TONJE DAMMAN - MASTER THESIS REPORT 2020

Towards a Circular Renovation approach

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Abstract

The difficulty lies, not with the new ideas, but in escaping the old ones.
- John Maynard Keynes

We are in a climate emergency. The UN panel on climate change has given us 10 years before irreversible feedback loops will have catastrophic consequences for millions of people and animals. Rapid and far-reaching reductions of GHG emissions must be made everywhere, and specifically savings that has an immediate effect. The building sector has a vital role to play, responsible for 39% of global carbon emissions. Part of the strategy to reduce the emissions related to buildings is renovations. However, it might result in a short term increase in upfront emissions from building materials. The concept of Circular renovation might pose as a solution, taking into account both the operational and embodied carbon during renovation activities.

This thesis therefore aims to explore how Circular Renovation projects can be adopted in the Danish building industry. And does so by exploring circular economy building principles and renovation strategies. By talking to industry professionals the goal is to gain an understanding of the challenges concerning the use of circular approaches, while an exploratory study of two renovation demo projects in Europe aims to give insight into the challenges for those involved in working with renovation. Findings from the empirical data show how governmental action and demonstration projects have the potential to influence the renovation agenda towards a circular one.

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Introduction

This chapter will give an introduction to the background of the problem and the specific problem area that this thesis focuses on. Further, the related problem formulation and a brief account of the analytical framework will be presented. Finally, the structure of the thesis will be outlined.

1.1 Background

The scientific consensus is clear, we are now in a climate emergency (World Green Building Council, 2019). The 2018 special report (SR15) from the UN International Panel on Climate Change (IPCC), Global Warming of 1.5°C, calls for "rapid and far-reaching and unprecedented changes in all aspects of society" to limit global warming to 1.5°C (IPCC, 2018). Stressing how urgent changes are needed if we are to prevent the dramatically different world we will inhabit if the temperatures rise beyond 2 degree celsius compared to a 1.5°C scenario. According to Priyardarshi Shukla, Co-Chair of IPCC Working Group III, a 1.5°C scenario would "reduce challenging impacts on ecosystems, human health and well-being" while a 2°C increase in temperature would, among other impacts, result in more frequent extreme weather events, sea level rise, near-total extinction of coral reefs, and loss of entire ecosystems ("Summary for Policymakers..", 2018).

SR15 also warns how exceeding climate tipping points triggers a cascade of events that can push the world into an irreversible path of extreme warming (IPCC, 2018). IPCC introduced the idea of tipping points two decades ago, suggesting that the threat of exceeding tipping points was only likely if global warming exceeded 5°C above pre-industrial levels. However, information summarized in the two most recent IPCC Special Reports now suggest that tipping points could be exceeded even between 1 and 2°C of warming (IPCC, 2018; IPCC, 2019). Stating how "abrupt and irreversible changes in the climate system have become a higher risk at lower global average temperatures."

In order to limit global warming to 1.5°C, human-caused GHG emission will have to be cut by 45% from 2010 levels by 2030 and reach 'net zero' around 2050, according to SR15 (IPCC, 2018). Requiring rapid and far-reaching emissions reductions in all sectors, including energy, land, transportation, buildings and industrial systems. However, current pledges made by countries under the 2015 Paris Agreement set us on a path of temperature rise of about 3.2°C this century, according to scientific estimates. These pledges are therefore deemed inadequate and nations are now urged to take immediate actions; having to make unprecedented efforts to cut their levels of GHG in the next decade to avoid climate breakdown. Where the executive director of UNEP, states how we need "quick wins to reduce emissions as much as possible in 2020", stressing the urgency in "catching up on the years in which we procrastinated" (Harvey, 2019).

1.2 Problem Area

In responding to the climate emergency, the building sector has a vital role to play (World Green Building Council, 2019). The built environment is currently responsible for 39% of global carbon emissions (UN, 2017). Decarbonising this sector is therefore seen as one of the most cost effective ways to mitigate the worst effects of climate breakdown. Of this sector contribution, 28% of the emissions comes from operational carbon; emissions related to energy used to operate the building or in the operation of infrastructure. Initiatives to address emissions attributed to operational carbon have already been set in place to accelerate the market towards net zero buildings; energy-efficient buildings powered by renewable energy sources that have net zero emissions. A critical step towards realizing a carbon neutral built environment.

However, emissions are released not only during operational life of a building, but also during the manufacturing, transportation, construction and end of life phases of both buildings and infrastructure. These emissions are commonly referred to as embodied carbon, and account for 11% of the global carbon emissions (Alter, 2019). As the world's population is approaching 10 billion, the global building stock is expected to double in size. The total global consumption of raw materials is therefore also expected to double, resulting in a significant increase in emissions and climate impact of embodied carbon. With estimations showing how half of the entire carbon footprint of new construction between now and 2050 will come from emissions released before the building or infrastructure is used, i.e. from embodied carbon.

Previously overlooked in the building sector, and perceived as insignificant compared to the 28% of emissions from operational carbon, World Green Building Council (WGBC) has now put embodied carbon on the agenda (World Green Building Council, 2019). Referring to IPCC´s warning of the urgency in reducing emissions within the next decade to avoid catastrophic climate breakdown, WGBC stresses how it is "imperative that we rapidly increase actions that achieve early emissions savings in the building lifecycle because these are using up our carbon budget now." Addressing emissions from embodied carbon gives a near-term carbon reduction, what is sometimes referred to as the time value of carbon, which according to WGBC "provides a stark and compelling reason to address embodied carbon in addition to operational carbon and to prioritise upfront emissions from materials and construction urgently". WGBC are therefore issuing an urgent call for action to all stakeholders in the building and construction value chain to increase their efforts in also tackling embodied carbon.

While the concept of energy renovation is an established approach to reduce operational carbon, "increasing utilization of existing assets through renovation and reuse" is presented as a key principle when aiming to reduce embodied carbon (World Green Building Council, 2019). However, these two approaches to reducing operational and embodied carbon are somewhat at odds. The focus on reducing operational energy use has had the unintended consequence of providing the argument for developers to increase demolition in order to build new, energy-efficient buildings (Moncaster, Birgisdottir, Malmqvist, Rasmussen, Wiberg & Soulti, 2018). Ignoring both the embodied carbon and energy costs of the demolition of the existing buildings and the construction of the new buildings, which might result in increasing whole-life energy and carbon emissions (Adlerstein, 2016). Further, the impact of demolishing old buildings, often built robustly and with heavy materials, are often not included in the impact calculations of new buildings. Here, the concept of "Circular Renovation" might be a solution. This is a new approach to renovation which has the potential to reduce both the operational- and embodied carbon. The recent initiative "Drive 0" that aims to promote circular renovation defines the concept as contributing to a circular built environment, and "is based on 100% life cycle renewable energy, and all materials used within the system boundaries are part of infinite technical or biological cycles with lowest quality loss as possible" ("About Drive 0", n.d.). The approach combines renewable energy technologies, which is the focus of energy renovation, with the reuse and recycling of resources and materials, which are approaches attributed to Circular Economy.

1.3 Goal

Renovation is now at the top of the European Commission's agenda for reducing emissions from the building industry. Launching on January 29, 2020 a "renovation wave" initiative which aims to double or triple the renovation rate of buildings in Europe (EU) (Simon, 2019). Stating how a faster renovation rate is necessary to improve energy efficiency and reduce GHG emissions long term. However, without a parallel focus on embodied carbon, the real savings that could be made right now are lost and might result in an increase in short term impacts (Moncaster et al., 2018). Michael H. Nielsen, director of Dansk Byggeri, addresses this challenge, stating how emissions from building materials will have a bigger role to play in future renovation projects in the Danish industry. He calls for more transparent information about the materials, enabling building professionals to choose more sustainable alternatives ("Renovering skal drive den grønne omstilling", 2020).

In light of the European Commission's goal, this thesis aims at exploring how Circular Renovation projects can be adopted in the Danish building industry. This will be done by focusing on the two main pillars of circular renovation: Circular Economy building principles and renovation strategies. More specifically, by talking to industry professionals the goal is to gain an understanding of the challenges concerning the use of circular approaches, while an exploratory study of two renovation demo projects in Europe aims to give insight into the challenges for those involved in working with renovation, and what it takes for them to also consider embodied carbon during the renovation.

1.4 Problem Formulation

Based on the problem area stated above, and the potential circular renovation has for reducing GHG emissions related to both operational- and embodied carbon, this report aims to:

Explore how the Danish building industry can move towards a Circular Renovation approach.

This will be studied by looking at challenges related to "circularity" and "renovation" separately. Further, in order to answer the main problem formulation, a number of sub-questions have been formulated:

- *What are the current challenges for circular economy approaches and renovation in the building industry?*
- *What can be learned from the demonstration projects?*
- *Given the findings from the questions above: how can circular renovation be introduced in Denmark?*

1.4 Addressing the problem

In order to explore how Denmark can move towards a circular renovation approach, empirical data has been collected from interviews from industry professionals working with circularity and renovation. Two exploratory case studies were preferred to provide practical insights on the project processes, drivers, enabling conditions and the perceived benefits and challenges of renovation. Moreover, the cases can be seen as demonstration projects, aiming to upscale the renovation efforts in Europe by doing large-scale, affordable renovation. The theoretical approach of Strategic Niche Management has therefore been selected to look at how these projects can inspire a shift in the European building industry towards circular renovation. While the theoretical concept of "circular economy" will be used to identify the challenges and opportunities that might arise when aiming to introduce sustainable building materials to the industry. The thesis concludes by pointing out issues and steps towards embracing a circular renovation approach in the built environment.

1.5 Thesis structure

The structure of this thesis is as follows: Chapter 2, *Reviewing the literature*, presents the literature that has been reviewed relevant to the topic of circular renovation. Chapter 3, *The Analytical Framework*, will cover the theoretical perspectives used in this study to explore the research question and analyse and interpret the empirical data collected and elaborates on the methodology carried out for this study. Chapter 4, *Ambitions for the future*, presents the current initiatives that are proposed by politicians in Europe and Denmark concerning renovation and circular economy. Chapter 5, *Case Description*, gives a description of the selected case studies. Chapter 6, *Analysis,* presents a detailed analysis of the current lock-in structures challenging circular economy and renovation, and presents the learnings from the selected case studies. Chapter 6, *Discussion*, discusses the findings of the study and gives relevant recommendations based on the results. Moreover, it outlines the limitations of the study. Finally, chapter 7, *Conclusion*, concludes the work that has been done and presents the contribution to theory and practice from this study, along with suggestions for further research.

Reviewing the Literature

This chapter presents the literature reviewed, covering both academic journals and grey literature. Seeing how the concept of circular renovation is currently not visible in academic literature, the literature review will rather focus on renovation and embodied carbon, aiming to cover the literature relevant for Circular Renovation. Further, grey literature has also been reviewed in order to cover a larger body of literature relevant to the topic.

2.1 Academic Literature

This section presents the literature review covering academic journals relevant to the research topic, including how the articles were sampled and analysed. Finally, the emergent themes and methodologies used in the publications are presented.

The literature review takes a meta-review approach that focuses on particular themes (Schweber & Leiringer, 2012), where the aim is to get an overview of recent publications which concern approaches to reduce embodied carbon in relation to buildings and renovation.

2.1.1 Sampling

The sampling of articles are based on the use of databases and keywords, ensuring a broad and possibly representative picture of the range of questions, topics and approaches currently being published. EbscoHost has been used seeing that it offers a large collection of databases, and covers a wide range of subjects. The search was conducted across all EbscoHost databases, covering the keywords "embodied carbon" and "building" in the abstract, yielding 142 scholarly (peer reviewed) journal results, with the publication pattern emerging between 2002 to 2020. Further, a second search included the keywords "embodied carbon" "renovation" or "remodeling" or "retrofit" or "refurbishment" or "retrofitting" or "repair" in the abstract, yielding 21 Scholarly (Peer reviewed) Journals, published between 2006 to 2020. Once all articles were assembled, each abstract was reviewed in order to make sure that the article was genuinely about embodied carbon and buildings. This led to some exclusions from the sampling. The final sample was thus composed of 182 articles in total.

The relatively small number of articles, within a limited time period (2002 to 2020) illustrates how embodied carbon is an emerging research area. Whereas reviewing the publication dates illustrates an increasing interest in the field, with a substantial increase in the recent years. As illustrated in Figure 1, the focus on embodied carbon in buildings started in 2002, only with a small number of articles published. It was not until 2011 that the field got notable attention within scientific research, with a sharp increase in 2018, reaching a total of 55 papers published on the topic of embodied carbon in buildings. Several researchers explain this phenomenon in their papers, stating how the previous focus on operational carbon has improved energy efficiency of buildings, which leads to an increasing importance of embodied carbon. Further, several researchers mention the IPCC report as a motivating factor for looking at embodied carbon, and why it must be taken seriously.

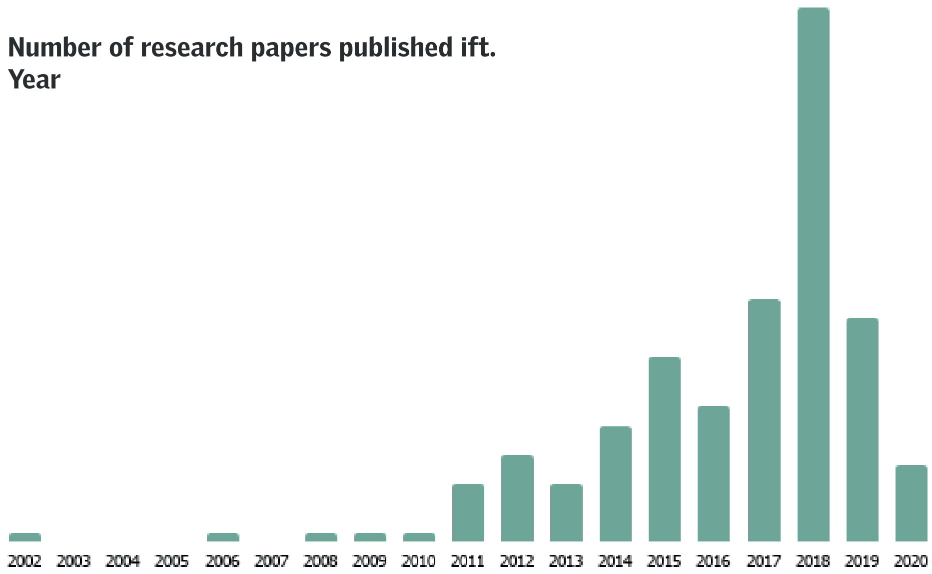


Figure 1: Illustrates the increase in research papers concerning embodied carbon

2.1.2 Data analysis

Reflecting the underlying interest of this literature review; to uncover relevant literature for circular renovation through its emergent themes and methodologies, the data analysis focused on the "research object" and "research approach" deployed in each article. The term 'research object' will be used to refer to what the authors are studying. 'Research approach' will be used to refer to how they are studying it, which is further divided between "positivist" and "interpretivist" methodologies. Here, 'positivist' research generally focuses on the identification of patterns in the relations between variables, taking the natural scientific method as a model. While "interpretivist" research assumes that human behaviour is mediated by meaning and seeks to identify types of processes and their expression in particular contexts (Schweber & Leiringer, 2012).

The data analysis was divided into two stages of coding. Firstly, the abstracts of each article were reviewed to develop an initial coding scheme, including a classification of research objects present in the articles. In the second stage, each article was coded based on a narrow set of research objects in order to get an overview of the most common research objects present. Further, the "research approach" was coded, including the type of method and methodology. The methods included interviews, observations, modelling/simulations and literature review, while the methodology included "positivist", "interpretivist" and N/A (not applicable).

2.1.3 Results

This section will present the research objects and the diffusion of research approaches identified by the literature review.

Research objects

Based on the coding approach stated above, three categories were identified as the most prominent research objects present in the literature. The categories include: renovation, building materials and calculation methods and tools. It is worth mentioning however, that some of the papers overlap between the categories. The data analysis revealed a relatively even distribution of the three research objects identified. The common focus across all research objects has been strategies to reduce embodied carbon in the building industry. The following section will outline the main subjects discussed under each research object.

Renovation
Several researchers recognise the future need to improve the energy performance in buildings through renovation (E.g. Feng, Liyanage, Karunathilake, Sadiq & Hewage, 2020; Brambilla, Salvalai, Imperadori & Sesana, 2018). Further, as the energy performance improves, there is an increasing relevancy of embodied energy (Brambilla et al., 2018). As stated by Brambilla (2018) "balancing the values of the operational and embodied energy is necessary to minimize buildings footprint on the environment". Further, Hasik, Escott, Bates, Carlisle, Faircloth and Bilec (2019) see renovation of the existing building stock as a major strategy to reduce the environmental impacts associated with building construction. They stress the need to repurpose existing structures in order to reduce the amount of new materials that have to be extracted, manufactured, and installed. Further pointing out how there is currently an abundance of research on energy efficiency retrofitting, while there is a lack of studies that investigate the differences in whole-building embodied impacts of major renovations.

A large body of articles concerning renovation compares renovation to new construction (e.g. Langston, Chan & Yung, 2018; Hasik et al., 2019; Ding & Ying, 2019; Feng et al., 2020). Where a study conducted by Hasik et al. (2019) showed 53–75% reduction across 6 different environmental impact categories when the renovation was compared to a new construction scenario. Identifying the reuse of the structural and envelope components having the biggest potential for emission reductions. Similarly, the comparative study of new build and renovation by Feng et al. (2020) showed that around 40% of the emissions came from the manufacturing stage in the new build scenarios, and that emissions generated from new builds are 5-6 times higher than renovation scenarios. Ding and Ying's (2019) research further reveals how it will take approximately 18-41 years to recover the embodied energy invested in the materials for new buildings. Several studies also mention how efficient structural design is a key aspect of reducing the carbon footprint of buildings (e.g. Zhou, Fang, Wang & Zhao, 2014). According to a study in the UK, the structural framework contributes about 20% of the total emissions of the building life cycle (Zhou et al., 2014). However, in the actual design process there is no effective method of calculating the environmental cost for structural engineers, leading them to ignore the environmental effects of the structure at most times.

Although the different studies vary a great deal in terms of the reduction potential, there seems to be a consensus regarding how renovating the existing buildings has less of an environmental impact. As stated by Clegg (2012), "An important implication of regenerative development is for the existing building stock to be treated as a valuable resource of embodied carbon; its prolonged life and avoided demolition are fundamental".

Building materials

A large body of the articles reviewed focused on building materials. Several researchers (e.g. Xiaodong, Fan, Yuanxue, & McCarthy, 2014; Kumanayake, Luo & Paulusz, 2018; Moschetti et al., 2019) stress the need to focus on building materials when aiming to reduce embodied carbon. According to Moschetti et al. (2019) the pathway strategy from zero-energy towards zero emission buildings must focus on the embodied energy and emissions of materials. This view is supported by Zhang & Wang's (2016) findings which indicated that materials manufacturing account for 80–90% of the total building embodied emissions. Where Basbagill, Flager, Lepech and Fischer (2013) state how the decisions made during a building's early design stages critically determine its environmental impact.

Several of the articles aim at reducing the environmental impact of conventional building materials. Examining and comparing the emissions on a variety of building materials, including both specific materials, such as timber (e.g. Rebane, & Reihan, 2016; Wells, 2011) and cement (e.g. Teng & Pan, 2019), as well as building components, such as different roof structures (e.g. Le, Whyte & Biswas, 2019), and windows (Seo, Kim, Yum & McGregor, 2015). Where Teng and Pan (2019) finds that the embodied carbon could be reduced significantly by adopting low carbon concrete such as replacing the ordinary Portland cement with blast furnace slag cement, which results in a 22.8% reduction potential. Multiple researchers also suggest using recycled aggregate concrete as a more sustainable construction solution (Xiao, Wang, Ding & Akbarnezhad, 2018; Banjad Pečur, Štirmer, & Milovanović, 2015; Arrigoni, Pelosato, Dotelli, Beckett, Ciancio & Grillet, 2018). Similarly, Siddique, Chaudhary, Shrivastava and Gupta (2019) propose how the use of ceramic waste from deformed or broken ceramic products can be a substitute for natural fine aggregates in concrete. Findings also show the benefits of using waste materials in a masonry wall system (EcoBrick) (Kyriakidis, Michael, Illampas, Charmpis, & Ioannou, 2019). Several researchers also compare the different materials, providing guidance for the best alternatives (e.g. Kua & Maghimai, 2017; Sazedj, José Morais & Jalali, 2017; Volf, Lupíšek, Bureš, Nováček, Hejtmánek, & Tywoniak, 2018; Robati, McCarthy, & Kokogiannakis, 2016). E.g. Nordby and Shea (2013) explore the embodied carbon in three different exterior walls., while Hawkins, Orr, Ibell and Shepherd (2020) suggest using thin-shell floors as a substitute to flat sab to reduce embodied carbon.

Researchers are also exploring new, innovative solutions to building materials that show potential for reducing emissions, but are not yet adopted as conventional building materials in the industry. Among these new materials are the use of organic materials, including bio-based facade elements (Lupíšek, Nehasilov, Mančík, Železn, Růžička, Fiala, Tywoniak, & Hájek, 2017), straw bale panels (Gross, Maskell, Mander, Walker, Wall & Thomson, 2015), bamboo-structure (Yu, Tan & Ruan, 2011) and insulation panel produced with fibers from Eucalyptus bark (Casas-Ledón, Daza Salgado, Cea, Arteaga-Pérez & Fuentealba, 2020). Alternatives to concrete have also been examined, where hemp concrete has been identified to have a big embodied carbon reduction potential compared to conventional concrete (Jami, Karade & Singh, 2019; Haik, Peled, & Meir, 2020). Further, Teoh, Noor, Ng, and Swee (2018) explore the potential of recycled and reused waste materials to manufacture environmentally friendly roofing tiles. While Brás (2017) identifies how the use of cork in mortars has a big potential in reducing embodied carbon dioxide and increasing energy efficiency.

Insulation materials and methods are also discussed in the literature. Whereas Hammad, Oldfield and Akbarnezhad (2018) discusses the tradeoffs of adding more building material to improve the operational carbon, which can result in a bigger impact of the embodied carbon emissions.

Calculation methods & tools

The final category identified is the research into calculation methods and tools to reduce embodied carbon, either during new build or renovation activities. Here, several researchers are stressing how there is a lack of consistency in calculation methods (e.g. Ekundayo, Babatunde, Ekundayo, Perera & Udeaja, 2019; De Wolf, Yang, Cox, Charlson, Pomponi & Moncaster, 2018), where many develop frameworks (e.g. Gan, Deng, Tse., Chan, Lo & Cheng, 2018; Li, Yang, Zhu & Gao, 2014) or models for better accuracy in calculating embodied carbon (e.g. Victoria, & Perera; 2018; D'Amico & Pomponi, 2018; Pomponi, Moncaster & De Wolf, 2018).

A large portion of these calculation methods are deterministic in the sense that it does not take into account any random variables, which Shipworth (2002) and Shillaber, Mitchell, Dove and Ostrum (2017) critique, pointing out the uncertainties present in the building industry. According to Gantner, Fawcett and Ellingham (2018), "Any attempt to measure the embodied carbon in buildings or building components encounters numerous issues of uncertainty". They further identify insufficient and incomplete information (e.g. lack of data on construction materials, geometry of the building, etc.), inaccuracies in simulation models (e.g. energy simulation software, building utilisation forecasts, etc.) and unpredictability of future events (e.g. changes of use, duration of service life, technological changes, socio-economic changes, etc.) as problems architects, planners and other decision makers struggle with during construction projects, affecting all aspects of design, construction and management. According to Gantner et al. (2018, p.25-26), looking specifically at how to measure or estimate embodied carbon presents the following uncertainties:

1. *Uncertainty about the current embodied carbon of construction materials, components and whole buildings*

Gantner et al. (2018) states how it is difficult to get exact estimates of embodied carbon in building components and construction processes due to lack of record keeping for the specific elements. Instead, construction projects must rely on general estimates of elements found in databases. Gantner does, however, point out how we can expect better record keeping and larger and more complex databases in the future due to the increased focus on embodied carbon, which will reduce uncertainty measures.

2. *Uncertainty about the future embodied carbon of construction materials and components, including technological innovation*

Current environmental issues are pressuring decarbonisation in the building industry, which might, according to Gantner, result in a lower embodied carbon in construction materials and components in the future.

3. *Uncertainty about future events in the service life of built assets, including length of component life, component replacement or substitution, changes of use, end of life*

Gantner states because of the long lifecycle of buildings, buildings are exposed to many more uncertainties compared to short-life manufactured products. Changes in technology, society, regulations, energy sources and changes in use are factors that can compromise analysis that projects the current situation into the future.

4. *Uncertainty about system boundaries and methods of measurement*

The final source of uncertainty mentioned by Gantner is the boundaries to use when measuring embodied carbon. In order to make a valid comparison between two measurements, the same methods of measurement should be applied. Here, standards that define boundaries aim to ensure that same system boundaries are set in all cases, thereby making comparability between measurements possible. However, Gantner also notes how there always is a question about what the appropriate boundaries to use in particular cases are.

Several researchers are calling for standardisation in LCA in order to reduce the uncertainty (e.g. Dixit, Fernández-Solís, Lavy & Culp, 2012; Victoria & Perera, 2018; Chastas, Theodosiou, Kontoleon & Bikas, 2018; Din & Brotas, 2016). Whereas Meneghelli (2018) states how there is a lack of agreement on a standardized embodied carbon calculation method, associated boundaries, and the Embodied Carbon Coefficient (ECC) and databases used for these calculations. Din and Brotas (2016) further identifies a calculation method giving an acceptable accuracy with the least amount of input data required to implement regulatory standardisation within the industry. Stating how designers prefer simple embodied carbon calculation methods. Researchers are also investigating the possibility and advantages of using BIM based tools (e.g. Nizam, Zhang & Tian, 2018; Gan, Deng, Tse, Chan, Lo & Cheng, 2018).

De Wolf, Pomponi and Moncaster (2017) analyse "incentives in the available building codes, standards, and benchmarks, and existing methodologies, tools and datasets to identify the barriers to the effective measurement and reduction of embodied CO2 in practice". Recommending that Governments mandate for improved data quality and "support the development of a transparent and simplified methodology". Similarly, Scott, Roelich, Owen and Barrett (2018) argue that "policies based on material and product demand can support domestic climate change mitigation and reduce the emissions gap".

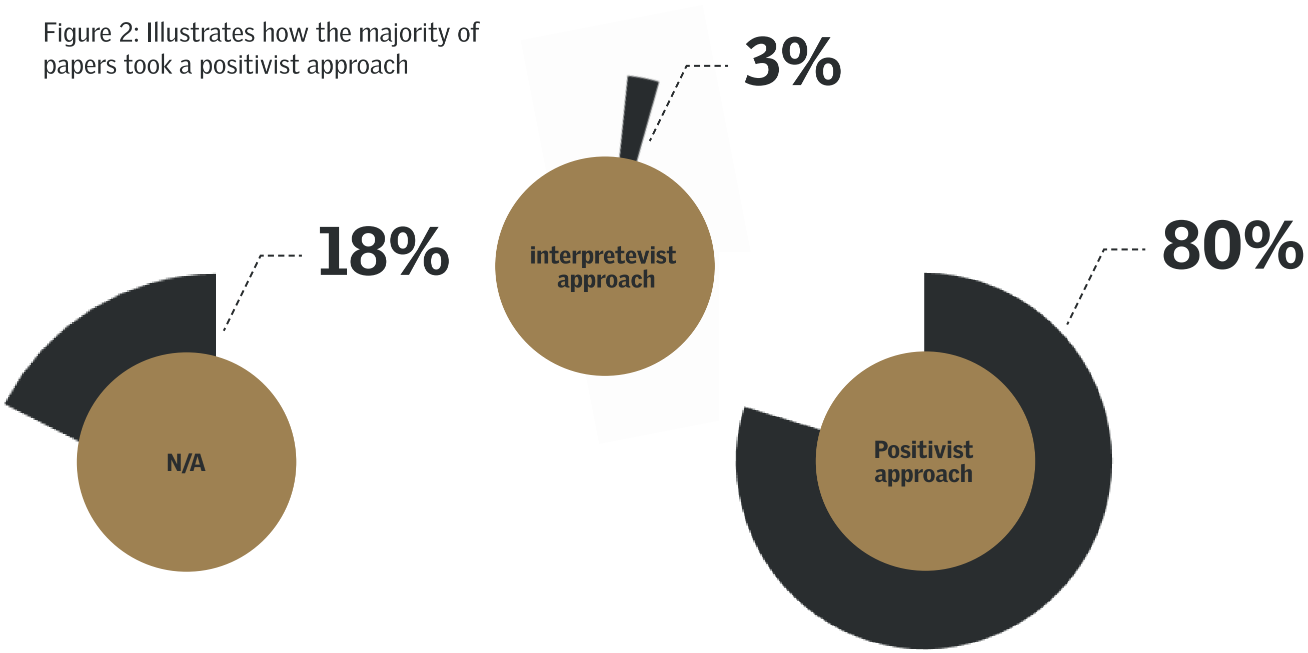
Research approach

Analysing the research approach deployed in the sampled papers uncovers a gap in academic papers taking interpretivist approaches towards renovation methods that also involve embodied carbon and sustainable building materials. Where out of the 182 articles, only 5 were identified as taking an interpretive approach, while the majority, a total of 145 articles, took a positivist approach (Figure 2). Among the research methods identified, modelling/simulations/scenarios were the most prominent method used among the articles, with a total of 110 out of 182 articles (Figure 3). While only 5 papers conducted interviews. This gap might be explained by how embodied carbon is an emerging research area, which implies that it is not a well established practice in the building industry. Therefore, a majority of articles propose how it can be done in theory, but few describe how in practice.

A limitation of papers taking positivist approaches with the objective of generalising the result of the research, is how it risks neglecting the individual understanding and interpretations related to events, phenomena or issues that can reveal truth about reality (Johnson & Onwuegbuzie, 2004). Where the general findings of the research outcome can prove challenging for researchers to apply in particularly local contexts. This limitation is pointed out in one of the articles taking a positivist approach, acknowledging how examination of data at a deeper level "does not equal that achieved in a purely qualitative approach whereby stakeholders are interviewed or surveyed directly" (Wilkinson, 2012). When the aim is to explore how the building industry can move towards a circular renovation approach in the specific context of Europe, it therefore becomes relevant to take a interpretivist approach.

The interpretivist approach recognizes how the knowledge related to human and social sciences cannot be the same as its usage in physical sciences because of how humans interpret their world and then acts based on the interpretation, while the world does not (Hammersley, 2013). According to interpretivist approaches "a single phenomenon can therefore have multiple interpretations rather than a truth determined by a process of

Figure 2: Illustrates how the majority of papers took a positivist approach



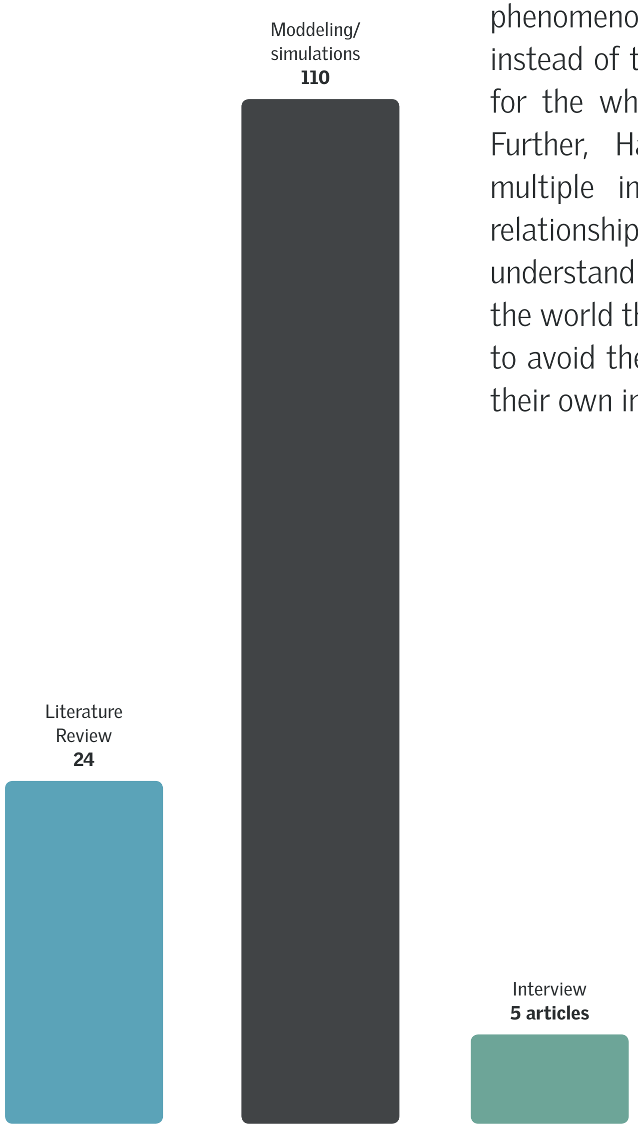


Figure 3: Illustrates the distribution of research methods among the papers reviewed.

measurement". The interpretivist perspective therefore tend to give researchers a deeper understanding of the phenomenon and its complexity in its unique context instead of trying to generalise the base of understanding for the whole population (Creswell, 2007, as cited in). Further, Hammersley (2013) emphasises that since multiple interpretation is developed among humans' relationship, interpretivist researchers should try to understand "the diverse ways of seeing and experiencing the world through different contexts and cultures" and try to avoid the bias in studying the events and people with their own interpretations.

While recognizing the positivist research approaches and the work they support remain critical, Schweber and Leiringer (2012) argue that there is a need for research that examines the processes, understandings, and motivations which produce observed patterns and systems in the development of energy and buildings. Stating how there is a need to widen the scope of construction research and embrace interpretivist approaches to complement those that are already in use. Calling for studies that undertake "problems of how to explain and thus support the uptake, diffusion and use of new technologies, systems and processes".

2.2 Grey Literature

Reviewing the grey literature revealed several approaches within the European building industry that are deemed relevant when focusing on circular renovation, which will be outlined in the following section. Covering approaches within embodied carbon and circular economy.

2.2.1 Embodied Carbon

The recent and increased awareness into the field of embodied carbon has sparked research into the carbon emissions of different materials and projects (World Green Building Council, 2019). Revealing how parts of buildings and infrastructure are often responsible for the majority of embodied carbon emissions. This does, however, vary depending on the type of construction, but some general trends have been identified. Allowing stakeholders to prioritize the embodied carbon reduction efforts where it is most effective.

Building elements

The superstructure elements of a building (e.g. foundations and frames) often represent the biggest contribution to embodied carbon (World Green Building Council, 2019). Both because of the large volumes of materials they use and also because these load-bearing elements often rely on carbon intensive materials such as concrete, steel and asphalt. Further, facades may also contribute significantly to embodied carbon emissions if they utilize large amounts of aluminium and glass, both of which have carbon intensive production processes.

The lifetime of the different elements of a building varies, where some require frequent replacement while others have the potential to outlast the asset and be reused. As illustrated in Figure 4, not only does the superstructure elements contribute to the majority of embodied carbon emissions, they also have the longest lifetime. Embodied carbon reduction efforts are therefore increasingly weighing the merits of retrofitting against those of demolition and new construction. Where a comparative study of the carbon saving value of retrofitting versus demolition and new construction done in relation to the United Nations headquarters makes a strong case for retrofits and renovations. The study found that if the campus were demolished and reconstructed, it would take 35-70 years before the operational carbon savings would offset the initial embodied carbon emissions. Stating how the "bones" of an existing building represent large embodied energy investments, and carry an even larger carbon emissions burden that cannot easily be offset by new construction, even if new construction is assumed to result in more energy-efficient building operations. The study advocates for a better understanding of the true cost of demolition, and highlights the benefits inherent in preserving the superstructure elements of an existing building (Adlerstein, 2016).

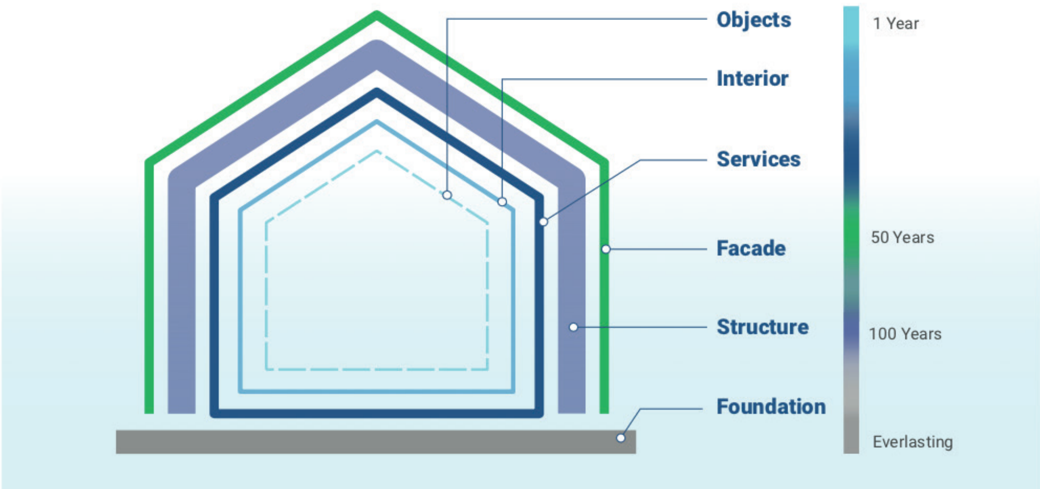


Figure 4: Illustrates the elements of a building and their typical lifetime before replacement is needed (World Green Building Council, 2019)

Building materials

A significant source of embodied carbon often comes from the upfront emissions from materials and products used to construct buildings and infrastructure or installed later during maintenance and renovation (World Green Building Council, 2019). Globally, steel and cement have the greatest environmental impact, whereas steel manufacture is responsible for around 7-9% of global carbon emissions, while cement contributes around 7%. Half of these emissions can be attributed to buildings and construction. The reason for the high emissions from these materials is because they require high temperatures during manufacture, resulting in an energy intensive production. Further, chemical reactions during manufacture also release carbon dioxide directly out in the atmosphere. The emissions from these materials have therefore been considered difficult to reduce (Material Economics, 2019). Similarly, aluminium and glass are also conventional construction materials that use high temperatures during manufacture. Further, much of the energy for industrial heat is currently supplied by fossil fuels, while waste and biofuel are used in some industries and parts of the world. By 2050, the global steel production is projected to increase by 30%, while cement production is expected to increase with 12-23%. These materials will therefore continue to have a crucial role in human society, and the future decarbonisation efforts.

Reducing embodied carbon

The biggest potential for reducing embodied carbon can, according to World GBC, be realised at the earliest stages of a project. Stating how making design changes in order to reduce embodied carbon becomes increasingly more challenging and costly as the project develops further. As seen in figure x, the best opportunity for reducing carbon during project development is to build nothing, followed by building less, building clever and lastly, to build efficiently. Further, World GBC defines four key principles that support the ideas presented in Figure 5.

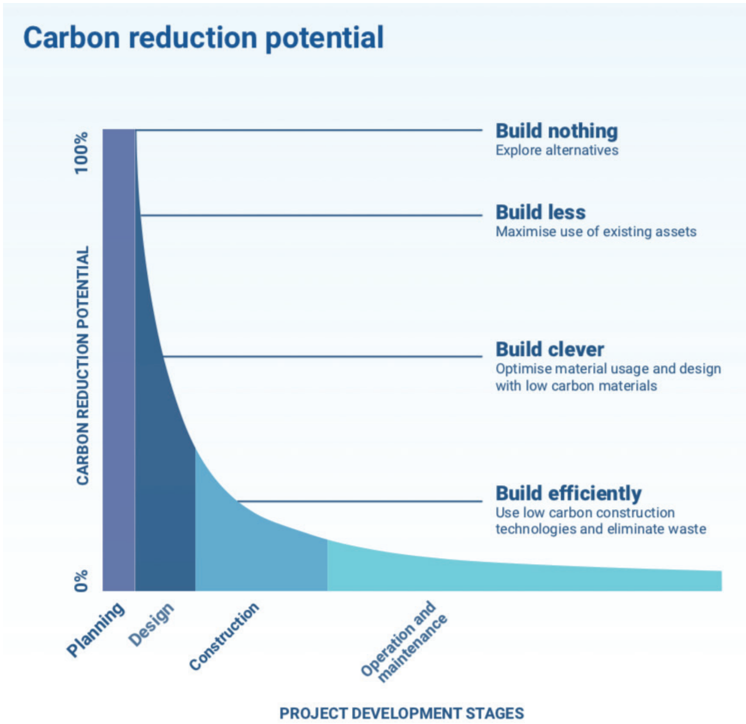


Figure 5: Illustrates the opportunities to reduce embodied carbon during the design process (World Green Building Council, 2019)

1. Prevent

According to World GBC "the best way to reduce embodied carbon is through prevention". They recommend taking embodied carbon emission and reduction strategies into consideration from the very beginning of either a project or for a single product. Suggesting that stakeholders question the need to use materials at all, and rather find alternative strategies for delivering the desired function, "such as increasing utilisation of existing assets through renovation or reuse".

2. Reduce and optimise

The second principle recommends using low carbon design guidance and calculation tools and benchmarks as a whole life approach to help evaluate each design choice related to upfront emission reductions. Focusing on minimising the amount of new material required, prioritizing materials which have low lifecycle impact (e.g low or zero carbon, responsibly sourced), and lastly, choosing construction techniques which are low or zero carbon with maximum efficiency and minimum waste on site.

3. Plan for the future

In order to "build clever", World GBC advises stakeholders to consider future use scenarios and end of life. Mentioning how a focus should be put on maximising the potential for maintenance, repair and renovation and to ensure the flexibility for future adaptation. Further stating how the approaches of design for disassembly and deconstruction can help facilitate future reuse, as well as selecting materials that can be recycled and easily extracted and separated for easy processing.

4. Offset
The last principle is listed as "a last resort", where World GBC proposes offsetting residual embodied carbon emissions either within the project or organizational boundary or through verified offset schemes.

2.2.2 Circular Economy in the building industry

The concept of a "Circular Economy" is for many perceived as a new way of transforming the current linear economy into a regenerative economic system which will exist within the planetary limits (Beaulieu, Durme & Arpin, 2015). Presented as a solution to sustainability and thriveability for both business and planet. The Ellen MacArthur Foundation's definition of the concept states that Circular Economy is restorative and eliminates waste by design through better materials, products and systems design, enabled by innovative business models.

Circular economy is seen as having a huge potential to help reduce emissions in the building sector in Denmark (Ministry of Environment and Food, 2018). However, many approaches relate to new builds, which is not relevant for this study, as it often refers to decisions made early in the design process. This section therefore aims to outline some of the approaches currently being discussed in the grey literature that are relevant in connection to renovation activities. The approaches identified have been categorized into the three subsequent levels that help shape the built environment: "buildings", "components" and "materials" (StopWaste & Arup, 2018).

Buildings
Increased utilization and occupancy
Increasing the utilization of the existing building stock by sharing spaces and a higher occupation rate is proposed as an approach to advance the circular economy in the built environment. Suggesting how a large space can be subdivided in order to house multiple users, or converting portions of single-family homes into accessory dwelling units. Further, the strategy of increasing occupancy rates in residential properties can help address the housing crisis (StopWaste & Arup, 2018).

Retrofits
Retrofitting is a second approach found in the literature that supports the circular economy in the building industry. Suggesting how improving the "resiliency and quality of existing buildings extends their useful lives, generating additional square-footage-years of utility with minimal new material investment" (StopWaste & Arup, 2018). Proposing how deep energy retrofits aiming to minimize and decarbonize the operational energy usage of buildings

can significantly reduce the environmental impact over its lifetime. Similarly, "longer lifetimes for products and structures" are presented as an opportunity for carbon reductions in heavy industries (steel, plastics, ammonia, and cement industries), where "a combination of reuse and remanufacturing can ensure materials and products stay in use much longer, reducing the need for new material" (Material Economics, 2019).

Adaptive reuse

Adaptive reuse is the renovation of an existing, often underutilized, building that changes the buildings programming. Allowing for the building to be made to be a better fit to community needs. The concept offers the same benefits as retrofits, only adding the flexibility to accommodate the community's changing needs. This is exemplified by how a factory that is no longer needed for industrial purposes can be adaptively reused into an office, warehouse or converted into multifamily housing, depending on the need of that specific community (StopWaste & Arup, 2018). Further, the concept of "whole house reuse" is proposed as an approach that relocates the existing houses (e.g. vacant buildings) to other locations that are being redeveloped. This strategy has the value of preserving community character and history, while also adding density in new underdeveloped zones in an architecturally and historically appropriate way.

Components

Deconstruction

Deconstruction is presented as an option in contrast to demolition, where the buildings are disassembled into reusable parts rather than the conventional demolition process where all materials are mixed together into waste, whose value can only be reclaimed through recycling processes. Deconstruction on the other hand, allows greater access to valuable building materials more readily for next life, and thereby reduces labor time and emissions related to the processing of recycled materials (StopWaste & Arup, 2018).

Similarly, the Danish Advisory Board for Circular Economy (2017) and Ministry of Environment and Food (2018) propose selective demolition as an approach to get more value out of existing buildings by putting a focus on reusing construction materials. Stating how fast and unplanned demolitions often result in the construction material being mixed, making it difficult to separate the valuable parts of the waste (Ministry of Environment and Food, 2018). Proposing to conduct an analysis to define criteria for selective demolition covering entire buildings and large-scale renovation projects (Advisory Board for Circular Economy, 2017). By drawing up a demolition plan prior to selective demolition, materials and the content of hazardous substances can be assessed in order to review the recycling/reuse value of the materials and specify how demolition should be performed. Thereby increasing the value of building materials, and improves protection of the environment through waste management.

Reusing products and components

Reusing products and components is proposed by the Ellen MacArthur Foundation as an approach to reduce the GHG emissions and transition towards a circular economy. Stating how the "reuse measures have one purpose and that is to conserve the embodied energy and other valuable resources used to manufacture products, components, and materials" (Ellen MacArthur Foundation, 2019). Also pointing out how keeping products and materials in use helps avoid GHG emissions associated with new material production and end-of-life treatment. Similarly, "longer lifetimes for products and structures" are proposed as a strategy for reducing the emissions of heavy industries, proposing a combination of reuse and remanufacturing to ensure that materials and products stay in use much longer, and thereby reducing the need for new material (Material Economics, 2019). Further, StopWaste & Arup (2018) suggest repurposing salvaged materials in new buildings or retrofit after a building is deconstructed. Whereas GXN Innovation (2019) lists windows and doors, wooden floorboards, bricks and roof tiles, sanitary appliances and electrical switches as building components that have good potential for reuse, and is often possible to buy second hand (GXN Innovation, 2019).

Materials

Recirculating materials

Recirculating materials is a key approach to reduce GHG emissions according to the Ellen MacArthur Foundation (2019), referring to recycling of materials in both the technical and biological cycle. This approach helps avoid extracting new virgin material and end-of-life treatment, such as incineration and landfill. Pointing out how recycling activities require much less energy input than the production of virgin materials. Exemplified in steel recycling, which uses 10–15% of the energy required in the production of primary steel. This approach is in line with the emission reduction strategy "Materials recirculation and substitution", which is proposed as one of the solutions for the heavy industry in Europe to achieve net-zero by 2050 (Material Economics, 2019). Stating how recirculating steel, plastics, and cement can bypass the process emissions of primary production processes, avoid end-of- life emissions, thereby significantly reducing the energy use compared with new production. StopWaste & Arup (2018) also propose maximizing recycling rates of materials at end of life, pointing out how the first priority should always be to reduce the volume of demolished material through deconstruction approaches, whereas the materials that are not possible to salvage should be recycled to the highest degree possible.

Materials efficiency

"Materials efficiency and new business models in major value chains" is proposed as a pathway for the heavy industry to achieve net-zero emissions by 2050 (Material Economics, 2019). Presenting "Less over-specification" as a solutions to achieve materials efficiency, pointing out how construction projects often use 35–45% more steel than is strictly necessary, and how the same structural strength can often be achieved with only 50–60% of the cement used today, both by reducing the cement content of concrete and by using less concrete in structures. Similarly, GXN suggests the approach "keep it simple" - stating how building professionals should aim to reduce the material they use. Pointing out how it not only saves resources, but also saves time and money (GXN Innovation, 2019).

Selecting materials for minimal impact

Selecting materials for minimal impact is proposed as an approach to material sourcing. Where certifications, material passports and EPDs can help guide the user to select the most sustainable materials (GXN Innovation, 2019). Stating how this might make it possible to recycle the materials in the future, as well as creating a healthy indoor environment without toxic emissions. Where choosing materials with material passports or EPDs (Environmental Product Declaration) that contain information about the resource use and environmental impact of the material or product can ensure that sustainable and circular products are selected.

The Analytical Framework

This chapter presents the theoretical perspectives and methodological approaches used in this study to explore the research question and analyse and interpret the empirical data collected. The first section introduces and describes the theoretical framework, while the second section describes the methods used, covering literature review, case study and data collection methods.

3.1 Understanding Transitions

This section presents the theoretical background of the analytical framework of this study. Lock-in Theory and Strategic Niche Management (SNM) explained in the coming subsections are the theory pillars which support the analysis (see Chapter 6).

3.1.1 Lock-in

Implementing innovative solutions in established industries, such as the building industry, often suffer from restrictions by lock-in mechanisms; conceptualised as mechanisms which reinforce a certain pathway of economic, technological, industrial and institutional development and can lead to path-dependency (Unruh, 2002). These lock-in mechanisms tend to give priority to already settled technologies and organizational structures (Unruh, 2000). Positive feedback mechanisms decrease production costs and create additional benefits for users, while the cost and performance of a new technology are more uncertain compared to incumbent technologies (Klitkou, 2015). As a result, incumbent technologies have a distinct advantage over new entrants, not because they are necessarily better, but because they are more widely used and diffused. For this study, it is therefore important to understand and detect the different lock-in mechanisms at play in the building industry in order to design a solution that supports doing things differently and leaving behind the status quo. Where Martin and Sunley (2006) states how analyzing lock-in mechanisms in ongoing transition processes can help develop a clearer understanding of transition processes as being the result of an "interplay of path dependence, path creation and path destruction" (Martin & Sunley, 2006).

Lock-in sources

Unruh (2002) presents the concept of carbon lock-in in order to make self-reinforcing barriers to change visible, and identifies five different lock-in sources: technological, organizational, industrial, societal and institutional (Table 1), which can be helpful when analyzing lock-in mechanisms. These barriers are created by what Unruh terms a techno-institutional complex (TIC), which are the cumulation of the co-evolutionary process among technological infrastructures, organizations, society and governing institutions. These barriers inhibit policy action in a global climate crisis even when cost-neutral or even cost effective, technological alternatives are available.

Lock-in sources	Technological	Organizational	Industrial	Societal	Institutional
Examples	Dominant design, standard technological architectures and components, compat-ibility.	Routines, training, depart-mentalization, custom-er-supplier relations.	Industry standards, tech-nological inter-relatedness, co-specialized assets.	System socialization, adap-tation of preferences and expectations.	Government policy inter-vention, legal frameworks, departments/ministries. '

Unruh (2002)

Table 1: Lock-in sources identified by Unruh (2002)

Strategies to escape lock-in

Unruh (2002) identifies two sources at the core of TIC which can play a role when escaping carbon lock-in; (1) technological and (2) social/institutional. However, Unruh also points out how these two sources are interrelated, where changes in one area can directly influence and cause changes in other areas. Stating how "the escape from carbon lock-in should not be seen as the result of a single change, but rather a series of complex, interconnected changes in multiple variables." (p.321)

Technological change

According to Unruh (2002), increasing returns on both the supply and demand side are large contributors to drive market transitions to new technologies, and suggest the strategy of focusing new technological development in specialized niches. Here, the "technology can be "nursed" into increasing returns driven expansion (Unruh, 1998) and achieve scale dependent improvements that allow them to overtake the dominant design" (Unruh, 2002). However, Unruh also points out how niche approaches might be insufficient to resolve environmental problems if the environmental degradation processes are faster than the niche market evolution. If that is the case, it calls for more direct policy action.

Institutional change

The second strategy for escaping lock-in stresses the importance of institutional change, which requires new government policy. However, for such pressure to arise, institutional priorities have to change, which is often a slow and gradual process. Here, Unruh (2002) identifies the potential of social movements driving policy action on environmental issues. Where change might occur "when a sufficient number of influential members of society recognize or become convinced that continued expansion of a technological system is no longer tolerable". Unruh further suggests how policy makers can establish a critical mass or social consensus for policy action by facilitating the "recognition" of how environmental degradation is caused by fossil fuel technologies through scientific research and public education policies. As a last resort, Unruh sees the possibility that policy makers might have to wait for a focusing event, before implementing new policy frameworks. Stating how "natural systems will have to provide a very clear and alarming signal that climate disruption is accelerating before action is induced".

3.1.2 Strategic Niche Management

Originally, SNM was presented as a method to make the introduction of new technology more successful, however, Kemp, Rip and Schot (2001) argue how SNM "is now part of a broader framework: the build-up of new technological regimes and the possibility of intentionally working toward desired regime change". They see it as a method for constructing a path through the creation and management of protected spaces for promising technologies and as a tool of transition. Similarly, Hoogma, Kemp, Schot and Truffer (2002) states:

"*Ecological restructuring of production and consumption patterns will require not so much a substitution of old technologies by new ones, but radical shifts in technological systems or technological regimes including a change in consumption patterns, user preferences, regulations, and artefacts. It is here that the SNM approach makes a contribution"* (p. 5).

The "protected spaces" provide platforms for new social networks to emerge, such as pilot projects and demonstration projects, where protection may include subsidies or regulatory exemptions. According to Raven, Heiskanen, Lovio, Hodson and Brohmann (2008) "those new emerging networks can negotiate, struggle, learn and experiment in a partially shielded environment provided by, for example, subsidies or strategic investments by powerful actors" (p.3). In these protected spaces, the regime rules (e.g. price/performance ratio, user preferences or regulatory requirements) are not applied broadly, thereby making new practices possible (Raven et al. 2008).

Several SNM scholars have investigated how sustainable innovations can benefit the wider transition process in series of experiments and local projects (Raven & Geels, 2010). Arguing how projects do not emerge in a "vacuum" but they are based on experiences from similar projects (Raven et al. 2008). This was conceptualised by Raven and Geels (2006) as "global niche level", where niche development is progressing at two levels simultaneously: projects in local practices and global niche level. Where a number of local projects might gradually add up to an emerging field (niche) at the global level. The "global niche level" forms the collection of rules (e.g. general organizational models, financing structures, technical standards, shared ideas about what users want, best-practice publications) for specific fields of innovation that has transcended local contexts (Smith & Raven 2012). While the "local practices" refers to experimentation in specific places with local contexts, supported by local networks, and generating lessons accordingly. The relations between the two levels occurs in both directions, i.e. while the local is guided the level above in terms of design specifications, market choices, type of partnership, the global is shaped by local variations of local actors which reinterpret and reinvent them by learning under local circumstances (Raven et al. 2008).

Raven (2005) classifies four types of experiments or local practices that may play a role in creating niches:

- "**Explorative experiments:** their most important role is to help researchers define problems, discover user preferences, explore possibilities for changing the innovation, and learn how future experiments should be set up. They are especially useful at the very early stages of learning, when there are many uncertainties about the potentials and impacts of an innovation;

- **Pilot experiments:** their objective is to raise public and industrial awareness, stimulate debate and open policymaking. Such experiments can test the applicability of innovations in locations with similar conditions to those where the explorative experiments were conducted, and also test the feasibility and acceptability of innovations in new environments;

- **Demonstration experiments:** the main purpose of such experiments is to show potential adopters how they may benefit from the innovations. They may either be the follow-up of explorative or pilot experiments, or be designed specifically to promote the adoption of an innovation.

- **Replication or dissemination experiments:** these experiments aim to disseminate tested methods, techniques or models through replication. They involve full-scale implementation of a technological system" (p.37).

Researchers have also explored "how and under what circumstances is the successful emergence of a technological niche possible?" (Geels & Schot, 2008, p. 540). They identified three processes central to achieving this goal: (1) voicing and shaping of visions and expectations, (2) the building of social networks and (3) the learning process.

Voicing and shaping of visions and expectations

Expectations are according to Geels and Schot (2008), considered crucial for niche development. It provides direction to learning processes, attracts attention and legitimacy for relevant actors (e.g. users, policy makers, entrepreneurs, project managers) to invest time and effort into a new technology that does not have any market value. Raven et al. (2008) gives a specific example of how the use of expectations relates to projects managers:

"Project managers also use expectations strategically and rhetorically when they make promises to attract attention and resources from sponsors and try to persuade potential partners and stakeholders to participate. This indicates that reinterpretation and reinvention requires dedicated work and efforts, because it is likely that in many cases potential partners and stakeholders hold different interpretations and thus articulate different expectations. Successful negotiation of expectations about the future project is thus at the heart of successfully implementing a local project variation of an emerging niche technology" (p. 466).

The building of social networks

The second process central to achieve nice formation is the building of social networks. Often, transition experiments require a new combination of actors from different fields and disciplines in order to "create consistency behind the technology, and to get together and make new social networks emerge" (Raven 2010, p. 64). Suggesting the successful network creation should consist a broad range of relevant stakeholders (including firms, users, policy makers, scientists, and other relevant stakeholders from various domains eg. science, technology, politics, social, and both regime actors and outsiders) where alignment is achieved through regular interactions between actors.

The learning process

The last process identified in SNM is the learning process. Stating how learning is central in the experimental introduction of technologies in society, and enables adjustment of technology and or social embedding to increase chances of successful innovation. According to researchers a good learning process is both broad and reflexive. Broad in the sense that it does not only focus on the technological performance or economic feasibility, but also on alignment between the technical (e.g. design specifications, infrastructure and maintenance networks) and the social (e.g. market and user preferences, regulations and government policy and cultural and symbolic meaning). Further, it is reflexive by not only focusing on the accumulation of facts and data, but also by questioning underlying assumptions such as social values, and willingness to change course if the innovation does not match the assumptions.

Limitations of SNM

SNM researchers have also identified barriers that make the journey from experiments to regime shift more complicated. Geels and Schot (2008) points out the issue of competition, where different projects often compete with others. This might lead to secrecy where actors are not willing to share their learning experiences. Further, they argue how diversity is seen as productive for niche development because it enhances learning and network development. However, too much diversity may restrict developments due to creating uncertainty, fragment resources and preventing the emergence of a stable set of rules. Similarly, Hoogma, Kemp, Schot and Truffer (2002) describes the following limitations associated with SNM:

"*For one thing, we were certainly over-optimistic about the potential of SNM as a tool for transition. ... The positive circles of feedback by which a technology comes into its own and escapes a technological niche, are far weaker than expected and appear to take longer than expected*

(5 years or more). ... The experiments did not make actors change their strategies and invest in the further major development of a technology. ... The experiments were relatively isolated events. It seems difficult for the actors to build bridges. Although more could perhaps have been done and achieved, there are limits to the power of experiments. Only occasionally will an experiment be such a big success that it will influence strategic decisions. Experiments may tip the balance of decision-making, but they will not change the world in a direct, visible way .... Experiments influence the world but do not bring particular futures about. Their influence is more indirect." (Hoogma et al. 2002, p. 195–196)

3.2 Methodology

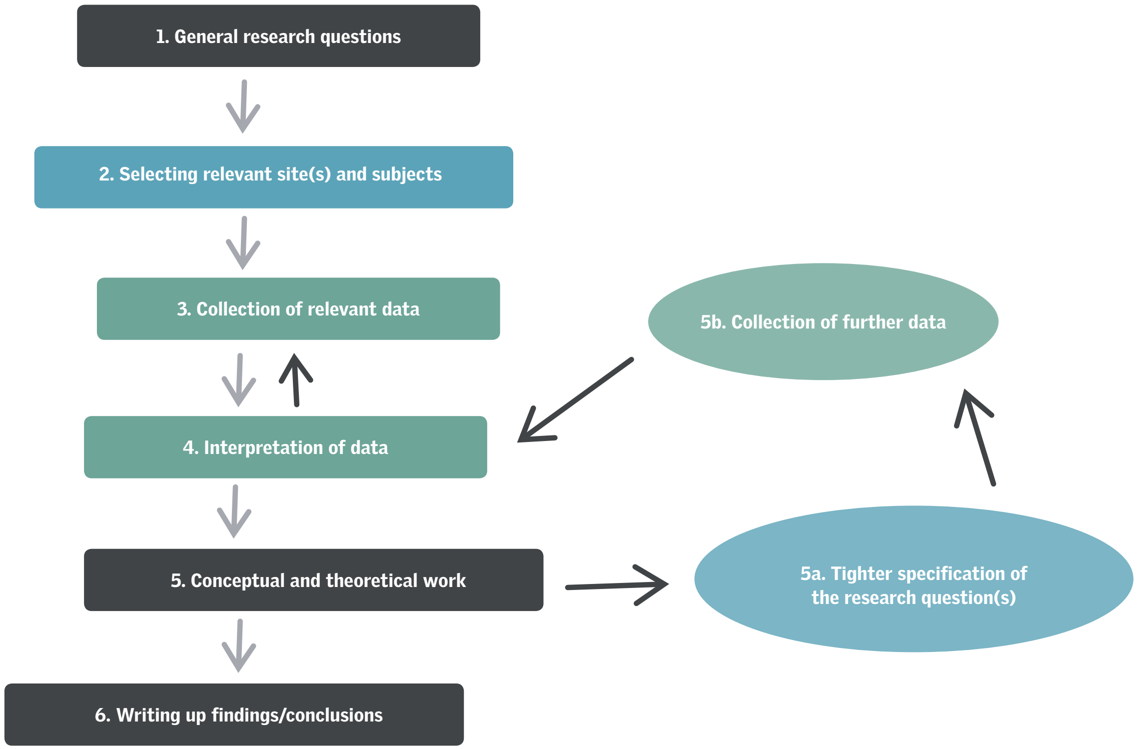


Figure 6: Illustrates the research process of this study

The following section describes the methodological approaches adopted by this research in order to answer the research question.

3.2.1 Research design

Having identified a lack of interpretive approaches within the research (section 2.1.3), and recognizing its importance for understanding specific contexts and human processes, motivates the choice of methodology to explore the research question in this paper. Following, qualitative methods have been selected as an approach. Qualitative studies aim to ensure a more in-depth understanding of the topic as well as a deeper understanding of certain aspects from the respondent's perspective (Bryman, 2008). This study has followed the six main steps, identified by Bryman, that a qualitative research process should follow (Figure 6). As illustrated in Figure 6, the collection and interpretation of new data informs and redevelops the theoretical framework, while narrowing and refining the research question.

3.2.2 Literature review

A literature review was conducted both empirically and theoretically. Firstly, an assessment of the published articles covering embodied carbon and renovation was performed, providing an overview of the emerging themes within the published literature relevant for circular renovation and uncovering potential gaps needed for further research. To cover a broader body of literature, grey literature covering embodied carbon and circular economy approaches relevant to renovation was also reviewed. These publications are produced directly by organizations, e.g. government departments, NGOs and commercial consultants, whereas some common types include reports, discussion papers, briefings, theses and guides (Lawrence, Houghton, Thomas & Weldon, 2014). Finally, the literature review also explored the theoretical concepts of transition theory, including Strategic Niche management and the role of demonstration projects, and lock-in theory.

3.2.3 Case study

A case study approach was chosen because it enables in-depth study of renovation experiments within a specific context, as it is in the case of RenovActive. Whereas case study is mentioned as a key methodology that not only can help interpretivist researchers to describe objects, humans or events, but also deeply understand them in social context to and gain the insider's insights of the research objects (Tuli, 2010). Further, as Flyvbjerg (2006) points out, the closeness of the case study to real-life situations and its level of detail can both aid the researchers learning process as well as provide valuable understanding of human behavior.

RenovActive was selected as a case study based on the expectation of the information content; what Flyvbjerg (2006) categorizes as "information oriented selection". According to Flyvbjerg, a representative case or random sample may not be the most appropriate strategy when the objective is to achieve the greatest possible amount of information on a given problem or phenomenon. "The typical average case is often not the riches in information." While the atypical or extreme cases often reveal more information because they activate more actors and more basic mechanisms in the situation studied. RenovActive is identified as such a case, serving as an example for how to do large-scale climate renovations in an affordable manner.

The approach to renovation taken in the RenovActive case can be seen as a demonstration project, aiming to showcase a new approach to doing renovation which Denmark might learn from when scaling up their renovation activities. Proving as an interesting case study seeing how it is a new approach to renovation that aims to demonstrate how the renovation efforts in Europe can be scaled. Further, a central focus within the project is affordability, which is, according to the Drive 0 circular renovation project, one of the single most important factors when building owners chose to renovate. This study therefore aims to explore the knowledge and experiences gained through the case study in order to shed light on challenges concerning renovation projects, while the learnings can help facilitate implementation of best practices that will aid in a successful scale-up of climate renovations in Denmark.

3.2.4 Data collection

A qualitative research method was employed for the data collection in this study. Interviews were used as the primary data source, supplemented by secondary data.

Interviews

One of the main sources of qualitative data source was provided by semi-structured interviews, seen as a key method within the interpretivist approach. Allowing the "researcher to investigate and prompt things that we cannot observe, researchers can probe an interviewee's thoughts, values, prejudices, perceptions, views, feelings and perspectives" (Wellington & Szczerbinski, 2007). Thus, enabling the researcher to collect valuable data that will provide the researcher with better insights for further action later. When conducting this form of interviews, the interviewer can prepare a list of predefined questions or topics, customized for each interviewee, making it possible to secure knowledge within some predetermined selected topics (Brinkmann & Kvale, 2009). The method also allows for flexibility, where the interviewer does not necessarily have to ask all questions or in any particular order, rather, the questions are open- ended; allowing flexibility for a discussion with the respondent rather than a straightforward question and answer format. This flexibility makes it possible to dig deeper into topics that are interesting or important for the case (Bryman & Bell, 2015), which might lead to the discovery of new and relevant topics that the respondent addresses, previously unknown for the researcher.

The semi-structured interviews applied to this study included both interviews with project members from the case studies and expert interviews with professionals in the building industry. The first interviewee were sampled based on convenience sampling; due to having the central role as project owner of the RenovActive case. Further, the subsequent interviewees were sampled via snowball method; a method that is an efficient and cost-effective way to access people who would otherwise be difficult to find (Polit & Beck, 2009). In this method, the first few samples were asked to identify actors from the RenovActive case relevant for the research topic. The sampling continued until data saturation, reaching a total of 6 interviewees from two RenovActive projects (see table 2). This method provided the opportunity to communicate better with the subsequent samples, as they were acquaintances of the first sample, and the first sample was linked to the researcher. The case study interviews provided information about knowledge, experiences, opinions, and feelings on the RenovActive case study and renovation projects in general. Following, two expert interviews were carried out with building professionals who had specific knowledge that supplemented gaps identified in the literature review.

List of interviewees

RenovActive Interviewees	Expert Interviews
Lone Feifer, Project owner, VELUX	Lone Feifer, Director of Sustainability & Architecture, VELUX
Sabine Pauquay, Public Affairs Manager, VELUX Belgium	Maja Chief Consultant, Lendager TCW
Jonas Lindekens, Lead Architect, ONO Architectuur	
Friedl Decock, Consulting Engineer, Daidalo Speutz	
Klara Bukolska, Senior Architect, VELUX Slovakia	
Petr Král, Marketing manager, VELUX Slovakia	

See QR codes for recodings in Appendix 1.

Table 2: List of interviewees, including expert- and case interviews

Secondary data

Secondary data is data originated from another researcher or a member of an organisation, which originally was not intended for the current research (Bryman & Bell, 2015). It can be information collected by government departments, organisational records and documents, and other data that was originally collected for other research purposes.

In this research, secondary data was collected to provide background information for structuring the interviews as well as supplement the analysis. Information related to the case study was collected from the company's website and internal reports. Further, background information about the building industry was collected, and included e.g. internet disclosure materials, reports, conference presentations, discussion papers, briefings, Phd Theses, books and brochures concerning circular economy approaches, embodied carbon and renovation.

Analysis

The collected data was analyzed in order to extract meaning about the data collected and subsequently answer the research question. Firstly, the interviews were organized and analyzed into common themes using a coding approach, writing down quotes relevant for the research question. E.g. common barriers actors experienced concerning renovation, and learnings they have had during the demonstration project, that could support the upscaling of large renovation projects. Further, the secondary materials were analyzed based on the lock-in sources identified by Unruh (2002) and the case study materials based on SNM theory.

Ambitions for the future

This section will outline policy frameworks and strategies for carbon reductions in the building industry relevant for renovation and circular economy, focusing on Europe and Denmark. Aiming to outline what the future potential is for the introduction of Circular Renovation in Denmark.

4.1 Legislation at EU level

This section presents current policy actions that are put forth in European legislation relevant for CE approaches and renovation.

4.1.1 The European Green Deal

TThe European Green Deal is a set of policy initiatives developed by the European Commission aiming to put Europe on track to reach net-zero global warming emissions by 2050 (Simon, 2019). Stating how the European Green Deal "sets out a detailed vision to make Europe the first climate-neutral continent by 2050, safeguard biodiversity, establish a circular economy and eliminate pollution, while boosting the competitiveness of European industry and ensuring a just transition for the regions and workers affected" (European Parliament, 2020). Ursula von der Leyen, president of the European Commission, stated how the European Green Deal would be Europe's "man on the Moon moment", as it would make Europe the first climate-neutral continent (Simon, 2019).

In order to achieve this goal, a number of initiatives have been proposed. Firstly, the commision is planning to review existing law on its climate merits, while also introducing new legislation on the circular economy, building renovation, biodiversity, farming and innovation. Furthermore, the pricing of carbon emissions is mentioned as a key element to ensure that every person in every sector contributes to the plan. The European commission also proposed a "European Climate Law" that sets a climate-neutrality, legally binding, target for 2050 and establishes a framework for achieving that objective (European Parliament, 2020). A new "European Climate Pact" is also proposed, aiming to bring together regional and local authorities, civil society, industry and schools to agree on commitments to change behaviour. The European Commision also established the "Just Transition Mechanism", which will provide financial support and technical assistance to help people, businesses and regions that are most affected by the move towards the green economy. Helping mobilise at least €100 billion over the period 2021-2027 in the most affected regions (European Parliament, 2020).

Renovation Wave in the building sector

Under the first priority of the 'European Green Deal', the Commission announced its intention to launch a 'renovation wave' initiative in the buildings sector. This is one of the flagship programmes of the Green Deal, with the key objective of "at least double or even triple" the renovation rate of buildings in Europe, which currently stands around 1%. Pointing out how a faster rate of renovation is therefore "necessary to improve energy efficiency and reduce greenhouse gas emissions" ("RENOVATION WAVE INITIATIVE IN THE BUILDINGS SECTOR", 2020). Where funding from the European Investment Bank (EIB), which recently overhauled its energy lending policy, could be an option "to ensure residents don't have to find tens of thousands of euros upfront - which they simply don't have" Frans Timmerman, the Vice President of the European Commission, explained (Simon, 2019). According to the work programme, this initiative should be adopted in the third quarter of 2020. Starting with an assessment of Member States' national long-term renovation strategies. In order to ensure that the relative prices of different energy sources provide the right signal for energy efficiency, the Commission will work on the possibility of including emissions from buildings in the European emissions trading. Moreover, the Construction Products Regulation will be reviewed to ensure that the design of new and renovated buildings are, at all stages, in line with the needs of the circular economy strategy, and lead to increased digitization and climate-proofing of the building stock (European Commision, 2019).

In addition, the Commission also plans on collaborating with stakeholders on a new renovation initiative in 2020. This includes the development of an open platform that aims at bringing together the buildings and construction sector, architects and engineers and local authorities to address the barriers to renovation. The initiative will also include innovative financing schemes under the financial program "InvestEU"; aiming to make "EU funding simpler to access and more effective" ("What's next?", 2020)". Stating how an essential aim of these financing schemes would be to organise renovation efforts into larger blocks to benefit from better financing conditions and economies of scale. The Commission also plans to work on lifting national regulatory barriers that inhibit energy efficiency investments in rented and multi-ownership buildings. Paying particular attention to the renovation of social housing in order to help households who struggle to pay their energy bills (European Commission, 2019). Further, they point out how focus also should be put on renovating schools and hospitals, "as the money saved through building efficiency will be money available to support education and public health"

4.1.2 Circular Economy Action plan

A new "Circular Economy Action Plan, for a cleaner and more competitive Europe" was presented in March 2020, as part of a broader EU industrial strategy. Promoting the sustainable use of resources, especially in resource-intensive sectors with high environmental impact, such as textiles and construction (Simon, 2019). The plan will include a 'sustainable products' policy to support the circular design of all products based on a common methodology and principles, and prioritise reducing and reusing materials before recycling them. Other strategies included in the plan are the possibility to set in place "legal requirements to boost the market of secondary raw materials with mandatory recycled content (for packaging, vehicles, construction materials and batteries)" ("New Circular Economy..", 2020), as well as setting minimum requirements to prevent environmentally harmful products from being placed on the EU markets and strengthening extended producer responsibility (European Commision, 2019).

4.2 The Danish context

This section presents policy actions relevant for CE approaches and renovation in the context of Denmark.

4.2.1 The Danish Climate Act

Denmark has taken a progressive step to reduce their emissions, agreeing on a legally binding national "Climate Act" 6th of December 2019. The Climate Act commits current and future ministers to cut greenhouse gas emissions by 70 percent by 2030 compared to 1990 level, and becoming carbon neutral by 2050 (State of Green, 2019). Each year the Danish Council on Climate Change will develop "Climate Action Plans" that will "outline concrete policies to reduce emissions for all sectors: energy, housing, industry, transportation, energy efficiency, agriculture, and land use change and forestry" in order to achieve this goal ("About the Danish Council..", 2020). Further, 13 climate partnerships among the biggest industries in Denmark have also been established in order to achieve the targets stated in the Climate Act, where each industry is obligated to present reports and steps to reduce the emissions in their sector. Here, the actions proposed from the Danish building sector is especially valuable to look at in relation to the focus of this report.

Among key recommendations from the Danish building sector are energy renovation of the existing building stock and demanding carbon budgets for every building project in the future (Nielsen, Liborius, Weidinger & Lund, 2020). The building sectors vision for 2030 is to reduce the emissions from buildings drastically. Aiming to reduce the energy consumption in existing buildings by 25%. Further, they also predict how buildings will rarely be demolished in the future, stating how it would be too expensive due to the carbon budgets that will be required. Rather, most buildings are renovated in order to save large amounts of waste and emissions.

4.2.2 Recommendations from The Danish Advisory board

In order for the Danish building industry to realise the potential of the circular economy, the government's Advisory Board for the Circular Economy (2017) has issued a wide range of concrete recommendations. The proposed initiatives relevant to this study are listed below.

Funding

The Advisory Board recommends the allocation of funding to the circular economy. The suggestion includes taking advantage of existing capital by the establishment of circular investment fund under private control, or under The Danish Growth Fund, increased lending from The Danish Green Investment Fund and the development of new financial instruments aimed specifically at circular enterprises. Stating how the initiatives "will help boost the financing of circular enterprises through more effective use of existing capital and enhanced attraction of capital to a circular economy". Further, the Advisory Board recommends the allocation of new funding to the circular economy through long-term grants from Innovation Fund Denmark, the Eco-innovation programme (MUDP) and the Market Development Fund.

Collaboration and partnerships

The Advisory Board is promoting collaboration between enterprises and research institutions, which "will ensure that research results in solutions can easily be put into practice, and thus accelerate the transition to the circular economy and contribute to growth, employment and export of the environmental approvals". The Advisory Board also recommends that the Danish government sets up a national forum, called "Circular Denmark", which can "bring together industry, the authorities and academic institutions to collaborate on applicable knowledge across sectors and value chains, to help bring about the circular transition of the Danish business community". Moreover, the Advisory Board proposes that "the government sets up a single point of entry to the public authorities, where circular enterprises and partnerships encountering barriers to the development of new circular solutions and business models can enter into contracts – known as "Green Deals"". These Green Deal contracts aim to commit relevant authorities to collaborate with circular enterprises or partnerships to find solutions that can accelerate the development of circular solutions within existing regulations.

Standardisation and information

To combat the lack of standardisation regarding circular economy, the Advisory Board are recommending that Danish Standards set up and run secretariats for the development of certain international standards designed to promote the circular economy, as well as a secretariat for the development of an international standard for product passports. The Advisory board is also recommending the development of a standardised, digital and freely available building passport and product database for suppliers with digital fact sheets for building products. Explaining how standardised building and product passports will ensure transparent information about the building and products which can be maintained and traced, making it cheaper to both maintain, repair and renovate, and possible to get more value out of materials and products in connection with reuse and recycling. Furthermore, easier and better identification of hazardous substances will promote healthy indoor climates, whilst securing that harmful waste will be landfilled to a greater degree.

They also propose how all new buildings and large-scale renovation projects should be required to deliver information about material content, the amounts of reused, recycled and recyclable materials, and undesirable substances used in the building. Calling for the introduction of a voluntary sustainability classification system in 2020 that forms the basis for a mandatory sustainability classification system from 2025.

In order to make circular products more visible for consumers, and thus easier to select it as an option, the Advisory Board recommends that the government bring further focus on circularity by developing existing official eco-labels, as well as new eco-label criteria for more services. Stating how utilizing eco-labels can give the Danish enterprises better opportunities to market circular solutions while giving consumers a better chance to choose circular products.

Education

Finally, the Advisory Board recommends incorporating circular economy into the entire education system, including primary education, vocational and upper secondary education and relevant higher education courses. Stating how a higher education level on the circular economy will give productivity and wealth gains for society.

Case Description

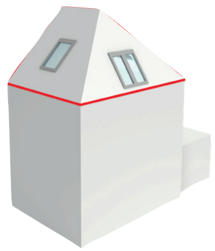
In order to explore what the Danish building industry can learn from the demonstration project in scaling up the renovation efforts, the RenovActive project has been selected as a case study. This chapter will give a description of two RenovActive cases carried out in Belgium and Slovak. The two cases can be seen as demonstration projects, envisioning a future where the building industry values renovation.

5.1 RenovActive Belgium

Figure 7: RenovActive Belgium

RenovActive is a large-scale concept for climate renovations initiated by the VELUX Group. The pilot project began in 2013, aiming to demonstrate how large-scale climate renovations can be realised by renovating the first out of the 385 houses in the social housing complex of Bon Air, Belgium, owned by the social housing company "Le Foyer Anderlechtois" ("Affordable renovation," 2015) (Figure 7). Designed by the architectural firm ONO architectuur, the architectural and technical blueprint for the RenovActive House were developed in close cooperation with experts from Le Foyer Anderlechtois and the VELUX Group. The project would "act as a learning exercise and a demonstration" from the VELUX Group, illustrating affordable and replicable renovation techniques that not only improves the energy efficiency of the dwelling but also focuses on providing a good indoor environment (Slipek, n.a.).

The RenovActive project is intended to serve as an example for future renovations. Acting as a source of inspiration and reflection, and a model which can be reproduced on a large scale for existing buildings. Stating how, by the use of existing techniques and materials, "the RenovActive concept offers an example of how to transform European housing into healthy and sustainable living space, and provides a renovation concept that can be replicated on a large scale" ("VELUX opens RenovActive," 2016). In order to achieve this goal, the project was based on three main criterias; affordable, easy to reproduce and scalable. Firstly, the renovation concept seeks to drive the cost of renovation down, thus eliminating the barrier of high cost when homeowners decide whether to renovate or not. Further, the ability to reproduce the idea was a key part of the project. VELUX therefore selected a widespread type of building in Belgium and Europe, designing a concept for two-façade and three-façade homes. Choices regarding techniques and materials were also made to guarantee optimum efficiency (including energy efficiency), at reasonable costs, so that the concept could be reproduced and scaled in as many homes as possible ("Concept", 2016). In order to support the reproducibility and scalability of the concept, seven cost-effective and replicable renovation solutions were defined. These solutions were created to give existing buildings the ability to perform on the same level as new builds, and can be adapted to the specific project depending on the existing building design and renovation budget. The seven are listed in the figures below:



1

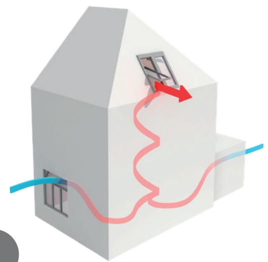
Attic conversion

Growing from within
- The attic is converted into 12,5m² quality living space, using roof windows to ensure plenty of daylight and ventilation. The attic is connected to the home via a newly constructed open stairwell.

2

Increased window area

Daylight treatment
- A balanced distribution of windows ensures a pleasant and bright indoor environment with plenty of daylight in every room and on every floor.



3

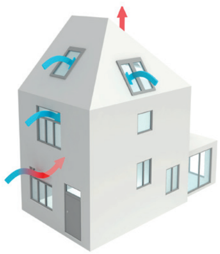
Staircase shaft for daylight & ventilation

Respiratory channel
- An open stairwell guarantees enhanced daylight distribution to all floors and central rooms of the home.
- The stack effect ensures efficient airing through open roof windows and doors.

4

Dynamic sunscreening

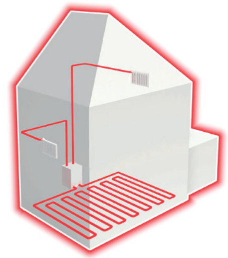
3rd skin
- Dynamic external sun screening reduces solar heating during summer and helps to maintain good indoor thermal comfort.



5

Hybrid ventilation system

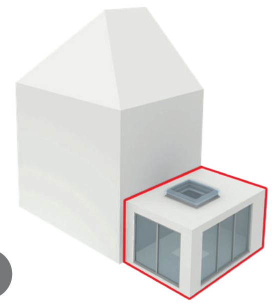
Hybrid respiration
- During the summer, windows and stairwell are used to provide natural cooling in the building, e.g. using the stack effect for efficient air replacement.
- During the winter, mechanical ventilation helps to maintain good indoor air quality and reduce the risk of draughts.



6

Improved thermal envelope

Envelope
- New facade insulation, a new roof construction and new windows all around ensure reduced energy consumption and optimal indoor comfort.
- New floor heating on the ground floor as well as modern radiators on the 1st and 2nd floors provides superb indoor comfort and greater energy efficiency.



7

Building extension

New life space
- The extension measures 15m² and creates additional living space on the ground floor to accommodate a family of five people.

Although the RenovActive project focused on a single renovation, Ono Architectuur developed the all-encompassing concept that proposed an overall refurbishment of the entire neighbourhood in the Bon Air district, which could be implemented by local authorities. Envisioning a community energy system to cover the energy needs of the entire neighbourhood. Further, proposing the production of collective energy via a network powered by wind turbines, solar panels, photovoltaic panels, heat pumps and rainwater collection and treatment system (Slipek, n.a.).

Following a 7 month renovation, the VELUX group officially opened the doors of the RenovActive demo building on 18 May 2016, which were available for visits for a period of one year. Here, housing companies, authorities and professionals from all around Europe visited (see Figure 8). Following the spring of 2017, a family of five moved into the house for two years. During this period, the energy, heat and water consumption, as well as the family's interaction with the house were monitored and analyzed ("VELUX Opens RenovActive," 2016).

Figure 8: Open House event


VELUX
welcome
Budovy a ich dopad na zdravie
x1.7
x3
40
€82 bn
73
75
110 million
#HealthyBuildings
velux.com/health
Zdravie

In order to realise the project, VELUX joined forces with various commercial partners who provided products for the renovation. Including windows, insulation material, plaster panels and mortars from the Saint-Gobain group, ventilation systems from Renson, rainwater collection pump from Grundfos, smart control system from Somfy, roof tiles from Wienerberger, second hand furniture from De Kringwinkel and finally, kitchen solution from Kvik. Further, the architectural design of the house was assigned to ONO Architectuur, while the implementation and monitoring of the renovation was undertaken by the construction company Troubleyn.

Illustrated in the figure below, RenovActive is currently being replicated on 86 houses in the Bon Air district (see Figure 9). Where the concept has been to different needs without losing economic advantage from replication. Illustrating how flexibility is a very important part of the concept.

Figure 9: Illustrates the scaling of RenovActive projects in Belgium. The colored houses are owned by the housing company, whereas the red houses are currently being renovated after RenovActive principles.

5.2 RenovActive Slovakia

Figure 10: RenovActive Slovakia

Slovakia was the second country in the world to undergo a RenovActive renovation, inspired by the pilot project in Belgium. Choosing Slovakia as the location for the second RenovActive project was not accidental; the current speed of the renovation process in Slovakia is seen as insufficient. Half of the Slovak population live in detached or terrace houses, built by the end of the 1970s (see Figure 10). These buildings are far from meeting present-day criteria concerning energy consumption and indoor environment quality. Where Dagmar Plevačová, General Manager of VELUX Czech Republic, explains how "In Slovakia, there are 950,000 family houses. Only about 37% of them have undergone renovation. Several hundred thousand houses are still waiting for renovation" ("VELUX makes new..", 2019). In most of these cases their inhabitants are also their owners, and the condition of the house and its possible renovation is therefore the responsibility of the owner. The RenovActive project aims to change these statistics by serving as a model example of a solution to how an aging housing stock can be renovated, not only in Slovakia but also in the surrounding countries. Aiming to inspire Slovaks to renovate their house in a financially optimal way, which takes housing quality, environmental impact and operating costs into account.

Figure 11: Widespread building type

Similar to the pilot project in Belgium, the project in Slovakia followed the 7 core principles of a RenovActive project, as well as choosing a widespread building type, the "square house"; found in every Slovak village, to renovate (see Figure 11). Further, they suggested dividing the renovation project into several stages or to renovate gradually, starting with the most necessary principles (e.g. improved thermal envelope or ventilation system). This way, the renovation project could adapt to the financial possibilities of every house owner, making it easier for them to start the renovation project ("7 principles of renovation", n.a). In order to support the renovation process of building owners, the VELUX Group also provides the building owners a free-to-download guide on how to renovate the house and turn it into a healthy and modern housing. Where Petr Král, marketing manager of VELUX for Slovakia, explains how "The biggest problem with renovations is that people don't know where to start. Our goal is to show financially affordable reconstruction options in terms of healthy living in Slovak conditions" ("The RenovActive project..", 2018).

Analysis

When aiming to answer the RQ, the two sub-questions "What are the current challenges for circular economy approaches and renovation in the building industry?" and "What can be learned from the demonstration projects?" have been used to guide the analysis. Further, in order to analyze the empirical material collected, lock-in theory has been used as the foundation for exploring the challenges of circular economy approaches, while SNM theory has been used to explore the learnings from the demonstration project.

6.1 Challenges for CE approaches and renovation

In this section the five sources of lock-in identified by Unruh (2000) (technological, organizational, industrial, societal and institutional) have been used to analyze the different lock-in situations that hinder circular economy approaches and renovation in the Danish building industry. Insights gained from interviews, literature review and secondary materials have been used as the basis for this part of the analysis.

6.1.1 Technological barriers

Habitual thinking

The expert interviewee, Lone, explains how the building sector is locked into habitual thinking, stating how "everybody in the building industry does what they did yesterday, that is what they know and is good at." This is exemplified in the material choices, whereas concrete is the most frequently used material, while also being one of the materials with the biggest environmental impact. As pointed out by one of the expert interviewees, Maya, many building professionals chose concrete because it is what they know how to build with, not considering other options. According to Unruh (2000), technologies with inferior designs become locked-in due to increasing returns to scale. Where he mentions learning economies as one of the major classes of increasing returns to scale, stating how they tend to reduce cost and improve performance as specialized skills and knowledge accumulated through production and market experience. The specialized skills and knowledge of building professionals can therefore prevent them from doing things differently, in a more sustainable way.

Expectations

Unruh (2000) explains the concept of adaptive expectations as a result of how the increase in adoption of a technology reduces uncertainty and both users and producers become increasingly confident about quality, performance and permanence. This can act as a big barrier for new and more sustainable building materials, as stated by Maya "many construction firms are afraid of the associated risks with new materials, if they haven't used them before they are not certain that the quality is good enough".

Network dependencies

The development of co-specialized, interdependent and complementary assets can be seen in the building industry, creating lasting barriers for competing technologies and challenging the status quo. What Unruh (2000) defines as "inter-industry network dependencies", exemplified by the automobile industry, which were dependent on multiple supporting technologies and industries in order to create a functional system. Supply industries (e.g. petroleum, glass, rubber) where necessary to build cars, while large quantities of asphalt, concrete and machinery were required in order to construct roads. Similarly, the building industry might be locked-into a network of actors from both the supply and demand side who reinforce the established ways of doing.

6.1.2 Organizational barriers

Lack of skills and competencies

When talking about the organizational barriers, Unruh (2000) points out how the "rules of thumb" or standard operating procedures that emerge in the organizational structure can act as a barrier for new carbon-saving technologies. Where firms tend to focus on- and continue to re-invest in dominant design competencies, which results in constraining the knowledge acquisition of the firm. Similarly, scholars are calling for new knowledge and education in the building industry. Stating how there is a need for new competencies in the field (World Green Building Council, 2019). Where the Advisory Board for Circular Economy (2017) points out how many Danish enterprises "lack the skills, network and capacity to reap the potential benefits of circular product design, production processes and business models". Stating how enterprises' existing networks, culture and know-how are based on linear business partnerships, making it difficult to incorporate circular economy into their core business and strategic management. They also point out how the current education system does not provide the necessary know-how and courses on the circular economy. Resulting in employees in enterprises lacking the skills and know-how to realise the economic and environmental potential of a circular economy.

The expert interviewee, Maya also states how Architects need to develop new skills in order to support the transition towards circular economy. Advocating for architects to take bigger responsibility in the building process; from traditionally being responsible for designing the buildings, Architects should now also make sure that the project is executed as planned. Explaining how architects should be more visible at the building sites, providing guidance for construction firms that lack the knowledge of building with sustainable materials, and how to preserve existing materials. Similarly, the expert interviewee, Lone, expressed how architects need to be educated in renovation, which is currently lacking in the educational program today. Teaching Architects to see value in preservation of existing buildings, and not only how to make "buildings look good".

Bottleneck organizational structures

Organizational structures were identified as challenging many renovation and circular economy approaches. Where the report by Stopwaste & Arup points out how there is a range of actors involved over the building's lifetime (owners, financing entities, planners, architects, builders and developers), which can prove challenging when considering the future outcomes of the building. Often, buildings have a change in ownership, occupancy and use over time, and the building's operation over the long term or its end of life disposal is therefore rarely considered. This can lead to liability with potential cost for municipalities and communities at the end of life of buildings, where large amounts of materials may end up at landfills which can contaminate air, water and soil (StopWaste & Arup, 2018). This in turn might make it difficult to salvage the building materials for future use. Where Maya stated how collaborating with demolition workers was key to salvage waste material before it would end up as landfill.

Maya also argued how the organizational structure should change to support reuse of materials. Rather than spending time and money on purchasing new materials, firms can invest time in developing and refurbishing recycled materials, whilst saving money on the cheaper materials. This would however, require reorganizing the standard operating procedures in the firm, where new competencies and knowledge for handling and improving the qualities of "waste" materials must be acquired. Similarly, Kemp, Schot, and Hoogma (1998) point out how the introduction of new technologies may require adaptation of the existing infrastructure. Exemplified in the context of vehicles, they explain how it requires a high number of vehicles for it to be profitable to create a new infrastructure. Same can be said when it comes to the development of sustainable building materials. Kemp et al. (1998) also asks the critical question: "who is responsible for the development of the new infrastructure and how the initial costs can be covered?". Further pointing out the issue of the so-called sunk investments in the existing infrastructure, where the groups responsible for the current infrastructure form a strong lobby for their own interest.

6.1.3 Industrial barriers

Unfavourable standards and certifications

The current industry standards and certifications might challenge renovation projects and CE approaches. Where Maya pointed out how CE marking was a big challenge when using recycled materials. Stating how many of the recycled materials was unable to fulfill the CE- marking requirements, which in turn would make the buyers question the quality of the materials. While Lone expressed concerns about how obtaining building certifications for renovation projects were more challenging than new builds.

Lack of standardisation

In the Danish building industry, there is currently a lack of standards able to support the circular economy within product design and production processes, remanufacture, reuse and waste management (Advisory Board for Circular Economy, 2017). These standards are vital to create confidence in content, traceability, quality and price of the recycled raw materials. Similarly, the climate partnerships point out how lack of standardisation and knowledge is a key barrier for increasing the potential of circular economy in reducing emissions (Klimapartnerskaber, 2019).. Where this lack of information regarding the actual composition of materials and hazardous substances in buildings and products can, according to the Danish advisory board, make it expensive to maintain and renovate buildings or repair products while they are still in use. Finally, when the building or product reaches the end of its life, the lack of knowledge can hinder recycling and thereby results in loss of considerable value.

The literature review identified how there is a lack of standardised tools and methods to assess sustainability in the building industry. Where a large body of the literature proposed new methodologies to measure embodied carbon. However, Maya explained how they would only use the tools if they could be used quickly to examine and compare the different materials. Stating how time was a limiting factor when it came to implementing new tools as part of their daily work.

6.1.4 Societal barriers

Lack of awareness/knowledge

Lack of awareness was identified as a barrier when looking at the societal source of lock-in. Where a survey conducted by the United Nations' Economic Commission for Europe, indicated how stakeholders had low awareness about the benefits of energy renovation, which is currently the key factor of the investment in- and financing of- energy efficient projects (Rockwool Group, 2018). According to the climate partnership for the Danish building industry a lack of interest for the buildings energy consumption act as a barrier for renovations and smart control systems, stating how "that is why energy efficiency is moving too slowly in Denmark" (Klimapartnerskaber, 2019). Where studies show how many building owners believe they live in an energy efficient building when they don't, and therefore postpone their renovation. Further, studies made by Energistyrelsen show how few people chose to renovate their buildings because of the environment, but rather chose to renovate because of the energy bill (Energistyrelsen, 2016).

Furthermore, lack of clear communication of circular products makes it hard for consumers and enterprises to choose products that support the circular economy. Stressing how "Danish enterprises lack a tool enabling them to clearly communicate on circular products (Advisory Board for Circular Economy, 2017).

6.1.5 Institutional barriers

Regulatory barriers

The Advisory Board for Circular Economy states how enterprises working with the circular economy encounter new and often more regulatory barriers than others. Explaining how that is because circular business models are innovative, and that regulations do not accommodate enterprises working across existing value chains and regulation. This can result in a long wait before a regulation is clarified, which can impede the development of new circular solutions.

Financing

According to the climate partnership for the Danish building industry the biggest focus in the building industry today is to deliver at the lowest price possible, because that is the most important factor for the customers. Correspondingly, one of the expert interviewees stated "money is everything in the building industry". Except for a few showcase projects, this demand for low price act as a barrier for climate-friendly solutions, where taking the climate footprint and life cycle of the building into consideration is unusual in the Danish industry today. Furthermore, the Danish Advisory Board stress how there are a number of problems facing circular enterprises when looking for financing. Stating how this might be due to how some circular enterprises have a technical approach rather than a commercial one, and that the use of some circular business models can lead to a relatively strong balance sheet but low liquidity, and that there can be greater uncertainty and limited experience in the financial world when it comes to financing and investing in circular initiatives and enterprises.

The monetary system also acts as a barrier when it comes to energy efficient renovation. Fossil fuel subsidies are keeping the price of energy artificially low for consumers, thereby reducing the potential economic savings of improved energy efficiency (Rockwool Group, 2018). Another key barrier for energy renovation is rent control. Seeing how it limits landlords from increasing the rent following a renovation, even though the energy bill of the tenant is reduced. Thereby reducing the incentive for landlords to carry out renovations aimed at lowering energy consumption including potentially more attractive long-term energy efficient renovations.

6.2 Learnings from the demonstration projects

SNM has been used as the foundation for the analysis of the empirical material collected from the case studies, allowing to identify learnings from the demonstration projects relevant for moving the Danish building industry towards a circular renovation approach. This section relies on data mainly collected from interviews with the project members of RenovActive, as well as secondary materials concerning the case study (e.g. material present on RenovActive website, facebook page, documents and presentations). Taking a case study approach allowed for practical insight into the challenges experienced by various stakeholders, accessing both their expertise and insight into the chosen subject.

6.2.1 Visions and expectations

According to the commercial material found online, the purpose of RenovActive was to illustrate how renovation can be made affordable and easy to reproduce. However, talking to the different project members of both the pilot project in Belgium and the secondary project in Slovakiet identified somewhat different visions. Whereas the vision presented by actors involved in the pilot project focused on healthy indoor climate and affordable renovation, while the project in Slovakiet focused more on the upscaling of renovation projects, aiming to demonstrate how renovation can be done easy and affordable.

Several of the interviewees also stated how the demonstration project was used as a tool to influence regulatory bodies. Whereas the project owner stated that their aim with the project was to influence the Energy Performance of Buildings Directive (EPBD) to include the health factor, which was previously not present in the legislative framework. This attempt was successful, with the new and updated EPBD also taking indoor air quality into consideration. Sabine, the project manager, further pointed out how the RenovActive project challenged the passive house standard. This standard requires renovation projects to meet the same standard as new builds, which according to Sabine were impossible. The standard also posed as a barrier for the social housing company and their 87 houses that needed renovation. The RenovActive case demonstrated how difficult it would be to achieve a passive house standard in a renovation, which according to the project manager "was an eye opener for the authorities". Resulting in the Belgian authorities alleviating the requirements for renovations.

The interviewees also experienced difficulties when developing a common vision among the team members. Expressing how the different objectives of the stakeholders made it challenging to define the project, where the goal of some actors were to sell as many products as possible, while others wanted to make the optimal solution for the end-customer.

The use of expectations was an important driver to initiate the RenovActive project and motivate partners to join. Similar to how Raven et al. (2008) exemplify the strategic use of expectations to attract attention and persuade stakeholders to take part in a project, the project manager of RenovActive in Slovakiet also stated how they used the pilot project in Belgium to convince partners to join. Stating how it made it easier to explain to the stakeholders what they were talking about, saying "look at Belgium, they did this great project and we would like to copy it in Slovakia".

6.2.2 Social networks

The building of social networks was central for the successful execution of RenovActive. Whereas the establishment of partnerships in the pilot project provided the necessary resources, e.g. money, people and expertise, for the project to succeed. The open house demonstration of the finished project also facilitated interactions between relevant stakeholders, and as stated by the project manager: "made it possible for us to reach target groups that we previously had difficult reaching", mentioning ministers, architects, specifiers and directors of social housing companies. Explaining how the open house acted as "neutral information", not appearing to sell products, which often would act as a barrier to attract the interest of actors. The open house therefore made it possible for the actors to come and see and get inspired by the concept, possibly creating a network of supporting actors. According to the project owner, the goal of the open house was both to show authorities the importance of a good indoor climate when renovating buildings, while also inspiring housing companies to scale up renovation projects, showing them that it is easy and affordable. Thereby putting future renovation projects in the hands of the housing companies and authorities. The social network of the pilot project was therefore limited to the established partnerships and the subsequent actors it was exhibited to. While the project in Slovakia also expanded beyond these actors. Contrary to the pilot project, which aimed mainly to inspire other actors to adopt the renovation project, Slovakia are also taking the responsibility to scale RenovActive projects in Europe by establishing networks of supporting actors.

Aiming to upscale renovation projects, their strategy is to create a network of specifiers who can adapt the RenovActive concept to specific buildings. These specifiers will be located around the company, making it easy for end-users to find someone who can assist them in their renovation project. As stated by the marketing manager for RenovActive in Slovakia, "it should be easy for the end-users to find a specifier who can help them in their area". Further, they are also planning on establishing a network of construction companies who will have the knowledge of how to carry out the renovation projects, as well as dealers who can provide the necessary products.

A drawback of establishing these partnerships was how they restricted the use of other, more sustainable materials. Where interviewees explained how they were not able to use other material options due to having to use the partners' products. As that was the agreement between the actors involved. Consequently, other, more sustainable options were not even taken into consideration. Choosing only the products that the partners offered. The partnerships might therefore have reduced the amount of embodied carbon savings that could have been possible during the renovation.

6.2.3 Learning process

Learning was, just as it is for SNM, central to the RenovActive project. Where the project owner, Lone, explained how the lack of knowledge concerning how to work with old buildings inspired VELUX to initiate the project. Stating how the challenge for building professionals are not new builds, but the existing building stock. The project was therefore intended as an experiment, aiming to learn from the process. Stating how the project "might fail, but it might also work". Similarly, the project manager explained how the goal of VELUX in doing demonstration projects was to test products in practice, "not just in the lab". Rather than taking the conventional approach of using tools to calculate the expected energy consumption of the building, the project got results from the building used in practice. Stating how "VELUX was a frontrunner" in taking this new approach.

Driven by the underlying goal of RenovActive in scaling up renovation efforts in Europe, led the project to share their learnings with the industry. This was particularly important in Slovakia, where open source materials were shared to inspire more end users to renovate. Sharing a template of renovation drawings for free that a large portion of the buildings could follow aimed at making it easier and cheaper for people to renovate. Only having to spend money on adaptation of the drawings and on construction of the actual renovation.

Following, learnings mentioned by the interviewees relevant to the topic of this study are described below, covering the reflections and challenges that relates to scaling up renovation efforts and circular economy approaches.

1. Questioning underlying assumptions

According to the lead Architect, Jonas, more sustainable building materials could have been used during the RenovActive project in Belgium. Pointing out how lime plaster would have been a better alternative with less environmental impact, but was not used because "it didn't come up". Further reflecting upon "why didn't we question it?", and coming to the conclusion of how the underlying assumptions on how things should be done needs to be questioned and re-examined. Stating how "only then you start changing your habits".

2. Lack of knowledge and expertise

The lack of knowledge and expertise proved as a challenge when scaling up the neighbourhood renovation, and choosing sustainable building materials. Where Jonas explained how the subsequent renovation of the other social houses in the Bon Air district did not achieve what they did in RenovActive. Stating how "a lot of the concepts that needed to be carried out closely was not". This might have been due to how the housing company lacked the expertise to lead the project, and chose to save cost by not hiring an external architect. Further, lack of knowledge was identified in relation to choosing sustainable building materials. Where the engineering consultant, Friedl pointed out how lack of information about the different materials prevented them to calculate its environmental impact.

3. Things need to happen quickly

The project manager explained how the project initially had put in place a complex procedure that aimed at documenting the process. This proved challenging and time consuming, stating how the process needed to be more agile and be able to continuously re-adjust and react quickly to changes. Time constraints also prevented calculating the embodied carbon of building materials. Where the lead Architect stated how they had to use common sense when selecting building materials due to difficulties gaining access to data and it being time consuming. Expressing how they would need easy and efficient tools that fit into the time investment and not slow down the decision process, if they were to calculate the environmental impact of the building materials.

4. Cost guiding the decisions

According to the consulting engineer, cost cutting was the biggest factor when taking decisions in the RenovActive project. Mentioning how the use of carbon budget could have helped guide the decision process to take more environmentally friendly decisions, and ultimately create more sustainable buildings. Further, Klara (senior architect) stated how they were "not able to do more than we had money to". Explaining the challenge of the building company not willing to separate the waste material, leaving it up to the building owner. Where the workers "only do the things they have to do, and they will receive the same salary if they separate the waste or does not".

5. Problems with communication

A challenge mentioned by both the project manager and consulting engineer of RenovActive Belgium was concerning the communication when working in an international group. Stating how not having direct contact to the different people involved in the project was challenging, which were prevented by a hierarchical structure in the VELUX Group. Where Friedl stated how the many questions from different people was the most frustrating thing in the project, "that I never knew where does the question come from and why do they want to know that." Stating how it would be more time efficient to be in direct contact with decision makers in VELUX.

6. Renovation is the future

Several of the interviewees reflected upon the future of renovation, where Jonas believed new build will increasingly become the exception in the future as the environmental issues in the building industry will become more important. Stating how "completely demolishing a building to build something new will just have too large of an environmental impact, so that in the end it will become too expensive. So i think that improving existing buildings will be to a large extent the task of architects in the future. And only when you can prove that building new will have less environmental impact than refurbishing, only then new buildings will replace an existing building." Pointing out how "we need to reflect on what we are actually doing here". Klara also stressed the importance of renovation, stating "we have too many houses which are after their lifetime, and we need to speed up the renovation process. In all of Europe." Pointing out how despite renovation and new build having the same environmental impact, "the load of the old house is still there." Which is why "renovation is crucial for our climatic goals". Klara also called for governmental support in the renovation project, suggesting donation programs or better loans from banks for renovations in order to support end users with more money or reduced taxes.

Discussion

This chapter reflects upon the findings and results presented in the previous chapter in order to explain new understandings and insights about the problem and, ultimately, answer the research question. Future recommendations for advancing the research on Circular Renovation are proposed, and finally, the limitations of the study are discussed.

7.1 Steps towards adopting Circular Renovation in Denmark

This section discusses the findings concerning the challenges for circular economy approaches and learnings from the demonstration projects relevant for the scaling of circular renovation in Denmark.

7.1.1 Lock-in in the Danish building industry

The lock-in situation in the Danish building industry has made it difficult for new ideas to succeed (By- og Boligministeriet and Erhvervsministeriet, 2000). The Danish government (the Ministry of Housing and the Ministry of Trade and Industry) explain how the actors are locked together by how the traditional practices, process technologies, infrastructure, common procedures etc. are shaped towards specific actions, which might have been purposeful once, but no longer are. Where the risk of trying new approaches and innovation is deemed greater than the reward. Resulting in the industry becoming a "quiet lagoon", where there is a tendency towards how the passive actors profit the most.

According to the Ministry this lock-in situation can only be solved if more barriers are removed, thereby making it possible for more actors to drive the change process. Stating how a shift would require action from all actors (e.g. property developer, companies, employees and the public sector) that provides the framework for private actors. Similarly, Pomponi and Moncaster (2016) states how no single mitigation strategy seems able to tackle the problem, and rather suggest that a pluralistic approach is necessary. Where key elements for a quicker transition towards a low carbon built environment includes the use of materials with lower embodied carbon, better design, an increased reuse of embodied carbon intensive materials, and stronger policy drivers.

7.1.2 The role of demonstration projects

RenovActive was an opportunity to show "visions of the future" in how to conduct large-scale renovation. The project resembles how urban experiments are defined, as «purposeful small-scale interventions that test alternative urban futures» (Cashmore, Jensen & Spath, 2018), which are often seen having the potential to restructure governance activities by configuring new ways of thinking about the urban environment. Explaining how conducting such urban experiments, certain narratives that promote some imagined futures above others can be established (Cook, Horne, Potter and Valdez, 2018). Similar to what Gaziulusoy and Ryan (2017) calls visual thinking; creating future glimpses and scenario visualizations, which they see as a «fundamental component of normative scenario development for sustainability transitions».

Demonstration projects can also protect the less established innovation from the lock-in structures that hinder its adoption. Where both the concept of large scale climate renovation and sustainable building materials are new innovations, and not established approaches within the building industry. Therefore, for it to succeed and become the mainstream approach to future renovation projects, it is both important to remove the barriers and support the innovation.

7.1.3 Strategy towards a Circular Renovation approach in Denmark

Education

Firstly, the need to develop new skills and competencies were a common finding across both the reviewed literature and interviews. Placing circular renovation as part of the education system could therefore help advance the scaling of the concept in Denmark. Maya and Lone also suggested how the role and focus of architects should shift, both in order to support CE approaches and focusing on renovation rather than new build. However, this shift would not take place by itself. The educational system should therefore also aim to teach practitioners about CE approaches, not only to new build but also renovation. As identified in the grey literature (section 2.2) approaches could include teaching the value of renovation seeing how it follows the first principle "prevent" of reducing embodied carbon, rather than "plan for the future", which is what is often thought today (e.g. design for disassembly). Further, there should be a focus on reusing or recirculating materials, challenging the linear way of thinking. Where the conventional way of looking at materials should shift to support circular renovation, e.g. reflecting on material efficiency and selecting materials for minimal impact.

Further, the unconscious decisions being made by industry professionals should also be taken into consideration in the educational system, where underlying assumptions and established practices should be questioned and challenged. Demonstration projects also provide the opportunity for developing new, practical skills among the actors involved.

Transparent information

The many actors involved in the building lifetime and lack of information were pointed out as being challenging when considering the buildings end of life. Better transparency not only in producing material passports and EPDs, but also of the entire lifecycle of the building could be a solution to this issue. Seeing how GXN Innovation (2019) are recommending databases with EPDs, I suggest taking a system approach by establishing a database of the entire building lifecycle. Giving industry professionals an overview of the history of the building and the involved actors. Which in turn could support the planning for selective demolition.

The lack of information concerning the quality and hazardous materials also hinder salvaging or recycling and reusing building materials. Manufacturers are therefore encouraged to provide information about their materias, however, this often applies to early in the design stages of developing building materials or a new build in the future. Not taking the renovation activities happening now into consideration. An approach to circular renovation could therefore be the concept of "material mapping", where the existing materials and its qualities are assessed prior to renovation or demolition. Thereby making it easier for building professionals to identify materials and products that can be reused, or salvaged from demolition projects and repurposed in a circular renovation.

Tools

The development of tools supporting CE approaches is mentioned in the literature as an important factor to advance CE approaches in the building industry. A focus should therefore also be on tools that also support Circular renovation. An example could be to develop a tool to support material mapping and reuse of materials and products. However, it is also important to keep in mind those who will use the tools. Where several of the interviewees stated how they needed to be fast and easy to use. The templates from RenovActive is a good example of an "easy to use tool" that helps guide the renovation efforts. Adopting this approach, a circular renovation guide could therefore be presented to assist building owners in the process, defining steps to perform a circular renovation project (e.g. by utilizing the CE approaches identified in section 2.2.2). Further, implementing carbon budgets as a guiding tool also has the potential to help reduce emissions, and hopefully guide the actors to choose more sustainable building materials.

Networks

In an effort to upscale circular renovation projects in Denmark, establishing networks of supporting actors can possibly help speed up the process. Putting in place several initiatives at the same time. Following Ravens principle of how projects are based on experiences from similar projects (Raven et al., 2008), circular renovation projects can build upon the approach of RenovActive Slovakia. This would entail the establishment of a network of supporting actors with the right competences and knowledge to execute circular renovation projects. Further, considering how the vision of RenovActive to renovate the whole neighbourhood was prevented by cost and knowledge, establishing a network of actors having the skills to execute circular renovation in Denmark while also implementing financial support systems could help support large-scale circular renovation projects.

Demonstrate circular renovation
Taking a demonstration approach to circular renovation could prove promising in illustrating how it can be done in practice. Similar to how the RenovActive projects in Slovakia are planning to scale projects in all of Europe, this approach could also be taken with circular renovation, showing end-users and governmental bodies how renovation can- and should be done. Further, findings also indicated how industry professionals were worried about the risk of new and less established solutions, and locked into traditional ways of doing things, not questioning how it could be done in a different way. Where Maya explained how their new, innovative solutions needed to be tested extra carefully compared to other more established products, as well as being cheaper. Demonstration projects can provide a solution to this challenge, by showing actors what is possible, thereby making them trust the solution and having the potential for unlocking current established ways of doing. Thereby alleviating the barrier of adaptive expectations by demonstrating how it is feasible to use sustainable building materials in renovation.

Although the SNM approach has been criticized for not being able to move things, stating how "only occasionally will an experiment be such a big success that it will influence strategic decisions" (Hoogma et al. 2002), the RenovActive demonstration project proved differently. It was able to successfully influence the Energy Performance of Buildings Directive (EPBD), as well as proving to authorities that the passive house standard could not be implemented in renovation projects. Similarly, circular demonstration projects could have the potential to influence or challenge unfavorable regulations and standards in a protected space. Establishing a protective space could help shield circular renovation from network dependencies, as well as protecting the niche by providing financial support, thus removing the money barrier that inhibited making sustainable material choices in the RenovActive case.

Multiple demonstration projects
Moreover, adopting RenovActive Slovakia's approach, I suggest moving beyond single «visualizations», and rather continuously conduct experiments in real life settings, that can «build on each other and gradually reinforce themselves» (Ceschin, 2014). Where, Ceschin stress the need for repeating experiments in different contexts in order to change the dominant regime; «sequences of articulated local experiments can gradually add up to wider changes» and «new practices, culture and institutions, that are initially local, broad and unstable, can become more articulated, specific and stable, and potentially capable of producing effects on a macro scale". Similarly, Koch-Ørvad, Thuesen, Koch and Berker (2019) finds how a lineage of exploratory projects is essential to transforming the ecosystem and thereby supporting the breakthrough of the innovation. Taking this approach might, as Geels and Schot (2008) explain add up to an emerging field at the global level. Thereby changing the rules of renovation,

towards circular renovation. A strategy to introduce circular renovation to Denmark could therefore be to initiate a lineage of demonstration projects, focusing on the most common building types in Denmark.

Policy action

The niche market evolution is, however, a slow moving process, exemplified by how the first Renovactive project took three years to complete. Where Unruh points out how niche approaches might be insufficient to resolve environmental problems if the environmental degradation processes are faster than the niche market evolution, which might very well be the current situation we are in. Seeing we only have 10 years to reduce emissions and not reach the tipping points. In that case, Unruh (2000) calls for more direct policy action, where the institutional priorities have to change.

The many initiatives identified in Chapter 4 might suggest that this change is taking place. However, seeing how regulations were mentioned as a barrier for CE business models (Advisory Board for Circular Economy, 2017) and as a challenge during the renovation project, policy action that supports circular renovation is needed. The plan to review current standardisations and regulations should therefore also be reviewed in light of circular renovation. This could help speed up the adoption of a circular renovation approach. Further, considering how cost cutting was preventing the RenovActive project to choose more sustainable materials that would reduce the embodied carbon emissions, either the initiative to introduce mandatory carbon budget, taxes from the danish government or financial support systems could help with this issue in the future. Following, answering Kemp et al. (1998) question of who should be responsible for the development of new infrastructure and covering initial costs: governments should be the frontrunner. Another option is big companies such as VELUX, however being aware of how they might have underlying, counterproductive goals (such as promoting their products) is important.

COVID-19 as a focusing event?

In order to bring about institutional change, Unruh (2000) sees the possibility that policy makers might have to wait for a focusing event, before implementing new policy frameworks. Stating how "natural systems will have to provide a very clear and alarming signal that climate disruption is accelerating before action is induced". Although Unruh sees the focusing event as triggering positive change, it might also inhibit it. The many policy initiatives currently being suggested in Europe and Denmark illustrate how politicians are moving towards a new priority in climate and how it is being taken seriously. Where the Eurobarometer found in 2019 that Europeans rated climate change as the second most serious problem in the world. But Europe was in a similar situation in 2008, when the European commission president declared how the EU was "taking the lead" on climate change with a plan to "transform Europe into a low-carbon economy" (Rankin & Harvey, 2020). Back then, people were watching An

Inconvenient Truth and quoted Nicholas Stern's landmark report on the cost of climate change. Europe was ready for change. But this climate imperative was forgotten when the stock markets crashed and new problems were on the agenda. We should therefore be prepared for how COVID-19 could very well result in the same fate.

7.2 Limitations

This section reflects upon some of the limitations identified in this study.

7.2.1 Selected Case studies

There are several limitations to this study. Due to time restrictions, only a limited amount of interviews were obtained with interviewees where most of them were employees within VELUX. It can be argued that it could give a limited perspective on the topic. COVID-19 also made it difficult to come in contact with interviewees, where a case study of circular economy approaches were prevented due to the crisis. Further, the RenovActive cases did not take place in Denmark, which was the focus of this study. Experiences from the project team members who were interviewed might therefore have been different that of professionals in Denmark.

7.2.2 Interviewees

In order to get a more holistic overview of the topic, rather than individual perspectives, semi-structured interviews or questionnaire surveys could have been conducted on other professions and key stakeholders such as investors, developers and manufacturers within the building industry, which could have led to identifying different challenges regarding circular economy approaches and renovation. Multiple practitioners with the same background could also have been sampled in order to provide the basis for relevant comparison. Due to the fact that all interview questions were prepared and adapted based on each interviewee, and the next interviewees were often chosen based on results from previous interviews, time did not allow more interviews. Moreover, it often took a long time to get a response from possible interviewees, and sometimes there was no response, which limited the number of perspectives.

Conclusion

The objective of this study has been to "Explore how the Danish building industry can move towards a Circular Renovation approach", which has been done by looking at lock-in structures in the building and evaluating the role of demonstration projects. Several sub-questions have been used to guide the analysis of material, which will list the main findings of this study.

What are the current challenges for circular economy approaches and renovation in the building industry?
Analysing the technological-, organizational-, industrial-, societal- and institutional- barriers for circular economy approaches and renovation helped identify a number of challenges in the Danish building industry. Findings show how building professionals lack the knowledge and tools for CE- and renovation approaches, and are worried about the associated risks with new solutions that have not been tried out before. Further, the current organizational structures, standardisation and regulations does not support initiatives favorable for circular renovation, and can therefore act as a barrier.

What can be learned from the demonstration projects?
The RenovActive demonstration projects illustrated how renovation activities could be scaled up in Europe. Both by providing a protected space from current barriers that exist in the building environment and establishing a network of supporting actors. The demonstration project also made it possible to show "visions of the future", inspiring other actors in the building industry to take the same approach.

Given the findings from the questions above: how can circular renovation be introduced in Denmark?
Based on the challenges identified in the building industry, as well as learnings from the demonstration project, I propose the combination of policy action supporting circular renovation and initiating a series of demonstration projects to show how circular renovation can be done in the Danish building industry. In addition, the educational system should also put a bigger focus on renovation and tools supporting circular renovation. Thereby developing the skills and knowledge of the industry necessary to move towards a circular renovation approach.

8.1 Future Recommendations

Considering how the concept of circular renovation is a new approach to renovation, there needs to be established a consistent definition of what "Circular renovation" is, and how it should be executed. There is currently a lack of information regarding the concept and its advantages, which needs to be explored further, and shared with the building industry. Further, making it clear for industry professionals how to approach a circular renovation project, might make it easier for them to choose a circular renovation approach in the future. Research is also needed on how to introduce the concept to the industry. Not only building professionals, but also building owners. As mentioned previously, tools to support circular renovation can also be an area of future research, which will be elaborated upon in the oral examination of this thesis.

A secret of change is to focus all your energy, not fighting the old, but on building the new.

- Socrates

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Appendix

Appendix 1: Recordings from interviews

Lone Feifer

Klara Bukolska

Jonas Lindekens

Maya Færch (Part 1)

Maya Færch (Part 2)

Friedl Decock

Note. Some interviews have not been included due to privacy and/or not having recorded the conversation.

Appendix 2: Interview questions

Date of interview: 10. March 2020
Name: Lone Feifer
Contact information: lone.feifer@velux.com
Organization name: VELUX
Job title: Director of Sustainability

Short history of RenovActive

How did the project start?

What was your role?

What are the drivers of doing it?

Why renovate and not build new?

What are the benefits by doing it?

How is the lifecycle of the whole building taken into consideration?

How did you design for low maintenance and replacement?

What happens to materials when they are past their best?

How is it made affordable?

Did you have to do any compromises? What?

How is it reproducible?

In what types of homes?

Are you considering different types of buildings?

How is it environmentally sustainable?

Was the main goal to reduce energy consumption during use phase?

What about Embodied carbon (short term emissions)?

What are the barriers for reducing embodied carbon?

Who did you collaborate with? And why did you choose these partners?

What was their roles?

What are the prerequisites for making RenovActive projects?

Do you plan to develop and build other social housing concepts in Europe?

Why has it not been done in Denmark?

Are there any regulatory barriers?

Different conditions in Belgium?

Subsidiaries? Regulations/legislations?

What were the barriers/challenges?

What have you learned from this project?

How are you working to communicate this project out to the building industry?

Contacts?

Date of interview: 18. March 2020
Name: Sabine Pauquay
Contact information: sabine.pauquay@velux.com
Organization name: VELUX
Job title: Public Affairs Manager

What were the enabling factors of the project?

Which actors were an important part of the project?

What is the benefits of RenovActive?

What barriers did you encounter? E.g. in regards to:

Culture

Policy

Technology

Markets

Industry

What were the biggest challenges of the project?

How was the project made economically feasible?

What considerations were made (if any) to reducing embodied carbon?

E.g. materials used during construction

Construction waste

What did you learn from the project?

What could have been done better?

How can this project be applied to different contexts?

Slovak?

Belgium vs Denmark? Regulations

Who could i contact? Architect? Constructors?

Date of interview: 25. March 2020
Name: Jonas Lindekens
Contact information: Jonas.Lindekens@ono-architectuur.be
Organization name: ONO Architectuur
Job title: Architect

Please describe your role in the project

How did the concept of RenovActive come into being?

what tools/methods did you use?

Please explain the concept and thought behind an overall refurbishment of the Bon Air Neighbourhood

What are the benefits of RenovActive?

What barriers did you encounter during the process? E.g. in regards to:

- Culture
- Policy
- Technology
- Markets
- Industry

What did you experience as most challenging in the project?

How was the project made economically feasible?

How was the "environmental" factor of Active House principles taken into consideration? E.g. elaborate on:

- Sustainable construction
- Environmental load

What considerations were made (if any) to reducing embodied carbon? E.g.

- material choices
- construction waste
- If not - why?

What did you learn from the project?

What could have been done better?

Is the project replicable in different contexts? E.g.

- Apartment buildings?
- All countries in Europe?

Final reflections:

How was it for you, as an Architect to take part in a renovation project? E.g. in regards to artistic freedom, architectural refurbishment

What do you think of renovation projects in general? And the future of renovation?

Date of interview: 26. March 2020
Name: Friedl Decock
Contact information: friedl.decock@daidalospeutz.be
Organization name: Daidalos Peutz
Job title: Engineering consultant

Please describe your role in the project

What were the enabling factors of the project?

Which actors were an important part of the project?

What are the benefits of RenovActive?

What barriers did you encounter? E.g. in regards to:

- Culture
- Policy
- Technology
- Markets
- Industry

What did you experience as most challenging in the project?

How was the project made economically feasible?

How was the "environmental" factor of Active House principles taken into consideration? E.g. elaborate on:

- Sustainable construction
- Environmental load
- Did you have a CO2 budget? Why/why not?

What considerations were made (if any) to reducing embodied carbon?

- material choices
- construction waste
- If not - why?

What did you learn from the project?

What could have been done better?

Is the project replicable in different contexts? E.g.

- Apartment buildings?
- All countries in Europe?

Final reflection: What do you think of renovation projects in general?

- Renovation vs. new build?
- The future of renovation?

Date of interview: 14. April 2020
Name: Maya Færch
Contact information: mlf@lendager.com
Organization name: Lendager
Job title: Chief Consultant

Indlejret energi

Hvad er dine tanker omkring indlejret energi? Hvorfor er det vigtig?

Hvordan kan bygning sektoren i Danmark reducere indlejret energi? Hvor er det størst potentiale?

Hvordan måler i, Lendager, indlejret energi i dag?

Hvilke udfordringer er der?

Kunne det blevet gjort på en bedre/nemmere måde? Hvad er dine anbefalinger?

Materialer

Hvilke materialer anbefaler du at bruge i Bbyggeriet? Og hvilke materialer skal vi ikke bruge?

Hvilke udfordringer ligger deri at bruge genanvendt materiale byggeriet? Og hvad er mulighederne?

Hvordan får i, Lendager, tilgang til bæredygtige materialer og hvilke udfordringer ligger i det?

Uddyb gerne de forskellige kilder for genbrugsmaterialer: affald fra industri, affald fra nedrivning og renovering, og affald fra byggepladsen

Hvordan sikrer i kvaliteten på materialerne,og hvem har ansvaret hvis kvaliteten ikke overholder forventningerne?

Hvordan tror du at brug af bæredygtige materialer kan blive den udbredte praksis i byggeindustrien?

Hvilke barrierer er der? F.ex. i forhold til kultur, teknologi, marked, reglement, økonomi.

Økonomisk bæredygtighed

Hvordan kan brug af bæredygtige materialer bliver gjort på en økonomisk bæredygtig måde?

Hvilke udfordringer er der? Er der områder i skal gå på kompromis?

Kan du forklare konceptet «embedded financials»? (Fra Arkitekturgalan præsentation.)

Hvordan blev projektet «Lilleakerbyen» økonomisk bæredygtig?

Hvilke forretningsmuligheder ligger det i at genanvende de eksisterende materialer?

Hvordan blev materialerne kartlagt? Og hvordan blev "material mapping" brugt som et værktøj for samarbejde blandt de involverede aktører?

Samarbejde og partnerskaber

Hvorfor er det så viktig at etablere partnerskaper på tværs af værdikæden når en snakker bæredyktig byggeri?

Hvilket arbejd laver i, Lendager, i forbindelse med at etablere partnerskaper og samarbejde i industrien?

Hvordan kan du som arkitekt forsikre at den originale ide bliver implementeret? Til trods for risici og tvivl fra byggefirmaer. (Fra Arkitekturgalan præsentation.)

Reglement og fremtidens byggeri

Kan du fortælle lidt om hvilke standarder, certificeringer og reguleringer i følger eller kan være en udfordring for jeres arbejde i Lendager?

Hvilke krav til bryggeriet vil du gerne se i bygningsreglementet i fremtiden?

Hvordan mener du vi skal bygge i fremtiden? Hvorfor?

Hvad er din holdning til renovering?

Date of interview: 22. April 2020
Name: Klara Bukolska
Contact information: klara.bukolska@velux.com
Organization name: VELUX Slovakia
Job title: Senior Architect

Please describe the project and your role in it.
What were the enabling factors of the project?
Which actors were an important part of the project?
What role did the pilot project in Belgium play in your work?
What are the benefits of RenovActive?
Which barriers did you encounter during the process?

- Culture
- Policy
- Technology
- Markets
- Industry

What did you experience as most challenging in the project?
How was the project made economically feasible?
How was the "environmental" factor of Active House principles taken into consideration? E.g. elaborate on:

- Sustainable construction
- Environmental load

What considerations were made (if any) to reducing embodied carbon?

- material choices
- construction waste
- If not - why?

What did you learn from the project?

What could have been done better?
Is the project replicable in different contexts?
Final reflections:

- How was it for you, as an Architect to take part in a renovation project?
- What do you think of renovation projects in general? And the future of renovation?