terms like three to seven years lead to a disproportionate impact of residual value on valuation, compromising the quality of cash flows (Hordijk & Van De Ridder, 2003)

Literature offers various approaches for estimating terminal value, including book value methods comparative methods, liquidation methods, multiplier methods and replacement methods. However, the income concepts based on definite or perpetual cash flows, such as the income capitalization method, are the most commonly used solutions in this field (Żelazowski, 2014; Hordijk & Van De Ridder, 2003; Ling & Archer, 2018). That means calculating the terminal value by capitalizing the cash flow of the last holding year plus an additional year. Additionally, the Gross Exit Yield (GEY) is used, which indicates the return an investor aims to achieve upon selling the property (Hordijk & Van De Ridder, 2003). The general formula for calculating the terminal value is as follows:

$$Terminal\ value\ at\ t = \frac{CF_{t+1}}{GEY}$$

## Required internal Rate of Return

The determination of the Req IRR, also referred to as the discount rate, entails considering the comprehensive required return on investments, encompassing income, capital appreciation, and the associated risk level (Riggs, 1996). The determination of required internal rates of return stems from the investor's opportunity cost associated with the subject investment. The discount rate used should reflect the total return that the investor could potentially earn from other investments with similar risk profiles. As these alternative investments are traded in the capital market, they provide a benchmark for setting the appropriate discount rate (Ling & Archer, 2018). The Req IRR plays a crucial role in evaluating the present value of cash flows. In the absence of an IRR, the NPV equation would simply involve the addition and subtraction of cash flows without considering the time value of money. A higher IRR leads to a lower NPV, while a lower IRR leads to a higher NPV (Pšunder & Cirman, 2011).

The required return can be broken down into the return from risk-free rate in the economy plus a risk premium (Pšunder & Cirman, 2011; Ling & Archer, 2018 Greer & Kolbe, 2003). Risk-free interest rates represent the theoretical return on an investment that carries no risk of financial loss. Often associated with the return that is available on a government bonds or security from economically stable countries (Binsbergen et al., 2022; Ling & Archer, 2018). A risk premium is the expected additional return on an investment that an investor requires as compensation for taking on a higher level of risk compared to a risk-free investment. It's essentially a reward to investors for tolerating the extra uncertainty. (Jones & Trevillion, 2022). How reliable or uncertain the forecasted net operating incomes are. Risk premiums are largely influenced by the capital markets because they provide the financial resources, including debt and equity, necessary for the development and acquisition of real estate assets. Within the capital markets, the required returns for a wide range of investment opportunities, including real estate, are determined (Ling & Archer, 2018).

This dynamic of risk premiums and required returns ultimately reflects the demand and supply in the capital markets, where these two elements together shape the financial conditions and opportunities within the real estate sector. Ho et al. (2015) found that risk premiums can also be attributed to property law and inflation. Finally, Crosby et al. (2016) concluded in their research that both macro and micro-economic factors impact the required IRR, with their results detailed in Table 40.

*Table 40 - Influence of economic factors (macro and micro) on risk premium (Crosby et al.2016)*

| | Spatial Scale of Influence | Returns to Reflect | Drivers | Variables |
|---|---|---|---|---|
| Macro ↑ | Investment and Capital Markets | RFR | Expected inflation, time preference | National level measures such as Treasury Bill rates, Gross Redemption Yields on government bonds, and actual and expected inflation rates |
| | Real Estate Market | Risk and growth expectations | Performance and volatility of real estate relative to other assets | Macro-economic and industry estimates of income and capital returns and key drivers in assets market at local market levels |
| | Sector | | Market specific factors, economic/ catchment profile | |
| | Location | | | |
| | Stock/Asset | | Tenants | Credit worthiness |
| | | | Lease | Multi/single-let, period to expire of leases |
| | | | Location | Micro locations / Accessibility |
| ↓ Micro | | | Building | Sustainability rating, Obsolescence |

# Appendix VII - Additional explanation Jonas

Step 1: Setting a strategy

**General**

Within Amvest, the approach of "setting a strategy" is employed. Amvest's strategy for its funds is reevaluated annually through a portfolio plan that outlines the strategy for the upcoming three years. This plan describes the overall fund strategy. The core of this strategy, which also encompasses the main objectives, is defined in the fund's terms and conditions. These conditions address both legal and tax aspects and outline the fundamental terms and objectives that the fund must adhere to. One of the primary objectives of the fund is to invest in Dutch rental properties to generate returns for entities such as pension funds and insurers. The aim is to achieve stable returns over the long term and provide sustainable and a pleasant living environment while also pursuing a positive impact on the world. Amvest's fund is open-ended, meaning there is no fixed exit strategy or term.

**Jonas**

In the case of the Jonas acquisition project, Amvest did not specifically alter its overall strategy. However, the project was initially established with a strong emphasis on sustainability, partly driven by agreements with the municipality and the developer. While Jonas may not be the most sustainable project in the Netherlands, Amvest has drawn valuable lessons from it. These lessons do not necessarily stem from the sustainability aspects of the building alone but also from other challenges that arose during the project, such as the contractor going bankrupt. Most importantly, Jonas has become a reference point for Amvest in terms of sustainable construction and the importance of embodied carbon. However, to conclude, reducing embodied carbon has had no impact on step 1.

Step 2: Establishing return/risk objectives.

**General**

Amvest employs a structured strategy in determining its return/risk objectives, focusing on a fixed Internal Rate of Return (IRR) requirement. This IRR is set at the fund level, applies to the entire portfolio, and all individual acquisitions must meet this criterion. To compensate for regional variations in the Dutch real estate markets and achieve the targeted IRR, Amvest has established a regional classification. Various indices are determined based on these regional classifications. Using specific expectations, such as market growth and vacancy rate expectations, Amvest creates an index for each region, enabling them to adjust their investment approach. This flexibility allows them to achieve varying returns in different regions, ultimately aiming to realize the same IRR based on those specific expectations. According to the interviewee, it was not clear how that required IRR ever originated, but it is likely based on a set of parameters. However, direct parameters related to the required IRR are not employed for this reason

**Jonas**

No specific adjustments were made to the return/risk objectives within Jonas; the goal here was also to achieve the fixed required IRR.

Step 3: Forecasting and evaluate expected costs returns

**General**

Amvest utilizes its own IRR model, validated by PWC, for acquisitions. This model incorporates all specific project characteristics, such as square meters, number of homes, rent price levels (including considerations like mid-range rent regulations), project planning, and the final purchase price. Certain indices (such as rent growth, cost increases) based on regional categorization are used to feed the model. By inputting these data, an IRR is calculated to determine whether the investment meets the return requirements. These calculations and projections, such as vacancy rate and rent price, can be project-specific. Regarding the calculation of the terminal value, the exit yield is seen as an output variable in their model. They both calculate the terminal value with the $Cashflow^{t+1}$ and the vacancy value. This yields a specific terminal value, from which the exit yield is calculated. Additionally, the IRR calculation employs a standard ten-year holding period, which determines various features like vacancy rate, rent price, turnover rate, and operating expenses.

**Jonas**

Within the project, no direct adjustments were made in terms of how the holding period, cash flow, and terminal value were determined. This means that a holding period of 10 years was maintained, and the above parameters were used. However, Amvest did meet its customary IRR requirement and even exceeded it. This was primarily due to the timing and market conditions in which Jonas was acquired, as described above.

Step 4: Assessing investment risk

**General**

When assessing risks, Amvest employs a risk matrix within their investment proposal. This matrix is qualitative in nature and evaluates risk on fifteen different points. These points are categorized as low, medium, or high risk, followed by an explanation of the specific risk and whether measures need to be taken. The assessed risks encompass aspects such as reputation, collaboration with partners, technical risks, legal risks, location, vacancy, marketing, and the feasibility of the planned schedule.

**Jonas**

For Project Jonas, the same risk assessment method described in the previous chapter was applied. The results showed that 80% of the assessed points had a low risk, while some had a medium to high risk. One of the discussed risks, for example, was the solvency and reliability of the contractor, and the unique concept of Jonas, targeting a specific audience with small housing units, also brought risks such as vacancy risk. Nevertheless, specific risks related to Project Jonas, such as the choice of sustainable materials or the pursuit of BREEAM outstanding, were not directly incorporated into the risk assessment. This was because Jonas was a turnkey acquisition, with the development risks lying with the developer and not with Amvest. In conclusion, despite some new elements in Project Jonas, there was no difference in risk assessment compared to other projects.

Step 5: Making a risk-adjusted evaluation of the forecast costs and returns

**General**

At Amvest, the step of risk-adjusted evaluation is always applied if it is necessary, mainly concerning cash flow and returns. After the risk matrix is filled out and discussed, they assess which risks are high and how they can be mitigated. Various risks can be taken into consideration, such as expected vacancy of a project, where the purchase proposal factors in vacancy costs. Another example is marketing (how attractive a building is to tenants) and location. Location plays a crucial role in determining the project's return for t=0 but also at the end of the appraisal period. As discussed above, Amvest uses a specific indexes for each region these can be adjusted on a project-specific basis based on the anticipated risks.

**Jonas**
No specific adjustments were made to the cash flow concerning the identified risks in the risk matrix for Jonas. This was because, as mentioned above, the final IRR was already above the required IRR.

Step 6: Implementing Accepted Proposals

**General**
Amvest follows a structured method and approach from the moment of purchase. Once the project begins construction, there is a clear division of roles and collaboration between the technical manager, the asset manager, and the supervisor. These individuals serve as counterparties for the contractor and participate in construction meetings to monitor the construction process. As the completion date approaches, roughly six months in advance, the leasing process begins, involving the initiation of marketing initiatives and engaging relevant parties, including the property manager, to ensure a smooth handover.

**Jonas**
At Jonas, Amvest followed its usual process, similar to their general approach, where they applied their structured method and approach.

Step 7: Auditing operating performance

**General**
At Amvest, there is a strong focus on post-delivery project monitoring. Their financial control department and real estate analysts oversee the buildings to verify if they meet the expectations outlined in the investment proposal. This primarily concerns aspects such as rental prices. Continuous monitoring is conducted on factors like vacancy rates and realized rental prices. This monitoring also serves as a benchmark for future projects, especially in areas where multiple buildings are delivered. They assess the demand for different types of housing, and this knowledge is incorporated into upcoming projects. Furthermore, feedback on the Program of Requirements (PvE) is collected and adjusted based on both internal and external input.

**Jonas**
With regard to Project Jonas, given that the project has been recently completed, there has not yet been a comprehensive audit of its operational performance. However, it has been confirmed that someone will be appointed to monitor the project's performance as it becomes relevant.

# Appendix VIII - Additional explanation Timberhouse

## Investment decision-making process

Step 1: Setting a Strategy

**General**

At Coltavast, 'Step 1: Setting a Strategy' seems to be a flexible affair. They adopt an opportunistic approach to investments, identifying opportunities rather than actively following a predefined strategy. However, their investments are currently limited to Utrecht and Amsterdam, excluding old canal buildings. Recently, they have started considering whether their projects align with the requirements of pension funds for future sales. Additionally, investments are not pursued if the required equity contribution is too high and there is too much uncertainty. In conclusion, achieving financial returns is Coltavast's top priority.

**Timberhouse**

For Project Timberhouse, Coltavast’s general approach remained unchanged. However, financial return was somewhat deprioritized in this project, with the goal of purchasing a building to enhance visibility and green their portfolio. This would demonstrate to banks their commitment to sustainability, potentially leading to more favorable green loans.

Step 2: Establishing Return/Risk Objectives

**General**

Each project aims for a minimum internal rate of return (IRR) on its invested capital. The rationale behind this required IRR is not entirely clear, but there is a strong belief that investing elsewhere is preferable if this return is not met. They target a gross initial yield (GIY) that is slightly higher than the market standard, including a minimum profit upon potential exit.

**Timberhouse**

The IRR and GIY targets were initially set lower at the beginning of the project, reflecting the desire to include a sustainable project in their portfolio to showcase their investment in sustainability to banks.

Step 3: Forecasting and Evaluating Expected Costs and Returns

**General**

At Coltavast, forecasting and evaluating expected costs and returns are done through a combination of foundation costs and an annual cash flow calculation. The foundation costs consist of construction and land costs. Then a similar DCF calculation is made based on one year, including income from two sources: rental income (net cash flow) and the sale of the project at t=2. Annual rent is calculated based on the number of apartments or Gross Floor Area (GFA). The project’s terminal value can be calculated in two ways: empty value at market comfort or predetermined GEY. From these revenues, operational costs (a percentage of annual rent) and interest costs, which depend on construction time and loan repayment, are deducted, resulting in an annual cash flow. The vacancy rate is not included in the calculation as experience shows that when a tenant leaves, the property is usually re-rented within 2 or 3 days, thus avoiding vacancies.

**Timberhouse**

Same as General

### Step 4: Assessing Investment Risk

**General**

Coltavast conducts risk assessments with a flexible, oral approach, without a standardized risk list. Risks are intuitively assessed on a project-dependent basis, with the company owners deciding whether to proceed or not. This decision heavily relies on their personal sense of feasibility and the project's location.

**Timberhouse**

For Project Timberhouse, no significant difference in risk assessment was applied compared to other projects, despite the focus on sustainability and the use of wood. However, the risk assessment did reveal that building with wood posed a risk due to its novelty for them and the uncertainty of its long-term effects. Nevertheless, the investment risks were considered low because the property could always be used by the family, indicating an inherent value. Assessed risks were based on fixed figures like the cost of leasehold land and the number of mandatory parking spaces, determined by a tender from the alliance.

### Step 5: Making a Risk-Adjusted Evaluation of the Forecast Costs and Returns

**General**

After identifying risks, certain elements within the calculation can be adjusted. If a project seems financially viable but is characterized by higher risks, the decision depends on the family's willingness to take these risks.

**Timberhouse**

In evaluating Timberhouse, Coltavast saw building in wood as a risk. Due to unfamiliarity with the maintenance of a wooden building, the maintenance cost percentage was slightly increased from 10% to 15%. This was a higher estimation to cover the risk associated with the wood.

### Step 6: Implementing Accepted Proposals

**General**

Coltavast approaches the implementation of accepted proposals with a thoughtful strategy. They hire construction supervisors for each project to oversee the process. Coltavast itself manages budget monitoring, remaining actively involved throughout the entire development, from life appointment to the Definitive Design (DO). Collaboration with a fixed construction company and cost calculation bureaus is a standard part of their method. These parties are crucial for maintaining budget control, especially in the DO phase where changes in materials can still have an impact based on market insights and price fluctuations.

**Timberhouse**

For Project Timberhouse, it was found that Coltavast used a fixed contract sum and that the implementation of the project was standard, similar to other projects. The project was small-scale for Coltavast and considered an interesting location and a good initiative. It was more seen as a learning process and possibly an opportunity to gain experience in small-scale and potentially sustainable projects. The process of accepting proposals and their execution followed the usual trajectory, where embodied carbon did not bring about changes in Coltavast’s approach.

Step 7: Auditing Operating Performance

**General**

The performance of the building is monitored annually after completion, looking at rental income and maintenance costs. Additionally, the building is appraised annually to determine its value.

**Timberhouse**

The value has increased more than assumed, due more to the market and the growing popularity of the location.

# Appendix IX - Additional explanation SAWA

## Investment decision-making process

Step 1: Setting a strategy

**General**

There is no specific strategy employed within Focus on Impact. However, it must fulfill one of the following points: it must serve the development branch, offer a return better than the market, or be a truly exceptional project.

**SAWA**

Same as general.

Step 2: Establishing Return/Risk Objectives

**General**

There is no standard IRR or GIY that must always be achieved; the IRR or GIY is based on the market at that time and is also always examined on a product-specific basis. However, the return is determined based on the type of product they are creating and it must be higher than the market.

**SAWA**

The targets were set lower in advance.

Step 3: Forecasting and Evaluating Expected Costs and Returns

**General**

Within Focus on Impact, a DCF model is used. The holding period can vary from 10 to 15 years. This is all determined on a project-specific basis and is often dependent on the potential scenario of selling rental apartments as imposed by the municipality. The terminal value is calculated based on both cash flow in year t+1 and the vacancy value.

**SAWA**

At SAWA, the standard method was used for forecasting and evaluating expected costs and returns. A holding period of 10 years was used. Regarding the cash flow, the following was concluded: the rent is capped at a mid-rent of 1050. Additionally, the vacancy rate within the project is 0% because it is mid-rent, so they know it is always full. However, the final IRR was significantly lower than their standard requirements compared to a traditional project and therefore lower than the market, mainly due to the higher initial costs and the rent cap.

Step 4: Assessing Investment Risk

**General**

This is done for each project and is carried out qualitatively. They do this themselves, but sometimes external parties are hired to research certain risks. The aspects considered include rent, location, technology, quality, materialization, sound, fire safety, and environment.

**SAWA**

At SAWA, various risks were analyzed. However, there were four major risks, three of which were related to the choice of wood as a material. The risks were: the building's fire safety, the availability of wood at that time, the maintenance of the wood, and whether they would receive green financing in time. Without the green financing, the project could not proceed.

Step 5: Making a Risk-Adjusted Evaluation of the Forecast Costs and Returns

**General**

Yes, they do this when necessary.

**SAWA**

Within SAWA, of the four risks, only the risk regarding maintenance directly influenced the cash flow, with the maintenance percentage slightly increased. However, they did a number of things that did not directly affect the cash flow. The developer is the asset management of the building for the first 5 years, meaning the investor is not responsible for the maintenance for the first 5 years. Additionally, regarding fire safety, they required that sprinklers be installed in the building, although these are naturally costs for the developer.

Step 6: Implementing Accepted Proposals

**General**

Yes, there is a standard method that is followed, with people within the company having different roles and responsibilities. In addition, this is done for each project based on a pre-calculation and then a post-calculation.

**SAWA**

The same method as general, but they were more involved in the project.

Step 7: Auditing Operating Performance

**General**

After each project is completed, the project's progress and whether the assumptions made are correct are examined based on the pre-calculation and the post-calculation. Then, based on semi-annual reports and annual accounts, it is checked whether the assumptions are correct.

**SAWA**

Not applicable yet.