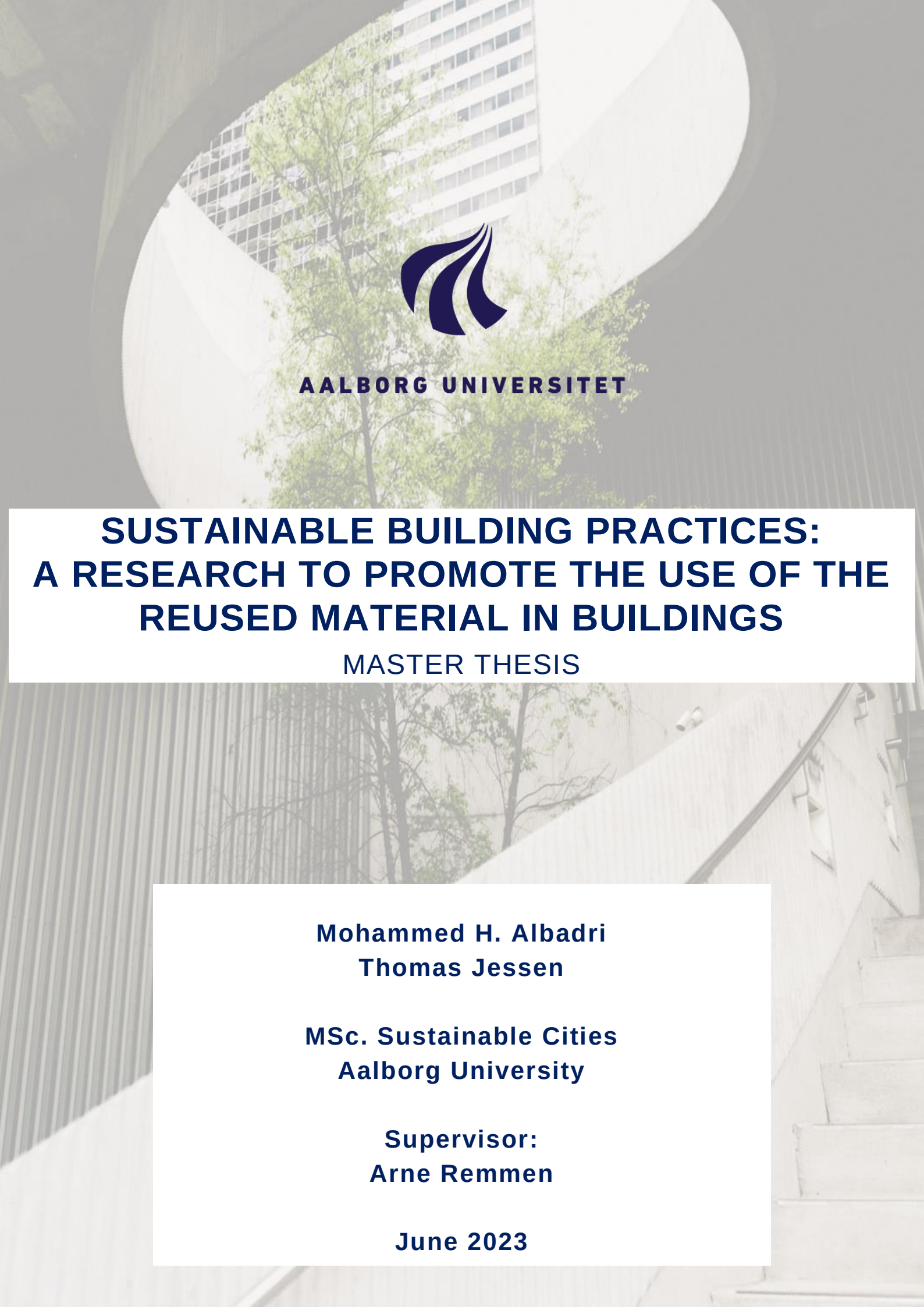

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SUSTAINABLE BUILDING PRACTICES: A RESEARCH TO PROMOTE THE USE OF THE REUSED MATERIAL IN BUILDINGS

MASTER THESIS

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By signing this document, each group member confirms that everyone has participated equally in the project work and is therefore collectively responsible for the content of the thesis.

SYNOPSIS

This thesis is based on a collaboration with Fælledby and the development of a new urban area. The focus is on the current sustainable transition with a focus on reducing the climate impact of construction.
Fælledby works with a number of sustainable initiatives in their project, including a holistic approach to sustainability that touches on social, environmental and economic aspects. Based on a thorough analysis and dialog with Fælledby, it has been assessed that there have been challenges regarding the implementation of reused materials in the buildings. Thus, the project has worked with the following problem formulation;

What are the major obstacles faced by the building sector in adopting reused materials on a large scale, and what measures can be taken to overcome these barriers and promote the transition towards a sustainable building sector?

To answer the problem statement, three research questions will be investigated, which aim to shed light on what Fælledby specifically focuses on in terms of sustainable initiatives, then create an understanding of why it has been a challenge to implement reused materials in construction, and finally investigate how these barriers can be broken down and promote reused materials in construction.

Based on the analysis, this thesis provides recommendations for what future building projects should be aware of when implementing reused materials.

To strengthen this thesis, various actors from the building sector have been involved and contributed with knowledge and experience.

Resumé

Denne afhandling tager udgangspunkt i byudviklingsprojektet, Fælledby, som er et byområde under udvikling. Byområdet kommer til at huse 2000 boliger. Fælledby er et helt unikt projekt, da deres fokus har et bredt bæredygtighedsperspektiv. Afhandlingen tager afsæt i hvordan en ambitiøs bygherre arbejder med bæredygtighed i praksis. Der ønskes at undersøge om hvorvidt de ambitiøse, bæredygtige tiltag kan blive implementeret. Ved at kortlægge dette, kan der sættes fokus på de områder som stadig findes svært at realisere.

Det konkluderes i projektet at det er fundet svært at indarbejde genbrugte byggematerialer i Fælledby projektet, selvom der var stor villighed fra både bygherren og aktørerne, som vandt rettighederne til at bygge boligerne. Derfor er fokusområdet for opgaven at kigge ind i hvordan processen til at indarbejde genbrugte byggematerialer var i Fælledby, og dernæst hvordan genbrugte byggematerialer kunne fremmes i projektet.

Flere barrierer gør det udfordrende at integrere genbrugsmaterialer i byggeprojekter. Dog vil genbrugsmaterialer blive en uundgåelig del af fremtidens byggesektor, i takt med den stigende fokus, og de skærpede krav, som underlægges sektoren. Med den nye justering af bygningsreglementet (BR18) fra 2023 er det blevet klart, at genbrugsmaterialer kan bidrage til at leve op til kravene som er beskrevet heri.

Denne afhandling fokuserer på hvordan aktørernes samarbejde kan have indflydelse på at muliggøre brugen af genbrugte byggematerialer. Her fokuseres der både på aktører involveret i byggeprojektet, men udbredes også til at fokusere på aktører der med fordel kan inkluderes.

Afhandlingen tager afsæt metoderne casestudie og kvalitative interviews til at undersøge problemområderne. Det teoretiske afsæt er bundet op på Pragmatisme, Aktør-Netværks Teori og bruger overordnet Cirkulær Økonomi som forståelsesramme.

Resultatet er at der er behov for mere åbne og fleksible samarbejder ved udvikling af byggeprojekter. På baggrund af det er følgende anbefalinger lavet:

- Sikre en forventningsafstemning i henhold til projektplanerne og udbudet

- Undersøg flere muligheder for at fremskaffe genbrugsmaterialer, enten fra byggemasse på byggegrunden, fra nærtliggende nedrivningsprojekter eller fra materialeudbydere som f.eks. materialebanker.
- Sørg for at indgå i en transparant proces ved at være åben over for innovative idéer og nye perspektiver. Dette kan gøres ved at invitere en mere bred aktørgruppe og ved at lave idégenerering fra start.

Denne afhandling tager udgangspunkt i aktører fra individuelle byggeprojekter og deres mulighed for at påvirke det enkelte projekt. Dertil skal det også medtages at andre elementer vil kunne have kraftig påvirkning på at muliggøre et større incitament for brugen af genbrugte byggematerialer. I diskussionen bliver emner såsom lovgivning, deling af viden og erfaringer, og økonomiske incitamenter bliver behandlet, da disse også har en vigtig del i udbredelsen af genbrug i sektoren.

Udviklingen af byggebranchen skal bæres af visionære aktører. Der er behov for at tænke sammen og at tænke innovativt, og kun derved kan den nødvendige omstilling af sektoren skabes.

Abstract

This thesis has studied the case of Fælledby, the development of an urban area. Fælledby aims to become a more sustainable urban area, and the initiatives to ensure this was investigated. It was concluded that the only sustainable aspect with a narrow focus was within the circularity of materials.

This thesis has therefore investigated how reused materials can become a more significant part of the building sector. Multiple barriers make it challenging to integrate reused materials, but reused materials will inevitably become a more significant part of the future building sector. With the new adjustment of the building regulation (BR18) of 2023, it has become clear that reused materials can benefit future building projects to reach the requirements and make competitive buildings. This is further strengthened by the addition of BR18, expected to be introduced in 2024, which ensures that the reused material's climate footprint will be calculated as 0 kg CO_2-equivalent/m^2/year from an LCA perspective.

Action can already be taken to integrate reused materials in building projects. Under the direct influence of non-human actors like the building regulation, standards, and the influence of the master plans and tenders, there are still options and possibilities that can cause reused materials to be integrated today. This thesis maps three recommendations that should be included in the early stage of a building project. These will take point in that the solutions that can enhance the number of circular solutions to be integrated into the project. The three recommendations are to:

1. Align expectations in relation to project plans and tenders
2. Source for possibilities of obtaining reused materials, either on the project ground, nearby demolitions, or by material providers such as material banks
3. Be open to innovative ideas and new perspectives by doing idea generations

By enduring an open process and having an open mind to changes, the actors of the building sector will have a better opportunity to be prepared for the already planned requirements within the building regulations.

Preface

This thesis is the final project from the Master's Sustainable Cities at Aalborg University, Copenhagen. It has been made in the project period from the 1st of February, 2023, to the 2nd of June, 2023. The case of the thesis has been planning of the urban area, Fælledby. The project's objective has been to develop a framework making the integration of reused materials more accessible for the actors within the building sector.

We would like to express our gratitude to *Arne Remmen*, our supervisor, who deserves special recognition. Remmen has been a significant source of inspiration throughout the entire project.

Furthermore, we would like to thank *Stig Hirsbak* for his inspiration during the project. We would also like to thank *Martin Baltser*, director of project development in Fælledby, for the good collaboration throughout the project. This has provided us with the necessary insight into the case to conduct our thesis.

The project was made with contribution by the following:

- **Erling Thygesen** Director of Fælledby
- **Rune Guldager Thomsen** project manager at Tscherning
- **Rasmus Overgaard Bertelsen**, project planning manager at ABC Rådgivende Ingeniører
- **Lone Hedegaard Mortensen**, head of Sustainability at ABC Rådgivende Ingeniører
- **Niels Jakubiak Andersen** owner and managing director of NÆSTE
- **Jørgen Dalgas Hedeager** Founder of JDH-BYG
- **Linda Sønderskov** chief consultant at NÆRHEDEN P/S
- **Henrik Dam Nielsen** head of consulting at GreenDozer
- **Knud Erik Hansen** member of Amager Fælledes Venner

We hope that this thesis will contribute to the building sector's transition to become a more sustainable part of society.

Contents

1 Introduction

Sustainability is a topic that has gained international attention and has become a debated topic in the building sector. With growing awareness of the world's environmental challenges, as well as national environmental challenges, and the need to preserve the planet's resources, it is crucial to find innovative solutions that reduce the negative impact of building on the planet. In this context, incorporating reused materials is crucial in creating sustainable buildings.

In recent decades, the building sector has become one of the largest consumers of resources and producers of waste. Traditionally, buildings have relied on new materials that require large amounts of energy and resources for production and transport. This has led to environmental issues such as greenhouse gas emissions, destruction of natural resources, and waste accumulation.

This requires a transition towards more inclusion of circularity and sustainability in the building sector. Reused materials are essential in this transition, as they can solve environmental challenges and the lack of virgin resources. By utilizing these materials, we reduce the need for new resources, decrease waste and minimize the negative impact on the environment.

The integration of reused materials in buildings offers a wide range of benefits. First and foremost, it reduces waste and saves resources. By reusing materials, landfill or energy-intensive decomposition is reduced. This helps reduce CO_2 emissions and the environmental impact of traditional building materials.

This introduction outlines the importance of sustainable building and the integration of reused materials as an essential factor in this context. With their environmental, economic, and cultural benefits, reused materials represent a key component in creating more sustainable and circular building practices. It is crucial to take the following steps to raise awareness, promote research and innovation, and create the necessary political and economic framework to promote the use of reused materials in buildings.

Problem analysis 2

2.1 The need for a green transition

In March 2023, the latest IPCC report was released. This summary of the sixth assessment report provides information on climate change, its risks, and impacts. It furthermore discusses strategies for mitigating and adapting to minimize the impact.

Climate change has a direct impact on human beings. Approximately 3.3 billion to 3.6 billion people are estimated to live in places with high vulnerability to climatic hazards, such as floods, droughts, and storms. In comparison, regions that have low vulnerability had 15 times lesser change of human mortality from floods, droughts, and storms between 2010 and 2020 [IPCC, 2022]. A large impact on our world will happen if the temperature exceeds 1.5 degrees Celsius, and an even bigger impact will occur if exceeding 2 degrees Celsius. However, it is estimated that the first breaking point of 1.5 degrees Celsius will already be exceeded by the planned and existing fossil fuel infrastructure, meaning that it is certain with high confidence that the threat to the planet will go into a new phase. [IPCC, 2022]

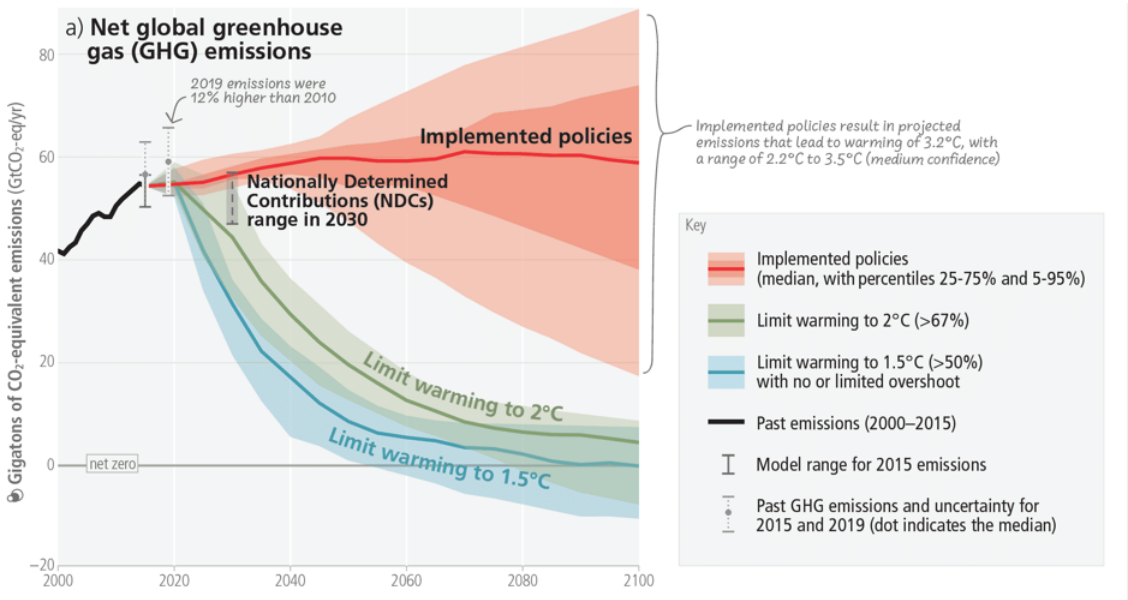

Figure 2.1. Impact of the building sector regarding the rise in temperature. [IPCC, 2022]

What is shown in Figure 2.1 is to ensure the temperature stays beneath 1.5 and 2 degrees Celsius, a heavy drop in GHG emissions must be implemented immediately. IPCC [2022]

As an answer to the climate issues, Denmark has adopted The Climate Act, stating that Denmark's climate emissions are required by law to be reduced by 70% compared to the 1990 level. It is further stated that Denmark will be climate neutral no later than 2050. [Klima-, Energi- og Forsyningsministeriet, 2021]

The building sector is an indispensable part of the Danish infrastructure. However, the sector contributes to a large part of the negative impact on the climate. In Denmark, the building sector is responsible for:

- Approximately 40% of the energy consumption in the use phase corresponds to 20% of Denmark's total CO_2 consumption.
- Approximately 35% of Denmark's waste generation.
- Approximately 10% of Denmark's CO_2 consumption is generated from the building's production phase.

[Regeringens Klimapartnerskaber, 2021]

The following section will investigate the building sector and what initiatives can contribute to making the sector less harmful.

2.2 The building sector and its need for a sustainable transition

Severe changes must happen to reduce the impact of climate change. Reduction Roadmap is one of the initiatives addressing how the building sector needs to adapt to reduce the impact of climate change. [Effekt et al., 2022]

The Reduction Roadmap is developed by a cross-sector partnership that includes advisors, research institutes, architects, and NGO's. It is linked with the Planetary Boundaries, working on getting the building sector operating within a safe operating space. To do this, the global emissions from the building sector need to be reduced by 96%. In a Danish context, the measurements that need to be taken can be translated to go from today's level of emissions of 480 kg CO_2-eq/m^2 to 20 kg CO_2-eq/m^2 to stay within the safe operating space. [Effekt et al., 2022]

Reduction Roadmap addresses several action points that must be focused on to ensure the needed transition. The initiatives described by Reduction Roadmap is following:

- Reduce the number of square meters in the buildings by setting annual limits on how much that can be built per year.
- A change within social sustainability to accept to live on a reduced amount of square meters per person.
- Re-use of building materials, building elements, and buildings. It is furthermore necessary to be aware of using materials with low carbon footprint when newly produced materials are the only solution.
- Implement life-cycle thinking as a starting point when producing materials.
- Use renewable energy for ventilation, heating, and cooling.
- Collaborate across the sector and create partnerships to innovate new solutions to reduce the CO_2-impact.

[Effekt et al., 2022]

The following sections describe how the Danish building sector uses the circular economy.

2.3 Circular economy in the Danish building sector

Gaining profit from a product or a service is the dominant factor in the building sector which can be created by reducing the time used for the building process and minimizing

risks. This does not align with a circular economy in the building sector because the solutions to include often will be less tested and riskier than building in business-as-usual. [Realdania, 2023]

It will be of great importance to focus more on using the resources already extracted in the future. As mentioned in the previous section, it can benefit from a CO_2 perspective. Another essential argument for focusing on a more circular building sector is nonrenewable virgin materials, like gravel. The quantities in the Danish regions are estimated to contain raw materials to supply the sector for 14-43 years in the areas pointed out for extraction [Smith et al., 2020]. However, the shortage of raw materials is already a problem today. It is, for instance, experienced that there can be a shortage of raw materials used for concrete that must be of a certain quality. [Smith et al., 2020]

There are, however, barriers to the use of reused materials in Denmark. Danish Technological Institute has mapped current issues influencing the reused materials market from ten business case studies. In most cases, it was experienced that the prices for using reused or recycled materials were more expensive. It was furthermore hard to source materials that had the necessary documented quality. Furthermore, the developer has a major role in integrating reused materials in a building project, and it was seen that this could be a barrier, too, because it was seen in the cases that some developers were not interested in giving more for the materials. The most interest regarding reused materials was found if the materials had a good history, aesthetics, and were made of good craftsmanship. However, although barriers still significantly influence the use of reused materials, well-tested practices of using more reused materials already exist. The following section will three roads to secure more circularity in the building sector. [Sørensen et al., 2019]

2.3.1 Three roads to secure more circularity in the sector

The Knowledge Institution of Circular Economy in Denmark (VCØB) has mapped three pathways to enhance the circular economy in the building sector in Denmark. It is pathways that already is well-tested and can be implemented in building projects in current building projects. These three pathways are selective demolitions, reuse, and recycling. [VCØB, 2022]

Selective Demolitions of existing building mass is crucial for the circular economy to

become a more significant sector. Selective demolition is when demolition is made to recirculate as many of the materials as possible. The current regulation that includes requirements for selective demolitions, BEK nr. 282 by 18/04/1997, is only required for governmental demolition projects. It aims for the selectivly demolished materials to be used as efficiently as possible. [VCØB, 2022]

However, a new regulation will be introduced in 2023 from the political agreement from 2020 called 'Climate plan for a green waste sector and circular economy'. This will introduce standardized plans for selective demolitions and describe requirements ensuring valuable materials are reused and recycled before being used for degrading purposes like road filling [Realdania, 2021a]. An important aspect when conducting selective demolitions is that a thorough mapping of toxic materials is done, and environmental remediation is conducted if necessary. This should happen before the demolition to ensure that good-quality materials can be used as close to the original purpose as possible. [VCØB, 2022]

The other two pathways consist of **Reuse** and **Recycle**. Reused materials are defined as using previously used building materials in new buildings or renovations. A well-tested example of this in Denmark is by reusing bricks. Recycling is defined as when these materials are used for a new product. This is often seen in concrete, where crushed concrete is blended into the new concrete. [VCØB, 2022]

The next section will introduce how legislation is in relation to the building sector and what strategy it has decided to follow.

2.4 Regulation, standards, and certifications of for the building sector

Reused materials must meet the requirements of the building regulation, which are the exact requirements for new materials. Besides regulation, other types of measures to ensure the necessary quality exist too. The following section will look into regulations and standards as requirements and means to ensure the necessary quality of circular materials. [Gustafsson et al., 2021]

Standards: Both international, European, and national standards have an influence on the Danish building sector. Some of these have been directly described in regulation, and others are voluntary. Denmark is part of the ISO system, an international standardization

program that creates building sector standards. In a European context, several different standard systems exist that focus on different aspects. Because it is in a European context and Denmark is a member of the EU, as well as some of the specific standardizations such as CEN and CENELEC, the standardization made within these organizations must be integrated within the national regulation. Among the European standards is the Construction Product Regulation (CPR). This describes the requirements for building products as the following:

- Mechanical resistance and stability
- Fire protection
- Hygiene, health and environment
- Safety and access when using the product use
- Protection against noise
- Energy savings and thermal insulation
- Sustainable utilization of natural resources

[Gustafsson et al., 2021]

Approximately 20% of the building materials are not included in the CPR. If a building material is not included in the standards of the CPR, they have to live up to national regulations. [Trafik- og Byggestyrelsen, 2021]

Building Regulation (BR18) is the Danish regulation concerning the building sector. It specifies by law what requirements must be complied with in a building project. The BR18 includes specific requirements for the building of the building, technical requirements for the materials and products, and requirements for the building process. In 2023, the Building Regulation introduced a new set of requirements to limit emissions from building projects [Andersen, 2022]. These requirements will tighten until 2031, as seen in 2.2. The new requirements include that buildings bigger than 1000 m^2, must not exceed the limit of 12 kg CO_2-equivalent/m^2/year. In 2025 these will include all types of buildings. Besides the requirements, a voluntary set of requirements have been introduced, introducing more ambitious requirements of 8 kg CO_2-equivalent/m^2/year.

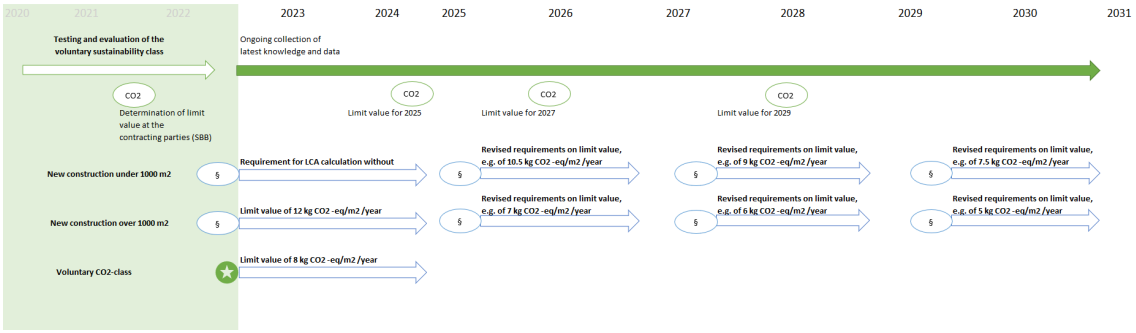

Figure 2.2. Sustainable building strategy in BR18. [Indenrigs og Boligministeriet, 2021]

The method used to calculate the emissions for the BR18 is based on Life Cycle Assessments (LCA). LCA has become a requirement for all building projects in the update of BR18 [Indenrigs og Boligministeriet, 2021]. The LCA documents the climate impact of a building over a period of 50 years. It includes the phases seen on figure 2.3, except A4 and A5 [Den frivillige bæredygtighedsklasse, U.D]:

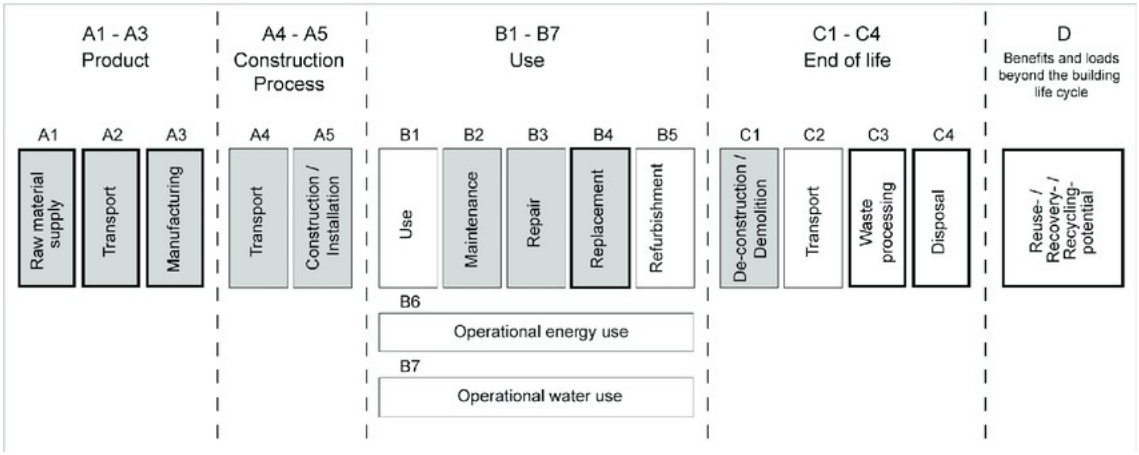

Figure 2.3. The phases of a LCA. [Schneider-Marin, 2020]

What has been found problematic with the new adjustments of BR18 and the requirements of the LCA was that calculations do not include any benefits regarding the emissions of using reused materials compared to new materials. To create a bigger incentive to use reused materials, a new adjustment of the BR18 is in a national hearing. This will reward the use of reused materials by setting their climate impact to 0 kg CO_2 in the LCA calculation. [Trafik- og Byggestyrelsen, 2023]

Certifications in the Danish building sector: A certification is a voluntary system that can be applied to a building to show that it fulfills the requirements described in the specific certification system. A third party validates a certification. Certifications are

systems with higher ambitions than required in the regulation. The difference between the certification systems is their focus. The certification system of DGNB for buildings focuses on environmental quality, economic quality, social quality, technical quality, and process quality, whereas the certification of Svanemærket focus on energy consumption, indoor climate, the content of substances harmful to health and the environment in building materials and chemical products, sustainably certified wood, and the building process. [Gustafsson et al., 2021]

The following section will introduce the case of this thesis.

2.5 Introduction to Fælledby

Fælledby is the name of a new urban area in the southern part of Copenhagen. The project consists of 21 buildings that will create 2000 housing units, where 500 will be social housing. The area will also include community houses, a school, two daycare centers, housing units for the elderly, a healthcare center, and several stores. [Fælledby, 2023]

Fælledby P/S owns the area and is the developer of the urban area and the developer of the private housing units in Fælledby, which accounts for 16 of the 21 buildings. Fælledby P/S is owned by *By & Havn* and *PensionDanmark*. [Fælledby, U.D]

Fælledby is placed in a biodiverse area in Copenhagen called Amager Fælled. The area accounts for 8% of Amager Fælled. Because it is a part of Amager Fælled, there is a major focus on nature. The plans include that one-third of the area will be established as wild nature with a high value of nature and to ensure biodiversity for species. Fælledby furthermore has the desire to obtain DGNB certifications. This is both for the buildings and the whole area. The ambition for the buildings is that they at least will receive a DGNB gold certification, while the aim is to achieve DGNB Platinum for the urban area. [Fælledby, U.D]

Figure 2.4. The location of Fælledby. [Fælledby, U.D]

Besides focusing on biodiversity, Fælledby also focuses on building sustainable buildings. They aim to use wood for the bearing constructions and for some of the facades [Fælledby, 2023]. Fælledby also looks positively at initiatives regarding reused materials. The tender for the masterplan furthermore describes that Fælledby looks positively at circular economy in the project. They are, for example, looking positively at the use of materials from the demolition of the hostel on the construction ground. Another aspect is that they would like to include buildings, demonstrating the possibility of using upcycled materials. [Fælledby, 2019] Projections of how this could be done are made by the architect Lokal, who made a design proposal for community houses, and they can be seen on2.5. [Appendix 9]

Figure 2.5. Proposals for the design of community houses. One is designed with biobased materials as facades, and one is designed using reused materials [Appendix 9]

Problem formulation 3

3.1 Problem formulation

Based on the previous problem analysis, the thesis investigates how a sustainable planning process for incorporating reused materials can be promoted in buildings. This is done by formulating the following problem formulation:

What are the major obstacles faced by the building sector in adopting reused materials on a large scale, and what measures can be taken to overcome these barriers and promote the transition towards a sustainable building sector?

Research questions:

- Which specific factors and considerations influenced Fælledby's design strategy for their sustainable urban area, effectively contributing to reaching their visions regarding sustainability?
- What strategies and critical factors need to be considered when incorporating reused materials into building practices to enhance resource efficiency in the building sector?
- How can specific measures and mechanisms be implemented to establish a transparent process for the utilization of reused materials, ensuring transformable sustainable development in the building sector?

3.2 Limitations

This thesis limits from adjusting the following elements:

- Renewable energy
- Building phase
- Regulation
- Certification

- Economy
- Change and impact of non-human actors

This thesis's scope will be on how to promote reused materials in buildings by influencing the actor network. Here the focus will be on how the different actors can interact with each other and how they can achieve dialogue and consensus around a common vision. This is done within the frame of the mentioned elements.

3.2.1 Focus on reused material

There are several reasons to incorporate and focus on reused materials in buildings. Denmark aims to reduce its climate impact and promote sustainable development. Using reused materials in buildings supports these goals by minimizing the need for new products and reducing greenhouse gas emissions.

There is, first of all, the aspect of sustainability in relation to the use of reused materials, which will reduce the need for extraction and production of new materials. By incorporating material reuse in building, natural resource extraction can be minimized, mitigating environmental burdens typically arising from extraction, transportation, and production processes involved in acquiring new materials.

The government launched the "*Køreplan for et grønt Danmark*", introducing the pathway to achieve a 70% reduction by 2030, involving the following areas: energy, industry, waste, and transport. These areas will all be affected by building and the use of new materials [Regeringen, 2021]. Therefore, this thesis has chosen to focus on the Circular Economy and reused materials to accommodate achieving the goals and visions set out.

3.2.2 Choice of actors

This thesis will focus on the actors involved in the Fælledby project, including the developer, investor, consulting engineer, and the demolition company. These actors will be described in more detail in Chapter 6, which will later be used in the analyses. The use of reused materials in buildings is evolving, the network of ambitious actors is constantly expanding, and new laws and regulations are constantly changing the discourse in line with the increasing focus on the green transition for buildings.

Research Design 4

The following chapter describes and visualizes the framework for this thesis. The thesis begins with a problem analysis that provides an overview of the problems created by the current paradigm for building and why a focus on reused materials is essential to develop a sufficient reduction of greenhouse gas emissions. It presents the need for transformation in the building sector and how the circular economy should contribute to this transformation. Furthermore, the problem analysis presents the regulatory aspects of the building sector. The final section concludes by introducing Fælledby as a case study.

This thesis explores how to promote reused materials in building through the following problem statement:

What are the major obstacles faced by the building sector in adopting reused materials on a large scale, and what measures can be taken to overcome these barriers and promote the transition towards a sustainable building sector?

The primary theoretical frameworks used throughout the thesis are pragmatism, circular economy, and actor-network theory, which will be presented in chapter 5. This chapter will also describe what and how these theories will be applied throughout the thesis. The methods used in this thesis are qualitative methods in the form of semi-structured interviews and case studies, and the methods for this thesis will be described in chapter 6. The purpose of the chosen methods has been data collection, which will be used to answer the problem formulation and research questions.

The thesis consists of three analyses:

- *A sustainable urban area* (Chapter 7).
- *Working towards a mindset for reusing* (Chapter 8).
- *Transparency and the translation process* (Chapter 9).

The first analysis will provide an understanding of how Fælledby defines sustainability, and

here the different incentives and measures to be implemented in Fælledby will be presented. For the first analysis, the first research question will be answered: *Which specific factors and considerations influenced Fælledby's design strategy for their sustainable urban area, effectively contributing to reaching their visions regarding sustainability?*

The second analysis will work with reused materials, which are designed on the basis of the first analysis. In the first analysis, an account is given of what Fælledby has done regarding sustainable considerations and definitions. Still, it is expressed that it is limited how much reused materials have been included in Fælledby. Therefore, it is considered relevant to investigate what considerations can incorporate reused materials in Fælledby and what strategies exist in this field. Likewise, it has been chosen to investigate this analysis by: *What strategies and critical factors need to be considered when incorporating reused materials into building practices to enhance resource efficiency in the building sector?*

The third analysis will examine how to strengthen actor collaboration to promote the use of reused materials in building. A roadmap will be presented to clarify the dialogue between actors and how they can achieve constructive cooperation. This analysis will address the following research questions: *How can specific measures and mechanisms be implemented to establish a transparent process for the utilization of reused materials, ensuring transformable sustainable development in the building sector?*

After analysis three, the thesis will present recommendations for how actors can promote the use of reused materials in building in the future, which are designed based on the knowledge found in analysis three.

SUSTAINABLE BUILDING PRACTICES:
A RESEARCH TO PROMOTE THE USE OF THE REUSED MATERIAL IN BUILDINGS

Problem analysis

- The need for a green transition
- The construction sector and its need for a sustainable transition
- Circular economy in Danish construction sector
- Regulation, standards, and certifications of for the construction sector
- Introduction to Fælledby

Problem formulation

What are the major obstacles faced by the building sector in adopting reused materials on a large scale, and what measures can be taken to overcome these barriers and promote the transition towards a sustainable building sector?

Limitations

Which specific factors and considerations influenced Fælledby's design strategy for their sustainable urban area, effectively contributing to reaching their visions regarding sustainability?

What strategies and critical factors need to be considered when incorporating reused materials into building practices to enhance resource efficiency in the building sector?

How can specific measures and mechanisms be implemented to establish a transparent process for the utilization of reused materials, ensuring transformable sustainable development in the building sector?

First analysis:
A sustainable urban area

Second analysis:
Working towards a mindset for reusing

Third analysis:
Transparency and the translation process

Case study

Interview

Circular economy

Interview

Actor-network theory

Interview

Recommendations and actions

Discussion

Conclusion

Theoretical framework 5

This thesis presents a theoretical framework to analyze and understand how reused materials can become a more significant part of the building sector. The theoretical framework will provide a structured and systematic approach to investigate and explain the complexity of this issue.

This thesis will use *Pragmatism, Actor-Network Theory*, and *Circular Economy.* To understand how to enable more use of reused materials, it will be relevant to understand why this is necessary and how the building sector actors interact with each other.

5.1 Pragamatism

The chosen theoretical framework for this thesis is pragmatism. Pragmatism provides a valuable research approach that recognizes the inherent presence of contingency, responsibility, and the potential for failure when investigating ordinary experiences. Embracing a pragmatic approach means acknowledging the need to ground research in the real world rather than constructing artificial frameworks before grasping the true nature of reality. By adopting a pragmatic stance, researchers can strive to attain certainty through an engaged and practical exploration of the subject matter at hand. This approach emphasizes the importance of embracing real-world contexts and experiences as the foundation for meaningful and impactful research. [Boisvert, 1998]

The pragmatic approach adjusts the research of truth, meaning it is flexible to be influenced in new directions and create new results. [Boisvert, 1998]

This thesis has been researched with the understanding that truth has many grains, meaning that multiple aspects of the matter must be examined to understand and conclude the research questions fully. The truth that this thesis attempts to enlighten is the problem statement, which is open to be examined from several aspects, and the answer to it will only be one truth. This truth will be based on a methodological and theoretical foundation

with data to support the crucial claims.

Another understanding is within the role of a planner and generalist. This provides a function that many different positions need to be considered in the context of a case. Pragmatism emphasizes the importance of anchoring research and action to the needs and values of society. Regarding reused materials in building, pragmatism can help emphasize the environmental benefits of using reused materials. Focusing on sustainability and societal relevance can appeal to the actors within the building industry and create a broader awareness of the importance of promoting reused materials.

5.2 Actor-Network Theory

Reusing materials in a building involves complex relationships between different actors, such as developers, contractors, reuse suppliers, and the architect. Actor-Network Theory (ANT) provides an analytical framework to explore and understand these relationships and identify key actors and their influence on implementing reused materials. By mapping the actor network, it can identify the roles, conflicts, and collaboration opportunities that can promote the use of reused materials. [Dankert, 2012]

ANT also helps to identify the barriers and challenges that may affect the implementation of reused materials in buildings. These can be economic, technological, regulatory, or social factors that hinder the use of reused materials. By analyzing the actor network, it is possible to identify how different actors' interests, perceptions, and power relations can influence the implementation of reused materials. This can provide insights into opportunities to address barriers and incentivize the use of reused materials. [Dankert, 2012]

5.2.1 The definition of Actor-Network Theory

ANT is used in scientific and technological studies, labeled as a theory, but can also be defined as a research methodology that focuses on relationships and connections between human and non-human actors.

The relationship between human and non-human actors is built around four dimensions that govern the behavior of actors in a network:

- *Networks* are the institutional framework where nothing exists in force by itself.

Bruno Latour, is one of the founders of the theory that human actors can combine with non-human actors to ensure change. For example, building regulations can only have a strong impact if human actors ensure that the correct documentation is provided and that the rules are followed. A network consists of both human and non-human relationships between actors.

- *Perception* is about the actors' view of the network and the environment surrounding the actors. It highlights the actors' interests and how cooperation across the network can be achieved.
- *Values* address the actors' interests and motivations, which define the actors' motives for action.
- *Resources* define the actors' resources at their disposal, shedding light on how they will achieve their goals and interests. At the same time, resources will define where actors are constrained.

[Hermans, 2009]

Michel Callon, a prominent sociologist and theorist of ANT, points out that actors will try to influence each other in the translation process. The following section will look into how the actors influence each other from his perspective. [Callon, 1984]

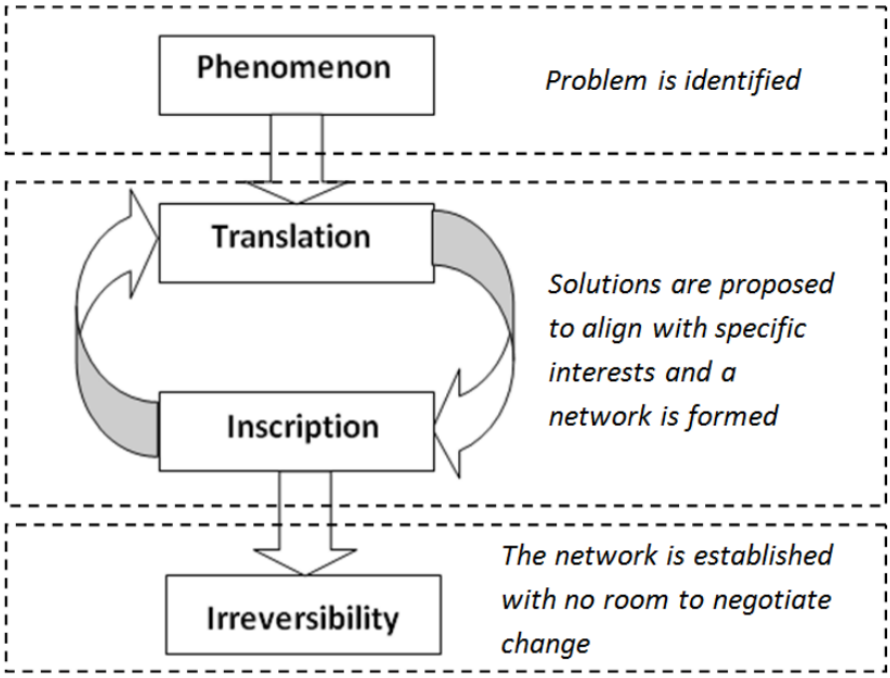

Figure 5.1. The phases of the Actor-Network Theory. [Carroll, 2014]

Translation process

In translation processes, actors want to stabilize and strengthen their visions and interests through other actors. Likewise, Callon defines four stages in a translation process:

1. *Problematization,* which involves identifying and problematizing the interests and intentions of the actors to find common passage points that the actors agree on.
2. *Interest building* is about actants obtaining new connections with other actants. This may be at the expense of actors' propensity to change their behavior and cooperate. Interest may change during the process.
3. *Enrolment* is where roles are defined and coordinated between the actants. Conflicts between actants may still arise, but aligning expectations as much as possible will be important to minimize conflicts.
4. *Mobilization* is about securing spokespersons who speak on behalf of the common project identified by the involved actors. The spokespersons must identify the network's common interests and represent all actors.

[Carroll, 2014]

Inscription

In this phase, the aim is to protect the actors' interests by using different tools, which could be done, for example, by creating rules. It is possible at this stage to articulate the actors' interests and visions and to create new links and networks. [Carroll, 2014]

Irreversibility

The final stage is irreversibility, which describes when no further changes can be made to the network. This means that actors have agreed on common interests and visions and that decisions or actions cannot be reversed or changed without costs or consequences. It is thus difficult to return to previous states or alternatives. [Carroll, 2014]

5.2.2 The use of Actor-Network Theory

In this thesis, ANT will identify the various actors involved in Fælledby to analyze their interrelationships, interests, and power dynamics to understand how they can influence and contribute to the promotion of reused materials. One can build networks and alliances that promote using reused materials in buildings by identifying potential collaborators. This

may involve forming new partnerships and relationships to develop sustainable solutions and create incentives for reusing materials.

5.3 Circular Economy

The circular economy is defined as an economic model that aims to optimize the use of resources by creating a closed-loop system in which products, components, and materials are preserved and reused for as long as possible. The circular economy can be part of the solution to the current climate challenges and help devise a better strategic use of resources. The opposite of circular economy is the traditional linear economy thinking, where new resources are extracted to make new products. In the linear economy, resources are seen as waste in their end-of-life phase, meaning they would either get deposited or incinerated no matter the quality of the product. The circular economy aims to minimize as far as possible the amount of extracted resources and materials used to produce new products. [Vind, 2019]

The Ellen MacArthur Foundation, a charitable organization that aims to promote the circular economy on a global scale, has developed a 'butterfly diagram' based on the idea that material flows can be divided into two interacting cycles: *the technical cycle* and *the biological cycle*. [ARUP, 2016]

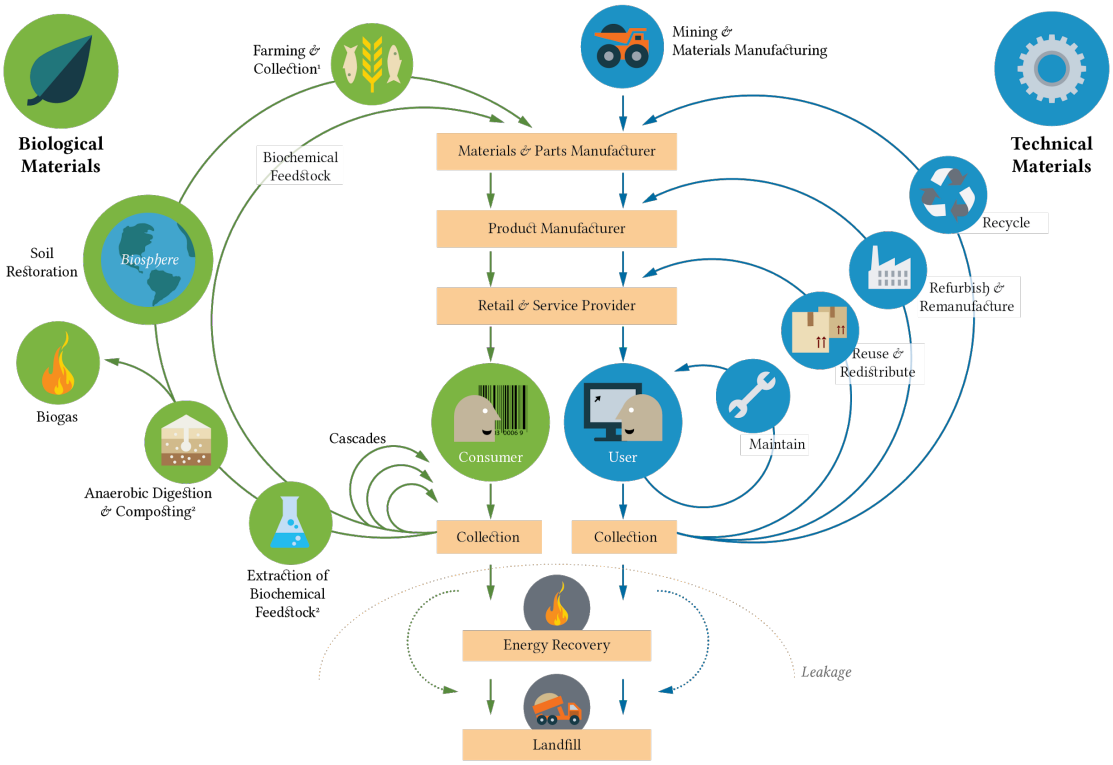

Figure 5.2. Ellen MacArthur Foundation 'Butterfly diagram'. [ARUP, 2016]

The biological cycle deals with the renewable and plant-based resources used to regenerate and return to the biosphere. The technical cycle deals with products that humans have created and designed. If repairing or reusing these products for their original purpose is impossible at the end of their lifetime, then other alternatives will be examined to either reuse or recycle the components. This reduces the creation of waste and therefore creates closed loops. [ARUP, 2016]

The following section will investigate the relevance of circular economy in the building sector.

5.3.1 Circular Economy in the building sector

Sustainability in buildings has evolved historically from relatively limited attention to a central factor in modern building practice. Traditionally, the building sector has used demolition materials, such as cement, bricks, and concrete, as road fillings as an example. However, as resources become scarce, companies are becoming more aware of the possibility of making better use of used materials. In this case, it would be more optimal if the old bricks were cleaned and reused in new buildings instead of producing new ones. [Vind, 2019].

From the perspective of the building sector, the diagram can be used as a tool to achieve more sustainability and incorporate circular strategies. The *"Butterfly diagram"* can be utilized in buildings across four phases:

- **The design phase** focuses on minimizing the waste generation of the building and the pollution that the building can cause. This can be done by choosing materials with low environmental impact and utilizing reused materials. In addition, this phase should also consider the dismantling and flexibility of the building.
- **The building phase** ensures that materials and components are used effectively in the building process. This can include reusing building materials and reducing waste through effective waste management on the building ground. Another example is by using fossil-free machinery for the project.
- **The operational phase** is about extending the life of the building and minimizing waste, which should be done through maintenance and repair of the building, which should contribute to extending the life of the building.
- **The end of building life** is the final phase, which is about separating and sorting the materials to be reused, thus keeping the building materials in the ecosystem.

[ARUP, 2016]

By implementing the Butterfly diagram in building, all phases of the building will be taken into account with a focus on circular incentives where resources are kept in the circular loop, waste is reduced, and environmental impact is being minimized. This will help to create more sustainable building. It is essential to work from the inner loop of the Butterfly diagram to achieve the highest potential for implementing circular economy principles in building.

The following section will examine the strategies to make a circular economy possible in a building project.

5.3.2 Conceptualizing circular strategies

This section will describe how the circular economy and its impact on resource effectiveness can be used practically. The principle of using resources circularly can be described through 9 R's as seen in figure 5.3:

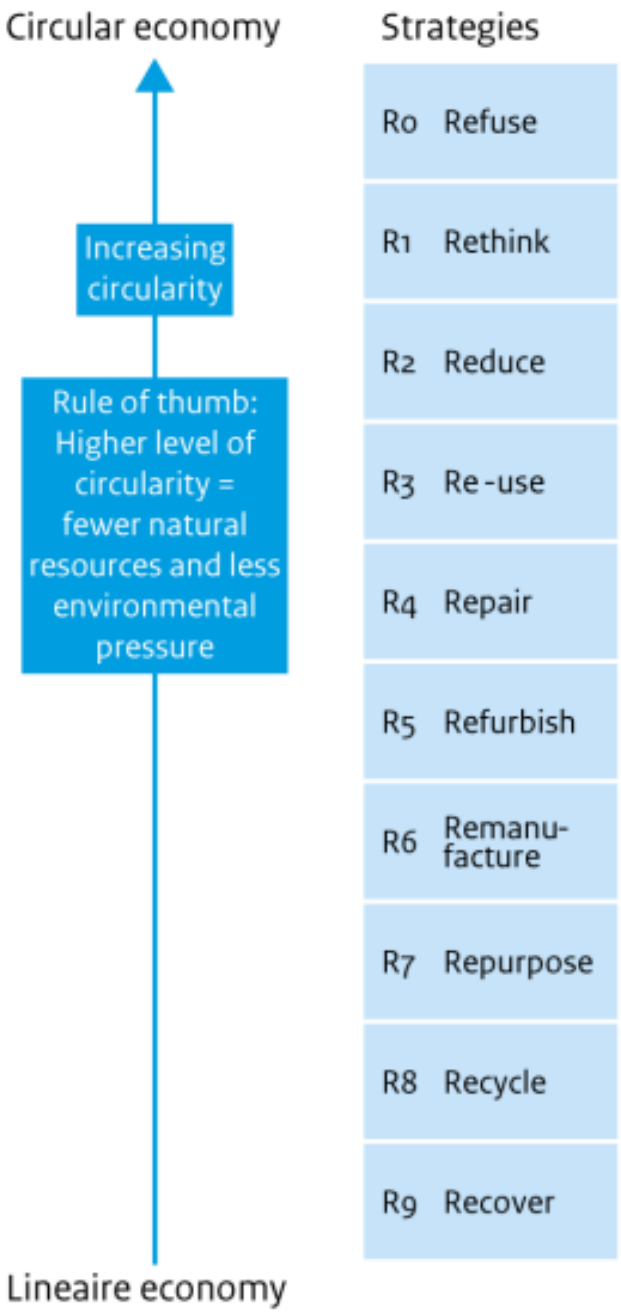

Figure 5.3. The processes of the two economic theories. [Kirchherr et al., 2017]

1. *R0 - Refuse: focusses on avoiding producing new products by offering the functions of the intended product in another way without using resources*
2. *R1 - Rethink: focus on using the products and resources more intensively by using the resources in products with more functions or by sharing*
3. *R2 - Reduce: focus on using less resources for products or increase the efficiency when manufacturing*
4. *R3 - Reuse: using a discarded product that still have the condition to be used in the*

original purpose

5. *R4 - Repair: ensures that measurements are taking to bring a product in such a quality that it can be reused for its original purpose*
6. *R5 - Refurbish: is when a product is restored and is renewed*
7. *R6 - Remanufacturing: is when discarded products are used in the production of new products with the same function*
8. *R7 - Repurpose: is when discarded products are used in the production of new products with another function*
9. *R8 - Recycle: describes the process where materials are used in the same high grade of function or a lower grade*
10. *R9 - Recover: is when materials are incinerated with the purpose of recovering energy*

[Kirchherr et al., 2017]

R0-R2 focuses on the production phase of products and materials, meaning it focuses on creating products that can be used more effectively from a resource perspective.

R3-R7 focuses on extending the life of products and their parts, impacting and reducing waste generation and resource extraction.

R8 and R9 describe when the resources get downgraded to become a part of a new product or to be incinerated for energy utilisation.

The R's is categorized, as seen in table 5.3, where R0 - Refuse is the most circular way to think of products and recover is the last option. [Hartini et al., 2021]

5.3.3 The use of Circular Economy

Overall, using the 9R model can help create more sustainable, efficient and economically advantageous building projects while addressing environmental and resource challenges.

The understanding of the different strategies to incorporate circular economy in the practices of building of a new urban area will be used to analyze the sustainable initiatives planned to be used in the building of Fælledby.

Methodology 6

In this section, the research methods will be presented and elaborated. This thesis uses case studies and data collection with qualitative methodology through semi-structured expert interviews. Next, this chapter aims to reflect on how the methods have been applied in the study.

6.1 Case study

This thesis is based on a case study of the project Fælledby at Amager Fælle. Methodologically, using case studies will take inspiration from Bent Flyvbjerg's article: *"Five misunderstandings about case studies"*.

A case study is a detailed study of one or more specific topics used to confirm or disprove a hypothesis or to generate knowledge about the exact topic. Working on a case study will provide contextual knowledge about the research topic, and case studies can help to develop a more nuanced view of reality. [Flyvbjerg, 2010]

6.1.1 The five misunderstandings about case study

According to Flyvbjerg, five misunderstandings about case studies have been identified, and these misunderstandings can have implications for research methods, results and conclusions. The misconceptions are as follows:

1. Misunderstanding: General and theoretical knowledge is more valuable than specific and practical knowledge.
2. Misunderstanding: A case study cannot generalize from one case, so case studies cannot contribute to scientific research.
3. Misunderstanding: A case study is best used to develop a hypothesis which means it is the first phase of a research project. At the same time, other methods are better for testing the hypothesis and for making theories.

4. Misunderstanding: The case study has a tendency to be biased compared to what results the researcher wants.
5. Misunderstanding: It is often difficult to conclude on a specific case study and develop general tendencies and theories based on it.

[Flyvbjerg, 2010]

The use of case studies will not necessarily be representative of the broader study of an area, which can lead to problematic generalistic results in relation to the context. However, by focusing on a single case, the researcher can gain a detailed understanding of the context, processes, and factors involved. In addition, case studies will gain contextual knowledge and understanding of complex real-world challenges. It will provide insight into the social, cultural, political, or economic factors influencing the problem field under investigation.

6.1.2 Choice of case

Fælledby generally wants to work ambitiously with a broad understanding of sustainability, considering social, economic, and environmental perspectives. This makes it interesting to study the case and examine what sustainable initiatives are planned to be implemented to see if some areas are overlooked.

Fælledby as a case study can be used to understand the process behind the realization of building projects in relation to project management and the cooperation between the actors, which can be addressed back to the *3. misunderstanding* that claims that a case study can be used to test a hypothesis. At the same time, several interviews have been conducted with relevant actors in Fælledby to ensure that the case study cannot be characterized as "biased," as described in the *4. misunderstanding*. These interviews will validate and verify the process in Fælledby. [Flyvbjerg, 2010]

There are two possible ways to select a case; *random selection* or *selection based on information*. By selecting a case randomly, it is ensured that the study is not biased as it is described in the 4. misunderstanding. However, there are different methods for collecting information in a case:

1. *Extreme/atypical case*: Provides information on unusual cases, which can be either specifically good or bad.
2. *Cases with maximum variation*: Provides information on how the selected cases differ from each other, with the selection of specific dimensions to compare them with.

3. *Critical cases*: This type of case study makes it possible to allow assumptions and generalize from the study results. On a practical level, it means that a result of an analysis can be applied to all similar cases.
4. *Paradigmatic cases*: When working with a paradigmatic case, the case study aims to make an exemplary deduction for similar cases to follow.

[Flyvbjerg, 2010]

In this thesis, we work with a paradigmatic case, as it is assessed that the Fælledby project is the start of developing a model example of a sustainability area where many considerations and attempts are being made to implement various sustainability measures.

6.1.3 The use of case studies in this thesis

The focus of this thesis is to create an understanding of how reused materials will become a more significant part of the building sector. To understand the obstacles that cause difficulties in using reused materials, the case of Fælledby will be examined. The case of Fælledby is planned to be an ambitious building project whose vision is to *"create the frames of a sustainable everyday life"*. This is furthermore elaborated by:

"If you live in Fœlledby, it should be easy and attractive to live climate-friendly with green transport, energy-friendly housing and good opportunities to recycle, swap and share with other residents."

[Fælledby, 2010]

This makes the case relevant to look into. What initiatives are included in the plans to make the project more sustainable, and what sustainable aspects of the case have been neglected. It is concluded that reused materials have had a narrow focus in the case, which makes using Fælledby a case change. The second analysis investigates how a broader focus could have been made, making it more accessible to use reused materials in the case. It will use the experience from Fælledby and the actors involved to create a more general understanding of what has to be included in a project that wants to integrate reused material in a project. The use of the Fælledby case aims to learn from its obstacles and planning to ensure that other projects and the developer of Fælledby will succeed in integrating more reused materials in future projects.

6.2 Qulitative method

This thesis uses a qualitative methodology to understand and interpret social phenomena and human behavior in-depth. This approach uses a wide range of data collection methods such as interviews, observations, and text analysis to understand better the context and the factors involved. Qualitative studies aim to answer 'why' and 'how' questions and emphasize the interpretation of data to gain meaningful knowledge. This method is widely used in disciplines such as sociology, psychology, and anthropology, where it helps to explore complex social interactions and individual experiences [Patton, 2014]. This thesis uses structured interviews, where the respondents are assessed as experts in their field.

6.2.1 The methodology of interviews

Interviews are a research method used to collect data and gain insights into respondents' perspectives, attitudes, and experiences. Interviews can be an in-depth and flexible method that allows for a rich and more nuanced understanding of the topic under investigation. One specific type of interview is semi-structured, which combines structured and unstructured elements. [Rapley, 2014]

Throughout the thesis, semi-structured interviews have been conducted, characterized by using an overall interview guide that contains some fixed questions and topics but also allows flexibility and the possibility to ask probing questions based on the provided answers. This allows the researcher to explore participants' perspectives in depth and obtain more detailed and rich data. [Rapley, 2014]

6.2.2 Expert interview

The thesis has addressed respondents who have certain knowledge in specific areas. These are also respondents who are directly involved in the Fælledby case or are indirectly involved in either the building sector or the case. The purpose is to collect specialized knowledge, experiences, and perspectives from the expert. While expert interviews are a valuable method for gathering expert knowledge, they also have certain drawbacks, including, for example, in cases where the expert's perspective may be characterized by personal attitudes, experiences, and bias, which may affect the data collected and the interview results. [Rubin, 2011]

The use of the expert interviews in the thesis

The expert interviews are conducted for two purposes.

- To obtain the necessary knowledge to investigate and understand the case of Fælledby regarding actor collaboration and sustainability.
- To obtain knowledge on other relevant areas, such as knowledge from people with knowledge of urban areas with a high level of social sustainability.

Besides obtaining information and knowledge that is hard to obtain otherwise, the interviews are used to investigate and assess how the involved actors' translation processes can be strengthened to ensure that the mapped initiatives can be implemented in the project.

6.2.3 The choice of the respondents in the thesis

This section presents the respondents who have participated in the various interviews. At the same time, there will be a justification for why it has been chosen to interview these respondents and why they have been assessed to be experts.

Interviews regarding the Fælledby project

In the process of understanding the Fælledby project, and the actors involved, it was considered essential to get in touch with the actors directly involved in the project. In order to find the most relevant actors, the project manager for the Fælledby project, Martin Baltser, was contacted for suggestions on which people would be relevant for answering the research questions. In this section, the actors interviewed about Fælledby will be mapped.

- **Erling Thygesen**, director of Fælledby. Thygesen contributes knowledge on behalf of the investor perspective in the thesis. As director of Fælledby, he has close contact with Pension Danmark and By- og Havn, which are the owners of Fælledby.
- **Rune Guldager Thomsen**, project manager at Tscherning. Thomsen was interviewed because of Tscherning's involvement in the project and their knowledge of circularity. Tscherning were the company responsible for the demolishing the old hostel and also for making the resource mapping.
- **Rasmus Overgaard Bertelsen**, project & planning manager at ABC Rådgivende Ingeniører, and **Lone Hedegaard Mortensen**, head of Sustainability at ABC Rådgivende Ingeniører. ABC Rådgivende Ingeniører is a consulting engineering

company responsible for three building sites in Fælledby. ABC Rådgivende Ingeniører contributes with knowledge about circular economy and bio-based materials and how to incorporate circular economy in building. They have knowledge about the process, as well as actor collaboration and the involvement of actors in ambitious, sustainable projects. Both respondents from ABC Rådgivende Ingeniører are considered to represent the company relatively broadly as both can contribute with different knowledge.

- **Niels Jakubiak Andersen**, owner and managing director of NÆSTE. Andersen is an architect and founder of NÆSTE, a circular design and building company. NÆSTE will deliver sheds for Fælledby made from reused materials. NÆSTE's vision is to change how resources are used, pointing out that this requires broad collaboration across the building sector.
- **Jørgen Dalgas Hedeager**, Founder of JDH-BYG. Hedeager is being interviewed based on his knowledge of building. In addition, the company is also involved in some building sites in Fælledby. JDH-BYG is a building company with experience in circular building, working with bio-based building materials and reuse.

In addition, interviews have been conducted with actors who can contribute knowledge to Fælledby.

- **Linda Sønderskov** chief consultant of NÆRHEDEN P/S. The company is a partnership between Høje Taastrup Municipality and Realdania By & Byg and operates and develops 65 hectares of land in Hedehusene. This area is considered an example of the future suburb, where the urban development area previously consisted of industrial, agricultural, and nature areas. Sønderskov will shed light on the knowledge and experience of urban development and buildings in Hedehusene, primarily focusing on social sustainability.
- **Henrik Dam Nielsen** head of consulting at GreenDozer. The company is an online platform for suppliers of reused materials. The company has knowledge about which reused materials can be incorporated into buildings and does also have knowledge of the current barriers to using reused materials. Nielsen will shed light on how GreenDozer sees the future of the building sector and how to promote the use of reused materials in building projects.
- **Knud Erik Hansen** board member and treasurer at Amager Fælleds Venner. Hansen has provided knowledge on other perspectives on the biodiversity of Amager

Fællede. Amager Fælledes Venner is against the building of Fælledby and this made it crucial to resarch their perspectives in order to study the case.

These actors have been selected based on their expertise, experience, or relevance to the problem area being studied. Through their participation in interviews, the thesis has gained valuable insights and perspectives that have enriched the analysis.

A sustainable urban area 7

As highlighted in the Problem Analysis (Chapter 2), the case of Fælledby describes a framework that clarifies what physical objects Fælledby will contain, such as buildings, nature, etc. The first analysis aims to clarify what a sustainable urban area should contain and how Fælledby embraces sustainability. Interviews with relevant actors will add an understanding of the initiatives that are planned to be included.

As a framework for the analysis, four steps have been mapped as essential aspects of the development of the urban area. The four steps are mapped from the initiatives claimed by Fælledby to have significant importance for the development of the urban area and have been mapped from meetings with Fælledby throughout the process and from their publicly available information on the project.

The following section will explain each of the model's four focus points.

Figure 7.1. The four steps in planning a new urban area. (Self-made)

The analysis will examine the four-steps model and analyze whether there is a high focus on sustainability. The following section will be based on the theory section describing the circular economy. The initiatives that have been chosen to implement will be analyzed in relation to how they are incorporated with the R-model in the circular economy. This analysis will also look into the DGNB Certification, which the urban area plans to obtain platinum.

7.1 Materials and low climate footprint

When implementing a new urban area, the choice of materials needs to be considered, as does the climate footprint relating to the different materials. The different types of phases regarding the impacts of a building project are illustrated within the phases of LCA, which can be seen in Figure 2.3. All the different phases and their environmental impacts are necessary to consider in the procurement process when deciding what materials to include in the project. At the same time, the materials must be of a quality that can fulfill the building regulation requirements. Besides, the materials should also be economically viable. Fælledby describes their vision for prices of the housing units as:

"We expect that the price of the housing units will be on a level with what is seen in the nearby areas such as Ørestad"

[Fælledby, U.D]

Thygesen from Fælledby describes the ambition of the pricing as following:

"If you look at Copenhagen and the different neighborhoods, Ørestaden is still probably the cheapest place to rent. And we have an ambition to be close to that rent level, so you could say that it will still be affordable housing."

This will influence how much can be spent on materials for the project's vision to be realized, providing the project with a frame of what is economically sustainable.

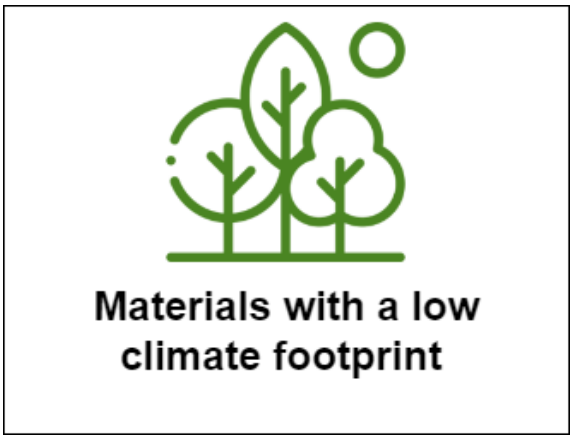

Figure 7.2. The first step in planning a new urban area. (Self-made)

7.1.1 Materials with a low climate footprint in relation to Fælledby

The following describes the initiatives taken regarding selecting materials to ensure a low climate footprint of Fælledby. The developer already had a clear vision for the selection of materials in the case competition stating the following:

"The neighborhood will be Copenhagen's largest concentration of completed multi-story buildings in wood."

[Fælledby, 2019]

The ambition is that the bearing buildings and some of the facades will be of wood. Biobased materials are wholly or partly originating from a biological source. A resource like wood is regenerative, meaning that wood can regenerate. The wood in Fælledby is FSC-certified, which implies that the wood comes from sustainable forestry. [Fælledby, 2023]

Among the requirements of FSC-certified wood are that the forest owner is responsible for securing the longsighted sustainability of the forest, focusing on the environmental, social, and economic aspects. This is further elaborated in the certification that the forest owner needs to ensure sustainable timber volume harvested, and this is described as:

1. Conservative and well-documented estimates
2. An updated wood mass balance
3. An evaluation of growth and the possible amount that can be harvested

[FSC, 2015]

Biobased materials used in Fælledby are not only important for their regenerative ability, which is secured by the FSC certification. Wood also has additional positive influences compared to heavier materials such as steel and concrete. According to the R-model, it is relevant to point out that it reaches the level of R2 - Reduce because fewer resources are needed for the concrete foundation. [Rambøll, 2016]

A downside of using wood in building is currently from an LCA perspective. When conducting LCA calculations as it is right now, it requires calculations for wooden materials to include a baseline scenario where the wood is incinerated in its end-of-life scenario, which is the circular strategy closest to a linear economy, R9 - Recover. The impact on the LCA

calculation is explained compared to other materials like concrete. Bertelsen from ABC Rådgivende Ingeniører states the following:

"You can clearly see how timber buildings gets off to the best start, lives best, but all of a sudden in the 49th year, it just goes on and on and on and on, because you burn down the wooden house."

This could provide a misleading indication of the climate footprint of the buildings in Fælledby, because it has become a requirement to do LCA's for all new buildings from the new requirements in the building regulation of 2023. [Bolig og Plantestyrelsen, 2022]

Bertelsen from ABC Rådgivende Ingeniører explains that it could be misleading by stating the following:

"...we don't really believe that in 50 years you would incinerate a wooden house. Because I think you could take some of the load-bearing elements and reuse them."

This concludes that if the methods of calculating LCA for wooden buildings were renewed to include reusability and the circular strategies that involve extending the life of the materials, the impact of Fælledby's buildings of wood would impact less from an LCA perspective.

7.2 Reused materials and resource mapping

When establishing a new sustainable urban area, a focus should be on reusing materials and how existing resources can be utilized because of its great potential for the building sector to become more sustainable, as described in Chapter 2. This requires a material mapping to clarify what resources can be used in the development of the urban area.

Resource mapping is a method to create an overview of the materials in a building, where quantity and an overview of the quality are registered. It is a good tool to understand what materials that can have the ability to be reused [VCØB, U.D]. A part of this quality assessment is the documentation of toxic substances in the materials, such as asbestos and PCB. [Butera, U.D]

Figure 7.3. The second step in planning a new urban area. (Self-made)

Resource mappings can be included in the tender for the demolitions, which means that the tender will include an inventory of available resources that can be included in the building of new buildings. [Teknologisk Institut, 2018]

Resource mappings can also give an overview of whether selective demolishing can be economically sustainable for the demolition company and developer. Further costs are associated with selective demolitions meaning the demolition company or the developer, depending on who owns the materials, needs to be able to either use or sell the materials. An example of places where selectively demolished materials can be sold is in material banks, which will be described in the next section.

7.2.1 Material bank

A material bank is a business that stores circular materials to recirculate them into new building projects. Material Banks were not used as a provider of circular materials in Fælledby. The only reused materials that were sourced were from a demolishing of a hostel on the construction ground. It was important for the project leader of Fælledby, Martin Baltser, to use materials of good quality from the demolition. Thomsen from Tscherning explained the process of handling the selectively demolished materials by stating:

"From the moment you take things down, there are two options. It's either to rebuild them in the project you're in or make sure that others rebuild them elsewhere. So you can say that there are some things that you can use one-to-one here now, and then there is

materials that need to be taken to storage or sold to others to be reused elsewhere. So that's kind of the mindset we've had."

This process was a part of the project management as well. The aim was to establish their material bank, use as many resources as possible, and otherwise sell or give the rest of the materials away. Thomsen from Tscherning explained that:

"Martin was given a list of what materials were available, and then he had the opportunity to drive out and look at it in the warehouse. This meant that he and his architect could go out and choose to say "this is what I can use", or "this is what I can't use", and based on that, they said this is what we can use, and this is what we need to find another solution for. You have to sell it or go out and search the market to find out who can use such things."

In conversation with Fælledby, it was later clarified that it has been difficult for Fælledby to find recipients for the materials. Baltser explained that he had tried to sell and eventually give out the materials not used for the project but was unsuccessful in reusing them.

7.2.2 Reused materials and resource mapping in Fælledby

Reusing materials can be seen as a reformation of the building sector and the current dominating practices of primarily using new materials for buildings. Using reused materials for building projects causes a change in the process. This process focuses on using after their end-of-use phase instead of using them in a process degrading their quality, such as *recycling (R8)* or even *recovering energy from them (R9)*. To ensure that materials can be reused as close to their original quality and function as possible, the buildings planned for demolition should be mapped to ensure the materials are used again. It was seen that the developer of Fælledby, who owned the reused materials, had a considerable interest in recirculating the materials, meaning that they were preferred to be used in a context where their lifespan would be extended. The group of circular strategies that can make this happen is *R3-R7*. *Recycle (R8)* was also eventually found interesting because the developer invested in getting some value out of the materials.

The ranking of the R-model has a significant importance when describing the initiatives regarding circularity within the selection of materials and whether the initiatives can be considered ambitious from a circular and sustainable perspective. It provides a circular

framework to describe what can be done to the materials to prolong their use. This section will look into the circular initiatives focusing on prolonging the use of the materials.

As described in Chapter 2, there was located on the construction ground of Fælledby, a hostel that was demolished selectively, and a register of the materials was made. The developer wanted to try to make the involved actors integrate circularity in their ideas for the individual buildings and get as many materials to recirculate. A meeting with approximately a hundred people was held by Fælledby in order to secure this. The actors attending this meeting showed a willingness to use the materials in their building projects. There was significant interest in using the materials such as facades and windows. [Appendix 4]

Using the windows directly without doing anything to them would be *Reuse (R3)* in the R-model. Still, the possibility for handling the windows could also have been on a lower grade of circularity. It could also have been necessary to *Repair (R4)* the windows, been needing to *Refurbish (R5)* them before using again or even needed to be *Remanufactured (R6)* before being able to use them. When it comes to windows, there are requirements in the building regulation describing certain criteria they must fulfill, such as achieving a U-factor of 1.8 $[W/m^2K]$ when installed against the outside [Bygningsreglement, 2022]. This makes it an individual assessment of how high the use of reused windows will rank on the R-hierarchy.

Despite a considerable willingness to use the materials, they were unusable because they contained toxic substances [Appendix 2]. This made it complicated to reuse because the process of remediation the materials would be costly. The materials from the hostel are no longer considered to be used in primary buildings in Fælledby. The concentration of toxic substances was so substantial that the concrete did not have the quality to be demolished and used as stabilizing material. The process was explained as follows:

"They were even considering crushing concrete and using it as a stabilizing layer or something. But there they also found traces of some filth that they just thought, we can't do this." - Bertelsen from ABC Rådgivende Ingeniører

The plans of integrating reused materials were limited to only focusing on the materials from the selective demolition of the hostel. However, the competition material described that:

"The neighborhood shall focus on resource efficiency. This will happen by presenting innovative solutions for the reuse of building materials and showing examples of how embodied energy can be reduced in the buildings, for instance, by upcycling buildings and using wood."

[Fælledby, 2019]

More specifically, they added this section about the hostel to the competition material for the masterplan:

"The building is not presumed to be preserved as a starting point, but proposals for how all or parts of it can be reused for some of the requested functions or for temporary functions in a transitional period are welcome."

[Fælledby, 2019]

This indicates that the developer wants to use reused materials in the project, but it also indicates that if reused materials are to be used in buildings, the initiatives must come from the individual project groups.

The only materials used from the hostel are wood from the facades and partition walls that will be built into sheds created by NÆSTE. This is equal to *Repurose (R7)* because the materials were used in a primary building and will be used for a secondary building with fewer requirements in the building regulation. NÆSTE specializes in crating secondary buildings, mainly sheds, by reusing wood and other materials that cannot be used for primary buildings. NÆSTE is working with secondary buildings like sheds for bikes because the barriers in the building regulation make it challenging to build with reused materials. Andersen from NÆSTE explains that their reason for focusing on secondary buildings is that it is challenging to integrate reused materials in primary buildings. He further explains that:

"We cannot document in terms of fire and strength."

Another aspect of their business model is that they would instead use reused wood for secondary buildings than for primary buildings when they cannot guarantee that the materials contain toxic substances. Andersen from NÆSTE explains that:

"So we basically don't know whether there are any residues of PCBs in small quantities, or whether there are any environmentally hazardous substances in small quantities in these things. Of course, environmental samples have been taken from the demolition, but we cannot be 100% sure. And in my world, this means that we have to be very careful about using reused wood, for example in children's rooms or school interiors, because we could potentially be exposed to a slightly greater health risk."

This means that care must be taken when reusing wood, as it can have an impact on human health.

7.3 Area utilization

The developer is aiming for Fælledby to receive the DGNB Platinum certification for the urban area [Fælledby, U.D]. This requires the urban area to obtain 80% of the certification points. By being certified with this certification, the urban area must limit the land withdrawal for the built environment and ensure the quality of the natural area in the best way (ENV 2.3). The outside areas must also be attractive from a social aspect, meaning that the areas, for instance, are comfortable to use (SOC 1.1), it must create the possibility for the residents to experience recreative areas and nature (SOC 1.6), ensure a safe environment that invites to social contact between the residents (SOC 1.7) and invite to a diverse area utilization that is inclusive towards different population groups (SOC 3.3). [Green Building Council Denmark, 2022]

Figure 7.4. The third step in planning a new urban area. (Self-made)

The DGNB manual for urban areas ensures good area utilization. If Fælledby reaches Platinum, as planned, it will show that the area is effectively used as an urban area because the functions of a sustainable urban area are met.

7.3.1 Area utilization in Fælledby

The competition material for the masterplan describes the following: *"a total of 11.8 hectares of the area can be built on - the remaining 6.3 hectares must be of nature and free space."* [Fælledby, 2019]

Fælledby wants to create a strong community and wants its residents to feel committed to caring for the area and its nature.

The method used in Fælledby to establish this strong community can be compared to how Nærheden in Hedehusene has been built up. Nærheden has been built with the same philosophy as Fælledby, building communities on three levels. **The first level** is that residents should be able to live somewhat privately in their own private areas. **The second level** focuses on the small community in the individual building clusters. In Fælledby, the clusters are called A, B, and C. **The third level** should be viewed as the entire urban area that will also provide room for residents to socialize between the clusters. A way to connect the clusters is by making areas with high biodiversity and areas with wild nature that can gather the people living in Fælledby. The area is furthermore supported by the use of multistory buildings, making room for public spaces that can ensure a strong community. This also lines with the requirement of ENV 2.3 in the DGNB certification because they require the developer to limit the use of the area for buildings and paving in favor of nature.

Figure 7.5. Example of how Fælledby is divided into three social levels. [Fælledby, U.Db]

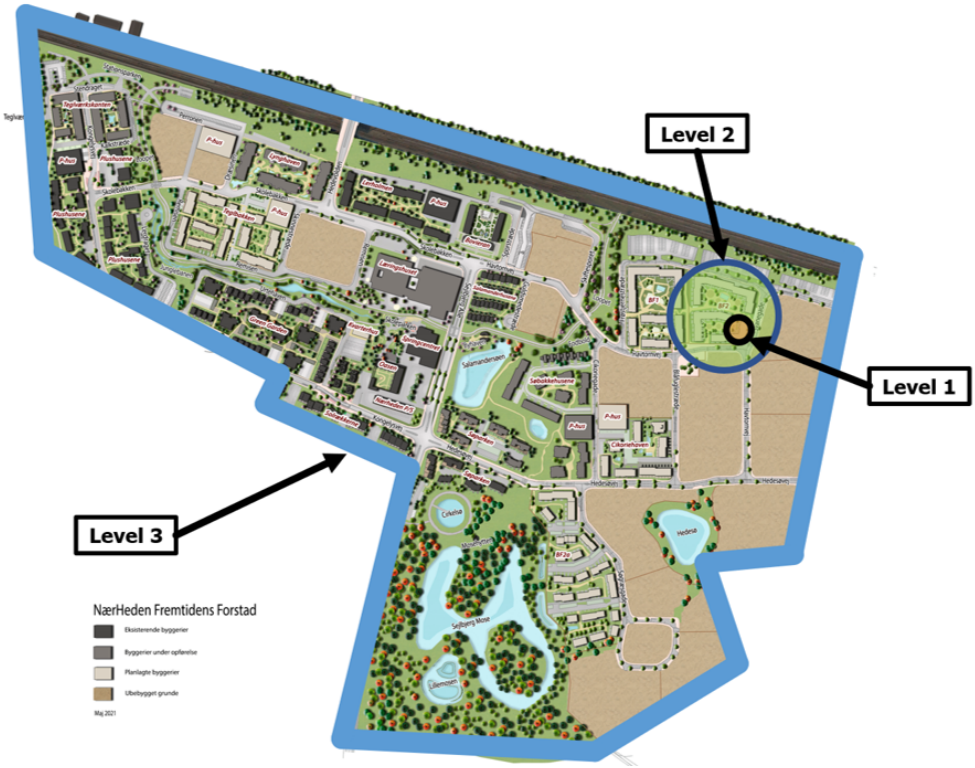

Figure 7.6. Example of how Nærheden is divided into three social levels. [Nærheden, U.D]

The figures 7.5 and 7.6 illustrate examples of how the urban areas are divided into the described three social levels, showing that the whole urban area is connected.

The ideas from the planning of Nærheden were that:

"It is very important that you don't create housing clusters that close in on themselves, but that you can pass through without feeling that you are disturbing anyone" and further states that: "they should also be allowed to have a small community in the housing cluster." - Sønderskov from Nærheden

This aspect is described in the DGNB certification in SOC 1.7, where aspects such as the feeling of belonging to the area and feeling safe are essential to give the residents the willingness and possibility to engage in social activities. As seen on 7.5, the clusters are built with open corridors, enabling the clusters to open up for the residents from other clusters and users of the area that do not live in Fælledby. [Green Building Council Denmark, 2022]

Besides making room for social sustainability from initiatives concentrating on nature, Fælledby will also create a strategy for a retail business that will include cafes and smaller shops, among others. Social diversity will furthermore be created by having diverse groups living in the area, such as housing units specifically for students and elderly people and housing units fitted for families. The diversity will be strengthened because a school and a daycare center are being built in the area [Fælledby, 2010]. Including different types of institutions, retail businesses, and housing types is a requirement in the DGNB certification. The inclusion will enhance the life quality of the residents and users because of the foundation of cohesiveness it provides the area [Green Building Council Denmark, 2022]. The DGNB certification describes it as follows:

"With DGNB, we have created a holistic system that focuses on environmental, social and economic sustainability, and besides that also look at process and technical solutions to get around the projects", and is further elaborated that: "Sustainability is put on a formula, and with a certification, the individual urban area can boast of living up to a wide range of sustainability objectives that are significantly more ambitious than ordinary legislation." significantly more ambitious than ordinary legislation."

[Green Building Council Denmark, 2022]

This concludes that if Fælledby reaches a platinum certification of the urban area, their initiatives included will have a suitable area utilization that benefits the residents.

7.4 Biodiversity

To obtain knowledge of an area and the environmental impact when a new urban area is being established, it will be necessary to carry out an environmental screening. This was furthermore a requirement for Fælledby to obtain the permit to build. The screening will provide an analysis of the area that can show what points of focus there need to be to strengthen the construction of an urban area. [Realdania, 2022]

Biodiversity is also a part of the DGNB certification of urban areas (ENV 2.4). It focuses on keeping diverse biodiversity with high quality focused on the local area of the urban area. The extension of cities is crucial in degrading natural areas by removing and splitting natural habitats. ENV 2.4 focuses on that good living places for nature are secured in the plans by keeping the existing flora and fauna and ensuring that nature can live in the urban area. [Green Building Council Denmark, 2022]

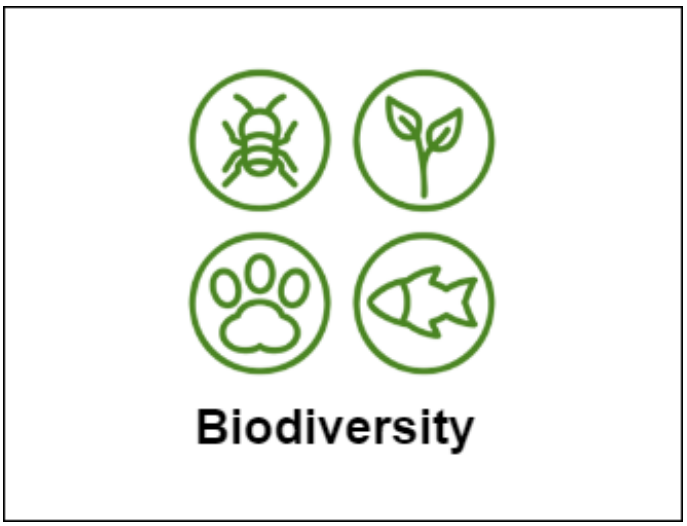

Figure 7.7. The fourth step in planning a new urban area. (Self-made)

7.4.1 Biodiversity in Fælledby

This section will describe the aspects concerning biodiversity in the area. The vision for developing the urban areas' nature can be seen in Figure 7.8. The vision of the project describes that the number of hectares of nature will go from 15.37 hectares to 9.72 hectares, but will enhance the value of nature in the area and therefore help to restore, increase and protect the biosphere. The next section will describe the differences between the values of natural areas.

Total of 18,1 ha	Existing	Future
Build area	1,70 ha	4,37 ha
Coated areas and paths	1,03 ha	4,01 ha
Nature area (low value)	4,57 ha	0 ha
Nature area (middle value)	6,60 ha	2,74 ha
Nature area (high value)	2,58 ha	5,36 ha
Protected nature	1,62 ha	1,62 ha

Figure 7.8. The change of nature regarding quality from before and after Fælledby is done. [Fælledby, U.D]

To ensure that Fælledby incorporates good measures to reduce the impact on the climate, a Nature Advisory Board was established to advise Fælledby. The Nature Advisory Board consisted of nine members, including three biologists, an urban horticulturalists, a board member of Danske Landskabsarkitekter, an environmental consultant, and a project leader. The members were chosen to include knowledge of plants, insects, birds, biodiversity, landscape, operation, and care. The large diversity of professions within the advisory board will help achieve the requirements met in the DGNB certification of ENV 2.4. [Appendix 10]

The Nature Advisory Board made three general recommendations which were:

- "Base the nature project on Amager Fælled's nature types and local species"
- "Think operation and involvement together and on the natural conditions"
- "Consider the residents as a resource and engage them in the care of nature"

[Appendix 10]

Besides listing the general recommendations, the nature advisory board also made specific recommendations for initiatives that would benefit and strengthen the project's impact on the area's nature and biodiversity. Examples of such specific advice are:

- Slopes should be made with high inclination because it would benefit the biodiversity.
- Ensure that larger animals also have access to hiding places.
- Designing habitats for birds and insects from the start. This can be standing, dead tree trunks, which work well as an alternative to insect nests and also as an alternative to bird nests.

[Appendix 10]

Fælledby wants to open the built areas for nature, which can be seen in Figure 7.9.

Figure 7.9. The city and nature merged together. [Fælledby, U.D]

Thygesen, director of Fælledby, describes the work to create good conditions for biodiversity by stating the following:

"We need to incorporate a number of biodiversity initiatives around what we want to achieve with our plantings, with our insects, and whether we can attract some new species and small animals, and if we need to make some gables with beehives and bird boxes." - Thygesen, Fælledby

Designing the urban area to be located in nature will also benefit the residents because nature is beneficial for the life quality of the residents. This is described in the criteria of ENV 2.4 and SOC 1.6.

Another aspect must be addressed when describing nature and the project's environmental qualities. The grounds of Fælledby have been used as an unsorted waste dump for several years, from the beginning of the 1930s to 1974, which has caused massive pollution of the soil [Københavns Kommune, 2020]. Extensive initiatives have been taken to keep pollution from the grounds on the building area from getting into the buildings. This has been done by using remedial measures to ensure the pollution will not affect the residents. Measures used to eliminate the threat of pollution are an extra layer of soil in the polluted area and a ventilation system that detoxifies the underground. This aspect is also relevant according to the DGNB certification because it also considers previous functions of the

area. Using old industrial areas is favorable and evaluated in ENV 2.3. [Green Building Council Denmark, 2022]

7.5 Part conclusion

This chapter analyzes on what sustainable elements are implemented in the Fælledby case. This is used to shed light on what a sustainable urban area should contain and how Fælledby incorporates sustainability. In order to map Fælledby's sustainability elements, four steps have been developed that identify which elements are implemented and initiatives for Fælledby.

The first step examines the choice of materials and their climate footprint. It emphasizes the need to consider the environmental impacts associated with materials throughout their life cycle. Fælledby aims to use wood as the primary building material, particularly for bearing buildings and facades. The wood that is used is FSC-certified, which ensures that it has been harvested responsibly. Using wood in buildings can create challenges when using the LCA as it is required to include the incineration of it in its lifetime.

The second step focuses on reusing materials and conducting resource mapping. Reusing materials and maximizing the utilization of existing resources are crucial for establishing a sustainable urban area. Resource mapping involves assessing the quantity, quality, and presence of toxic substances in building materials to identify opportunities for reuse. The analysis highlights the potential of selective demolition and resource mapping to reduce resource consumption and maximize reuse. It also discusses the concept of material banks, which stores circular materials for future use. The analysis further examines the circular initiatives in Fælledby's material selection and their alignment within the R-model, and in a circular framework. The focus is on prolonging the use of materials and considering different levels of circularity. Fælledby aimed to integrate reused materials from the hostel demolition into the project. However, the materials contained toxic substances, making them unsuitable for primary buildings. Despite this setback, the competition material for the project still emphasized the importance of resource efficiency and innovative solutions for reuse.

The third step illustrates Fælledby's intention to create a strong community and ensure that the residents feel engaged in caring for the area and nature. Parallels are drawn in the method that is used in Fælledby to establish this strong community with the method

used in Nærheden in Hedehusene. Both areas focus on building communities based on three levels. *The first level* is the residents' private areas, the *second level* focuses on the community in the individual building clusters, and *the third level* is the overall urban area, which also provides space for socializing between the clusters. To connect the clusters, areas with high biodiversity and wild nature are created to bring the residents of Fælledby together.

The fourth step focuses on biodiversity in the Fælledby project. The vision for developing the urban area's nature is to increase the value of nature within the clusters and the surrounding nature. However, the total amount of hectares of nature will be reduced after the project is built, making it even more critical that the value of nature is increased and protecting the biosphere is focused upon.

To ensure that Fælledby incorporates good measures to strengthen the area's nature, a Nature Advisory Board was established to advise Fælledby on plants, insects, birds, biodiversity, and landscape. The Nature Advisory Board made specific recommendations for initiatives to benefit and strengthen the project's impact on the area's nature and biodiversity. Fælledby wants to open up the built-up areas to nature and create good conditions for biodiversity.

Overall, the analysis highlights the importance of considering the climate footprint of materials, reusing resources, and implementing circular strategies in developing a sustainable urban area. Sustainable initiatives are an important aspect in the business case of Fælledby, which is clarified by Thygesen, director of Fælledby:

"It's becoming more and more important for people so they are willing to pay extra to own a home that is built with as many sustainable measures as possible." - Thygesen, Fælledby

Fælledby did face challenges in realizing its reuse initiatives. It was demonstrated that there was a commitment to sustainability by prioritizing wood as a building material and because they looked into the possibilities of using material reuse.

The following analysis will focus on the aspect of integrating reused materials. It will look at what possibilities could have enabled reused materials to be used in Fælledby and create a general framework for the developer and the other actors of the building sector to use in future projects to succeed in integrating reused materials and raise the level of ambition in the development of urban areas.

Working towards a mindset for reusing 8

This chapter describes the considerations that have to be taken to integrate reused materials in a building project. The first analysis (Chapter 7) found that the project of Fælledby initially had plans to use reused materials. However, it was found that reused materials did not get included in the final planning for the buildings. From the findings of the first analysis and the conducted interviews, this analysis will seek to investigate and elaborate on how the processes in the Fælledby-project could have been planned and organized to secure that more reused materials were used.

8.1 The integration of reused materials

As described in the first analysis (Chapter 7), the plan to use reused material relied on the selective demolition of the hostel, but this did not happen due to the low quality and toxicity of some materials. However, other ways exist to integrate reused materials in building projects project. This was elaborated by Thomsen, describing three ways in general to obtain reused materials:

- The first method is the most accessible by using the buildings already on the building site. This is what the aim was related to the hostel.
- The second method is by locating the materials from other demolitions in the nearby area. This could make the foundation of partnerships between different projects and could contribute to the incorporation of reused materials.
- The third method is using material banks or companies that sell materials from demolitions and surplus building materials.

These methods will be the foundation of this analysis to seek a process that will integrate reused materials. In addition to these aspects, it will also be looked into how to prevent using new materials, meaning using the current building mass directly with a focus on

renovations instead of demolishing the building.

Providing a process to enable the inclusion of reused materials

Understanding the process of a circular building project is necessary to make the integration of reused materials possible. This includes the following three steps where the first step is seen as the highest level of the R-model: *step 1: the existing buildings as a whole*, *step2: building components and materials*, and *step 3: source materials that fit into the existing design match.* [Birgisdottir et al., 2019]

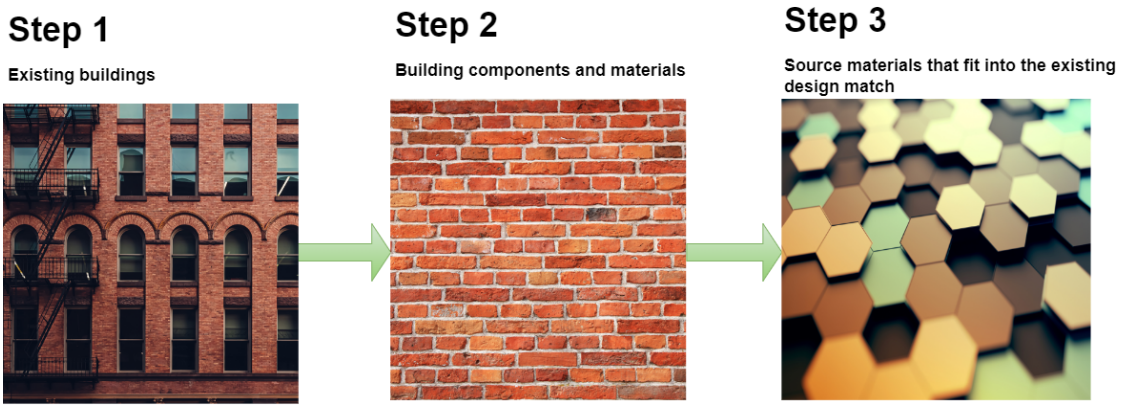

Figure 8.1. The three steps for embedding circular value in the building sector. (Self-made)

Step 1 looks at the existing building mass on the building site. This step urges the developer to investigate whether the existing building can be used directly for the new purpose or be renovated to fit the new purpose. Using the current building mass will enable the materials within the building to be used as effectively as possible. Within the R-hierarchy, it relates to the top of the model, meaning that it will be described as either R0 - Reuse, if the building can be used directly, or R1 - Rethink, if the building needs to be transformed. 5.3

As previously described, the hostel was the only building located on the building site of Fælledby. The hostel was a single-story building. As seen in picture 8.2, the building had a size and a location that would have complicated it to be integrated into the plans for a neighborhood with 2000 housing units.

Figure 8.2. The left side shows the location of the hostel, and the right side shows how Fælledby is planned to be built. [Fælledby, U.Da]

In addition to this, better land use, as described in 7, is relevant to take into consideration. Fælledby focuses on reducing the amount of built area to make room for nature of a higher value than before. If the current building mass was kept and the planned buildings were built, the total built area would have been 6.1 hectares out of 18.1 hectares (figure 7.8) [Fælledby, U.Da]. The focus should therefore be on the next steps, which is also a step lower in the R-model.

Step 2 focuses on conducting a resource mapping of the existing building mass and trying to locate any of the materials that can be either reused or recycled, where reusing is preferred, as described in the R-model from Chapter 5. The benefit of using materials already on the building site is that the environmental impacts of transportation are reduced. As described in the first analysis, this has been done in the Fælledby case. [Birgisdottir et al., 2019]

Step 3 in the process of integrating reused materials is to obtain materials from other actors not directly involved in the building project. This step includes ensuring that the materials from demolishing the building site that cannot be used are given away or sold so other projects can benefit from them, such as material banks. This action can also be reversed, meaning the actors too can locate and obtain reused materials from other places, such as material banks or nearby demolitions, for their building project. This step could have a significant impact on the Fælledby project. It could provide more options

for the actors to obtain and replace the reused materials from the hostel that were not fit to use because of their containment of toxic substances. The following sections will investigate how the process in the Fælledby project could have been done otherwise, so the possibility of using and gathering materials from other places would have been found realistic and would have made the involved actors consider integrating reused materials from an early-stage. [Birgisdottir et al., 2019]

8.1.1 Mapping of nearby demolitions

This section will focus on the **step 2** (Figure 8.1) of the process of integrating reused materials in buildings. It will analyze how cross-sector collaborations can be included to enhance the number of reused materials in constructing new buildings. The potential of using materials from planned demolitions of the current building mass in Denmark is high, with a building mass of 820 million m^2, and of these 2-3 million m^2 are demolished annually. [Realdania, 2021b]

To use materials directly from one demolition to another requires a strong actor collaboration and clear agreements that clarify who will be responsible for the materials if the recipient cannot use them [Gate 21, 2021]. This risk must be included in an agreement because of the uncertainties related to the materials. An example is the demolition of the hostel, where there was a lot of willingness to use the materials before the demolition, and lots of the actors saw the potential of using them. However, after it was discovered that it contained toxic substances, the plans to use the materials were abandoned. [Appendix 4]

The needed actor collaboration can be seen in the case of the newly built city hall of Høje-Taastrup, where concrete was recycled from the demolition of an apartment building used for the foundation. The following will describe the central experiences that can be transferred into the context of selective demolitions of nearby building projects. [Gate 21, 2021]

For a project regarding circular materials, gathering as much information about the materials is essential early. In the case of Høje-Taastrup, an environmental consultant was used to assess the quality of the concrete and if it contained toxic substances. This was done early in the process, creating transparency for the involved actors.

Another aspect that made the case succeed was the team of actors collaborating, making it possible. They all had the knowledge and willingness to do a more unusual project, which

it was at the time [Gate 21, 2021]. This aspect has also been visible in the case of Fælledby, where the developer had high ambitions from the start of the project. The building project has ended up consisting of actors with a strong sustainability profile, like JDH-Byg. This was ensured from the beginning by dialogs between the actors and Fælledby. An example of the early level of ambition shown by the developer is the following statement from Hedeager, JDH-Byg:

"Already when we priced the assignment early on, they actually suggested some measures to see whether reused materials could be included."

If supposing that the actors have ambitions to use reused materials in their projects, they can include them in their projections directly, meaning the possibility of reused materials being included will be high. As seen with the example of the hostel, the certainty of what materials were available made the actors use the materials from the hostel for the facades in their projects.

It can be a challenge when trading materials that the distance and differences in locations differ. This can cause logistical challenges, and therefore it would be optimal to map which buildings to demolish, the quality of the materials, information about the materials, and the number of materials.

The resource mapping should be carried out before a building is demolished, including understanding which parts of the building and materials from the demolition can be reused. This is connected to ensuring quality and that the materials do not contain toxic substances.

If it is realized that the materials do not fit into the project or in any nearby projects, other measures should be taken to secure their recirculating in the marked. This is the focus of the third step of integrating reused materials, which will be described in the next section.

8.1.2 The possibilities of a material bank

As described in Chapter 7, an internal material bank was created by Fælledby to redistribute the materials that were not used in Fælledby's building projects. As described, material banks could have had a more significant influence on the project if a collaboration were made with an established material bank. This could provide a more significant volume

of materials, giving the involved actors more possibilities of integrating reused materials. For material banks to have an impact on bigger projects, there needs to be a volume in the available materials. An example of the problems regarding low volumes of materials for the developer to use is described by Thygesen from Fælledby. He uses the example of using slate for facades: "If you look at a facade drawing, you would need a lot of square meters. If you want to use reused slate, you'd need a lot of square meters."

This is also a position that Tscherning and other major demolishers have taken and acted upon by delivering resources to the material bank, GreenDozer:

"We are a number of demolition companies that supports GreenDozer and said that we need more people to join forces on this is because it will not be enough if we all make our own system. In this way, we should be able to get more volume and have more options when you as a customer or as a developer, are looking for something that can be used in a project." Thomsen from Tscherning

GreenDozer was established in 2017 and is a platform selling building materials and products. This is both materials that have been selectively demolished but also surplus materials from building sites as an example. Their business model builds upon that it should be accessible for all actors related to the building sector to trade with building supplies that would have been downcycled or would have ended up as waste. [GreenDozer, U.D]

The concept of material banks is still in development, and Nielsen from GreenDozer explains *"We currently have a business that is mainly driven by B2C"*, which means that they primarily supply materials to consumers and smaller businesses.

The future for GreenDozer is to expand the business model and include larger building projects. An example is their involvement in the demolition of Gellerupparken, where they aim to reuse as much as possible. The director of GreenDozer, Jan Rohde, explains that:

"*Many developers and architects focus on reusing building materials when they are easy to find and order. And I have a clear expectation that some of the building materials from Gellerupparken will be put to good use in new buildings in Aarhus. Among other things, we are in dialogue with a developer who would very much like to have a small piece of*

Gellerupparken in his large building. There is both a climate benefit and a great story in this."

[Rohde, 2023]

This also states the importance for the developer and the involved actors to have a good overview of the possibilities of the materials that can be used for the projects.

8.2 The use of material banks

Two significant aspects should have been integrated in an early stage to work with reused materials in the project of Fælledby effectively.

The difference between a material bank such as Greendozer and the list of materials from the hostel provided to Fælledby by Tscherning is accessibility. An important aspect of the business model of Greendozer is that the materials they sell are accessible because they have an online platform. The list Tscherning provided did not include any platform, only a list of materials and products, that could only be seen by visiting the storage. This made it complicated for other actors to use, and it is furthermore the reason why collaborations with established platforms should be considered.

As described earlier, the market of material banks is still in an early phase, which could influence the possibilities of partnering up with a material bank with the relevant volume. However, having a demolisher, such as Tscherning, within the involved actor group could provide the necessary knowledge to establish a connection to a material bank that could make the materials more accessible.

The other way that Fælledby could have used material banks more actively was by buying materials from them. Collaborations with material banks would also allow material banks to use their connections in the search for specific products.

The following section will provide an example of a project involving GreenDozer where they a developer and a material bank collaborated to try to make the integration of reused materials possible. Nielsen from GreenDozer explains the process and the work with the developer's "wish list" of materials:

"*We have a dialogue about the fact that we cannot promise that we will get all the materials, but we have a deadline to inform them which materials we can procure so that*

they have time to buy conventional building materials."

This would also provide more flexible solutions for the actors involved when discussing the integration of reused materials in their projections of the buildings. Thomsen from Tscherning explains the difficulties of providing the involved actors with a list of specific materials like done in the Fælledby case with the example of the architects:

"*It is possible that there is an architect who has an opinion that it should be a different color, or that they should be more white, or something like that, and the materials may well be well stocked and ready to be used, but then it may not be quite what the architect wants. So that presents some challenges.*"

The beginning of the building process should include a mapping of which materials will be needed to realize the buildings. To do this, multiple actors must be included because they have different roles and needs. At the same time, it must be investigated which materials that are available in the material bank and whether the materials that is not available can be obtained elsewhere. [Smith, 2021]

Material banks should not be seen as the only solution to integrate reused materials in building projects. As described, multiple solutions should be investigated and used in combination when developing a building project. This will create the best opportunities for stakeholders to incorporate reused building materials in their plans.

8.3 Part conclusion

This analysis discusses the considerations for integrating reused materials into a building project. It builds upon the findings from the previous analysis, which revealed that although there were initial plans to use reused materials in the Fælledby project, they were not included in the final planning. The analysis explores alternative methods for integrating reused materials, such as using existing buildings on-site, obtaining materials from nearby demolitions, and utilizing material banks and companies that sell surplus building materials.

The analysis presents a three step process for enabling the inclusion of reused materials: *examining the existing building mass, mapping building components and materials*, and *ensuring an existing design match.* It highlights the challenges faced in integrating reused

materials, such as the low quality and toxicity of some materials and logistical issues related to material availability and location.

To address these challenges, the analysis suggests strategies for mapping nearby demolitions and fostering cross-sector collaboration to enhance the availability of reused materials. It emphasizes the importance of early collaboration, transparency, and knowledge sharing among actors involved in the building project.

The analysis concludes by emphasizing the need for early engagement with material banks, both by making materials more accessible to other actors in the building sector and by purchasing materials from material banks when needed. It highlights the importance of flexibility in accommodating specific project requirements and the collaborative effort required to integrate reused materials effectively. Additionally, it emphasizes that material banks are not the sole solution but should be considered alongside other methods to maximize the incorporation of reused materials in building projects.

Transparency and the translation process 9

This analysis will establish a framework that facilitates constructive cooperation among actors in a building project to ensure the integration of reused materials. The objective is to create frames that can establish a constructive process for the actors. The framework is planned to be used within an early dialogue to align expectations among the actors. The framework is designed to ensure that the actors' roles and ambitions regarding reused materials are similar, leading to a shared vision within the network of the project group. To develop this framework, the principles of Actor-Network Theory are used to understand the behavior of actors within the network. Before creating a framework that actors of a building project can use, it is important to understand what circumstances the actors operate within. The next section will investigate the non-human actors that influence the actors within the building sector.

9.1 The influence of non-human actors

Relevant non-human actors were described in Chapter 2, explaining how standards, regulations, and if chosen, certifications influence the actors. Both international, European, and national standards and regulations influence what requirements building materials must fulfill.

The PCR was described in Chapter 2. An example of how these influence the reuse of materials is when discussing bearing buildings. If wanting to reuse a bearing building, one must do the same documentation as for newly produced products. This is a problem because testing of qualities must be made to ensure that the product lives up to the requirements of fire and its static abilities for example.

This is also, as described earlier, the reason NÆSTE builds secondary buildings because:

"We cannot document in terms of fire and strength." - Andersen from NÆSTE

Thygesen, director of Fælledby, describes the difficulties of using reused materials within the frames of the non-human aspects by the following example on the reuse of windows and doors:

"We have energy requirements today. Energy requirements that must be complied with both in building components but also in general. And there are many of them that don't have the insulation capacity they need, or they don't have the soundproofing they need." - Thygesen, Fælledby

However, ongoing projects are already trying to innovate technologies to make testing methods of reused materials and products accessible to the market, such as StructualReuse, which focuses on non-destructive test methods by using ultrasound and electrical current, which will help provide information on quality and durability, providing the necessary documentation. [Mikkelsen, U.D]

With this, and the already planned tightening of the BR18 regarding emissions, the actors of the building sector must prepare themselves for development within the building practices. However, these standards and regulations describe what requirements the reused building materials, as well as new materials, must comply with. This sets an overall framework for what the actors can and can not do. This will influence the building of the framework to facilitate practical cooperation among actors in a building project to ensure the integration of reused materials, which will be looked into in the following section.

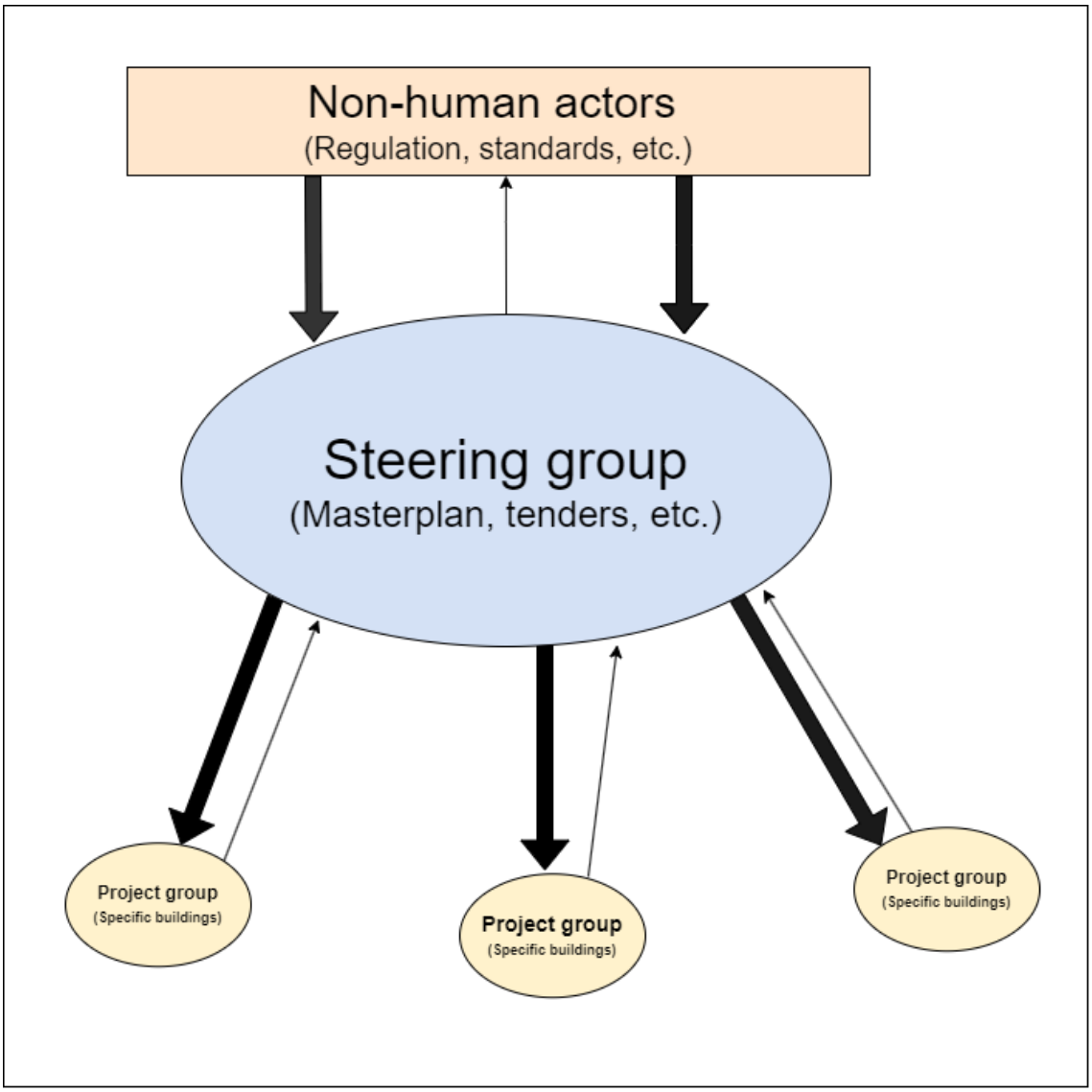

Figure 9.1. The figure shows how the actors are divided based on the impact they have on a building project. The strongest actors are presented at the top, having the most influence. The project group, that builds the buildings has the least influence. The model also includes the possibility for the actor groups to also influence upward. (Self-made)

Figure 9.1 takes point from Chapter 2 and the section describing the massive impact regulations, standards, and if chosen, certifications have on a building project. It shows that non-human actors, such as regulations and standards, significantly influence how the steering group forms the masterplan and tender because they have to comply with these. Elements such as the tender, masterplan, and certifications, if included, influence how the project groups of the individual building projects operate and include. The project groups furthermore get influenced by the non-human actors because they too must follow the regulation. Figure 9.1 also emphasizes that the actor networks can influence each other.

The actors working within the building sector do have the possibility to influence regulation. This can be done by making the projects ambitious, for example. By showing that building projects with a lower climate footprint are realistic or that reused materials can be integrated, it can provide knowledge to change the frames of regulation, making sustainability requirements more ambitious. [DI BYGGERI, 2020] This was seen in the climate partnership for the building and building sector. The partnership included more than 100 representatives from companies and specialists within the sector, providing the politicians with recommendations based on knowledge and experience on how to make the regulation more ambitious. [DI BYGGERI, 2020]

On a project level influence can happen as well. There is a dialog between the steering group and the project groups which can be seen as a collaboration where they influence each other. The following sections will enlighten how this is done on a practical level.

9.2 The road map to constructive cooperation

This section will investigate how a framework can be created to establish the necessary basis for the actors in a building project to ensure the integration of reused materials. The aim is to ensure a positive and successful process and establish a dialogue early in the project's initial phase. The framework will shed light on the actors' expectations, roles, and ambitions regarding implementing reused materials in building. This will help shape the actors' visions, which may not be similar initially, and create a shared vision in the actors' network.

Five tools have been developed to ensure a successful dialogue and process. This requires: *facilitator, alignment of expectations, idea generation, distribution of competencies, and organizing and responsibility.* The choice of these elements for the road map framework is based on the interviews carried out in this thesis and the building toolkit developed by Gate 21. [Gate 21, U.D]

These elements can ensure that actors achieve good cooperation with open communication, trust and respect, flexibility and willingness to compromise, conflict management and learning, and transparent leadership and coordination.

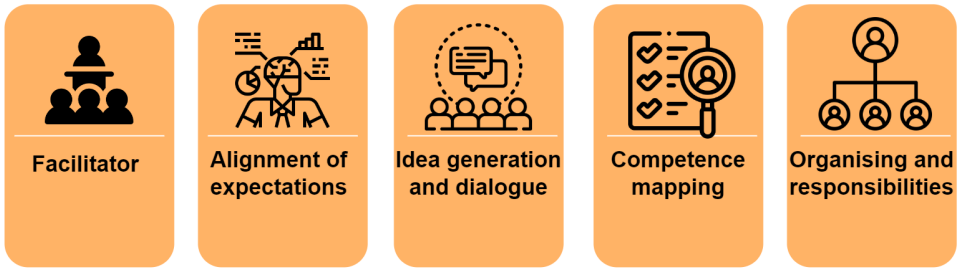

Figure 9.2. The five phases to ensure constructive cooperation to promote reused materials in building. (Self-made)

Facilitator

A facilitator in a building process is an actor who assumes the role of mediator and coordinator between different actors that are involved in the project. The facilitator facilitates cooperation and promotes dialogue between the actors to achieve constructive and practical cooperation. Their role is to create and maintain the framework for cooperation, set the standard, and invite dialogue so that all actors have a common understanding and shared ambitions [Gate 21, U.D]. The facilitator can be a developer, contractor, architect, or another actor with overall responsibility for the realization of ambitious aspects within a project. This role can be present at different levels in the construction of an urban area. A facilitator is needed to ensure that sustainable initiatives are presented on an overall level, understandable for all of the actors within the network. As mentioned earlier, it has great importance for the success of integrating reused materials that all actors within the network are willing to collaborate. The result, if one actor fails, is that the whole network will fail in integrating reused materials.

A facilitator can have a crucial role in promoting the use of reused materials and implementing circular economy. The facilitator can help identify and assess potential reused materials and reused resources in building projects, or ensure that other actors do it. At the same time, the facilitators must also be influential on a project level within the project groups and the specific buildings within the urban area.

An example of a successful circular building project where a strong facilitator has taken the responsibility to enable good collaboration within the actor network is the daycare center, Svanen, in Køge. The developer, the Municipality of Køge, had high ambitions and took leadership and facilitated the project by having close contact with all the actors involved. This caused the actors to become engaged in the ambitious, circular project. One of the involved actors claimed the following:

"What was great was the goodwill from everyone involved. This just had to be done [...] We really had a common desire and goals"

[Miljøstyrelsen, 2021]

Alignment of expectations

Expectations between actors must be aligned from the start to achieve a positive process. Therefore, a mapping of the actors' interests to understand where they agree or disagree will be relevant. Actors' interests and motivations will be reflected in their values, and therefore it cannot be excluded that these values will change to achieve common expectations within the network. The expectations can be economic aspects or the end goal, and here it would be evident for the facilitator to coordinate these in cooperation with the actors. This phase includes two processes: *identifying the problems and translating the interests to align the whole network.*

According to Berthelsen from ABC Rådgivende Ingeniører, there are fundamental elements where the value of the project is emphasized:

"It's very much about seeing the value of the project. What is it that adds value to this project? It could be something to do with where the building is located. It could be something to do with the people who are going to construct the building. What are their particular areas of focus? What do they want to focus on in terms of sustainability?"

Once the actors have defined these elements in cooperation with the facilitator, the interests will be formed based on the defined framework. And this is where the co-creation and dialogue on solutions will start. Although Fælledby has some visions and goals to be achieved, discussing this with the remaining actors will be relevant, as their contribution and knowledge may differ from the developer's. The result of this can differ. It can create the foundation of an ambitious project or it can create a foundation of a project that only fulfills the necessary requirements to obtain the points within a certification.

Idea generation and dialogue

Idea generation is the process of generating and exchanging ideas between different actors in a building process. It involves bringing forth new concepts, solutions, and perspectives related to the project's objectives and challenges.

Idea generation is an essential phase in the building process, where creativity and innovative solutions can be discussed. By opening up to a wide range of ideas, alternative approaches and methods can be found to improve the project's outcome. During this phase, different actors are involved and allowed to contribute their knowledge, perspectives, and expertise. This creates a more inclusive and collaborative environment where all opinions should be heard and valued. At the same time, it will be an effective way to try to tackle complex challenges. Generating multiple ideas can identify different approaches and opportunities to solve or optimize new approaches in the building process. This could be in terms of helping to find ways to optimize resource use and reduce waste. Exploring different ideas can identify ways to reuse or optimize the efficiency of materials and processes.

To realize the generation of ideas, actors need to have an open dialogue about the challenges and how to solve them. According to Nielsen from GreenDozer, it will be necessary to have an open dialogue about what reused materials can be sourced.

"We have a dialogue about the fact that we cannot promise that we will get all the materials, but we have a deadline to inform them which materials we can procure so that they have time to buy conventional building materials."

This open dialogue will ensure openness about realizing what materials will be needed and the reuse potential. Therefore, an early idea generation and dialogue will be relevant, which would also have strengthened the idea of reusing in the Fælledby case if this had been implemented.

In the Fælledby case, the developer had several meetings with the demolition company Tscherning about the reuse potential of the old hostel. In this phase, Fælledby is in the process of getting an overview of where the reused materials can be sourced from, but at the same time, it would also have been relevant to involve more actors earlier. This could have provided early knowledge on whether the materials were unable to be integrated into buildings or not.

The level of ambition between the different actors was lacking in Fælledby regarding material selection and implementation of reused materials. Idea generation and open dialogue will be essential in the process of including reusing materials in the project, as all actors can contribute with knowledge and competencies.

Competence mapping

The phase after idea generation and idea exchange will be competence mapping. Competency mapping is the process of identifying and assessing the individual competencies, skills, and resources of the different actors in a building process. It involves gaining a clear understanding of the actors' strengths and weaknesses.

Competence mapping has different purposes in the building process. The aim is to identify each actor's strengths and expertise. This makes it possible to optimize the use of resources and to allocate tasks and responsibilities based on the competencies of each actor. By knowing each other's competencies, the actors in the building process can work together more effectively. They can capitalize on each other's strengths, delegate tasks accordingly and establish a more coordinated and productive collaboration.

Competence mapping helps clarify each actor's competencies and ensures a more efficient and well-coordinated building process. Optimizing the use of competencies and addressing any gaps or training needs can improve collaboration, reduce risks and achieve better project outcomes.

It was enlighted in the conversations with Fælledby that actors such as JDH-Byg were chosen because of their previous work with reused materials. This was also seen in the early conversation between JDH-Byg and Fælledby, where Hedeager from JDH-Byg mentioned:

"Already when we priced the assignment early on, they actually suggested some measures to see whether reused materials could be included"

Organising and responsibilities

Once the ideas and solutions have been determined for the entire building project, they must be realized. An organization and areas of responsibility are necessary to develop a dynamic and constructive collaboration where roles are distributed. This is formed when actors create project groups with the aim of bidding on a tender. The division of roles and organization will be based on the actors' competencies. The organization will consist of a steering group representing different interests according to the actor. These steering group representatives must ensure that the established framework for the building is observed and followed, as seen on Figure 9.1.

To create a good dialog among the actors and to create trust, the steering group cannot

include all involved parties from the different actors. To ensure that the involved parties within the individual actors are involved as well, project groups are also established to represent the actor. The project team will operate within the defined framework and report on the process.

In organizing the network, actors will work together to create a structure accommodating different perspectives, ambitions, and strengths. They will seek to establish a shared vision and objectives that can bring together their different views and provide a basis for successful cooperation.

It was clearly seen in the conversation between Fælledby and JDH-Byg, from the section prior to this, that the strengths of the specific actors were focused upon to create the strongest collaboration possible.

9.3 Translation processes to ensure more reused materials

This part of the analysis will examine the three steps mapped in Chapter 8. It will take point in the conclusions of how reused materials can be used in a building project. However, mapping solutions to obtain materials is only one part. It is also necessary to look into which actors can have the power to choose reused materials instead of new materials. As described previously, using reused materials requires a more complex process than if it had been business-as-usual.

The project group, which consists of different actors with different tasks, is responsible for creating a submission for the tender created by the developer. Winning the tender gives them the power to decide and control their project and how it should be formed within the tender's frame, and within the frames of the described non-human actors. The project group's internal translation processes are of great importance when discussing reused materials. It is the relations among the actors of the project group that defines whether reused materials will be used or not.

Overgaard Bethelsen describes the importance of a strong connection between the actors in a project group and its influence on the outcome of sustainability:

"It is a shared premise, it is a thesis that we buy into together. We have to succeed, and if one party fails, then the whole team fails."

Even though the project group has a lot of power within its projections, other translation processes outside the project groups influence how it works with reused materials.

The Municipality of Copenhagen can be used as an example of how they use their tenders to influence the bidding consortia directly. An example is:

The consultant must incorporate recycled bricks in the project rather than new bricks if the local plan and other conditions allow it. This means that reused bricks must be chosen instead of new bricks. In addition, it must be a requirement of the project that the bricks are to be laid with lime mortar or other mortar that ensures that the bricks can be separated in the event of subsequent demolition or remodeling

[Københavns Kommune, 2022]

What should also be noted here is that the responsibility of integrating these is for the consultant of the project group, making this actor the facilitator of the project group.

What is meant by indirect influence is that the developer does not directly describe that reused materials from the demolition must be used and integrated. Still, the developer looks positively at integrating the reused materials from the demolition. This method was used in the Fælledby project, where the developer described the following:

"The neighborhood shall focus on resource efficiency. This will happen by presenting innovative solutions for the reuse of building materials and showing examples of how embodied energy can be reduced in the buildings, for instance, by upcycling buildings and using wood."

[Fælledby, 2019]

In this way, the actors are encouraged to integrate reused materials but are not required to do so. This example shows that the requirements described in Fælledby could have been more specific to integrate reused materials, as done in the tender material in the municipality of Copenhagen.

The following sections will take point in the three steps mapped in Chapter 8 and examine how the translation processes change towards a project group on how the reused materials are obtained.

9.3.1 Step 1: Translation processes for demolition of building mass on building site

When a developer buys an area to establish a new urban area, the sole responsibility of handling the building mass lies on the developer. The developers' role is to establish and plan for the new area. The developers role is, therefore, to plan for what to do with the existing buildings. If it is decided that the buildings should be demolished, the developer needs to find a demolisher to do the demolition. Furthermore, the developer's responsibility is to decide whether the demolition should be a selective demolition or a demolition as business-as-usual.

Step one emphasizes the importance of keeping as many of the materials on the building site as possible. This step furthermore emphasizes that it should be prioritized to keep the materials as high as possible in the R-hierarchy, described in Chapter 6.

The responsibility for using building materials already on the construction ground is solely the developers. However, the developer cannot be expected to have the knowledge and competencies to do the demolition or to evaluate what materials have the condition to be reused and included in the urban area plans. It should also be investigated whether there is a possibility that the materials contain toxic substances.

Fælledby faced these challenges when establishing and planning for the new area. The developer had also intended to include the materials from the demolished hostel, so they worked closely with Tscherning, who prepared a list of possible reused materials. Despite the willingness to reuse the materials, they were unfortunately unusable because they contained toxic substances. Therefore, this step was tested in the Fælledby case, but there were not enough materials for the required demand. The risk of toxic substances in the materials can have environmental and economic consequences.

9.3.2 Step 2: Translation processes for nearby demolitions with potential materials

The incorporation of reused materials is the focus of step two. There is a need for a facilitator to ensure that resource mapping happens and to facilitate meetings with the involved actors. In this step, the demolition company and the developer have the natural role of facilitators because they are the ones who have the overview of the project. But first and foremost, it requires that the facilitator realizes the importance of using

reused materials and that it aligns with the facilitator's wishes and vision. Secondly, the facilitator will involve other actors. It will be necessary for the demolition contractor and the developer to get an overview of the materials needed for the new building.

Once the facilitator has formed an overview of the material needs, a project group can be included or achieve cooperation with building owners who intend to demolish their buildings. These demolition projects will help to cover the need for the desired materials. Cooperation between the facilitator and the project group or building owner has been established on the possibility of selective demolition of the building and reuse of the materials in the new building, and this will be formed based on the alignment of expectations created throughout the network chain.

Establishing open and effective communication is essential to achieve aligned expectations between actors in a building project. Through ongoing dialogue, discussions, and workshops, all actors can have the opportunity to express their views, needs, and concerns. This is also where clear and specific objectives should be established and documented so all actors agree on the project framework and success criteria. This responsibility again falls on the facilitator to ensure this common framework.

By the facilitator involving the project groups early in the process and being open to conflict resolution, it can be ensured that different perspectives and interests are taken into account, and idea generation will, therefore be a significant part of the dialogue as well.

The idea is designed to ensure that all actors agree to reuse the materials in building and maximize resource efficiency. When a building is demolished, the demolition process should be selective to preserve the quality of the materials.

A competence mapping exercise must be carried out if actors delegate tasks. The demolition company has knowledge and experience with selective demolition, which must be coordinated with the developer.

The challenge in realizing step 2 will be that the facilitator cannot ensure enough reused materials are available to meet the project's demands. Then there is also a logistical problem of collecting, sorting, and storing these materials efficiently. Fælledby has had challenges storing these materials because it requires space. Secondly, the materials can be damaged by being stored in unfavorable conditions.

9.3.3 Step 3: Translation process for the use of suppliers for reused building materials

Step 3 is different from the prior steps because it is the responsibility of the project groups to buy materials. The project groups operate within the frame of the tender material, the master plan, and the requirements from the non-human actors. However, besides the listed requirements, the project group has lots of influence over what materials they want to use for their projects. On a practical level, it means that they have to have a shared vision of how they want to integrate reused materials and in what quantities, and then they will have to interact with suppliers of reused materials. This interaction differs depending on when in the process the dialog is made and what kind of supplier they interact with.

If there is no clear communication between the project team and the developer, it can lead to a lack of coordination and consistency in using reused materials across different building projects. In the Fælledby case, there can be challenges with the project groups, as many different building sites have different project groups. When the project groups have more influence on the choice of materials and make individual decisions on material selection, a fragmentation of the approach to reuse can occur. Each group may have different preferences, criteria, and standards for material selection, which can lead to a lack of cohesion between the different sites and a dispersion of resources and knowledge.

9.4 Part conclusion

This analysis focuses on the third research question and looks at what it takes to promote reused materials in building. Reused materials can be obtained in different ways. The steps to obtain reused materials have been mapped in Chapter 8 because reused materials are still in the initial phases.

Figure 9.1 shows the network that a building project works within. In this context, it will also be relevant to point out that the actors' ambition levels will be raised as the framework and regulation are clarified and tightened within the project group so they know what frames they are working within. The five phases (figure 9.2) presented in the analysis should be understood as a toolkit for how a building process can occur to promote the use of reused materials in building. At the same time, it can vary how reused materials can be sourced. Implementing the three steps (figure 8.1) in the translation process ensures more sustainable practices in the building and reuse of materials. By

involving different actors, resource efficiency can be increased, and materials can be reused in new buildings. It's essential to establish clear communication, collaboration processes, and shared expectations to successfully reuse building materials.

It must be pointed out that these three steps to promote reuse in building have their challenges, which must be considered during the process. Therefore, promoting reused materials in building can be challenging. These barriers can also vary depending on the building project and the expected vision. But it can also be due to who has the facilitator role, where the reused materials can be sourced, and the logistical challenges of collecting, sorting, and storing the reused materials. All of these factors need to be considered in the planning phase, ensuring coordination and consistency in using reused materials in building.

Recommendations 10

This section presents the thesis recommendations for the promotion of reused materials in buildings. These recommendations will be based on Chapter 9 and the five phases (figure 9.2) that can be used to promote reused materials in buildings.

The recommendations will help building projects increase awareness and knowledge about the use of reused materials. The intention of these recommendations is to provide a project group with the necessary broad framework to be influenced, and influence each other, so that new techniques, knowledge, and reliable new information can inspire and create the necessary confidence to use reused materials.

Recommendations to increase the use of reused materials in building projects

This manual is made by *Thomas Jessen* and *Mohammed H. Albadri* in connection with the master's thesis in Sustainable Cities, Aalborg University, Copenhagen.

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Recommendations to increase the use of reused materials in building projects is a manual developed as a result of the analyses conducted in the thesis, *Sustainable building practices: A research to promote the use of the reused material in buildings*. The thesis focusses on promoting the use of reused materials in construction.

This manual aims to inform the actors within the construction network on how to plan and facilitate a building process using reused materials. This manual acknowledges that actors may have different roles, interests and resources, and therefore the manual will appeal to a wide range of actors in the building sector.

The manual is divided into three sections:

- Align expectations in relation to project plans and tenders
- Sourcing reused building materials
- The journey from idea generation to implementation

The three sections should be seen as broad concepts and be based on what is possible in terms of legislation, documentation and technological development, but also in relation to the individual actors' ambition levels and experiences regarding the use of reused materials.

It is furthermore acknowledged that the use of reused materials is only one solution among many to enhance the level of sustainability within the sector.

Align expectations in relation to project plans and tenders

Aligning expectations within building projects is essential to ensure the integration of reused materials. By including reused materials in the early project plans and tenders can create demand, stimulate the market and promote sustainability in the project.

Actors' responsibilities in relation to project planning and tendering

The roles and responsibilities of the actors must be clarified through specific requirements to the process of sourcing and using reused materials. This can be done by requiring project plans and tenders to include clear requirements and specifications on the use of reused materials. This can include setting a minimum percentage of reused materials to be used in construction or specifying certain materials that must be reused. These requirements create a demand for reused materials and stimulate the market for them.

Therefore, it will be relevant to identify and assess the opportunities of reused materials to be included. This will require the performing of an inventory of available materials and require an assessment of their suitability for reuse. By integrating this process into the project planning and tender process, it will enable the reused materials to become more accessible and prioritized.

Collaboration and involvement of new actors

Collaboration and involvement of other actors than is usually found in building projects can benefit the process and should happen early in the process. This could be by working with Triple or Quadro Helix. A diverse group of actors could help strengthening the project plans and tenders and provide a more innovative view on a project. These new partnerships will bring knowledge and experience that the actors may not necessarily have. At the same time, early integration of these actors will ensure that reused materials can be prioritized from an early stage.

Sourcing reused building materials

It's important to be aware that the availability of reused materials can vary depending on location and local resources. It can help the process by mapping and sourcing local resources, networks and online platforms to find the best suppliers of reused materials for the specific building project. It is furthermore relevant to list what materials that is needed in the specific building project in order to know what materials need to be sourced.

Sourcing reused materials

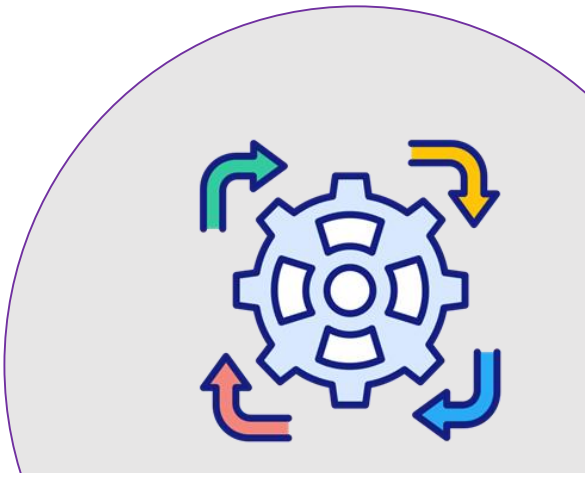
Three options for sourcing reused materials have been mapped in the thesis. *The first method* is to investigate whether there are materials and resources that can be used on the building site. This method is found relevant if demolitions of buildings are planned on the building site. By using materials from a selective demolition from the building site, it can provide benefits within the aspects of the environment, economy and social aspect of passing on the site's history.

An environmental benefit would be a reduction in the transport of materials. There may be a financial incentive, as the developer would own the building to be demolished. It would also provide the new building with history or aesthetics from the former use by using reused materials from previous buildings on the site.

The second method should be considered if the building site does not contain enough reused materials needed for the new building project. This method aims to investigate if the nearby area consists of any demolitions. Therefore, it will be relevant for the actors involved in a new construction project to collaborate with nearby demolition projects in order to secure the needed materials. These new collaborations can establish a sustainable supply chain for reused materials, which can have economic benefits for all parts.

The last method is if the demolitions cannot supply the needed materials the project. In this case it will be relevant to look into if any material banks or other suppliers selling reused materials could provide with the needed materials. The method of engaging with suppliers also opens op for the possibility of selling the materials for other projects to use, if materaials from a demolition is not used. In this way, the materials are utilized in other projects, and thus in this project.

While there can be challenges in sourcing reused materials for construction, there are also many initiatives and organizations working to promote and facilitate access to reused materials. With an increased focus on sustainability and circular economy, it is expected that the market for reused materials will grow and become more accessible over time.



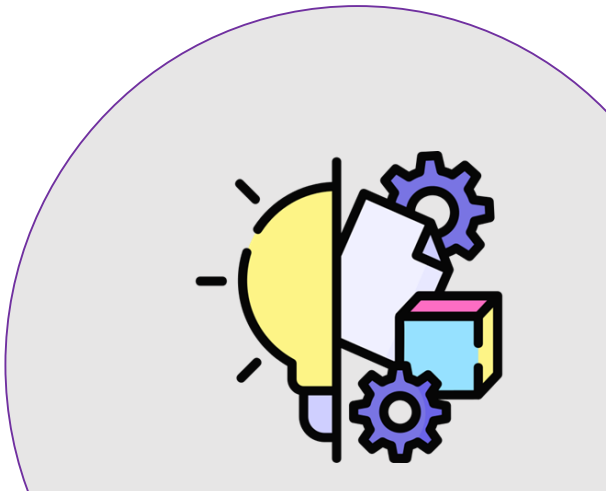
The journey from idea generation to implementation

By following the identified methods for reused materials to be integrated in a building project, it will enable a project team to get closer to finding materials that can be used and can reduce the carbon footprint of a building. The opportunities will increase as the use of reused building materials and the market matures. To stay ahead of future regulatory adjustments, this dialog tool should be included as a standard part of the design phase of a construction project.

From idea generation to implementation

To identify and explore different possibilities for utilizing reused materials in construction, the use of ideation will be relevant. This can lead to the discovery of new applications, techniques and solutions that utilize the potential of reused materials. At the same time, this tool can stimulate creativity and innovation and open for new ways to integrate reused materials into construction projects.

Idea generation will also provide opportunities to explore design considerations regarding the use of reused materials. This can include investigating material properties, sustainability assessments, structural aspects, aesthetic possibilities and compatibility with existing building elements. Idea generation helps to find solutions to any technical challenges and ensure that reused materials can be implemented correctly and efficiently. To strengthen the idea generation process, the involvement of several different actors will be needed. Engaging actors in the ideation process creates a broader understanding and acceptance of the use of reused materials in construction. It also provides an opportunity to gather feedback and perspectives from different professionals, which can help improve implementation and address any concerns or challenges. In order to move from idea generation to implementation, there will be a need to establish a framework that all the actors involved can adhere to. The implementation of reused materials needs to be incorporated into the overall project planning. This includes establishing timelines, resource allocation, workflow and coordination with other contractors and actors.



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Discussion 11

The following section will discuss relevant topics related to the thesis that must be considered when aiming to promote the use of reused materials in buildings. The focus of the thesis was narrow and specific in order to conduct a mapping of specific ways to promote the use of reused materials, taking point from actor collaborations within the project groups and the steering group. Different methods are necessary to achieve as many reused materials in a building as possible. Still, it should also be seen in a more complex interplay of other factors that either create barriers to the reuse of building materials or could be seen as a measure to enable more use of reused materials.

This discussion will focus on the following three aspects. They will provide a perspective on the thesis to better understand how to create better circumstances for collaborations regarding the use of reused materials. These three aspects consist of the following:

1. Regulation, incentives, and financial benefits
2. Education and information
3. Cooperation and network

Based on the interviews and data collection conducted in this thesis, it has been assessed that measures within these three aspects can have a positive impact on the use of reused materials in buildings, as these will be able to create more incentives for the actors.

11.1 Regulation, incentives, and financial benefits

Changing regulations and creating incentives and financial benefits for companies and other actors involved in the building sector can help create an interest in actively using reused building materials. This could be tax breaks, tax incentives, or incentive schemes that reward building projects that choose to implement reused materials [Miljøministeriet, 2014]. By making it more financially attractive to use reused materials, more actors will be inclined to embrace the practices.

Different measures can help create incentives for the actors within the building sector. What should be mentioned before mentioning the measures is that they all can positively impact the use of reused materials. It will give a bigger incentive if more measures are implemented, than just a single of the presented measures. The following section will investigate some of these incentives and discuss how they can have a positive impact.

A building project aims to generate a positive economic outcome. **Tax reductions or tax incentives** for companies using reused materials can enable for willingness to look into ways of including them in projects. This could include reduced VAT for reused materials, therefore making them more cost-effective compared to new materials. Incentives can also include tax benefits or tax credits for companies that demonstrate significant use of reused materials in their projects. Other financing options that support the use of reused materials also exist. This can include special low-interest loan programs or grant schemes that partially cover the costs, thereby becoming competitive with new materials. By reducing the financial barriers and costs of reused materials, companies will be more likely to integrate them into their projects. [Realdania, 2023] The willingness of the individual actor will depend on the economic incentive it would provide them. This concludes that the results from economic incentives will differ depending on how comprehensive the incentive is.

Public procurement should go in front regarding the use of reused materials if requirements on using reused materials were included in building projects. Public authorities can set policies that favor contractors and building companies that use reused materials. This could include extra points or advantages in awarding tenders to companies that demonstrate a high share of reused materials in their offers. As mentioned in the 2, this has been done before with requirements on selective demolitions for governmental demolitions for years. Requiring governmental or municipal building projects to look positive or even require reused materials would create a big incentive for the market to create solutions to use reused materials to win tenders from public developers. It would also provide a big incentive to actors in the building sector to focus on selling the materials from demolitions. This is a realistic proposal because it is already happening in municipalities like the municipality of Copenhagen, and would already be able to be implemented.

Certification schemes and eco-labeling can promote using reused materials in buildings. Certifications and labels can recognize sustainability performance and benefit actors that use reused materials. This can increase demand and create incentives for the

actors to use reused materials. As mentioned by Thygesen from Fælledby it would provide more incentives and greatly impact how buildings are designed if certifications rewarded the use of reused materials more. Thygesen says:

"(...) some things are changing, so you get more bonus or more points for using reused materials. And I think that will also have an impact when we design the buildings (...) It will make it much more attractive for architects, engineers, and developers in general. Right now, there's no incentive at all to try to reuse."

It must, however, be discussed how ambitiously certifications can make their requirements. Certifications, like DGNB, aim to be more ambitious than regulation and follow the regulation as changes occur. The certifications and regulations are therefore cohering in the transition. The level of ambition within the certifications therefore also relies on the regulation to work more directly with reused materials. Regarding regulation, it can also be discussed whether the additions in the BR18 from 2023 can be described as ambitious. In a report made by BUILD, 60 new buildings were assessed regarding their emissions. The median value was found to be 9.5 kg CO_2-eq/m^2 with a variation from 6.5 kg CO_2-eq/m^2 to 14.5 kg CO_2-eq/m^2. The new requirements related to CO_2-eq/m^2 are only for buildings over 1000 m2 with a requirement of 12.5 kg CO_2-eq/m^2. This will be tightened in 2027 to be 8,5 for buildings under 1000 m^2 and 7.5 kg CO_2-eq/m^2 for buildings over 1000 m^2 [Zimmermann et al., 2020]. It can be discussed how significant the impact of these regulations will be on the building sector compared to the existing high standards already present in the sector.

Partnerships and cooperation with material producers can include negotiating favorable prices, incentives, or lucrative deals that make a building more economically attractive with reused materials. If significant economic or regulatory incentives influence the actors, these partnerships and collaborations are essential for the projects to succeed. What has been concluded in the project is that all actors within a project group need to agree on using reused materials before it them being able to succeed. However, if the incentives were strong enough, it would provide a bigger willingness to work other than business as usual. Another way to create a strong incentive within a project group is if developers require reused materials to be incorporated in the masterplan or tender. This will force the bidding project groups to integrate reused materials into the plans.

The challenge in the missing economic incentives is that the business model of using reused

materials can vary depending on various factors, including material availability, geographic location, project scope, quality, and market conditions. It will therefore be necessary to assess the costs and benefits for each specific building project to determine if reused materials are economically beneficial.

Relevant aspects other than incentives must also be developed and worked with to ensure that reused materials will become a norm in the building sector. A significant barrier in documenting that the materials have the needed quality. Therefore, new technologies must be made to document the quality of the products. An example of a technology that is getting developed is the non-destructive test method. Quality documentation can be used with digital product passes. A digital product pass is currently voluntary, but it is conceivable that digital product passes will become more common as the focus on sustainable building and implementation increases and reuse becomes a norm in building processes. The primary purpose of a digital product pass is to contain and secure information about the material's quality and properties. A digital product pass is, therefore, highly relevant when building with new materials to ensure that the documentation for the specific product can be obtained in the building's end-of-life phase in order to reuse parts and materials again. The digital product pass can help create trust in reused materials for the actors, but it requires new ways of testing the materials if the information on the product does not exist.

11.2 Education and information

Various measures can be implemented to promote reused materials through education and information sharing. Education and raising awareness are essential to promote reused materials. This can include workshops, seminars, and guidance programs for all actors. As the focus on sustainable buildings and reused materials increases, actors will focus on design and procurement processes to raise awareness of reused materials and their use. Another aspect is that the transition is fast-paced regarding building practices and will most likely evolve even more in the coming years. Change must happen in order to stay within the planetary boundaries, as concluded by Reduction Roadmap, and the sector must be ready for this transition. To do this, the following measures are found highly relevant to help the sector in its transition.

Educational programs and workshops targeting actors in the building sector will provide

them with knowledge in recognizing and selecting reused materials and educate them on the benefits regarding sustainability and cost when using reused materials. Raising awareness and knowledge of reused materials can inspire greater use and acceptance in the sector. Knowledge needs to be transferred from knowledge institutions to the builder, and the good experiences from the builder must be transferred to the knowledge institutions.

This can be done by establishing platforms or networks facilitating knowledge sharing and best practices about reused materials. Networks like this already exist, such as the Knowledge Institution of Circular Economy in Denmark(VCØB) and others. This can be done through participation in conferences, workshops, and seminars that promote dialogue and exchange of information. Learning from experiences can create knowledge and confidence in using reused materials. However, it is important to realize that not all actors within the building sector have the resources to participate in webinars, read reports, etc. SMEs are an example of this. SMEs are responsible for the biggest part of the building sector. It is claimed that they typically do not even have the resources to conduct LCA, which will be done by a third party instead. This is currently problematic and argues that new knowledge-sharing methods must be made to educate and include SMEs in knowledge sharing as well. [Thomsen et al., 2022]

Another way to secure a more sustainable building sector is by mobilizing the users. If there is a demand for reused materials, there would also be a market that the sector could fulfill. Awareness-raising and information campaigns to highlight the benefits of reused materials could help create this demand. This can include brochures, guides, reports, or videos that clearly and visually demonstrate experience and knowledge on using reused materials in different building projects. This action will raise awareness of reused materials and their positive environmental and economic impact. It is already shown that there is great interest in reused materials when there are good aesthetics and history. [Sørensen et al., 2019]

A powerful tool to enhance the amount of reused materials in the sector is to show that it is possible to make buildings that include reused materials. It could either be a case like Lendager, showing new innovative ways to reuse in buildings, or it could be a regular case showing that reused materials can be built in a project and still make a good business case, like Svanen in Køge. Demonstration projects can be showcases that demonstrate the aesthetic, functional, and environmental benefits of reused materials. It requires frontrunners, and if incentives as described in the previous sections were present, it could

become less risky to do demonstration projects.

By having knowledge of the quality, benefits, and limitations of reused materials, the actors can make informed decisions about when and how to implement them in building projects, which will differ from each project. Knowledge helps identify the most appropriate uses of reused materials and ensures that they fulfill the necessary technical and sustainability requirements.

Furthermore, knowledge about reused materials can be fragmented and scattered across different sources, organizations, and knowledge institutions. Therefore, there must be openness between the actors to ensure no knowledge is lost and as much knowledge is transferred, also to SMEs.

11.3 Cooperation and networking

Various collaboration and networking initiatives can be implemented to promote reused materials in the building sector. Collaboration and networking will help to promote interest in using reused materials. By creating a dynamic, collaborative environment, efforts to increase the use of reused building materials can be strengthened. Ambitious projects, including reused materials, cannot be done by a single actor, so it is essential that the actors collaborate. The following will look into relevant measures to incorporate into the building process.

Actor networks and project groups can bring actors together. However, instead of creating actor groups as in usual projects with an architect, a builder, and consulting engineers, e.g., it could also include others. It could be found relevant to think in the Triple helix model, where interactions between industry, government, and knowledge institutions are emphasized, or even Quadro helix which also includes the users. This would provide a new type of knowledge to the actor group that could enable new innovative ideas to create ambitious, sustainable projects. Also, by thinking in networks and collaboration, it could make room for synergies to be exploited, resources to be shared, and common challenges to be addressed. An example used in this thesis is by mapping the building stock that is planned to be demolished and trade or sharing the materials more directly into nearby building projects or into material banks.

Supplier relations and supply chain optimization involving closer relationships with reused material suppliers are also found important. Before being able to use reused materials

in a building project, materials to use must be accessible. Establishing a trustful and quality-conscious supplier relationship can ensure reliable access to reused used materials while helping to strengthen the market for these materials.

Actors can together create a dynamic collaboration where knowledge, resources, and experiences are shared, but they all need to take action and contribute to the transition.

Trust among each other is important as well. As described in this thesis, none of the actors in a project group can fail to deliver on what was promised without the integration of reused materials fails. That is why competition and conflicts between different actors can become a barrier too. Some actors may be reluctant to share knowledge and resources as they see reused materials as a potential threat to their existing business models. This can result in fragmented and less collaborative networks that limit the ability to achieve synergies and create a shared vision.

Ultimately, actor networks are crucial for establishing a sustainable building culture where reused materials become the norm rather than an ambition. If the actors work together in overcoming the challenges, inspire each other, and share knowledge with each other, it will make a better foundation in order to create the necessary solutions to reach the climate goals.

Conclusion 12

The building sector is undergoing crucial development regarding sustainability and circularity. An increased focus on the carbon footprint and incorporation of circular thinking in the building sector is inevitable, to minimize resource and waste consumption. A driver of this is national and international climate goals. However, existing challenges make it difficult to integrate reused materials in buildings, which is why this thesis has been focusing on developing a framework to make it more accessible to integrate reused materials in building projects. This thesis uses Fælledby as a case study to investigate the practical barriers in more detail. To do this, it has been chosen to investigate and answer the following problem formulation:

What are the major obstacles faced by the building sector in adopting reused materials on a large scale, and what measures can be taken to overcome these barriers and promote the transition towards a sustainable building sector?

To answer the problem formulation, three research questions have been chosen to provide a clear picture of the existing barriers in the building sector. The thesis is based on three analyses that answer the following three research questions.

In order to find research the barriers to including reused materials in the project of Fælledby, it was found relevant to investigate how this actor has chosen to define and focus on sustainability in this project. This gave an understanding of whether the developer of Fælledby was ambitious regarding sustainability in other aspects. If the developer was not ambitious in other aspects of sustainability, it would not have been found realistic that the developer would try to integrate reused materials, and would have changed the focus of the thesis. This defines the first research question, which is as follows:

Which specific factors and considerations influenced Fælledby's design strategy for their sustainable urban area, effectively contributing to reaching their visions regarding sustainability?

It can be concluded, from the first analysis (Chapter 7) of the thesis, that Fælledby is ambitious about their sustainable initiatives planned to be implemented in the project. The initiatives have a wide range of sustainability, addressing social, environmental, and economic aspects. To understand how Fælledby's focus area has been according to sustainable values, it was decided to develop four steps (figure 7.1), which point out which initiatives have been chosen to implement in the area.

Fælledby has been successful with various initiatives to ensure a sustainable urban area. However, Fælledby faced challenges in integrating reused materials in its building projects. Fælledby intended to integrate reused materials from the demolition of a hostel, but challenges emerged along the way that meant this was not realized. The materials contained toxic substances, making them unsuitable for primary buildings. Despite this setback, there was still a willingness among the actors to reach better resource efficiency regarding reused materials. It can be concluded that sustainable initiatives have been an essential factor in the vision and business case of Fælledby. Fælledby believes that future residents will pay more for sustainability elements in their homes.

Since the first research question concludes that the experienced challenges made it difficult to integrate reused materials in Fælledby, it is chosen in analysis two (Chapter 8) to shed light on how to incorporate building materials by looking at building practices by the following research question:

What strategies and critical factors need to be considered when incorporating reused materials into building practices to enhance resource efficiency in the building sector?

It can be concluded from the interviews conducted with actors involved in the Fælledby project that the integration of reused materials should happen with the use of three methods: using existing buildings on the construction site, localizing materials from other demolitions in the surrounding area, and using material banks or companies that sell materials from demolitions and surplus building materials. These methods formed the basis for developing a process to integrate reused materials.

In Fælledby, it was realized that the materials from the existing building stock, a hostel, could not be used directly. This concludes that the focus on sourcing reused materials was narrow. It can also be concluded that to work effectively with reused materials in a building project like Fælledby, it is essential to establish cooperation with the actors and

create an incentive to involve them as well for them to integrate reused materials into their plans. In addition, there needs to be an early mapping of available materials. Both on the construction ground, of nearby demolitions and from suppliers. These steps furthermore require assessments of their quality to ensure the actors that the materials can be used. By integrating these aspects, more reused materials can be utilized, contributing to a more sustainable building industry.

The third analysis (Chapter 9) examines and clarifies the last research question, and works towards establishing a framework that facilitates constructive collaboration between actors in a building project. This will help ensure the integration of reused materials in building projects:

How can specific measures and mechanisms be implemented to establish a transparent process for the utilization of reused materials, ensuring transformable sustainable development in the building sector?

The framework ensures that the actors' roles and ambitions regarding reused materials are aligned, leading to a shared vision within the actor network. To develop this framework, the principles of Actor-Network Theory are used to understand the behavior of actors within a network. Before creating a framework that actors in a building project can use, it is essential to understand the circumstances under which the actors operate within.

Here it can be concluded that leading actors, so-called facilitators, play an essential role in the building process, where an actor acts as a mediator and coordinator between the different actors involved. The facilitator facilitates collaboration and ensures dialog between the actors to achieve constructive and practical solutions. Aligning expectations is crucial to establishing a common understanding and shared ambitions among the actors. It should also be highlighted that different actors can take on the role of facilitator.

Therefore, the problem formulation concludes that there are various barriers in the building sector to the use of reused materials on a large scale. Various measures can be taken to overcome these barriers. Still, an essential factor for it to happen requires a broad collaboration between actors and an understanding that multiple solutions are needed before being able to source and use reused materials. Therefore, reused materials must be included in the early planning phase, and actors need to create a clear framework for how they will be incorporated into the building. It can also be concluded that different elements

are needed to promote the use of reused materials in buildings, including regulation, financial benefits, education, and collaboration across the actor network.

The fast-paced development will continue throughout the years and the actors within the building sector must prepare themselves for tightened regulations, new technologies, and new requirements from developers.

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