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Multi-stakeholder collaboration in the building sector for building material reuse projects

Case-studies in Denmark

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Abstract

Reuse of building materials is gaining increasing interest in Denmark as a result of policy developments. The thesis aims to describe what actors find important regarding collaboration in investigated Danish projects involving reuse of secondary building materials and to relate these findings to stakeholder interdependency patterns and institution characteristics of the building industry. Five in-depth case studies were conducted whereby key project actors were interviewed. The thesis includes a literature review on policy developments regarding resource efficiency, on innovation in the building sector, and on collaboration. Interview results were analyzed using a framework consisting of 9 factors of successful collaboration: shared vision; mutual benefits; sharing risks; ability to compromise; the existence of trust; new partnerships and inclusion of affected members of the community; quality and transparency of information exchange; joint decision-making; and available additional resources. The analysis gives insight into collaboration practices in building material projects. Among others, it was found that relationship patterns in the examined cases showed a difference in many ways as compared to general relationship patterns in the industry. Results underline the necessity for systemic changes in the industry to facilitate reuse. The description of collaboration in building material projects may be of value especially to industry actors, who wish to engage in reuse. The findings can also be useful for policymakers and may contribute to building further research on the issue.

Keywords: reuse, building industry, Denmark

Executive Summary

The building industry is one of the leading economic sectors throughout the world while at the same time it is also responsible for a significant portion of negative environmental impacts. It plays a leading role in global energy consumption, GHG emissions, raw material use, and waste production. Meanwhile, most products in the industry are in the best case recycled into lower grade applications or are incinerated or landfilled. Recently, EU policy developments have turned attention to enhancing the lifetime of building materials/products also through other means. A recent policy example is the EU action plan for circular economy adopted in 2015. One widely discussed approach is reusing. Danish policy is a frontrunner in the EU, and in parallel, Danish industrial actors are also showing more and more interest. Scaling up circular practices requires systemic changes because norms, institutions, and practices in today's society are generally designed for the make-take-dispose system. For example, the bulk of the existing building stock was built with no consideration for what happens with the products at their end-of-life. Thus, materials reclaimed from demolished buildings cannot easily be reused for building new ones. This is just one challenge, for generally the building industry is considered as being conservative. The recent rising of interest in reuse practices in the industry raises the need for a better understanding of how actors in reuse projects overcome the challenges.

Industry-wide adoption of reuse practices can be considered as innovation because of bringing about lasting change in routinized value creation. Innovation in the building sector is a widely studied phenomenon and research on it also explains the reasons behind the conservative character of the industry. The stakeholder interdependency patterns and institutions that characterize the industry are believed to hinder the long-term change.

Bringing about changes in the complex building industry sector requires close interaction among actors for interdependencies are high and any changes may be beneficial to some and disadvantageous for others. Finding the optimum solution requires that actors jointly do the cycle of trial, feedback, and correction. Therefore, realizing changes in the building industry is closely connected to collaboration among actors.

The research is to contribute to the overall objective of better understanding collaboration for the reuse of building materials in a building industrial context.

The research aims are:

1. To increase knowledge on collaboration for building material reuse in the building industry.
2. To discuss collaboration practices for reuse in the building sector in regard to literature on stakeholder interdependency patterns and institutions in the building industry.

The thesis, therefore, aims to answer the following research questions, whereby the result of the first question provides input to the second one:

RQI: What is emphasized as important regarding collaboration for reuse of secondary building materials in Danish projects?
RQII: What conclusions can be drawn by relating the collaboration practices to general stakeholder interdependency patterns and institutions in the building industry?

To address the questions, five in-depth case studies were conducted on Danish projects involving reuse of building materials, whereby key project actors were interviewed. The research also included a thorough literature review on innovation in the building sector and on collaboration. To answer RQI, interview results were analyzed using a framework consisting of

9 factors of successful collaboration: shared vision; mutual benefits; sharing risks; ability to compromise; existence of trust; new partnerships and inclusion of affected members of the community; quality and transparency of information exchange; joint decision-making; and available additional resources. The findings on collaboration were then compared to general stakeholder interdependency and institutional patterns in the building industry as identified in the literature.

The following overall conclusions have been drawn regarding the two research questions:

Using secondary building materials poses significant challenges to actors and they adjust their collaboration to overcome them. Three main challenges were identified: availability of enough quantity of secondary building materials, the quality certification of the materials, and the non-standard technical novelties faced.

Actors developed new types of partnerships with stakeholders with whom they are normally not working together or would work less closely connected with. Some project organizations developed long-term partnerships which is considered unusual in the project-focused building industry. There was closer cooperation with suppliers of secondary building materials, with whom normally relationships are very loose due to the standardized material products in the industry. Tightening relationship with clients was identified, showing their major role in adopting reuse practices. All cases demonstrated improved quality and frequency of information exchange related to reuse compared to when well-practiced solutions are implemented. In grant-financed projects, the increasing frequency and quality of information exchange was accompanied by joint decision-making, while in other ones, decision-making happened according to contractual relations. In one case, the contractual relations that resulted in insufficient information exchange due to communication via intermediator instead of direct contact were pointed out as an important barrier to realizing reuse solutions.

A very important collaboration factor was found to be the availability of additional resources. These came in many forms, such as time, financial, and educational resources. Additional time was spent to develop and agree on non-standard solutions. Moreover, actors, such as clients and final users were engaged in acquiring secondary building materials, which is normally the responsibility of the contractors. Additional financial resources were spent directly on testing novel solutions as well as on incentivizing suppliers and clients to collaborate in the experimental phase of some of the projects. Workshops and boot camps provided additional educational resources.

Actors' willingness to compromise was also found important. For example, in some projects, actors focused on optimizing their processes with the whole group's interest in mind. Client's permissiveness about chosen solutions and related cost changes was also highlighted in a case.

Risks were an important topic in the reuse projects because the novelty of solutions increases uncertainties and therefore actors have to take up responsibilities usually not required. For example, the strong institution of standards requires quality certification of materials what poses challenges, because most secondary materials do not comply with them. Taking joint responsibility was a suggested solution. Moreover, the rearrangement of contractual relations to accommodate acceptance of risks may be necessary, in contrast to the standardized contracts typical in the industry. Non-the-less, in the grant-supported projects risks were not highly emphasized, it was rather in the non-supported projects.

Actors in projects involving materials other than brick mostly expected long-term benefits and there the relationship patterns suggested the presence of trust. It was also characteristic to these

cases that actors were not only focusing on their individual returns of benefits but also on the overall group interest. The lack of short-term benefits in non-brick reuse projects suggests that systemic changes are required in the industry to make them profitable. On the other hand, brick reuse projects are often also profitable in the short-term. But here too, challenges arise as contractors compete on price and are already running on a low budget, so they are resistant to endorse solutions that increase uncertainties.

Strong interdependency patterns and institutions in the building industry serve to overcome the challenge of creating complex building products. Actors in the industry generally show reluctance to endorse changes, for changes raise uncertainties. The project cases demonstrated actors' experimentation with new arrangements within the limits that the strong industrial patterns allow and brought findings on what actors have to undertake in reuse projects. For example, they must invest increased time to develop solutions that are normally included in the standards, they must invest more into acquiring material supplies, which they would normally just order from the store, they must take on roles they normally do not have to, and gain new skills not required when working with new materials. Risk-sharing and collaborative relationships were identified as important to overcome uncertainties that are not present when working with new materials. The cases show that experimental projects supported by grants create space for actors to test new arrangements with long-term return expectations, and this is necessary in such a complex system as the building industry. Nonetheless, all the examined cases brought the result that the present patterns of the building industry such as stakeholder interdependencies and institutions affect innovation challenging building material reuse. It is mainly the brick reuse projects that ripe short-term profit, suggesting that systemic changes are necessary to make reuse of other materials profitable too.

The findings could be valuable to industrial stakeholders wanting to learn about previous experiences in reuse. The findings could also be useful in further research on how systemic changes could best be brought about to facilitate reuse.

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Abbreviations

C&DW: Construction and demolition waste

CE: Circular economy

1 Introduction

The building industry is one of the leading economic sectors throughout the world and also is responsible for a significant portion of environmental burdens. It is estimated that considering the whole lifecycle of buildings, the global building sector is responsible for 40 % of the world's energy consumption, produces one third of global GHG emissions, is responsible for 30% of raw material use and 25% of waste production (Ibn-Mohammed, Greenough, Taylor, Ozawa-Meida, & Acquaye, 2013). In the meantime, it is also an industry where products at their end-of-life in the best case are recycled into lower grade application (downcycling) as an alternative to incineration and landfilling (Danish Environmental Protection Agency [DEPA] 2019). Recent policy developments have turned attention to enhancing building materials'/products' lifetime also through other means than recycling into lower grade applications, such as maintaining, reusing, refurbishing (Commission Communication COM(05)670 final; Parliament and Council Directive 08/98/EC; Commission Communication COM(11)571 final; Commission Communication COM(14)445 final; Commission Communication COM(15)614 final). It is held that the more energy, resources, labor, and costs embedded during the making of materials and products is recovered, the higher the environmental benefit gained will be (Wells & Seitz, 2005). Recovered materials, otherwise called secondary materials, are believed to contribute to a more sustainable society by reducing wasted resources.

The EU action plan for the Circular Economy was adopted in 2015 (Commission Communication COM(15)614 final). It is one of the most recent policy developments turning attention to resource efficiency. Circular economy emphasizes keeping material resources at their highest value in the value chain for as long time as possible before disposing of them. A non-exhaustive list of strategies to achieve a circular economy in the building sector comprises designing for disassembly, selective demolition, and reusing secondary building materials (Nußholz, Rasmussen, & Milios 2019). As increasing focus is turning towards circular economy, a significant amount of literature has been written on the topic (Bocken., Olivetti, Cullen, Potting, & Lifset, 2017).

Danish policy developments closely followed the EU ones regarding increased focus on resource efficiency (Danish Government, 2013; Danish Government, 2015; Danish Government, 2018). There are increased discussions on circularity also in the Danish building sector, meanwhile, among others, several building material reuse projects are conducted involving an increasing number of actors in the industry (Teknologisk Institut, 2019). Reusing building materials poses specific challenges, one of them is that the bulk of the existing building stock has been built during times when there was no consideration for what happens with the products at their end-of-life (Pomponi & Moncaster, 2017). Because of this important aspect, the thesis focuses on projects in Denmark that involve the reuse of building materials.

Scaling up the application of circular strategies such as reuse requires systemic changes because today's society is accustomed to the make-take-dispose system (Bocken et al., 2017). Technologies, rules, relationships, services are all designed for the linear economy. Bringing about such changes in the building sector can be considered as innovations.

Slaughter (1998) defines innovation as „the actual use of nontrivial change and improvement in a process, product, or system that […] does not have to be novel with respect to the existing arts, but only to the creating institution" (Slaughter 1998, p.1). Orstavik (2015) defines innovations as "humanly intended and enacted changes in the routinized and institutionalized ways of value creation" (Orstavik 2015, p. 18). While reuse of building materials may be not necessarily new in small scale constructions, its industry-wide applications have been very

limited so far. It is new to actors and projects that operate within the established institutional context of the industry (personal communication, April 2019).

The building sector has special characteristics that make innovation different as compared to many other sectors. Moreover, viewing the transition to increased reuse in building construction as innovation has the advantage that there is extensive literature on innovation in construction, while the literature on circularity in the building sector is still relatively new and less extensive. Therefore, this research study is examining reuse as an innovation in the building sector.

1.1 Problem definition

Bringing about lasting changes, an innovation, in a complex industry such as the building sector requires close interaction among actors for any changes made may be beneficial to some and disadvantageous for others (Orstavik, 2015). Finding an optimum solution requires that actors jointly do the cycle of trial, feedback, correction (Dubois & Gadde, 2002). Therefore, innovation in the building industry is closely connected to interaction among actors.

According to the literature, there are special characteristics in the building industry that make bringing about changes different than in other industries, such as in the manufacturing industry. First, it is a project-based industry meaning that teams form temporarily for projects and then dissolve to form new constellations in other projects (Dubois & Gadde, 2002). Building projects are executed by highly specialized and closely interdependent actors, while there is little connection among actors in the building industry outside of projects. This system, the focus on one-off projects hinders long-term joint learning by actors which is indispensable for developing lasting changes (Brown, Vergragt, Green, & Berchicci, 2003; Dubois & Gadde, 2002). There is much innovation in the building sector, but it is mostly problem-solving within construction projects, or it is in the material manufacturing industry (Loosemore, 2015; Orstavik, 2015; Clausen; 2003). Second, the products of the building industry, the buildings, are customized and complex products executed by always changing arrangements of actors (Dubois & Gadde, 2002). To make this complexity manageable, the sector is highly institutionalized, with rules, norms, standards, practices regulating actors' behavior assuring the efficiency of work in the temporary project constellations (Kadefors, 1995). The institutionalized system adds to the sector's resistance against changes. A building project is complex, interdependencies are high, so changes made in any element may affect other elements, making actors reluctant to endorse them (Kadefors, 1995). Collaboration is necessary for jointly testing new arrangements and finding a compromise between actors' interests.

Examining factors of successful collaboration in reuse cases gives insight into what approaches actors take to overcome challenges as well as make it possible to compare with general collaboration practices in the building industry. There is very limited research on collaboration focusing on circular building projects. One such research is that of Leising, Quist, and Bocken (2018), who examine these in specific building project cases. As they express, "social relationships and collaboration between supply chain partners are considered key to creating closed-loop supply chains and need to be taken into account for a transition towards CE" (Leising, Quist, & Bocken, 2018, p.2).

The thesis aims to increase knowledge on collaboration in reuse building projects to enhance the industry actors' understanding of this innovation work. The underlying assumption is that a better understanding of the process in reuse building cases will improve the management of further projects. As Adams, Osmani, Thorpe, & Thornback (2017) found, best practice case studies are considered significant enablers towards a transition to a circular economy in the

sector. The thesis, furthermore, relates the found collaboration practices with characteristic stakeholder interdependencies and institutions of the industry as identified in the literature.

The research aims are:

1. To increase knowledge on collaboration for building material reuse in the building industry.
2. To discuss collaboration practices for reuse in the building sector in regard to literature on stakeholder interdependency patterns and institutions in the building industry.

The research is to contribute to the overall objective of better understanding collaboration for the reuse of building materials in a building industrial context.

The objective to which the thesis is to contribute is the understanding of collaboration for reuse of secondary building materials in a building industrial context, by analyzing collaboration in Danish case-studies and relating findings to characteristic stakeholder interdependencies and institutions of the building industry.

1.2 Research question

Based on the problem definition and research objective above, the following main research questions have been formulated, whereby RQI provides input to RQII:

RQI: What is emphasized as important regarding collaboration for reuse of secondary building materials in Danish projects?
RQII: What conclusions can be drawn by relating the collaboration practices to general stakeholder interdependency patterns and institutions in the building industry?

1.3 Limitations and scope

The scope of this research is limited to entail five projects in the Danish building industry that involve the reuse of building materials. More specifically, four of the cases are building construction projects that involve the reuse of secondary building materials, and one case facilitates the reuse of building materials by improving access to these materials. Regarding the duration of the projects, there are short-term ones lasting between one to three years and also ones that are planned to run for long-term. Some projects specifically focus on building material reuse, while in other cases it is only part of the project.

The scope of the research entails examining the cases from the collaboration aspect, instead of, for example, examining technical details, such as architectural design or technical solutions applied by contractors. Thus, the thesis focuses on describing what actors found important in their collaboration and how their collaboration worked relating to shared vision; mutual benefits; sharing risks; ability to compromise; existence of trust; new partnerships and inclusion of affected members of the community; quality and transparency of information exchange; joint decision-making; and available additional resources.

The research focuses on obtaining results on collaboration from the managerial level perspective, therefore, the results will not convey the viewpoint of the craftsmen, subcontractors, etc. Each interviewed stakeholder has a key role in the reuse of materials in the cases, meaning stakeholders that are not involved in the reuse part of the project are not contacted.

The most important limitation comes from the case selection. The final choice of cases depended on the availability of actors. The architect firm was the same company across three of the cases, and two of the cases were the winners of the same competition, the Circular Construction Challenge ("Circular Construction Challenge," n.d.). Moreover, one-off construction projects were examined alongside long-term projects of different scale and type. Some of the projects exclusively focus on reuse, in other projects reuse is just one part. Therefore, case selection has implications on the comparability and also the generalizability of the results of the cases.

Another limitation comes from the literature. The thesis compares case findings with findings in the literature on the building industry. The literature findings are not specific to Denmark, therefore, comparability to findings in Danish cases has limitations.

1.4 Ethical considerations

Based on the Lund University's Research Ethics website available at http://www.researchethics.lu.se , this research has to undergo ethical review concerning the management of personal data. Confidentiality of interviewees is addressed through not including names, only organizational affiliations in the thesis. Moreover, all interviewees of the examined cases were sent either the notes taken during the interview or the final draft version of the case in order to receive consent to include the information in the thesis. Received comments were taken into consideration in the final version.

1.5 Audience

The thesis intends to produce value for stakeholders in the industry, for academics and policymakers, as well as for anyone interested in the topic. Industry stakeholders to whom the research could be of value for are those who intend to get involved in reuse projects as well as those who already have experiences in them. The paper aims to achieve this by conveying the experiences in collaboration of other cases. For policymakers, the research could be of value primarily by improving understanding of the implications of challenges on actors' work in reuse projects. For academics, the research could be of value to build further research on since this is a new, previously scarcely researched topic.

1.6 Disposition (outline)

Chapter 1 presents the nature of the problem, followed by a focused problem definition and the research questions, as well as the scope, limitations, intended audience of the thesis and the paper outline.

Chapter 2 gives a literature overview on policy developments within the EU and Denmark, on circularity in the building sector, on reuse as innovation, and on specificities of innovation in the building industry. This is followed by the development of the analytical framework on collaboration.

Chapter 3 presents the methodology of the research including the research design, data collection, and analysis.

Chapter 4 describes the findings in each case.

In Chapter 5 the findings are analyzed with the cross-case analysis method using the analytical framework. This is followed by a discussion relating the results to literature findings.

Chapter 6 presents the main conclusions of the analysis and the discussion, points out the contribution to the research field, and presents recommendations for future research.

2 Literature review

2.1 Context of the study

2.1.1 Policy developments

The below policy review aims to justify the relevancy of studying reuse projects in the Danish building sector through presenting policy developments related to resource efficiency in the sector. Recent policy developments have turned attention to enhancing building materials'/products' lifetime also through other means than recycling into lower grade applications, such as maintaining, reusing, refurbishing (Commission Communication COM(05)670 final; Parliament and Council Directive 08/98/EC; Commission Communication COM(11)571 final; Commission Communication COM(14)445 final; Commission Communication COM(15)614 final). An increasing number of companies are interested in the topic (Teknologisk Institut, 2019).

2.1.1.1 Towards a circular economy – EU policy developments on resource efficiency in the building sector

The life cycle stages of a building include the construction, use, maintenance, renovation and demolition phases. Environmental impacts throughout the lifecycle of buildings consist of material and energy consumption, GHG emissions, as well as waste production, acidification, toxicity, and radioactive radiation, among others (ECORYS, 2014). It is estimated that considering the whole lifecycle of buildings, the global building sector is responsible for 40 % of the worlds energy consumption, produces one-third of global GHG emissions, is responsible for 30% of raw material use and 25% of waste production (Mohammed et al., 2013). Energy consumption and GHG emissions during the use stage of the building are called operational energy and operational emissions, respectively. Until recently policy attention has almost entirely focused on lowering these (Pomponi & Moncaster 2017, Ibn-Mohammed et al., 2013). One example is the UK Government's policy framework target to have all new homes being zero carbon by 2016 (Department for Communities and Local Government 2007). To be considered zero carbon, the building had to be net-zero carbon over the year for all energy use in the home (space heating, cooking, electric appliances, etc.). Another example is Directive 2010/31/EU of the European Parliament on the energy performance of buildings that rules that by 2020 all new buildings shall be nearly zero energy buildings where energy is calculated based on typical use in buildings: heating, cooling, ventilation, lighting, hot water (Parliament & Council Directive 10/31/EU). A third example for the significant attention on operational energy in buildings is found in the contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change which in the chapter on buildings also focuses almost entirely on the buildings' energy use and energy efficiency (IPCC, 2014).

However, there are also significant energy requirements and GHG emissions associated with other life cycle stages of buildings that occur during raw material extraction, transport, processing, construction, maintenance, renovation, and demolition stages. The energy requirement and GHG emissions of these phases are called embodied energy and embodied emissions (Mohammed et al., 2013). Annually in the EU, around four times as much energy is used in residential buildings than is embodied in new construction materials (ECORYS, 2014). Non-the-less, in 2006 the total embodied energy in new construction materials used in residential buildings corresponded to 5,4% of annual final energy consumption in the EU 27 (ECORYS, 2014). Moreover, due to the significant policy attention on lowering the operational energy requirements of buildings and the spread of increasingly energy-efficient lighting, appliances, heating systems and improved insulation in buildings, the proportion of embodied

energy to operational energy is growing and is gaining increasing interest (Mohammed et al., 2013).

In 2005 the Commission of the European Communities presented the Thematic strategy on the sustainable use of natural resources with the objective „to reduce the negative environmental impacts generated by the use of natural resources in a growing economy – a concept referred to as decoupling" (Commission Communication COM(05)670 final). The strategy includes actions related to resource use to improve knowledge and understanding, develop tools for monitoring, raise awareness and develop plans to make improvements (Commission Communication COM(05)670 final).

In 2011, the European Commission presented the Roadmap to a resource-efficient Europe under the Europe 2020 Strategy's flagship initiative on „A resource-efficient Europe". The roadmap serves to define the objectives and develop the measures to set the European economy on a path that respects resource constraints and increases resource efficiency to allow decoupling of economic growth from resource use. The housing sector is identified as one of the key sectors contributing to overall environmental impacts. The roadmap, therefore, sets that the strong policies on operational energy efficiency and renewable energy use need to be complemented by policies that consider the whole life-cycle impacts of buildings (Commission Communication COM(11)571 final).

This roadmap is in line with the EU Waste Framework Directive that, among others, sets up a waste management hierarchy for application in EU Member States legislation. In this hierarchy, prevention is prioritized over preparing for reuse followed by recycling, recovery, and disposal. The directive also set the 2020 target for „the preparing for reuse, recycling and other material recovery […] of non-hazardous construction and demolition waste […] to a minimum of 70 % by weight" (Parliament and Council Directive 08/98/EC).

In 2014, the European Commission presented the communication on resource efficiency opportunities in the building sector (Commission Communication COM(14)445 final). The initiative aims to reduce the use of resources in the building sector by setting out the path to creating a unified framework of core indicators for the assessment of the environmental performance of buildings through their life-cycle.

In 2015, the European Commission increased the focus on resource efficiency by adopting the Closing the Loop – EU action plan for the Circular Economy that presents the plan towards a transition to a more circular economy. A circular economy is one where „the value of products, materials, and resources is maintained in the economy for as long as possible, and the generation of waste is minimized" (Commission Communication COM(15)614 final). A transition to a circular economy is expected to maintain economic growth, to create business opportunities and jobs, to secure resource supplies while contributing to global efforts in sustainable development. The plan addresses five sectors in a targeted way. One of the five priority areas is the construction and demolition sector, whereby the plan addresses the sector's waste generation and environmental performance throughout the lifecycle of a building. The plan includes a timeline for development of pre-demolition assessment guidelines, of a C&DW recycling protocol, and indicators for the assessment of building LCAs (Commission Communication COM(15)614 final ANNEX1). These indicators are in the application of the European Commission's 2014 Communication on resource efficiency opportunities in the building sector.

2.1.1.2 Towards a circular economy – Denmark policy developments on resource efficiency in the building sector

Construction and demolition waste (C&DW) constitute the biggest waste stream in the EU, accounting for 32% of the total generated waste (Commission Report COM(2019) 190 final; EEA, 2010). According to Eurostat, in 2016 the average rate of recovery of C&DW in the EU was 89% (Eurostat, 2019). The EU Waste Framework Directive set the 2020 target for „the preparing for reuse, recycling and other material recovery […] of non-hazardous construction and demolition waste […] to a minimum of 70 % by weight" (Parliament and Council Directive 08/98/EC).

C&DW accounts for around 1/3rd of total generated waste in Denmark excluding soil (DEPA, 2016). The country has historically been in the frontline in the recycling of C&DW in the EU. Recycling rates of C&DW in Denmark reached 90% already in the 1990s going up to 95% after 2000 thus meeting the EU 2020 target for recycling long ago (DEPA, 2016). In 2014, 87% of C&DW was recycled while 5% was incinerated and 7% was landfilled (DEPA, 2016). The decrease is attributed to increased attention on removing hazardous substances from recycled waste.

Despite high levels of recycling of C&DW in Denmark, most of the recycled waste is turned into low economic value secondary materials, such as aggregates. For example, concrete that constituted around 1/4th of the total C&DW volume in 2015 is crushed and recycled to a 90% rate almost exclusively as sub-base material under roads or other pavements or filling material in seawalls, embankments, etc (DEPA, 2019). Similarly, recycling of wooden C&DW is done dominantly into chipboards, recycling of roof tiles mainly means crashing and use under road pavements as sub-base filling material or as drainage material (DEPA, 2019).

Directive 2008/98/EC of the European Parliament and of the Council, among others, sets up a waste management hierarchy for application in EU Member States legislation. In this hierarchy, prevention is prioritized over preparing for reuse followed by recycling, recovery, and disposal. Article 29 of the Directive requires member states to establish waste prevention programs by the end of 2013. In November 2013, the Danish Government presented its resource strategy for waste management, Denmark Without Waste, that focused on increasing the quantity and quality of recycling (Danish Government, 2013). This strategy addresses C&DW mainly focusing on hazardous materials. This strategy was updated in April 2015, when the Danish Government presented its Waste Prevention Strategy, Denmark Without Waste II, that focuses on waste prevention and better, more efficient use of resources. The Waste Prevention Strategy directly addresses increased direct reuse of C&DW through the use of indicators such as volumes of C&DW that is used for new purposes, and through prioritizing initiatives such as stricter requirements on building demolitions, the analysis of barriers to reuse construction products, the Fund for Green Business Development, and the partnership for sustainable construction and waste prevention (Danish Government, 2015). This partnership is to foster collaboration among the construction value chain to identify barriers and common solutions.

In October 2016 the Danish Government set up the Advisory Board for Circular Economy (Ministry of Environment and Food of Denmark, 2017). In June 2017, the Advisory Board presented its 27 recommendations to the Danish Government with the vision to make the Danish industry a global leader and exporter of circular solutions by 2030 (Ministry of Environment and Food of Denmark, 2017). The objectives of the recommendations are for Denmark to increase resource productivity, to increase overall recycling rates, to become a leader in developing circular solutions, to increase population involvement in the sharing economy, and to increase the turnover of eco-labeled products and services (Ministry of

Environment and Food of Denmark, 2017). Four of the recommendations directly address the construction industry. Recommendation #12 regards building regulations and suggests the introduction „as from 2020 of an information requirement for all new buildings and large-scale renovation projects covering material content, the amounts of reused, recycled and recyclable materials, plus the amount and number of undesirable substances used in the building". Recommendation #13 suggests the development of standardized building and product passports.

In September 2018, as a follow up to the recommendations of the Advisory Board, the Danish Government brought forward its Strategy for Circular Economy (Danish Government 2018). Two of the total 15 initiatives of the Government's Strategy focus on paving the way towards a transition to a more circular construction sector. These initiatives are the development of a voluntary sustainability class and the propagation of selective demolition.

In 2016 the Danish Construction Association established the Knowledge Center for Circular Economy in Construction (Videncenter for Cirkulær Økonomi i Byggeriet – VCØB) ("Videncenter for Cirkulær Økonomi i Byggeriet" n.d.). The institution was previously called Knowledge Center for Handling and Recycling Waste (Videncenter for Håndtering og Genanvendelse af Byggeaffald – VHGB). VCØB's main focus remains the handling and recycling of construction waste but with increased emphasis put on engaging in dialogue with more actors, such as producers and architects ("Videncenter for Cirkulær Økonomi i Byggeriet" n.d.).

To support the work of the Partnership on sustainable construction and waste prevention, which was initiated by the Danish Governments Waste Prevention Strategy, the Danish Environmental Protection Agency commissioned a project to identify market conditions and barriers to recycling and reuse of three selected construction materials (concrete, wood and roof tiles) and to propose ideas to improve market acceptance of recycled and reused building materials (DEPA, 2019). This work published in March 2019 relies on desk study, interviews and case studies and provides an extensive summary of barriers and enablers of higher-level recycling and reuse.

2.1.2 Circular economy in the building sector

European and Danish policy developments on resource efficiency show increased attention on the concept of 3R, reduce, reuse, recycle, and a gradual shift in the focus from waste management towards resource supply safety. Circular economy emphasizes keeping material resources at their highest value in the value chain for as long time as possible before disposing of them (Commission Communication COM(15)614 final). This way, the circular economy propagates resource efficiency. It is an alternative to the present make-take-dispose linear economy, where energy, resources, labor and costs embedded during the making of materials and products are wasted after one or a few cycles of uses. The circular economy is perceived as a method to decrease the ever-increasing burden of the modern economy on the natural environment while also maintaining economic growth. As Esposito et al. 2017 put it, „the circular economy's goal is to preserve our current way of life by making it technically viable for the longer term" (Esposito, Tse, & Soufani, 2017, p2). Gregson et al. (2015) view it „as a form of geopolitical insurance; in a world where rampant economic growth in the developing world threatens the stability of economies long accustomed to having resources their own way, it offers insurance against the EU's increasingly apparent resource insecurity" (Gregson, Crang, Fuller, & Holmes, 2015, p.236).

Closing the loop requires the implementation of strategies throughout the whole lifecycle of materials and products. Developing a circular building sector also calls for strategies implemented throughout the whole life-cycle of buildings. There are strategies for all phases of a building's life-cycle from the material and component production to the design, the construction, the use and refurbishment, and the end-of-life phase. A non-comprehensive list of circular strategies in three of the life phases of buildings, the material and component production, design, and end-of-life phases, are shown in Table 1-1.

Table 2-1 Circular strategies in the building industry

Building life phase	Material and component production	Design	End-of-life
Circular strategies	Design for disassembly	Design for disassembly	Careful dismantling
	Use of secondary materials	Design for adaptability and flexibility	Selective demolition
	Avoid using hazardous and toxic materials	Design in reuse of secondary materials and products	
	Produce for prolonged lifespan	Design for modularity	

Source: Nussholz & Milios, 2017

Different actors operate at different life-cycle stages of buildings. A transition to circularity in the economy requires concerted action by actors who cannot overcome systemic obstacles in isolation (ellenmacarthurfoundation.org).

Identification of the actors in the construction industry is important for understanding their collaboration. The construction sector is comprised of 5 main groups of actors depending on their activities (Clausen & Bonke, 2003). There are the actors creating the regulatory context. These are the country governments, local authorities, the EU, industry organizations, and standardization committees. There are those actors that supply and transport construction products. There are those companies that plan, coordinate and implement projects, such as the architects, contractors, craftsmen, and consulting engineers. There are the customers who can be public and private investors and the final users. And finally, there are those actors that facilitate knowledge development and dissemination, such as technological institutes, governments, and industry organizations.

As explained before, closing the loop involves strategies implemented at different life-cycle stages. Strategies that will be mentioned in the thesis are defined in the following:

• Design for disassembly: Designing for easy disassembly at the end of life of the product. Product in the building industry can refer to the whole building or parts of the building. These products are interconnected and are also often systemic by themselves thus design for easy disassembly means designing for the possibility of the easy dismantling of the system.

• Reuse: The definition given by the Waste Framework Directive is that „'re-use' means any operation by which products or components that are not waste are used again for the same purpose for which they were conceived" (Parliament and Council Directive 08/98/EC).

• Recycling: The definition given by the Waste Framework Directive is that „'recycling' means any recovery operation by which waste materials are reprocessed into products, materials or

substances whether for the original or other purposes. It includes the reprocessing of organic material but does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations" (Parliament and Council Directive 08/98/EC).

Because of ambiguity as to what is considered reuse and what is considered recycling, in the thesis the term reuse will be used for all cases where materials are used again in same or higher grade applications.

• Downcycling: Reprocessing products and materials into lower grade applications such as subbase materials under roads, or other paved surfaces, and filling materials in revetments, seawalls, and embankments, etc.

Buildings are produced for tens of years, often for a hundred years, and therefore, there is a significant volume of building stock out there the material of which must be handled to avoid the landfills and incineration (Pomponi & Moncaster, 2017). This building stock was designed and built with no reuse in mind and, thus, their reuse poses significant challenges. Therefore, the thesis focuses on projects that include the reuse of building materials.

2.1.3 Reuse of building materials as innovation

Innovation is defined in a number of ways but the definition given by Slaughter (1998) is that it is „the actual use of nontrivial change and improvement in a process, product, or system that […] does not have to be novel with respect to the existing arts, but only to the creating institution" (Slaughter 1998, p.1). In other words, innovation is connected to an organization, so that a change in a product, process or system is novel for that organization, but not necessarily to another organization that may have already been using it (Slaughter, 1998).

Transition to increased reuse in the building sector requires changes to products, processes, and systems too. An example of change in products is the use of secondary products instead of new products. An example of change in processes is new demolition processes. An example of systemic change is the new forms of collaborations among actors. While reuse of building materials may not necessarily be new in small scale constructions, its industry-wide applications have so far been very limited. As well as it is new to actors and projects that operate within the established institutional context of the industry (Personal communication, April 2019).

Viewing transition to increased reuse in building construction as innovation has the advantage that there is extensive literature on innovation in construction. While the literature on circularity in the building sector is still relatively new and less extensive.

Innovations happen within established systemic contexts which provide a source of stability (Quist & Tukker, 2013). This context resists change due to existing beliefs, norms, rules, practices, technologies and institutions, among others. When this system is optimized, most actors can keep operating in their existing roles, only a small number of actors change their mode of operation, and the functions of partnerships are clear (Quist & Tukker, 2013). On the other hand, more systemic changes may require new actor collaborations and actors themselves may need to undergo substantial changes (Quist & Tukker, 2013). Systemic changes often start out from small niche developments where actors are experimenting with new concepts on a small scale (Quist & Tukker, 2013). The institutional context in the building industry is very strong and due to the complexity of buildings, actors are resistant to endorse any changes that increase uncertainties (Kadefors, 1995). The following chapter describes the systemic context while the project cases show how much flexibility there is in this system.

Innovation is characterized by a change in one element of the system and the resulting change in the linkages to other elements in the system (Slaughter, 1998). It is shown by the many barriers and challenges found in the literature and the policy documents that application of reused materials in construction requires systemic changes in linkages proving that concerted actions by several actors are needed to overcome the barriers presented by application of reuse solutions (Nussholz et al., 2019; DEPA, 2019).

Slaughter (1998) finds that depending on the extent of the changes in the component and linkages, companies should plan for different types of activities and resources for implementation. What needs to be considered is the scheduling of the commitment to the innovation's use in the specific project, meaning how early in the design or implementation stage needs the commitment to be made. Secondly, coordination requirements will need to be determined, what collaborations, negotiations, exchange of information will be necessary and what provisions in contracts will need to be made for acceptance of risks and penalties for late completion. Thirdly, innovation's application may require special resources that need to be considered. Fourthly, the implementation of innovation may need special supervision. The reuse project cases can show the relevance of this framework.

Uncertainty is a basic condition of the innovation process and the organizations carrying out the innovations are not in full possession of all knowledge. Directions and goals often form along the way. Therefore, innovation is an iterative process which implies a significant amount of learning and collaboration taking place, again (Clausen & Bonke, 2003). The construction industry, as a project-based industry, is unlike the manufacturing industry. There are no R&D departments, innovations happen rather through the day-to-day solving of problems on real-life projects where variables are unpredictable (Loosemore, 2015).

Other definitions of innovation exist as well. The definition given by Orstavik (2015) is that innovations are "humanly intended and enacted changes in the routinized and institutionalized ways of value creation" (Orstavik 2015, p.18). Innovations are primarily driven by the passion of humans who have 'uncompromising commitment to realizing their novelty' (Orstavik 2015, p18). Thus, innovations are not only and always driven by economic calculations, often they are driven by the human passion to achieve something. Project cases can bring examples to this perspective. Lizarralde, Bourgault, Drouin, and Viel (2015) argue that "innovation occurs when stakeholders distinguish a change in a product, process, organization or service and perceive in it sufficient value to adopt it or to adhere to it" (p.50). It follows from this definition that whether something is considered an innovation is subjective and that innovation is a change that lasts.

2.1.4 Innovation in the building sector

2.1.4.1 Managing complexity – patterns of interdependencies and institutions

This section describes the institutional context and patterns of relations between actors in the building sector. It is important to examine the systemic context within which the cases of the thesis take place to be able to draw conclusions in connection to the systemic challenge faced by the sector in transitioning to reuse practices.

Buildings are complex products. This is because buildings are customized products built in various places and environments, from a wide range of materials gathered from various sources assembled and handled in various ways. Buildings are built by an always changing collective of actors forming various teams during different time frames. How can it be that despite having to

face a new combination of solutions in each and every project the building industry is called "conservative and slow to change" (Kadefors, 1995, p.1)? This was the question asked by Kadefors (1995). The answer comes down to how innovativeness and change are defined.

Complexity in building projects, on the one hand, is a result of the always varying locations, teams, materials, etc. Complexity, on the other hand, derives from the interdependence of actors and activities within projects. Buildings are built by numerous actors of different trade where the actions and products of one actor intertwine and affect the actions and products of other actors. Actors within individual projects strongly influence each other, while there is little interdependence between actors outside and across projects. Dubois and Gadde (2002) argue that this behavior serves to cope with the complexity of construction tasks.

The building industry is project-based, meaning actors come together in temporary formations to accomplish projects and then dissolve to form new formations in other projects (Larsson, 2016). The reason for the project focus lies within the complexity of each project. Projects usually have tight timeframes within which the strongly interdependent activities have to be accomplished by an always varying collective of specialized actors of different trades (Dubois & Gadde, 2002). Because each building product is unique due to the possible combinations of locations, actors, teams, materials, etc. and because of the interdependent activities, each project requires localized decision-making and coordination, thus decentralization (Dubois & Gadde, 2002). The specialization of actors into different trades serves to structure and reduce complexity (Orstavik, 2015). This, on the other hand, results in that most tasks of actors are sequentially interdependent, meaning the output of one actor is the input for the other, and several tasks are reciprocally interdependent because the output of both actors is the input of both actors (Kadefors, 1995). Dubois and Gadde (2002) call this tight coupling. In turn, Dubois and Gadde (2002) call the little interdependence and influence between firms outside the projects loose coupling. Between loosely coupled firms connections are weak compared to other influencing factors.

Dubois and Gadde (2002) argue that next to the behavior of tight coupling within projects, the loose coupling across and outside of projects also serves to overcome the inherent complexity of construction projects. Loose coupling allows for higher flexibility in adapting to local specificities of the projects for example by easily scaling activities through subcontracting, it also provides a buffer against propagation of arising problems elsewhere in the network, it preserves a higher variety of firms, generates a greater number of novel solutions, and allows more self-determination (Dubois & Gadde, 2002; Orstavik, 2015).

On the other hand, given the loose coupling between the network of actors outside of projects, efficient work between actors within projects requires a strong coordinating mechanism. Kadefors (1995) argues that the complexity of the building process is made manageable through the institutionalization of the sector. Institutions are needed because of "the great need for coordination which arises when a large number of different firms perform heavily interdependent tasks in a temporary organization under strong time-pressure" (Kadefors, 1995, p.10). Institutions are trade-wide rules, patterns of action that homogenize actors' behavior and make it predictable, thus making coordination of tasks more efficient. Standardization is similar to institutions. Kadefors (1995) defines standardization as "formalized and explicit routines or rules" (p.7). Standardizations can be divided into three types: standardization of work processes controls behavior in routine situations; standardization of outputs specifies the final products; and standardization of skills and knowledge makes the behavior of actors in unspecified situations predictable (Kadefors, 1995).

Institutions in the building sector come in many forms of which Kadefors (1995) gives the following overview. One source of pressure that makes actors comply with expectations comes in the form of **governmental regulations**, for example, building codes which specify requirements of buildings. The second source of pressure resulting in homogenization originates from **industrial standards**. Standard contract types such as the general contract and design-build contract determine the distribution of power and responsibilities within projects. It has been observed that communication follows contractual relations so that communication between actors not in contractual relations happens through intermediaries, which is a source of problem in communication that can result in technical problems (Kadefors, 1995). The industry also provides technical standards for specification of building components and standards for documentation work processes to control behavior in routine situations. Standards thus homogenize products and behaviors reducing the number of possible solutions. The **tendering system** prevailing in the industry also calls for standardization and is the third source of pressure towards homogenization. The tendering system allows the buyer to reduce costs by making offers comparable and making possible the choice for the lowest bid. In order to make manageable the calculation of the cost of the task specified by the client and bid for it through tendering, the task has to be standardized. The fourth mode of managing complexity is through the **institutionalization of occupational roles**. There are three main roles in building: that of the client, the consultants, and the contractors. Some examples of consultants are the architects, the geotechnical and the electrical engineers, some examples of contractors are the builders of foundations or of the electrical systems. Standardization of these roles means that actors contribute uniformly in these roles across projects. Finally, the **institutionalization of skills and knowledge** is the informal way of controlling the quality of work of every actor which is necessary because every detail of the project cannot be specified in advance. Education and training standardize skills and knowledge and make sure that the actor can make decisions independently and take responsibility for it.

The institutions listed above constrain products, processes, behaviors, thereby reducing the amount of information that needs to be processed during coordination and resulting in the reduction of uncertainties. Institutions thus make coordination within projects easier to manage and more efficient. On the other hand, institutions also reduce freedom (Kadefors, 1995). Because of the tight coupling and interdependencies within projects, and the lack of knowledge on the effects of changes within the strongly institutionalized system, actors show high reluctance to endorse changes due to the resulting increase in uncertainties (Kadefors, 1995). The building sector is, therefore, characterized by inflexibility to changes in the institutions, because of the strong need to make the complexity of each project manageable. From the long list of institutions above it is also clear that government regulations are only one source of pressure towards institutionalization. The main pressure comes from the systematic need to manage complexity (Kadefors, 1995).

The strong institutional structure of the sector gives a frame of reference for the projects examined in the thesis. Reuse of building materials has implications on compliance with standards, may necessitate rearrangement of roles, skills, interdependencies between tasks and actors. In sight of the general high reluctance of actors to implement changes in the institutionalized system, the case studies in the thesis allow insight into how much flexibility the actors are willing to show.

2.1.4.2 Effects of interdependencies and institutions on innovation

In an interconnected system such as the process of building, bringing about changes is a concerted effort of several stakeholders. Each change brought about in the project is likely to affect a number of actors, some in a positive, some in a negative way. Therefore, the successful

realization of an innovative, lasting change relies on finding an optimum between the interest of actors which results in a net gain to the whole project. Orstavik (2015) concludes that actors need to be "somewhat modest with respect to their own interests and efforts in the projects", and "the best outcome can be realized only if everyone is willing to negotiate actively with a commitment to contributing to a balancing of all relevant concerns in the project" (p.24). It follows from the need to balance interests too that close integration of affected actors is a necessary prerequisite to bringing about changes. There is a close relationship between successfully implementing technical solutions and the quality of communication between the actors (Kadefors, 1995). Bringing about changes in the established patterns of the building sector to make reuse profitable affects many actors of the industry in one way or another and, therefore, the task comes down to balancing interests of actors. On the other hand, the interconnection patterns and institutions described in the previous section strongly affect the possibilities of concerted working and joint learning of the actors. This section serves to examine the effects of the existing structures in the building industry on bringing about innovational changes.

As described in the previous section, the building sector is a project-based industry where actors within individual projects strongly influence each other (tight coupling), while there is little interdependence between actors outside and across projects (loose coupling). The institutions and standardization that serve the management of complexity in the building sector also affect the actors' relationships. The system of standards and institutions makes the development of tight couplings outside of projects unnecessary (Dubois & Gadde 2002). For example, standardization of products, roles, skills, and knowledge homogenize firms and trades reducing incentives to collaborate more with one firm than the other. This is especially true in the case of collaborating with building material suppliers (Hakansson & Ingemansson, 2013; Dubois & Gadde, 2002). Tendering procedures also reinforce loose coupling beyond the projects by working against the development of close relationships between actors. At the same time, the practice of tendering also separates the actors within projects too in the design and the construction phase, because contractors have little say in the design and designers get little feedback on what needs to be designed (Dubois & Gadde, 2002).

The pattern of interdependencies in the network have effects on innovation indirectly through having effects on joint learning. Standardized roles of actors across projects facilitate the individuals' learning, as experience gained in one project can be used in the next (Kadefors, 1995). On the other hand, most lasting changes need the joint learning and knowledge of several actors. And the commonly gained knowledge of project organizations is not carried over from one building project to the next, because learning at the group level requires continuous interaction, joint plans, and the conditions to repeat trial, feedback and evaluation, which is not given across and beyond projects (Dubois & Gadde, 2002). Actors need to readapt to new teams in each new building project. "Companies temporarily and pragmatically are adapting their separate resources in each and every project without actually inducing long-term or mutual change and learning" (Bygballe, Håkansson, & Ingemansson, 2014, p.96). Although the continuously changing collective of actors generates more ideas, these ideas do not get a chance to diffuse across projects, because joint learning of actors beyond individual projects is necessary for generating the new elements and interlinkages of a lasting change, an innovation. Continuous joint learning is necessary for „attaining a critical mass of societal intelligence for sustainability transition" (Brown et al. 2003, p.24). Thus, the building industry faces special challenges in joint learning and, therefore, innovation.

Revisiting the question of Kadefors (1995), how can it be that despite having to face a new combination of challenges in each and every project the building industry is generally considered non-innovative? Taking the definition of Lizarralde et al. (2015) "innovation occurs when

stakeholders distinguish a change in a product, process, organization or service and perceive in it sufficient value to adopt it or to adhere to it". Orstavik (2015) argues that even though each project itself requires coordination of new arrangements, the strong institutional context and patterns of interconnections preserve behavior and the approach to value creation across projects remains constant, thus working against innovative change (Orstavik, 2015).

What are the economic incentives for innovation in construction in general, is a question posed by Orstavik (2015). He concludes that there is little incentive in the building industry to innovate on quality because prices attainable for building products do not reflect quality performance superior to the average. This is explained by the condition of severe asymmetric information. Most of the information gained by individuals during building projects is tacit knowledge. Teece (1998) define tacit knowledge as "that which is difficult to articulate in a way that is meaningful and complete" (p.9). Tacit knowledge is either not easy to formulate into words or codify or actors do not care to do so. Non-codified knowledge is slow to transmit (Teece, 1998). This exacerbates the uneven distribution of knowledge gained in the complex building process by the multitude of actors. Asymmetric information causes prices to go down in the markets because clients discount the value of the product to balance the uncertainties of incomplete information on performance. It follows that generally it makes no economic sense to innovate where "the link between performance and price is weak" (Orstavik, 2015, p.22). Orstavik (2015) concludes that information asymmetry is "the single issue that reduces economic incentives for innovation on the design and production of the built environment" and innovation makes sense mostly when it brings stronger or monopoly position in the market (p.25).

The little incentive to innovate on quality performance means firms in the building sector mainly compete on prices and a large number of firms with similar offers make the industry very competitive. This competition on prices is further reinforced by the tendering system (Hakansson & Ingemansson, 2013). Stakeholders that compete on low prices generally show reluctance to deviate from well-established practices that can result in unexpected costs. Most innovation practices aim at increasing efficiency and driving down costs (Lizarralde, Bourgault, Drouin, & Viel, 2015). The short timeframes between the client ordering the project and the start of the construction also give little opportunity to experiment with new organizational methods, materials, solutions (Hakansson & Ingemansson, 2013). The cases may show how price competitiveness affects reuse projects by making actors unwilling to face additional uncertainties.

Due to its mainly tacit characteristic, the knowledge gained by individuals in projects is slow to diffuse even within firms which is exacerbated by the situation that the decentralized coordination in building projects causes organizational units within firms to be independent (Dubois & Gadde 2002). Firms, therefore, have vast know-how accumulated and distributed among individuals, but not diffused across the firm. Diffusion of knowledge is also hindered by the tight project deadlines and lack of time for passing on knowledge (Dubois & Gadde 2002). In the thesis, the analysis of project processes does not allow examination of changing patterns at the firm level. But it does present the relevance of time available in the projects.

The pattern of tight coupling between actors within projects, loose coupling between actors outside of projects, the high specialization of actors into trades and the institutional system serve to make the coordination of the complex building tasks manageable and to reduce uncertainties. But in turn, this system hinders innovation, gaining the industry the reputation of being slow to change in the long term (Kadefors, 1995). Literature suggests other ways of managing complexity. Kadefors (1995) suggests a weakening of the institutional system through building less complex buildings or through expanding occupational roles by broadening the skills and

knowledge of individuals. Dubois and Gadde (2002) suggest increasing coordination outside of individual projects.

Despite the industry having a reputation of being conservative, Kadefors (1995) points out that it did undergo significant changes since the 1950s. Also, some authors examine innovation at the project level, for example, Kreiner (2015) reasons that innovations can also happen at a project basis in forms such as the redefinition of problems that seek solutions, redefinition of the evaluation of the value of products, redefinition of the relationship of actors to their tasks. Hakansson and Ingemansson (2013) define innovation as a renewal that lasts. Taking the industrial network approach, they examine renewal through change in relationships between stakeholders. They define relationships as bonds between actors, links between actors' activities, and ties between actors' resources. From this perspective, they found that the Swedish building industry is seeing significant lasting renewal. Some examples that stakeholders reported are the development of partnering relationships with clients, and more and more outsourcing relationships with subcontractors and as a result increasing coordination activities (Hakansson & Ingemansson, 2013). It is from this perspective, the organizational network, the relationships between actors, that the thesis approaches the examination of the transition of the Danish building industry towards adopting reuse practices. Relationships between actors determine what knowledge can be exchanged and what joint learning takes place which in turn determines the type of renewal the business relationships can go through (Hakansson & Ingemansson,a 2013). Thus, the thesis endeavors to study collaboration of actors in reuse projects.

This thesis focuses on describing the process of overcoming day-to-day problems related to reuse within specific projects, on describing collaboration practices. This may be useful to get knowledge of what practices of collaboration are considered useful in reuse projects to overcome day-to-day challenges. As Adams et al. (2017) found, best practice case studies are considered significant enablers towards the transition to a circular economy in the sector. This is similar to what Argyris and Schön (1978) call mapping. Mapping brings together the information scattered between actors to show patterns of interdependencies and thus contribute to learning (Argyris & Schön 1978, p. 158-160). On the other hand, the thesis does not endeavor to examine changes in the process that happen from one project to another, changes that happen across time. Furthermore, by relating the collaboration practices to stakeholder interdependency patterns and institutions in the building industry, the type of industrial renewal that can take place within projects is examined.

2.2 Analytical framework

The reality of the 21st century is that of interconnectedness (Svendsen & Laberge, 2005). Most issues cannot be addressed by one organization alone. Lasting change such as the wide diffusion of building material reuse practices requires developing solutions that balance interests of a network of actors. Development of these new solutions needs to happen in some form of interaction among actors. New ideas emerge at the intersection of different bodies of knowledge that each actor represents (Bygballe et al., 2015). Bringing about lasting change means testing these new ideas and creating a balance with the existing activities and resources of actors (Bygballe et al., 2015).

The industrial network approach studies innovation by focusing on actor relationships (Hakansson & Ingemansson, 2013). All actors are embedded in a network of relationships with other actors. Hakansson and Ingemansson (2013) separate these relationships into 3 dimensions. First, actors link their activities to increase total efficiency. Second, actors tie their resources to create new resource combinations. Third, actors simply interact with each other to create bonds and improve their network position. Changes in any company will result in changes

in these three dimensions of relationships, new types of bonds can emerge through new ways of engaging with the partners, it can be that activities of counterparts are linked in a new way, or that resources are tied to the counterpart's resources in a new way. Adopting reuse practices means changes in the activities and resources of companies and according to the industrial network approach, there will be changes in relationships with other actors. Hakansson and Ingemansson (2013) suggest that examining the changes in relationships gives insight to the extent and type of renewal that is taking place.

Cooperation, coordination, and collaboration are words describing relationships that differ based on the intent and degree of participation of the parties (Kvan, 2000). Cooperation is characterized by "informal relationships that exist without a commonly defined mission, structure or effort. Information is shared as needed and authority is retained by each organization so there is virtually no risk. Resources are separate as are rewards" (Kvan, 2000, p.2). An example of this could be buying and selling products. Coordination is characterized by "more formal relationships and understanding of compatible missions. Some planning and division of roles are required and communication channels are established. Authority still rests with the individual organization, but there is some increased risk to all participants" (Kvan 2000, p.2). Lastly, "collaboration connotes a more durable and pervasive relationship. In collaboration, authority is determined by the collaborative structure. It requires a greater commitment to a common goal than co-operation with an attendant increase in risk. For this to occur, the level of trust must be higher" (Kvan 2000, p.3). Collaboration is the level of interaction between actors that most likely contributes to developing solutions that balance interests.

Further definitions of collaboration can be found in the literature. Stank (2001) examines supply chain collaboration and defines it as "a process of decision-making among interdependent parties" (p.3). It is characterized by joint ownership of decisions and outcomes, commitment to working together, sharing resources, and having a common vision and goals (Stank, 2001). The benefits to the collaborating parties come in many forms, for example, the ability to undergo changes (Stank, 2001). These benefits emerge when parties work together, share information and resources, understand each other's viewpoint and achieve collective goals (Stank, 2001).

Mattessich and Monsey (1992) define collaboration as "a mutually beneficial and well-defined relationship entered into by two or more organizations to achieve a common goal. The relationship includes a commitment to: mutual relationships and goals, a jointly developed structure and shared responsibility, mutual authority and accountability for success, and sharing of resources and rewards" (Mattessich & Monsey 1992, p.11). They define 19 factors that influence the success of collaborations.

Barratt (2004) describes the elements of collaboration very similar to Mattessich and Monsey (1992). A non-exhaustive list of the elements are trust, commitment, mutuality of benefits, mutual risk sharing, quality and transparency of information exchange (such as whether there is intermediation), openness and honesty, cross-functional activities to break down boundaries, senior management support, joint decision-making, preparedness to commit resources, intra-organizational support of actors, focus on the network of actors, demonstrating the business case.

Collaboration encourages joint learning of the level necessary to bring about transitional change (Brown 2003). This is seen by the high overlap of factors of successful collaboration and factors that contribute to a higher level of learning. Collaboration contributes to a higher level of learning through:

1. Encouraging system thinking (Senge, 1990): Systemic view means that actors go beyond considering only their own goals, to being aware of the network's interrelations around a particular issue (Svendsen & Laberge 2005). System thinking is facilitated by increasing the number of involved stakeholders because that shifts the focus on the systemic structure (Senge, 1990). But also by the ability to compromise.
2. Interaction around a common goal (Kamp, 2004): The following conditions facilitate learning through interaction according to Kamp (2004):
    a. mutual interest in the process
    b. mutual trust between the actors.
    c. norms of openness and disclosure
3. Self-evaluation and reflection (Brown 2003).
4. Continuous group commitment (Senge, 1990): through resources such as time, financial expenses, organizational support.
5. A sense of urgency (Brown 2003): such as risk to reputation or prestige, high financial stakes or a mounting problem in need of a solution
6. Shared vision (Brown 2003):

Thus, collaboration is essential in innovation by facilitating higher level learning. Through drawing comparison between the different elements of successful collaboration as per Stank (2001), Mattessich and Monsey (1992) and Barratt (2004) and the factors that facilitate higher level learning and thus innovation, the following analytical framework was developed to analyze collaboration in the project cases.

<u>Analytical framework</u>

1. A shared vision of actors in the projects: vision defined as „the more or less explicit claim or expression of a future that is idealized in order to mobilize present potential to move into the direction of this future" (van der Helm 2009, p5)
2. A mutual interest in the process: organizations have incentives to enter and remain in the project (Mattessich & Monsey, 1992)
3. Sharing risks
4. Ability to compromise
5. Existence of trust between the parties. The key features of trust are (Gordon & McCann, 2000):
    i. will to undertake joint ventures without risk of opportunism
    ii. willingness to reorganize relationships without fear of reprisal
    iii. willingness to act as a group for common mutually beneficial goals, this involves being able to compromise
6. New potential partnerships and inclusion of affected members of the community
7. Quality and transparency of information exchange as a function of
    i. openness and disclosure of information
    ii. frequency of knowledge exchange
    iii. presence of intermediation
8. Joint decision-making
9. Type of resource commitment:
    i. available time for the project
    ii. actors' committed time
    iii. financial resources

iv. support of management in the actors' respective organization

The limitation of the framework is that not all factors of successful collaboration are examined, only part of the factors that influence collaboration.

3 Methodology

This thesis is a practice-oriented research as it is „meant to provide knowledge that can contribute to a successful intervention" (Verschuren & Doorewaard 2010, p.45), by exploring collaboration in reuse building projects. Using the case study method has advantages especially in practice-oriented research (Verschuren & Doorewaard 2010, p.184).

3.1 Chosen research method

Case studies allow the investigations of the uniqueness and complexity of contemporary phenomena where the natural context has implications on the results (Stake, 1995; Yin, 2009). Case studies allow for a holistic exploration of real-life events such as small group behavior, organizational processes (Yin, 2009; Verschuren & Doorewaard, 2010). In case studies the investigated phenomena are not manipulated (Yin, 2009). In case studies contemporary events are explored, therefore the method can rely on multiple data sources, for example, interviews, documents and on-site observations (Yin, 2009).

Different case study types exist based on purpose (Swiercz, 2003):

- Descriptive case studies provide detailed information on phenomena, but only that, leaving the reader to use the information without predetermined goals.
- Explanatory cases translate a difficult subject understandable to the reader.
- Exploratory cases guide the reader through a new terrain leaving the reader to explore this terrain.

Explanation of the choice

The case study research method was chosen for several reasons. Case studies examine real-life specific cases, rather than abstractions such as arguments, topics or hypothesis (Yin, 2009). Moreover, the case study is suitable when the aim is to explore phenomena in depth rather than in breadth (Verschuren & Doorewaard, 2010). Therefore, case studies suit the aim of the thesis of researching collaboration in specific building projects in depth. A case study is „suitable for probing, classifying, and interpreting unstructured data drawn from an inherently ambiguous and dynamic organizational process" (Swiercz, 2003), therefore it is appropriate for examining the dynamic and complex process of collaboration.

Using the case study method requires less initial structuring (Verschuren & Doorewaard, 2010). Case studies allow the initial case design to be modified based on new knowledge acquired during data collection (Yin, 2009). Since there is little prior research in the field of collaboration in reuse building projects, case study allows a better exploration of the terrain, by allowing more flexibility during the acquisition of data.

Regarding the type of case study based on purpose, the thesis is mainly descriptive, providing detailed information about the collaboration process, while leaving the reader to use the information without a predetermined goal. The descriptive type of research is chosen because of the new terrain with limited previous research in the specific area and the assumption that therefore description of the cases will be useful for the intended audience. It aims to enhance knowledge on the process of collaboration in reuse building projects for further use by the intended audience.

Units of analysis
The unit of analysis in the thesis are Danish projects that include the reuse of secondary building materials. More specifically, these projects are either building projects that reuse secondary building materials or are projects that facilitate the reuse of secondary building materials through improving the accessibility of them. A brief description of the cases is given in Table 4-1.

The choice between single or multiple case study and embedded or holistic case study
The choice for single case design is justified if the examined case is either critical, unique, representative, revelatory, or longitudinal (Yin, 2009). There is not enough prior information available to the author about building project cases that would allow making such categorization. Meanwhile, it is argued that „the evidence from multiple cases is often considered more compelling, and the overall study is therefore regarded as being more robust" (Yin, 2009, p.53.), which also supports the choice for multiple case design. Yin (2009) suggests, when choosing multiple cases, the selection should be done either with the expectation that they bring similar results or contrasting results for foreseen reasons. A third method is the snowball sampling one (Verschuren & Doorewaard, 2010), and this was used in this research.

Both single and multiple case designs can be either embedded or holistic. The thesis study is an embedded multiple-case design because cases will be analyzed both at the levels of individual project members and of the project organization as a whole.

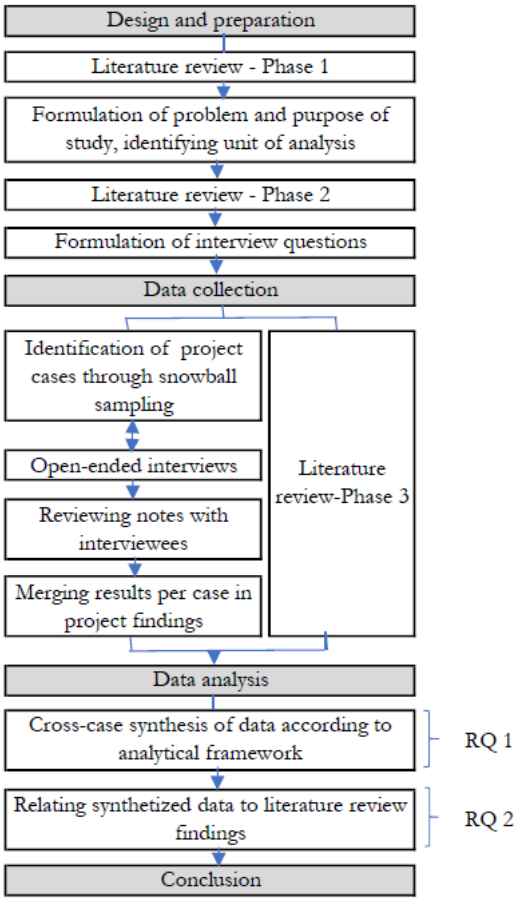
3.2 Research approach

The research approach is presented in Figure 3-1. and described in the following:

1. **Design and preparation:** Following a literature review on circularity in general, circularity in the construction sector, innovation in the construction sector, collaboration and learning, the purpose of the study was stated, research questions were formulated, the units of analysis were defined and the analytical technique was decided on. Initial interview questions were formulated based on theory. Letters of introduction were written to be sent out to potential interviewees.

2. **Data collection:** One of the principles of data collection in case-studies is to use multiple sources of evidence (Yin, 2009). Two types of data sources were gathered per case, documentation and interviews. Initial cases were selected and first interviewees were contacted. The focused, open-ended interviews lasted between 30 to 90 minutes. Most interviews were conducted face-to-face, while some were done on the phone or via Skype. Notes were taken during the interview, no voice recording was done. The notes were sent to most of the interviewees for review, but not to every one of them. The set of interview questions were slightly modified during the data collection period based on acquired knowledge. The interview guide is given in Appendix B. The interview guide slightly changed throughout the project to accommodate improvement: Questions were asked flexibly to adjust to the conversations, therefore not all questions were asked from all the interviewees. The results of some interviews contributed to the thesis in general, but not to specific cases. A whole list of interviewees is found in Appendix A. Following the snowball method, interviewees were asked for suggestions for further cases and interview contacts, to whom the letters of introduction were subsequently sent. In the meantime, the literature review continued during data collection. The data from each interviewee were merged per project case into findings using the case description strategy, which is suitable for descriptive case studies (Yin, 2009).

Figure 3-1 Research approach



3. Analysis and conclusion: This part deals with analyzing the data, drawing conclusions through comparison with literature, and drawing the overall conclusion of the thesis. The cross-case synthesis analytical technique was used to analyze the data and answer RQ1. Word table was created to help the analysis, as suggested by Yin (2009). In the table, the data from individual cases were organized according to the analytical framework. The table is presented in Appendix C. The results to RQ1 were related to literature review findings to provide answers to RQ2. Finally, overall conclusions were drawn to the thesis.

3.3 Selection of cases

A total of 5 Danish project cases were examined. Selected cases were chosen so that each of them involves the reuse of secondary building materials. Brief description of the projects in tabular form is given in Table 4-1. Three of the cases are one-off construction projects, one case is a long-term project for the construction of small sheds, and the last case is also a long-term project that facilitates the reuse of building materials by improving their accessibility. Although these are different types of projects, it was expected that the common theme of reuse will bring valuable results. Between 3 to 5 actors per case were interviewed. Together this provided sufficient data for the analysis.

3.4 The quality of research design

The quality of research design can be assessed based on four criteria, construct validity, internal validity, external validity, and reliability (Yin, 2009).

The following measures are directed to construct validity: Multiple sources of evidence were used by interviewing several actors per project. The interview notes and/or the draft case study report were sent to most, but not all key informants for review.

Due to the many variables in building projects between which identifying causal relationships is beyond the scope of the study, the study is mainly descriptive to avoid the threat to internal validity.

According to Yin (2009), generalization in case studies is unlike in survey research. In the latter, the generalization of the samples is to the wider universe, which is called statistical generalization. In the case of case study research, generalization is to a broader theory (analytical generalization). Due to the study being mainly descriptive, generalization to a broader theory is not an aim of the research.

4 Results

4.1 Introduction to the cases

This chapter presents the findings separately for each project. It summarizes the information received from the interviewees and acquired through document research. The project cases can be grouped in several ways. Some are grant-supported ones, others are privately or publicly financed. Some involve reuse of bricks, others reuse other secondary materials. Some are one-off construction projects, others are long-term initiatives. Some involve the construction of complex buildings, the others embark on creating other products. Some projects entirely focus on reusing materials, in other projects reuse is just one part.

All together five cases have been analyzed in the thesis. Brief description of the projects is shown in Table 4-1. Summary of the results in tabular form can be found in Appendix C.

Table 4-1 Description of project cases

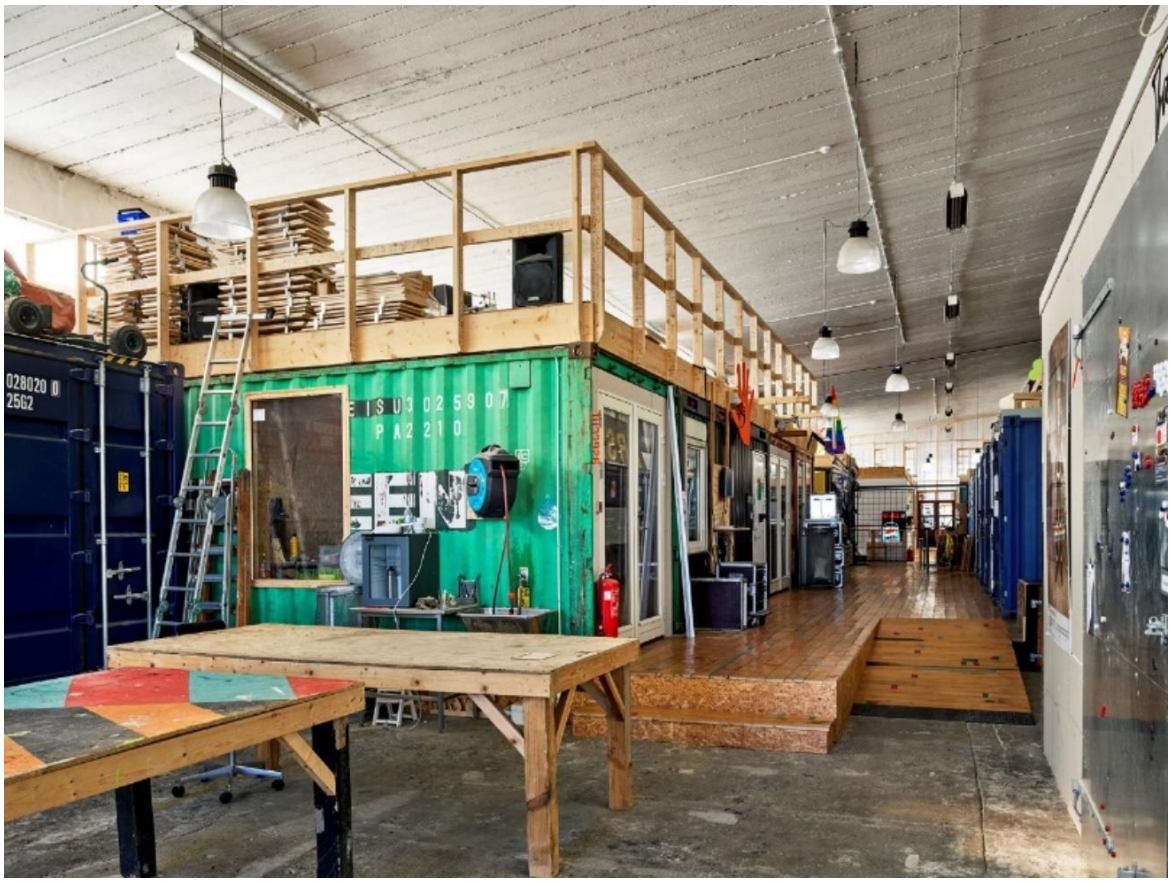
Project title	**Hal 7**	**Byhusene på Islands Brygge**	**Hvidovre Kindergarten**	**GENTRÆ**	**ReSkur**
Project status year	2016-2017	2013-2016	2017-still running	2018-still running	2018 - still running
Type of financing	grant supported	privately financed	publicly financed	grant supported	grant supported
Reused material	shipping containers, windows, doors, wooden floorboards, kitchen equipment	bricks	bricks	temporary construction timber	roof materials (clay pantiles, wood rafters, steel gutters)
Goal of the project	Refurbishment of old industrial building	Building housing units with reused brick facade	Building kindergarten house with reused brick facade	Introduction of reused building materials in large-scale retail sale	Building of high quality non-heated sheds
Number of interviewees	5	5	4	3	3
Document sources	(Manelius, Nielsen, & Kauschen, 2019)	Architectural tender plans Website on the development (Nybyggerier på Islands Brygge, n.d.)	Architectural tender plans	Project description on website of CCC (Circular Construction Challenge,. n.d.) Slide show presentation	Project description on website of CCC (Circular Construction Challenge,. n.d.)

4.2 Results of the individual cases

4.2.1 Hal 7

The Hal 7 project included the reuse of secondary materials other than bricks: containers, windows, doors, wooden floors, kitchen equipment. It was supported by a grant. Five actors of the project were interviewed representing the client Roskilde Municipality, two architects from Tegnestuen Vandkunsten, the contractor Egen Vinding og Datter, and the engineering company Steensen Varming.

Figure 4-1 Hal7 interior



Source: Picture by Kirstine Mengel

4.2.1.1 HAL7 project general description

The reuse project took place in Roskilde, a town half an hour by train from Copenhagen. One of its districts, Musicon, is located in the area of an earlier concrete factory. The Roskilde City Council adopted the vision for the brownfield urban development of Musicon district in 2003 to become a cultural hot-spot in Denmark, and the area is still undergoing development. The development includes the realization of some of the green strategies of the Municipality.

Hal 7 is a former industrial building in the Musicon district that was, under this project, repurposed into a Makers' Corner to accommodate a mix of social groups for social activities. The revitalization process lasted for around a year and Makers' Corner was put in service in September 2017.

The project was supported with a €791,000 donation by A. P. Møllerske Støttefond for the renewal of the former non-heated industrial building on the condition that the refurbishment utilized old shipping containers through reuse. Since Musicon is developing into an urban district, the long-term purpose of the Hal 7 building was not decided, and the refurbishment was to serve for the temporary use of 10 years. This became an argument to support the actors' wish for maximizing reuse since requirements for the quality of materials are less strict if materials only have to serve for 10 years. The 10-year lease also supported arguments to design for disassembly.

The available budget was too little for insulating the whole 880 m2 area of the building. Therefore, the concept of climate zones was introduced. The climate zone design required the insulation of the containers placed within the building. This presented a new technical challenge for the architect, the engineer and the contractor.

Another solution drawn from the low budget was to reuse more than just containers. Used windows, doors, wooden floors, and kitchen equipment were sourced and reused during the project.

HAL7

The Hal 7 construction project involved the temporary refurbishment of an old industrial building in Musicon, Roskilde Municipality, including the reuse of secondary building materials, such as used windows, doors, shipping containers, wooden floors, and kitchen equipment. It was a grant-supported project.
The project was performed by a group of visionary actors that are highly motivated towards reuse. Actors needed to adjust their way of working to accommodate overcoming challenges posed by reuse, such as the development of non-standard technical solutions and acquiring secondary materials. A flat network structure and close cooperation during the construction phase between the parties ensured successful implementation. Higher than usual flexibility, trust, and ability to compromise were key. Actors that usually are not involved in acquiring material supplies such as the client and the final users were indispensable in accessing the secondary materials.
The project was a success in several aspects. It is important to mention that several actors expressed their primarily long-term interest in taking part in the project.

As mentioned, the temporary nature of the solution was also a prerequisite to the possibility of reuse. For example, many of the windows and doors were not of good enough quality to serve as long-term solutions. The temporary nature of the project allowed the installation of the secondary materials without having to certify them based on standardized material requirements.

Besides refurbishment of the old industrial building, a second goal of the project was community development among the different groups of end-users of the new construction.

4.2.1.2 Results of collaboration aspects

4.2.1.2.1 Motivations, goals, visions, mutual benefits

The motivations, goals, and vision of the actors had a lot of similarities and were easily reconcilable to each other. The architect company Vandkunsten has been with an eye on sustainability by focusing on design for disassembly since the 1990s. Design for disassembly gives opportunities for new aesthetic motives, which has always been a driving force for Vandkunsten: to create visual outputs that challenge the eyes of the user. Vandkunsten considered the Hal 7 project as a strategic investment: to be among the first movers in reuse and design for disassembly, to improve their profile in reuse projects of this scale, and to gain experience in non-standard solutions. On the side of the municipality, the driving force for increased reuse came from a few motivated employees. The main representative of the municipality has herself completed several reuse projects previously in small-scale and was personally driven to include as much reuse as possible in the Hal7 project. The contractor

company Egen Vinding og Datter has, since its inception in the 1980s, been focusing on sustainability, with an eye to the cradle-to-cradle approach. This materializes by them developing non-toxic paints, low environmental impact clay stones, and long-lasting high-quality windows ("Vores Kompetencer", n.d.) In this project too, like in other projects, Egen Vinding og Datter aimed to include the most sustainable materials into the new construction. The engineering company Steensen Varming also has a deep concern for the construction industry's resource use and impacts and were highly motivated to support the cause of driving for change.

4.2.1.2.2 Some implications of applying non-standard solutions and using secondary materials on the activities of actors

The several non-standard solutions that derived from designing for disassembly, reuse, and insulation of containers indoors, and the climate zone design required changes in actors' working. Exact needs and requirements had to be clarified much earlier in the design phase compared to a conventional project. Inventing the non-standard solutions was time demanding.

Used windows, doors, wooden floors, and kitchen equipment were sourced from outside and reused during the project. This had far-reaching implications on the activities of different actors, the architect, the contractor, the client, and the final users. The contractor had to take up the unconventional task of searching for individual second-hand windows and doors instead of just ordering regular sized ones from a retailer, during which he developed new supplier relations. The architect had to be much more flexible in terms of finalizing the architectural drawings depending on the availability of specific secondary materials. The client took up the role, usually done only by the contractor, of harvesting secondary materials to be reused. For example, she coupled the problem of a burnt down building in the municipality with intact wooden floors and the need for floor boarding in the new construction. She organized the dismantling and cleaning of the wooden floorboards by volunteers and installing them as the new floor in the Hal7 building. She also arranged the kitchen equipment of a closing down sports facility to be reinstalled in the Hal 7 building. She contacted colleagues and acquaintances for un-needed but reusable windows and doors. Finally, the Hal 7 project relied heavily on the work of the final users. Their volunteer work in the Makerspace area was indispensable in reusing floorboards. The final users put many hours of voluntary labor into taking up the wooden floors of the burnt down building and cleaning them to be reused in the Hal 7 area in the frame of community work.

4.2.1.2.3 Quality and transparency of information exchange, mutual decision-making

Negotiations in the project had characteristics as follows, many of which were mentioned by the interviewees as different than in a conventional non-reuse project. There was no overall leader in the project, the network had a flat structure. The whole project was an iterative process in which all actors took part. Several practical solutions had to be worked out on the spot and needed close cooperation between the architect and the contractor. For example, when the contractor acquired some secondary material or considered a solution, it consulted the architect, who often had to finalize that part of the drawing on the same day which required much higher flexibility than is usual in non-reuse projects. The client was also very permissive about developed solutions, and also on cost changes requested by the contractor. Regarding negotiations on costs incurred by the contractor in the final versions of the project, the representative of the contractor company explicitly mentioned the presence of trust and honesty. The final user group was also directly involved in the project through the initial workshops and the voluntary work.

4.2.1.2.4 Mutual risk-sharing and trust

The very productive and collaborative nature of the project and the good communication had several positive effects. Despite the high uncertainties regarding time and expense requirements due to the unconventionality of the project, actors expressed that they were confident in success due to the way the team worked. Since solutions were developed in collaborative ways, together, the risks were shared and overcome by team mutual confidence. The representative of the contractor expressed that he learned that everything is solvable.

The second goal of the project, community building was also achieved with the additional success that the final users developed a feeling of ownership for the new building.

4.2.1.2.5 Additional insights

Some additional information from the actors.

The architect described how she learned to approach the drawings of reuse projects differently to accommodate the ping-pong process of developing solutions in the construction phase. But, to go beyond increasing efficiency under the present industrial context, the core solution to the main problem would be to improve the accessibility of secondary materials. Knowing well in advance what materials are available, it would make possible to plan with them without the excessive energy on being flexible during construction.

From the client's point of view, the main lesson from the project was that it is imperative to start the planning of a reuse project early in terms of calculating labor costs and searching for secondary material supplies. This is necessary in order to assess whether the reuse project is feasible at all. For example, as she stated, the Hal7 project would not have been feasible without the contribution of voluntary working hours due to high Danish labor costs.

4.2.2 Byhusene på Islands Brygge

The Byhusene på Islands Brygge project was a brick reuse project running from 2013 till 2016. Five project actors were interviewed: the project leader of the developer/investor NCC Bolig, the project leader of the turnkey contractor NCC Construction Nybyg, two architects from the architect company Vandkunsten, and the project leader of the supplier company Gamle Mursten.

Byhusene på Islands Brygge

Byhusene på Islands Brygge was a real estate development in Copenhagen featuring brick facades from reused bricks. It was a privately financed project. Motivations of actors to implement the solutions varied, but of primary importance was the developer/investor being convinced of the aesthetic quality of the reused facade raising the value of the investment and thus they were pushing for the solution.

The project showed how the price competitive building industry poses a challenge in realizing reuse solutions as for the contractors that are competing on price novel solutions are too risky to endorse.

The main challenges in the project related to the acquisition of sufficient quality and quantity of used bricks and the decision on the type of mortar to be used between the bricks. In these cases, actors needed to take responsibility for risks that derived from the uncertain quality of the used bricks and the uncertain quality and installation time of the mortar. The necessity of redistribution of risks was raised.

The project demonstrated that timing is crucial in novel reuse projects for the timely beginning of negotiations on the reuse solutions, for the availability of used bricks, and for the sufficient time availability for plannings, negotiations, and development of solutions.

Figure 4-2 Byhusene på Islands Brygge façade

Source: Picture by Mads Frederik

4.2.2.1 General information on the project

'Islands Brygge' is a neighborhood in Copenhagen on the island of Amager. Recently it underwent extensive real estate developments (Nybyggerier på Islands Brygge, n.d.). One of the developments was the so-called Byhusene på Islands Brygge: High-density terraced housing near the waterfront with concrete construction system featuring brick facades from reused bricks. The houses are certified with the Nordic Ecolabel. Brick reuse is not explicitly rewarded under the Nordic Ecolabel, the reused brick façade was rather chosen for its aesthetic qualities.

Discussions on the reused brick façade solution began well at the beginning of the project. The developer/investor commissioned the architect firm for the architectural design requesting a new solution of unique, high degree architectural quality that would increase the value and the selling power of the 110 housing units. One of the elements of the project brought forward by Vandkunsten to meet that request was the reused brick façade.

In 2016 the Byhusene på Islands Brygge project won Copenhagen Municipality's Building Prize.

4.2.2.2 Results of collaboration aspects

4.2.2.2.1 Goal, motivations, benefits

The architect company has been pushing for sustainable solutions, among them for reusing building materials for many years. Besides, the company is highly convinced of the aesthetic value of reused brick facades and strives to include the solution in many of its projects. The developer/investor was motivated to take advantage primarily of the aesthetic properties of the reused brick façade which was believed to significantly increase the value of the housing units and therefore to reap financial benefits. For the turnkey contractor company not having previous experience in reused brick facades the perceived risks seemed to outweigh the motivation to engage in pioneering solutions at the beginning. For the old brick supplier company specializing in the reuse of old bricks, the project has become the biggest project in the volume of bricks since their inception in 2003.

4.2.2.2.2 Results on the development of the project

The developer/investor was convinced about the superiority of the reused brick solution by the architect by demonstrating the aesthetic qualities and feasibility of the reused brick walls in another running project and became highly motivated. The architect was involved in the developer/investor negotiations, which can be considered quite unusual. Normally, when an architect firm is commissioned only for architectural work it has reduced say in negotiations. This could be attributed partly to the fact that the developer and investor of the project were from the same company. The contractor was also involved in the negotiations about the reused brick façade from the beginning, but details on the technicalities of the solution were only discussed later in the project.

When the technicalities of implementing the reused brick façade arose, extensive negotiations followed centering around the topic of who was to take the risks deriving from the use of reused brick façade. First of all, the risks related to the technical quality of the bricks. Construction bricks have certain characteristics, such as dimensions, compressive strength, water absorption, etc. In the case of bricks reclaimed from old buildings deriving from different production facilities and that have been preused, handled, dismantled and mechanically cleaned, their quality can vary significantly. Therefore, the responsibility for the quality had to be decided on, as at the time of the Byhusene på Islands Brygge project the supplier did not have CE marking for its non-standard old brick products yet. Eventually, the architects prescribed the quality requirements of the bricks based on the existing standards, and the supplier took the responsibility of guaranteeing it. This means, if one of the bricks gets damaged during the lifetime of the building, it has the responsibility to provide replacements. But the actual replacing of the damaged bricks remains the responsibility of the contractor. Therefore, risks were taken by the contractor too.

The supplier and the contractor carried out a quality check of the bricks to be delivered to the construction. Based on the results it was agreed that, even though the number of bricks tested did not provide a representative result, none-the-less, the risk seemed to be less than originally anticipated. Also, to further assure the quality of the bricks throughout the lifetime of the buildings, a maintenance manual for the reused brick façade was created.

Moreover, a smaller reference wall and later a whole wall section was built to demonstrate how the color composition would and should look because bricklayers do not normally take on the role of deciding the color composition of the wall.

Unlike new bricks the size of secondary ones can differ and is not homogeneous that requires additional time in the bricklaying process. This also resulted in much negotiation, but, going into more detail on the bricklaying process helped to arrive at an agreement.

Another risk generating intensive negotiations related to the type of mortar to lay the reused bricks with. Normally, the architect and the construction engineer together describe the technical properties of the mortar to be used, and the bricklaying subcontractor is responsible for laying the bricks with the specified mortar. But two challenges arose, namely complying with standards and longer time of construction.

The type of mortar used determines whether the facade bricks will be reusable at the end of life of the new building. If lime mortar is used, it will make it possible to clean and reuse the bricks, cement mortar will not. At that time, the supplier of the lime mortar could not provide the necessary documentation on its strength and other properties. Furthermore, none of the actors took the responsibility of applying mortar that does not comply with the standards. It is worth mentioning however that half a year later a lime mortar complying with the standards and provided with the needed documentation was developed.

Additionally, for technical reasons, using lime mortar to lay bricks takes longer. Therefore, its usage raised the risk of some delay and additional costs for the contractor.

Due to these two reasons, in the end, cement containing mortar was chosen, and as a consequence, a part of the idea of reuse was lost, as the facade bricks will not be reusable at the end of life of the new buildings.

4.2.2.2.3 Additional insights from the interviews

In the present system of standards and quality certifications, the architects describe the quality requirements of materials, and the suppliers have to comply with them. The system is designed to assure each actor to be safe from later disputes. However, certifications and standards for reused materials are very few, the actors cannot rely solely on them. Reusing materials may need risk-accepting behavior to some degree. For example, if the facade discolors, one might find it a beautiful patina and accept it, or one might consider it as a defect. Collaborative and joint risk mapping can be a possible solution. Whether or not the risk is acceptable should be decided jointly. Sharing the risks of reuse even with the end-user might be a necessary prerequisite.

In the Byhusene project risks related to reuse were shared to a high extent as mentioned earlier: The architect firm and the developer/investor took on risks by pushing for the reuse solution, the contractor by executing the construction, while the supplier by ensuring the quality of the bricks.

Almost all interviewees stressed the significance of introducing reuse early on into the project for improving the chances of success. Firstly, having the reused brick facade solution endorsed by the developer/investor early in the project was decisive. Their strong conviction that the reused brick facade would increase the value of the property significantly made them push for the solution even when technical difficulties arose. The advertisements and sales of the properties included this technicality as an asset of the housing units.

It was decisive that the developer/investor was strong in its demands and was pushing for the reuse option during negotiations with the contractor. The contractors usually compete with each other on price. By giving the lowest price, they prefer to go for a safe solution with the least risk and having the most knowledge and experience on. As a result, they are not inclined to a reuse

solution with additional risks. It had to be the client pushing for the reuse solution. The project showed that the contractor should be involved in the reuse project as soon as possible, because the contractor will not seek for such opportunity on its own, but if it knows about it well ahead, the negotiations will become easier.

Finally, early involvement is also imperative to ensure sufficient supply of old bricks. The project has been the biggest one in terms of brick quantity for the supplier, and thus the acquisition presented a challenge to them. It was the favorable timing that helped them to overcome it. A building in Copenhagen was just being demolished from which the 700,000 bricks could be gained for reuse. According to the supplier, contacting them one year ahead of construction gives enough time to acquire the materials, and also allows for more favorable brick prices. None-the-less, as long as discarding waste is cheap for the demolishing companies, supply will always be an issue.

The actual timing was indispensable also from another aspect. The project had an unusually long time for planning and negotiations among the actors. As compared to the usual 2 months, there were 4 months to develop the plans. Since reuse solutions have uncertainties deriving from their novelty, the high workloads, the tight deadlines and the quick delivery of jobs work against them. A long enough planning period could compensate for the additional difficulties.

There was a further peculiarity of negotiations namely that the developer/investor took up the unconventional role of negotiating prices with the brick supplier normally done by the contractor company.

4.2.3 GENTRÆ

GENTRÆ is a grant-supported project involving reuse of temporary construction timber (i.e. guardrails, toe boards, stairs, framework panels, plywood hoarding, etc.). GENTRÆ is one of the three winning projects in Denmark's "Circular Construction Challenge - Rethink Waste", initiated by the philanthropic association Realdania. The Challenge is a one year process and the developed prototypes are expected to be showcased in autumn, 2019. The companies that form the core team of the project are the waste management company Solum Group, the environmental consultant company Golder Associates, and the retailer and distributor of building materials Stark Group. The project leaders from all three companies were interviewed.

The Circular Construction Challenge focuses on addressing the global problem of resource use and waste production of the built environment. The Circular Construction Challenge is a one-year program. Realdania launched it in August 2018, and the first 6 months were spent on selection and setting of teams. Out of the 39 submissions, the three winning teams were announced in late January 2019. The winning teams each receive €130,000 financial support and throughout February to June are supported by external experts in 3 boot camps organized by Realdania. By September-October, 2019, the three teams are expected to present their final prototypes ("Circular Construction Challenge", n.d.). Therefore, this experimental case is examined not in retrospect, but during the running of the project.

Figure 4-3 Temporary construction timber

Source: "GENTRÆ", 2019

4.2.3.1 Results of collaboration aspects

4.2.3.1.1 Vision

The vision of the GENTRÆ project is the introduction of reused building materials in large-scale retail sale. The project team believes that by introducing reused building products alongside new building products in large-scale retail sale they will become natural alternatives to builders and constructors and thereby contribute to a paradigm shift in resource consumption.

On the long run, the plan is to introduce several types of reused building materials under the brand name GENTRÆ. The first building material to be developed under the GENTRÆ assortment was chosen to be temporary construction timber (i.e. guardrails, toe boards, stairs, framework panels, plywood hoarding, etc.). This is because temporary construction timber has limited requirements for the material, contains no hazardous substances, has fast turnover and short lifespan, moreover, annually 50000 tons are disposed of it as combustible waste.

GENTRÆ

GENTRÆ is a competition-winning project supported by a grant aiming for the reuse of temporary construction timber. The project aims to recirculate temporary construction timber that otherwise would be disposed of as combustible waste. It is not a one-off but a long-term project which was, at the time of the interviews, at an early stage of development.

Core team members facilitate the collection and processing of temporary construction timber and its redistribution. Close collaboration is established with 5 contractor companies that supply the used timber and that are also the clients of the GENTRÆ product. A law firm helps the team as part of the consortium to overcome challenges relating to the quality certification of used timber. Finally, a web application developing company works to develop the application that contractors use to order a pickup of the used timber. Core team members expect mainly long-term benefits from the project.

Team members take up novel approaches in their way of working. They work closer than usual with the whole supply chain, moreover, the core team adopted the open-book approach. The contractor companies are given short-term incentives to stay in the project, such as saving on the waste management costs of used timber. But they are also driven by long-term expected benefits, all-in-all, bringing competing contractors to negotiate at the same table.

4.2.3.1.2 Development of the partnership

The partnership development started by the consulting company approaching the waste management company, to partner up to address the issue of wood construction waste. The waste management company has the expertise to handle waste, but for the materials to be reused, they needed a partner that puts the reused product back on the market. This is why they partnered up with a large retail store and distributor of building materials that brands and markets the GENTRÆ product, as well as provides logistics expertise in transport if the quality of the product is good and it complies with legal requirements.

Next to the core team, second-level partnerships were established with 5 contractor companies, a legal advisor company, and a web application developing company.

The contractor companies supply the secondary wooden material from their construction site and are also the customers of the GENTRÆ products. These contractor companies have obligated themselves to deliver the sorted secondary materials and purchase the GENTRÆ product at a pre-fixed price. To facilitate the convenient collection of the sorted used wooden secondary materials, the team is developing a web application where contractors can easily register a pickup. The empty return trucks of the retailer from the building sites are utilized to transport the secondary materials to the waste management company for material processing. Material processing involves weighing, sorting, sawing, quality checking, labeling, and packing according to requirements. The GENTRÆ project is also a social enterprise because it employs socially vulnerable people at the processing site. The final products are delivered from the material processing site to the building merchants again utilizing empty return trucks of the retailer.

One of the main challenges the GENTRÆ team is facing is the certification and quality assurance of the GENTRÆ product. Therefore, partnership with a legal advisor company was established that identifies and clarifies legal issues related to producing and marketing reused construction materials on a large scale. This, for example, includes clarifying the requirements for the CE marking of the GENTRÆ product. Together solutions are developed.

There are changes this collaboration has meant in the work of actors with partners. For example, the retailer normally focuses on its immediate material suppliers and its immediate customers (major contractors, builders, consumers, distributors, and industries). In the GENTRÆ project, however, the retailer works with the whole supply chain. For example, it collaborates with companies it would not normally work with, such as a waste processing company. Moreover, there is much closer collaboration with major contractor companies than is usual in its business. Close collaboration with the supply chain helps companies to be asked questions that help them develop further.

4.2.3.1.3 Individual motivations and goals

Each member of the core team has their own goals. For example, the retailer aims to be able to offer materials that no other competitors offer and also to optimize its logistics and lorry transfer costs. The consultant company is gaining valuable networking partners and a name in the green business. But the core team together also has the common goal of making a business case out of GENTRÆ.

There is a high dependency of each actor on the other actor in achieving success. They are investing a lot of time and energy into the project. And it is only if they make a business case out of it can they reach their goal and fully harvest the fruits of their work. If the concept proves to be a success, 2 of the core team members can eventually purchase the resulting company.

The motivation of the contractors is, first of all, increased by the core team through the provision of economic incentives. During the prototype development phase, the contractors can dispose of their used wooden materials freely through GENTRÆ, rather than having to pay for its waste management. Secondly, contractors are motivated to get on board the GENTRÆ project because their competitors are also taking part. Thirdly, these contractors also want to be forerunners in the circular economy.

4.2.3.1.4 Quality of information exchange

Negotiations among actors happen in different constellations and frequency. Firstly, the core team has weekly skype meetings. Secondly, monthly meetings are held with the wider group. Thirdly, the team takes part in the boot camps organized by Realdania. During these boot camps, among others, they evaluate their work and external experts review their progress and provide feedback. And fourthly, there are extensive negotiations with the contractor companies.

Negotiations with contractor companies show high importance in the project. First of all, negotiations are to overcome barriers related to the quality of the GENTRÆ product. Contractors, as customers, are closely consulted to find out their expectations on the quality of the GENTRÆ product, and what they are willing to compromise on. As suppliers of the secondary materials, they are given incentives to sort the secondary wood according to requirements and are educated on the proper sorting on site of the used wooden materials. Therefore, whenever a new construction site begins, the foreman of the construction site is informed. As suppliers, they must also be consulted on whether they are satisfied with the logistic system that collects the sorted material.

One of the interviewees expressed that collaboration with contractors is unique, because under the umbrella of the GENTRÆ project these contractors – that are otherwise each other's competitors – come, sit and work together at the same table to discuss the project.

For the consulting company, this project means getting much deeper insights into their core partners' business models/business numbers then they normally do during business-as-usual consulting. Normally, companies keep their business models and great ideas to themselves. But in this collaboration, there is openness about each other's costs, business models, business partners.

In the beginning, agreements were made through letters of intents. In the letters of intent, the core team agreed on, for example, the number of hours each will invest into the project, on sharing business numbers, and on the willingness to buy the share in the end. These documents are not legally binding, but they have proven to be strong enough to work.

The GENTRÆ project also affects the internal relationships in the companies. For example, all departments within the retailer company must work together to accomplish the project. Employees are convinced by making them feel proud about working in a company that cares about sustainability.

4.2.3.1.5 Resources

The project is 40% financed by the Realdania fund and 60% by the core team. The core team members are working on the GENTRÆ project besides their normal working hours.

It has been expressed that collaboration with the major contractors is very much facilitated by the circumstance that there is no money transfer at this point which is possible because of the

support of the grant. On the long run, contractors will be required to pay for the service of their wooden materials being taken care of. But at this point, they are not required to pay for this service. And, therefore, they are more willing to sort the materials and accept the uncertainty of the value of the final GENTRÆ product. This way discussion and dialogue begins, and once the project is running, matters of money may be discussed, such as the price value of the GENTRÆ product.

4.2.3.1.6 Other insights

The legislation does not state that if something is used it loses its CE marking. If a CE marked wooden plank is used, will it retain its CE marking? The legislation also does not state that if a building material is used it must be re-certified before it can be reused. But in the construction industry, there is a tendency for precaution, a tendency to certify everything. The opinion is that implementing circularity requires the rethinking of the present system of certification.

4.2.4 ReSkur

ReSkur is another winning project of Denmark's "Circular Construction Challenge - Rethink Waste" (see 4.2.3. GENTRÆ). The companies that form the core team of the project are the demolition company Tscherning, the architecture company Krydsrum Architects, and the construction company Enemærke & Petersen. The project leaders from all three companies were interviewed. This project is still running.

Figure 4-4 ReSkur shed drawing

Source: "Krydsrum", n.a.

4.2.4.1 Results of collaboration aspects

4.2.4.1.1 Common vision and the development of the partnership

The vision of ReSkur is to create high-quality non-heated sheds from reused roof materials. By creating a new circular shed with vintage storytelling the team wants to provide the society with an easy first step towards a green transition and to create the demand for high-quality long-life materials that would otherwise be disposed of during renovations ("ReSkur", 2018).

Originally, the contractor set up a competition to generate ideas for a solution to recycle the waste they generate during their main business activity, renovation work. If not reused, this waste needs to be handled according to the waste legislation which means downcycling or incineration. The competition was won by the architecture company with its idea ReSkur.

The idea was further developed in a two-day workshop Match & Create organized by Bloxhub, a Nordic hub for sustainable urbanization. With this further developed project they applied for the Realdania's Circular Innovation Challenge, where they became one of the three winners.

The rest of the consortium partners were gathered through an open call for which industrial stakeholders could apply: a demolition partner, 2 customers, an advisor, an industrial partner, and a consultant organization were chosen. Together they won the Circular Construction Challenge.

ReSkur

ReSkur is a competition-winning project supported by a grant that aims to make high-quality non-heated sheds from reused roof materials. It is not a one-off but a long-term project which was, at the time of the interviews, at an early stage of development. The core team consists of an architect company designing the sheds and keeping the value chain motivated, a contractor company building the sheds, and a demolition company harvesting the roof materials. The core team works with open books optimizing processes with the whole group's result in mind. New ways of working include the architect selling products rather than his hours and maintaining closer collaboration with the contractor during the development of the sheds. The core team members entered the project with long-term benefits in mind, becoming part of the circular economy being a key motivating factor. The main challenge is to create a business case and to achieve the right price for demolition and construction works and to hit the right price for the finished sheds. Close cooperation is maintained with future clients to find out their priorities and overcome quality certification issues.

The roles of the core team members are as follows. The architects are the designers of the sheds. Moreover, as much as they are designers, they are also so-called "circular chain operators". This is the new term for those that connect the value chain, make sure that everyone stays motivated, and that the necessary optimizations for the business case are put in place. The demolition company is responsible for harvesting the roof materials through demolition as well as quality checking, cleaning and delivering them to production. The contractor is responsible for the industrial pre-fabrication, production, mounting and future servicing of the sheds.

There are several unconventional characteristics to the collaboration among the three core team members. Each actor works in the area of its competency but at the same time, each actor aims to optimize the processes with the group outcome in mind. Actors are motivated to act this way because the success of each depends on the group's success. If the project develops into a scalable solution and a business case, the three core members of the team can purchase the company.

The main challenges the team faces in creating a business case are to achieve the right price for the demolition works and acquisition of secondary materials, to achieve the right price for the construction works of the new sheds and to create demand for these new sheds.

At the time of the interviews, the project was in the prototype building phase. This was preceded by the secondary material acquisition phase where the demolition company was carefully disassembling roofs and assessing costs. In this phase, the team already faced the challenge of acquiring a sufficient supply of materials at the right price. The team is already considering that a supply problem could arise should the team succeed to hit the right price for the sheds and should demand surge.

4.2.4.1.2 Motivation and goal

Each company has their motives and together they have joint goals as well. The architect company frustrated by the waste generated during retrofitting projects is motivated to find a solution to it and make a business out of it. It is hoped that ReSkur will contribute to improving the company's brand image. It is a strategic investment and a way to show competency in this area. The contractor is motivated due to the belief that the circular economy is here to stay and has the will to make a business out of the waste created during normal operations. ReSkur also serves as a change agent within the company. The demolition company considers ReSkur to be a demonstration project that helps in entering the circular economy and in delivering and selling materials at a higher value. This would mean a refinement of business through having more dismantling instead of demolishing. The joint goal of the group is to create a scalable solution and a business case for ReSkur.

4.2.4.1.3 Quality and transparency of information exchange, trust, resources

To facilitate finding solutions to arising challenges, the core team works with open books and shares information to a much larger extent than normal across companies. For example, the demolition company provides information on the incurred costs during demolition works of roofs through sharing data on the manhours and used technology.

There are other ways in which the ReSkur project requires the actors to engage in new ways of working. The architect company is used to selling its work by the hour during counseling. In ReSkur it is selling products which requires a different kind of responsibility taking. Therefore, there is a redistribution of risks in this project. Additionally, for the architect finding solutions is also a result of a higher level of collaboration than usual. Because of the novel solutions in the development of the new sheds, it is often the architect that is the one asking the questions from the craftsmen. The contractor company normally works in projects that are of a significantly bigger scale and, therefore, ReSkur's small size makes it a different business from the mainstream one. The demolition company is reclaiming materials that they usually incinerate which requires careful dismantling and new ways of approaching the work.

The architect company is the leader in the project, the one who holds together all the actors. Actors work and decide within their own competency and work in small groups to find solutions, when and with whom it is necessary. Additionally, the project is developed in boot camps organized by Realdania. Here mentors give help in asking the right questions and by giving feedback on whether the project is progressing in the right direction and help actors to align their visions and understandings.

The partnership with future clients is important to learn of their requirements and also to overcome certification issues. Clients are invited to take part in the workshops. Firstly, clients provide information on their priorities. Secondly, clients are also incorporated in overcoming some of the challenges the ReSkur project faces. One such challenge is that of the certification of the secondary materials that are used for the building of the sheds. Clients are asked to take part of the responsibility of lack of certification of the secondary materials at this stage and are given some rebate in return from the competition prize of the Circular Challenge.

4.2.5 Hvidovre Kindergarten project - Børnehuset på Bytoften, Hvidovre

The Hvidovre Kindergarten project is a brick reuse project running since 2017. At the moment it is in the contractor tendering phase. Interviews were conducted with the project

representatives of the client Hvidovre Municipality, the architect firm Vandkunsten, the engineering firm DJ-MG, and the brick supplier company Gamle Mursten.

Figure 4-5 Børnehuset på Bytoften drawing

Source: Architectural tender plans

4.2.5.1 Project timeline

Hvidovre is a suburb of Copenhagen located 15 minutes from central Copenhagen. The municipality adopted its environmental policy in 1998, stating, among others, that the municipality works to limit the environmental impact of any buildings, constructions, productions, and operating tasks. ("Politikker og strategier", n.d.)

The project involves the renewal of a building for a kindergarten whereby it is to be demolished and a new building is to be raised instead.

The commitment of the municipality for the environment has been demonstrated in the Hvidovre Kindergarten project. At the beginning of the project, surveys on the building facing demolition included, in addition to hazardous materials, also resource mapping. The surveys were carried out by the engineering company and showed potential for the reuse of, among

Hvidovre Kindergarten

The Hvidovre Kindergarten project involves the renewal of a municipal kindergarten's building whereby bricks from the demolished building are to be reused as the facade of the new building. At the moment, the project is in the contractor tendering phase. The municipality demonstrated its commitment to reusing building materials through commissioning a resource mapping report and choosing the winning architectural tender that included the reused brick façade.
The project faces challenges regarding the price of applying reused bricks. The project shows the significance of involving all reuse related actors early in the project, of early communication on possibly arising risks, and of direct communication between reuse related actors.

others, bricks. The resource mapping survey, therefore, demonstrates the strong commitment of the municipality to engage in resource savings.

The survey report states good potential for reusing bricks based on their appropriate quality, including lack of hazardous substances and the mortar type identified, and also on the market surge for cleaning bricks at that time. At the beginning of 2017 when the resource mapping report was written, there was a downturn in the construction industry and contractor companies were more open to turning to new business areas such as brick cleaning.

During the architectural competition, evaluation took into consideration sustainability including reuse solutions of the architectural plans, e.g. reuse of most construction materials in the most optimal way. The evaluation was performed by the engineering company. According to the winning plan bricks from the old building were to be reused after cleaning as the façade for the future building.

The architect company became the advisor to the client. Therefore, it had a central role in negotiating with all the actors: the client, the contractors, the demolition companies, the environmental advisor, the brick supplier, the engineers, etc. Negotiations with the brick supplier began during the material solutions planning phase, and materials were chosen based on availability and budget. At that time, the only company to supply and clean bricks was Gamle Mursten. Based on its opinion it would not be economical to transport and clean the bricks from the building facing demolition, instead, old bricks from other sources should be reused in the facade. The building survey advisor was also involved in the project after the architectural tenders, but only regarding hazardous materials.

Finally, the call for contractor bids was announced including the reused brick solution without the restriction of sourcing the bricks from the building facing demolition. But all bids exceeded the available budget, partly, as a consequence of the brick reuse solution. Therefore, the municipality decided to wait until summer to run a second call for tender. The representative of the client expressed his intention to address the politicians of the municipality by informing them that the reuse option increases the prices so that either the budget has to be increased or the reuse solution would possibly be dismissed.

4.2.5.2 Goal and motivation

The initial goal was to build the façade from used bricks sourced from the building facing demolition. As mentioned earlier, the architect company strives to include the reused brick solution in many of its projects. The Municipality demonstrated its goal of incorporating reused materials in the project by ordering the resource mapping report and choosing the winning architectural tender that included the reused brick façade. The engineering company expressed its long-term business strategy to increase its engagement in reuse projects.

4.2.5.3 Quality of information exchange, decision-making, trust

Negotiations on reusing bricks centered mainly around the question whether the old bricks for the facade could be sourced from the building facing demolition itself or need to be sourced from other demolition sites. Reusing bricks sourced from the site raised questions on costs of careful handling of bricks. Reusing bricks is a relatively new process, and for this reason, carries higher costs. This is because actors are less familiar with careful demolition, cleaning, and certifying the quality of the old bricks or because, as in the present case, there was only one actor to negotiate with about the cleaning and transport of bricks.

Most of the actors reflected on the significance of involving all reuse related stakeholders early in the project. Actors involved in reusing materials should be incorporated from the beginning until the end, furthermore, communication on the risks arising from reuse should start and agreement be made on sharing the risks at the very beginning of the project. The problem of intermediation due to contractual relations also arose. The engineering company was a subcontractor during the resource mapping survey, therefore it was not in direct communication with the client. Direct communication with the client would have been important to explain the additional risks, time, and costs arising from secondary material reuse, as the client is "the actor with the wallet". Also, involving the supplier/cleaner of bricks early in the planning phase is important to clarify prices early.

Similar as in the Byhusene pa Bytoften project, it was expressed that the usual way of working in the construction industry does not encourage reuse because actors aim to cover themselves from risks, while for successful reuse projects risk sharing seems to be an important element.

Concerning risk-sharing, until today the Hvidovre Kindergarten project was very similar to any conventional project not involving reuse. For example, in a conventional project the architect, as an advisor to the client, is selling its hours, providing objective information about possible solutions. It takes on the responsibilities of assessing the technicalities and forming recommendations to the client as objectively as possible. That is its responsibility, but the final choice is made by the client, and it is the final decision-maker who takes on the risks of the decisions. That was the case in the Hvidovre Kindergarten project until now. So, in the sense of who is taking on the risks that arise with reusing building materials, this collaboration was very similar to a conventional construction without reuse.

5 Analysis and discussion

5.1 Analysis

This section provides a description of collaboration based on cross-case analysis using the framework. Since each project case is different with several interrelated variables where causalities are impossible to determine, these results are not meant for generalization, but to provide knowledge on what actors emphasized as important in their collaboration.

Having examined the project cases this section aims to answer the research question:

RQI: What is emphasized as important regarding collaboration for reuse of secondary building materials in Danish projects?

Shared vision

The cases seemingly support the presumption that shared vision plays a role in successful collaboration. Two of the projects, ReSkur and GENTRÆ explicitly have their stated visions. In Hal7, the role of the deep motivation of core actors for supporting the cause of sustainability in the success of the collaboration was especially emphasized by most interviewees.

	Hal7	Byhusene	GENTRÆ	ReSkur	Hvidovre
Shared visions	Emphasis on participants being visionary	–	Clearly stated vision	Clearly stated vision	–

Mutual benefits

Benefits of taking part in the reuse projects expressed by actors consisted of both long- and short-term ones. Long-term benefits mentioned are

- becoming first movers in reuse,
- achieving a long-term competitive advantage,
- obtaining a name in the green business,
- improving brand image,
- gaining the ability to offer products not offered by competitors,
- getting experience and knowledge in the non-standard design and the new material processing solutions,
- improving networking relationships,
- making a business case out of waste generated during normal operations,
- optimization of normal operations such as logistics,
- using the project as a change agent in own company.

Short-term benefits were mainly financial ones.

Grant supported projects were characterized by mutual benefits, most of them were long-term ones, whereby many project actors were ready to sacrifice short-term financial advantages. Two interesting cases are the ReSkur and GENTRÆ projects, where additional to each actor having its own separate incentives, they also all have a stake in the overall outcome of the project by having the opportunity to buy a share in the business if it proves to be a success. On the other hand, lack of mutual benefits was emphasized in the privately financed Byhusene project where initially the turnkey contractor saw high uncertainty in short-term financial returns. That created

a significant need for enhanced negotiations on the technicalities of reuse in order to find a compromise, which was eventually achieved.

	Hal7	Byhusene	GENTRÆ	ReSkur	Hvidovre
Mutual interest	Actors express strong motivations to do the project and mainly long-term incentives	Short term financial incentives as well as long term incentives. Emphasis on initial lack of mutual interest, but eventually compromise was found	Actors have their individual, mostly long-term incentives, there is also a common joint incentive	Actors have their individual, mostly long-term incentives, there is also a common joint incentive	Both long and short-term incentives among all actors

Sharing risks

The project cases can be divided into two groups, those cases where risks were not emphasized by the interviewees, and those ones where risks played a dominant role in the discourse. The grant supported projects make up the first group. On the other hand, in the privately financed Byhusene project, there was a high emphasis on risks despite the fact that each actor took up risks related to the reused brick façade. In this latter group, several actors emphasized that the way responsibilities are distributed among actors in the industry today does not facilitate reuse practices because secondary materials present uncertainties that new materials do not do. A way to overcome the resulting risk is new ways of distributing responsibilities between project participants.

	Hal7	Byhusene	GENTRÆ	ReSkur	Hvidovre
Sharing risks	Risks originate from time and expense requirements. Actors say they didn't feel the risk because of the way the team worked	Emphasis on uncertainties originating from the secondary material quality and the novelty of the solution. All the actors took responsibilities regarding reuse. The necessity for new ways of distribution of risks is emphasized	Joint stakes of core actors in the mutual outcome. Mutual contribution to the outcome.	Joint stakes of core actors in the mutual outcome. Mutual contribution to the outcome. Redistribution of risks when architect sells products rather than his hours	Sharing risks as in conventional projects. The necessity for distribution of risks is emphasized

Ability to compromise

Several examples of the ability to compromise were found. For example, it was stated that in the ReSkur project each actor optimized its processes with the whole group's outcome in mind and that is considered to become a key for the joint success. Furthermore, in the Hal7 project, the client's permissiveness about developed solutions and on cost changes proposed by the contractor was found important to facilitate the joint outcome. In the Byhusene project, despite initial incongruence in expected benefits, the actors eventually arrived at a compromise.

	Hal7	Byhusene	GENTRÆ	ReSkur	Hvidovre
Ability to compromise	Client's permissiveness on solution and cost changes	Initial incongruencies were solved	–	Actors optimizing processes with whole group outcome in mind	–

Trust

(examined through the will to undertake joint ventures without risk of opportunism, willingness to reorganize relationships without fear of reprisal, and willingness to act as a group for common mutually beneficial goals)

Several examples of key features of trust were identified in the projects. Especially, the grant-supported ones showed key features of trust. Their actors reorganized their relationships in many ways. In ReSkur and GENTRÆ the core teams, also consisting of actors that normally do not work together, adopted the open-book approach thus having much deeper insights into the processes of the others. In Hal7, actors took up a close working approach of being flexible in finding and agreeing on solutions, this way sharing the consequences of their decisions. Several Hal 7 interviewees mentioned that they were very willing to work in the project because of the way the team worked, suggesting a strong team feeling. In both the ReSkur and the GENTRÆ projects, the full harvesting of the fruits of their work could only be achieved if the goal, making their product a business case is realized. This implies high interdependency in the group making the actors optimize the processes for the whole team, and work as a group for the mutually beneficial goal.

	Hal7	Byhusene	GENTRÆ	ReSkur	Hvidovre
Existence of trust between the parties	Reorganization of relationships around achieving the common goal	–	Adoption of open-book approach; Establishing a long-term partnership	Adoption of open-book approach; Establishing a long-term partnership; Each actor undertaking a new type of business	–

New partnerships, the inclusion of affected members of the community

In most of the projects, partnerships were formed between actors that would normally not work together or would work less closely connected. And many of these new partnerships were made to facilitate the secondary material supply. For example, the client in the Hal 7 project connected with personal acquaintances and institutions, the final users took part as volunteer workers in acquiring the secondary materials, while the contractor established new connections with suppliers. In the Byhusene project, the success heavily depended on finding a demolition site in Copenhagen from where the 700000 reused bricks could be sourced from. In the GENTRÆ project, a long-term partnership is established between the core actors. Moreover, they established collaboration with a law firm to overcome secondary material quality issues and with socially disadvantaged people to work at the processing site. What is more, they established a close relationship with the contractors, who are both suppliers and clients. ReSkur is also a long-term project between the core actors, moreover, the core actors consist of the supply chain from material acquisition to ready product. Furthermore, other actors are also involved in the collaboration, such as clients.

	Hal7	Byhusene	GENTRÆ	ReSkur	Hvidovre
New partnerships, inclusion of affected members of the community	Final users work as volunteers, New connections between contractor and suppliers of secondary materials; New connections between the client and sources of secondary materials	Connection with demolition site where the reused bricks were sourced from.	Long-term close collaboration between core team; Involvement of the whole supply chain; Second level partnerships; Stronger than usual collaboration with partners; Employing socially disadvantages people	Long-term close collaboration between core team; Involvement of the whole supply chain; Second level partnerships; Stronger than usual collaboration with partners;	–

Quality and transparency of information exchange

(openness and disclosure of information, frequency of knowledge exchange, presence of intermediation)

The frequency and quality of information exchange increased around the issue of reuse solutions to a different extent in the cases. As mentioned earlier, in ReSkur and GENTRÆ the core team members adopted the open-book approach. Both of these cases are characterized by frequent direct information exchange among the whole consortium as well as the availability of a platform for feedback in workshops. In Hal7 there were daily negotiations among actors for finding and agreeing on solutions. In the Byhusene case, there were improved direct negotiations on reuse in which also actors (the architect) whose contractual relation would normally not justify it, were involved. In the Hvidovre Kindergarten case, communication via intermediator instead of direct communication due to contractual relations presented a problem. Moreover, the need to involve the relevant actors throughout the whole project from the very beginning was emphasized.

	Hal7	Byhusene	GENTRÆ	ReSkur	Hvidovre
Quality and transparency of information exchange	Direct and frequent communication among all actors	Increased direct information exchange around reuse; Parties involved whose contractual relations would normally not justify it; Additional activities undertaken; Earlier start of negotiations emphasized	Regular direct information exchange among core actors; Open book approach; Education of and frequent consulting with contractors; Regular meeting between all consortium members; Workshops,	Direct frequent interaction; Working with open books, Workshop, Continuous communication between architect and craftsmen	Intermediary type of communication due to contractual relations identified as a problem; Involving stakeholders related to reuse throughout the whole project emphasized as important

Joint decision-making

Joint decision-making was especially emphasized in the Hal7 project where all the main actors, the architect, the client, the engineer and the contractor made decisions on possible solutions jointly. Also, in the ReSkur and GENTRÆ cases, the frequent direct negotiations among the core team members go along with joint decision-making. On the contrary, in the non-grant projects, decisions were made based on position according to contractual relations.

	Hal7	Byhusene	GENTRÆ	ReSkur	Hvidovre
Joint decision-making	Finding and agreeing on solutions through iterative process jointly	–	Finding and agreeing on solutions jointly	Finding and agreeing on solutions jointly	The final decision is the client's

Resources

All the cases showed additional resource input needs due to the novelty of reuse solutions. A lot of them came in the form of additional time spent on finding, developing, negotiating and agreeing on solutions related to the new technology of reusing materials. As mentioned earlier, the clients undertook the task of contractors in sourcing or negotiating the price of secondary materials in two cases. In the Hal 7 more time was required in the construction phase to develop the final drawings due to the unpredictability of used material supplies. In the Byhusene project, additional resources were spent on building the pilot demonstration walls and conducting additional quality tests on the bricks. Moreover, in this project, unusually long time was available to develop plans compared to usual, which was said to have played a role in the success of the brick façade.

Availability of grants in the supported projects facilitates successful collaboration. For example, in the GENTRÆ project, it allows contractors as suppliers to have their materials taken away without service fee, thus making them more inclined to engage in the project and to sort the materials properly. In the ReSkur project, the grant is used to compensate clients for the lack of quality certification of the secondary materials in the product. Finally, the workshops in these projects are a source of feedback and learning opportunities.

	Hal7	Byhusene	GENTRÆ	ReSkur	Hvidovre
Resources	Grant; Organizational support behind actors; Volunteer work; Investment of more time developing and negotiating new solutions and acquiring material supply; The client also taking part in acquiring secondary materials	Increased time for the plan drawing phase; Increased time devoted to negotiate reuse solution; Developer's time to negotiate secondary material prices; Investments in additional activities	Competition prize; Core team's investment;	Competition prize	Investment in resource mapping survey; Increased time spent on reuse solution

In summary, examining collaboration showed what do organizations embarking in reuse projects undergo, how relationship patterns are characterized, what additional resources are used, and thereby showed the significance of collaboration in reuse practices.

5.2 Discussion

This section answers the research question:

RQII: What conclusions can be drawn by relating the collaboration practices to general stakeholder interdependency patterns and institutions in the building industry?

Results of collaboration practices as found in the Analysis section are related to the findings in the literature on general interdependency and institutional patterns in the building industry.

Interdependencies between actors in the investigated projects show differences in many ways to what is identified in the literature on general patterns in the building industry. First, the literature emphasizes the frequent lack of continuous dialogue between architects and contractors resulting in the lack of inputs and learning opportunities benefitting both sides (Styhre, Josephson, & Knauseder, 2004). This is said to be exacerbated by the tendering system, whereby the plan drawing and the construction stages are separated to a large extent (Dubois & Gadde, 2002). On the contrary, in two examined cases architects explicitly mentioned how the design solutions were/are closely developed with the contractor and craftsmen, and in a third case, the architects were involved in developing solutions with the contractor on reuse. This was necessary because reusing building materials requires non-standard technical solutions.

Second, literature characterizes the industry as a project focused one, where actors form new temporary organizations in each project, and there is little interdependency between the actors beyond the projects (Larsson, 2016). In contrast, two of the examined cases are unique because core actors grouped up with the purpose of long-term collaboration. As a member of ReSkur stated, building 3 sheds is not the goal (Personal communication, April 2019).

Third, literature reports the loose coupling between suppliers and contractors due to the standardized building material products of the industry (Hakansson & Ingemansson, 2013; Dubois & Gadde, 2002). As a result of the standardized products, the offer of one building material supplier is easily substitutable with that of another one, and therefore, there is no necessity to form a close relationship with a specific supplier. In building material reuse projects, on the other hand, material suppliers are more closely involved in the projects. In one project the demolition company sourcing the materials is included in the core team, in another one there is a close collaboration with the contractors as suppliers, furthermore, the brick reuse projects focus on one specific supplier. In the fifth project cooperation with the final users, institutions and private individuals helped to source the needed secondary building materials. The importance of a closer relationship with suppliers was expressed by the demolition company, Tscherning as well. They are ready to provide secondary building materials through careful demolition of buildings, but they need information on what is needed (Teknologisk Institut, 2019). These findings support what has already been identified in the literature that sourcing secondary building materials in the right quantity and quality is one of the main challenges of doing reuse projects (Nußholz & Milios, 2017; Teknologisk Institut, 2019). As expressed by an interviewee, teams have to plan 2 years ahead in order to secure the required secondary materials (personal communication, April 2019). What is a matter of placing an order in a store in case of new building materials, becomes one of the biggest challenges in the case

of secondary materials. Actors suggested the establishment of an information system on what buildings will be torn down in the coming years (personal communication, April 2019).

The next finding is also related to sourcing secondary materials namely that some of the actors took up roles uncommon in the industry. In two project cases, clients took part in the sourcing of building materials and/or in negotiating their prices that is a task normally done by the contractors. Moreover, in one project the final users took part as volunteers in acquiring building materials, which is also not common. This shows a change in the institutionalized roles of the actors in the industry. Actors also gain skills beyond what is required in the institutionalized system through, for example, designing and solving non-standard tasks.

The literature identifies the important role of clients in endorsing innovative solutions since they are commissioning the work (Larsson, 2016). The cases seem to support that assumption since clients of all the cases were supportive of realizing reuse projects. In some cases so much that they took up the unconventional roles mentioned earlier. As an architect of one of the projects said, the case was unique, because the client was actively supporting the reuse solution (personal communication, April 2019).

New collaboration practices arose due to the challenge of certifying secondary materials' quality: Partnership is formed with a law firm, clients are involved in close collaboration to find out their expectations, and project actors undertake increased negotiations and additional activities. This is in correlation with literature findings identifying certification of secondary materials as another main challenge (DEPA, 2019). Standards are one of the main institutions of the industry, and the cases demonstrate how they pose a challenge to reuse. In projects where short-term financial benefits were crucial, the risks deriving from non-compliance with standards was highly emphasized. The way responsibilities are distributed among project actors in the industry through contractual relations works against adopting reuse practices, for actors face uncertainties regarding secondary building materials that do not exist with new ones. Some actors suggested new ways of sharing responsibilities is necessary (personal communication, April 2019).

According to the literature, generally, it makes sense to innovate on quality in the building industry only if it brings about stronger or monopoly position in the market (Orstavik, 2015). This is because quality performance does not get reflected in prices due to the asymmetrically distributed information in building projects. The way information is exchanged among the number of actors in building projects results in the asymmetrical distribution of knowledge, and clients discount the value of the products to balance their lack of information. The fact that prices in the industry do not reflect quality performance means that actors compete on prices and not on quality (Orstavik, 2015). The implications on innovations such as reuse were shown in one of the cases where the contractor's reluctance to do the reuse solution was a consequence of the tight budget not allowing additional cost uncertainties. The assumption that it only makes sense to innovate when it brings stronger market position is supported by the findings in the grant-supported projects where several actors were embarking in the projects with long-term benefit expectations on the cost of short-term financial losses.

Brick reuse projects are considered as low hanging fruits. They are the first generation of reuse solutions whereby the materials are reused in their original function and it is hard to repeat this success. (personal communication, April 2019). There are several examples of successful brick reuse projects ("Referencer", n.d.) On the other hand, non-brick reuse projects are mostly strategic investments with long-term benefit expectations as seen in the cases and expressed also by other interviewees (personal communication, April 2019). This implies that systemic changes are required in the present industrial patterns to make non-brick reuse projects profitable.

Slaughter (1998) says that depending on the extent of systemic change an innovation requires in the established norms and practices, actors should plan differently the scheduling of commitment, coordination requirements, and the necessity of additional resources in building projects. Case results suggest that project actors related to reuse should start information exchange early in the project, for reuse requires arrangements unlike when using new materials. Contractual relationships need to be changed to accommodate acceptance of risks. Moreover, case projects showed the need for additional resources such as time for negotiations beyond what is necessary for projects using new materials.

Strong interdependency patterns and institutions in the building industry serve to overcome the challenge of creating complex building products. Actors in the industry generally show reluctance to endorse changes, for changes raise uncertainties. The project cases demonstrated actors' experimentation with new arrangements within the limits that the strong industrial patterns allow and brought findings on what actors have to undertake in reuse projects. For example, they must invest increased time to develop solutions that are normally included in the standards, they must invest more into acquiring material supplies, which they would normally just order from the store, they must take on roles they normally do not have to, and gain new skills not required when working with new materials. Redistribution of risks and collaborative relationships were identified as important to overcome uncertainties that are not present when working with new materials. The cases show that experimental projects supported by grants create space for actors to test new arrangements with long-term return expectations, and this is necessary for such a complex system as the building industry. Nonetheless, the examined cases brought the result that the present patterns of the building industry such as stakeholder interdependencies and institutions affect innovation challenging building material reuse. At the moment, it is mainly the brick reuse projects that ripe short-term profit, suggesting that systemic changes are necessary to make reuse of other materials profitable too. But then again, the system as it is now is there to make the building of complex products manageable. Therefore, there is high resistance to endorse changes in it (Kadefors 1995).

6 Conclusions

The thesis focuses on the reuse of building materials, a topic which has been gaining increasing attention in the Danish building industry. Danish policy has been following the EU policy trends toward resource efficiency, and there is increasing interest among industry actors in the country. Adopting reuse practices in the sector requires systemic changes, for the present economy is accustomed to the make-take-dispose economy. The construction industry has a reputation of being conservative, which has been attributed to its specific characteristics: for example, the patterns of interdependencies between actors, the institutions, and the competition on price (Kadefors, 1995; Dubois & Gadde, 2002). Bringing about lasting changes needs concerted actions by actors in order to find a compromise between different interests, for every change is expected to be beneficial to some and disadvantageous to others. Building material reuse projects are important to test what works and what doesn't. Collaboration is, therefore, crucial in bringing about changes. The thesis examines collaboration in Danish projects involving reuse of building materials.

Through investigating projects involving reuse of building materials, the thesis sets out to answer the following questions:

RQI: What is emphasized as important regarding collaboration for reuse of secondary building materials in Danish projects?
RQII: What conclusions can be drawn by relating the collaboration practices to general stakeholder interdependency patterns and institutions in the building industry?

Approaching the second research question, valuable findings have been obtained based on *RQI*. The overall joint findings are as follows:

Using secondary building materials poses significant challenges to actors and they adjust their collaboration to overcome them. Three main challenges were identified: availability of enough quantity of secondary building materials, the quality certification of the materials, and the non-standard technical novelties faced.

Actors developed new types of partnerships with stakeholders with whom they are normally not working together or would work less closely connected with. Some project organizations developed long-term partnerships which are considered unusual in the project-focused building industry (Dubois & Gadde, 2002). There was closer cooperation with suppliers of secondary building materials with whom normally relationships are very loose due to the standardized material products in the industry (Hakansson & Ingemansson, 2013). Tightening of relationships with clients was also identified, showing their major role in adopting reuse practices. All cases demonstrated improved quality and frequency of information exchange related to reuse as compared to when well-practiced solutions are implemented. For example, actors that normally do not have continuous dialogue in building projects, such as the architect and the contractor, were developing solutions together during constructions to develop the non-standard technical solutions. Some project teams adopted the open-book approach to working and sharing business numbers. In grant-supported projects, the increased frequency and quality of information exchange was accompanied by joint decision-making, while in other ones, decision-making happened according to contractual relations. In one case, the contractual relations resulted in insufficient information exchange due to communication via intermediator instead of direct contact.

An important collaboration factor was found to be the availability of additional resources. They came in many forms, such as time, financial, and educational resources. Additional time was spent to develop and agree on non-standard solutions. Moreover, actors, such as clients and

final users were engaged in acquiring secondary building materials, that is normally the responsibility of the contractors. Additional financial resources were spent directly on testing novel solutions as well as on incentivizing suppliers and clients to collaborate in the experimental phase of some projects. Workshops and boot camps provided additional educational resources.

Actors' willingness to compromise was also important. For example, in some projects, actors focused on optimizing their processes with the whole group's interest in mind. Client's permissiveness about chosen solutions and related cost changes was also highlighted in a case.

Risks were an important topic in the reuse projects because the novelty of solutions increases uncertainties and therefore actors have to take up responsibilities usually not required. For example, the strong institution of standards requires quality certification of materials what poses challenges, because most secondary materials do not comply with them (Kadefors, 1995). Sharing risks were identified as important, suggesting the need for change in contractual relations, or joint risk-sharing. None-the-less, in the grant-supported projects, risks were not highly emphasized, it was rather in the non-supported projects. An explanation could be that in the grant-supported projects more factors of successful collaboration were present.

Actors in projects involving materials other than brick mostly expected long-term benefits and there the relationship patterns suggested the presence of trust. It was also characteristic to these cases that actors were not only focusing on their individual returns of benefits but also on the overall group interest. The lack of short-term benefits in non-brick reuse projects suggests that systemic changes are required in the industry to make them profitable. On the other hand, brick reuse projects are often profitable also on the short-term. But here too, challenges arise as actors compete on prices and are already running on a low budget, so they are resistant to endorse solutions that increase uncertainties. The strongly price competitive nature of the industry, therefore, poses another challenge in applying reuse. Strong competition on price is a result of the information exchange patterns characteristic in the industry (Orstavik, 2015).

The complexity of creating building products is made manageable through the stakeholder interdependency patterns and institutions in the building industry (Kadefors, 1995; Dubois & Gadde, 2002). Changes in the established routines create uncertainties that building industry actors generally demonstrate to be unwilling to take (Kadefors, 1995). The project cases demonstrated actors' willingness to experiment with new arrangements: to build new types of relationships compared to business-as-usual to overcome problems arising from reuse; to take up roles and learn new skills they normally are not required to when working with new materials. The cases show that experimental projects can be efficient facilitators for jointly doing the trial-feedback-correction cycle. They also bring examples of how institutions and stakeholder relationship patterns in the industry affect reuse practices. It is mainly the brick reuse projects that ripe short-term profit, suggesting that systemic changes are necessary to make reuse of other materials profitable too. But the complexity of the building process will still need mechanisms to make it manageable, limiting the type of changes that can be carried through (Kadefors, 1995).

6.1 Relevance of the study

Detailed insight on collaboration in five Danish projects involving the reuse of building materials has been given. This was done so by conducting five case-studies, interviewing key actors in projects. Interview results were analyzed using a framework consisting of 9 factors of successful collaboration. The findings on collaboration were then compared to general interdependency and institutional patterns in the building industry as found in the literature.

Through examining the specific project cases, the paper had two aims:

1. To increase knowledge on collaboration for building material reuse in the building industry.
2. To discuss collaboration practices for reuse in the building sector in regard to literature on stakeholder interdependency patterns and institutions in the building industry.

The findings in the project contribute to understanding the process of innovation within the building industry context by examining how actors manage collaboration within specific projects. This is relevant as the adoption of reuse practices are increasingly gaining interest and focused research is yet scarce. Through a descriptive approach, collaboration was presented. By drawing a comparison with the patterns of interrelations and institutions in the sector, the source of challenges faced by industry actors gains more visibility. While most of these challenges have already been identified in previous literature, the value of the study may be the description of collaboration which may facilitate better management of future ones. Results on collaboration present what conditions regarding collaboration may be necessary for reuse projects. The patterns of stakeholder relations and institutions in the sector are strongly established to make the complexity of building projects manageable, and this need limits the type of systemic changes that can be carried through to facilitate industry-wide increased reuse.

Studies on collaboration in projects involving reuse of building materials are yet scarce, and best example case studies are considered important enablers towards reuse. While this study is mainly descriptive, its findings may be valuable for practitioners to see how others coped with challenges and what are the best case practices. It may also be of value for academia to base further research on. And it may contribute to policymaking through conveying the experiences of practitioners.

6.2 Suggestions for future research

Practitioners in the industry expressed their willingness to engage in more reuse practices and the need to facilitate reuse through systemic initiatives. Research on cause and effects of systemic initiatives on the reuse practices could speed up the adoption of these initiatives by investigating the most efficient ways to facilitate industry-wide increased reuse.

Collaboration is a requirement for learning, and learning is crucial for innovation. One way of examining the success of projects is through the level of learning that takes place. For example, Brown et al. (2003) examine the success of experimental mobility projects. Examining the level of learning in building material reuse projects could bring important insights as to what facilitates learning and innovation in these projects.

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Commission Communication COM(15)614 final ANNEX 1. Annex to the communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions on Closing the Loop – An EU action plan for the Circular Economy.

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Appendix A

List of interviewees

Interviewed actors of the specific projects		
Project name	Role of actor	Name of actor organization
Hal7	Client	Roskilde Municipality
	Architect 1	Vandkunsten
	Architect 2	Vandkunsten
	Contractor	Egen Vinding og Datter
	Engineer	Steensen Varming
Byhusene på Islands Brygge	Developer/Investor	NCC Bolig
	Turn-to-key contractor	NCC Construction Nybyg
	Architect 1	Vandkunsten
	Architect 2	Vandkunsten
	Supplier	Gamle Mursten
GENTRÆ	Retailer	Stark Group
	Consultant	Golder Associates
	Processing company	Solum Group
ReSkur	Contractor	Enemærke & Petersen
	Architect	Krydsrum
	Demolition company	Tscherning
Hvidovre Kindergarten	Client	Hvidovre Municipality
	Architect	Vandkunsten
	Engineer	DJ-MG
	Supplier	Gamle Mursten
Interviewed actors that were not involved in the specific projects		
Name of organization	Number of interviewees	Interviewee's role in the organization
Vandkunsten	4	Architect
Lendager	1	Architect
AG Gruppen	1	Construction manager

Appendix B

Interview guide

Questions posed generally to all actors

1. What was your organization's role in the project?
2. What additional actors were involved? What new partnerships were formed?
3. What would you say about collaboration between actors in the project? What were interesting characteristics about it that is uncommon in business as usual projects?
4. Was there a leader in the collaboration?
5. What main problems did you encounter in the project that affected collaboration?
6. What helps in your collaboration to overcome risks that come with the reuse in the project?
7. How did you get feedback that you are heading in the right direction?
8. Do you work on creating shared understanding, shared goals between the actors?
9. What benefit did your organization hope to gain from the project? What was the motivation to take part?
10. If you would restart the project again, what would you do differently?
11. What unconventional roles did you need to take up in this project, which you would not normally take up in business as usual projects?
12. What did you learn from this project related to reuse?
13. What could improve collaboration in future reuse projects?

From clients additionally these questions were asked:

14. As a client, were your roles any different than in a conventional construction?
15. What convinced you of the superiority of a reuse solution?

Appendix C

Empty spaces in the table mean that the information was not mentioned in the interviews.

	Hal7	Byhusene	GENTRÆ	ReSkur	Hvidovre
Shared visions	Emphasis on participants being visionary	–	Clearly stated vision	Clearly stated vision	–
Mutual interest	Actors express strong motivation to do the project and mainly long-term incentives	Short term financial incentives as well as long term incentives. Emphasis on initial lack of mutual interest, but eventually compromise was found	Actors have their individual, mostly long-term incentives, there is also a common joint incentive	Actors have their individual, mostly long-term incentives, there is also a common joint incentive	Both long and short-term incentives among all actors
Sharing risks	Risks originate from time and expense requirements. Actors say they didn't feel the risk because of the way the team worked	Emphasis on uncertainties originating from secondary material quality and the novelty of the solution. All the actors took responsibilities regarding reuse. The necessity for new ways of distribution of risks is emphasized	Joint stakes of core actors in the mutual outcome. Mutual contribution to the outcome.	Joint stakes of core actors in the mutual outcome. Mutual contribution to the outcome. Redistribution of risks when architect sells products rather than his hours	Sharing risks as in conventional projects. The necessity for distribution of risks is emphasized
Ability to compromise	Client's permissiveness on solution and cost changes	Initial incongruencies were solved	–	Actors optimizing processes with whole group outcome in mind	–
Existence of trust between the parties	Reorganization of relationships around achieving the common goal	–	Adoption of open-book approach; Establishing a long-term partnership	Adoption of open-book approach; Establishing a long-term partnership; Each actor undertaking a new type of business	–

	Hal7	Byhusene	GENTRÆ	ReSkur	Hvidovre
New partnerships, inclusion of affected members of the community	Final users work as volunteers, New connections between contractor and suppliers of secondary materials; New connections between the client and sources of secondary materials	Connection with demolition site where the reused bricks were sourced from.	Long-term close collaboration between core team; Involvement of the whole supply chain; Second level partnerships; Stronger than usual collaboration with partners; Employing socially disadvantages people	Long-term close collaboration between core team; Involvement of the whole supply chain; Second level partnerships; Stronger than usual collaboration with partners;	–
Quality and transparency of information exchange	Direct and frequent communication among all actors	Increased direct information exchange around reuse; Parties involved whose contractual relations would normally not justify it; Additional activities undertaken; Earlier start of negotiations emphasized	Regular direct information exchange among core actors; Open book approach; Education of and frequent consulting with contractors; Regular meeting between all consortium members; Workshops,	Direct frequent interaction; Working with open books, Workshop, Continuous communication between architect and craftsmen	Intermediary type of communication due to contractual relations identified as a problem; Involving stakeholders related to reuse throughout the whole project emphasized as important
Joint decision-making	Finding and agreeing on solutions through iterative process jointly	–	Finding and agreeing on solutions jointly	Finding and agreeing on solutions jointly	The final decision is the client's

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Resources	Grant; Organizational support behind actors; Volunteer work; Investment of more time developing and negotiating new solutions and acquiring material supply; The client also taking part in acquiring secondary materials	Increased time for the plan drawing phase; Increased time devoted to negotiate reuse solution; Developer's time to negotiate secondary material prices; Investments in additional activities	Competition prize; Core team's investment;	Competition prize	Investment in resource mapping survey; Increased time spent on reuse solution