The Circular Economy and redevelopment of utility buildings

Uncovering the functional diversity in a circular building process

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Master Thesis

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“***If you want to build a ship, don’t call in the men asking them to collect wood, and order them to build a ship. Instead, teach the men to desire the vast, endless ocean.***” (Antoine de Saint-Exupéry).

PREFACE

This document you are about to read marks the end of some great years as a student, officially. Unofficially however, I aspire to hold on to the unlimited curiosity I have been lucky to possess as a student and exploit this characteristic for the years to come. I would like to take this moment not only to express the fun I had doing this research, which for me was a great opportunity to feed my endless desire to understand “things”, but also by thanking the people who have supported me throughout this project when my curiosity was not enough to keep me going.

Starting with this, I would like to thank my thesis committee; Eefje Cuppen, Erwin Heurkens & Marije Vos. In general their enthusiasm was already a solid basis for the fun I had discussing with them about the Circular Economy concept, but I also had great pleasure with getting to know them, and I was happy that our meetings in general were filled with the sound of laughter. Nevertheless, they know exactly when to be critical as well, which kept me sharp and focused. They know how to use their expertise and experience to help me as a student to write my thesis. Without doubt I would recommend them as supervisors. Additionally, I would like to thank Wouter Spekkink for committing to exchanging ideas on the approach of this thesis.

Another person I would like to thank is Freek Wullink, who I had the pleasure to work with on a more practical side of the Circular Economy. He invited me to come along with meetings related to the CE topic, both internally and externally of Arcadis. This proved to be of great value, especially when as a graduate student your mind is stuck and you need someone to pull you out of your bubble. Next to that working with Freek gave me a lot of inspiration for my research as well, and most importantly we had a lot of fun. That being said, other Arcadis colleagues have always been ready to help me when necessary, or tell me about their experiences in their work, for which I would like to thank them. In addition, I want to thank Saman Mohammadi and Mariëtte Pol for providing me with good discussion on the results of my work and placing my results in perspective to their day to day practice

Finally, I want to thank my friends and family, whom I could always count upon for having fun after work, which gives the extra energy necessary when working hard. Special thanks to Selma. At certain times I needed to find the inspiration to keep going and stop procrastinating. A specific quote has helped me through these times, which I’d like to share: “Yesterday you said tomorrow, so just do it**!**” (Shia LaBeouf, 2015).

EXECUTIVE SUMMARY

The circular economy (CE) is a concept that promotes the closing of material loops, in order to provide an answer to depleting resources and the associated consequences. The roots of the concept date back form 1976, but has only recently been popularized by the Ellen MacArthur Foundation in 2013. Since then, a rising number of companies have communicated their support for the circular economy. This is not only due to possible resource supply issues in the future, but also the potential recognized in rising markets concerning recycling, refurbishing, redistributing and reusing. The built environment is one of the sectors where the CE has gained attention and where first attempts have already been made to apply CE principles in projects. The larger part of materials used in the building sector are sand, iron and gravel, which are resources that do not face depletion in the near decades. However, the construction sector is indirectly dependent from more resources that do face sooner depletion, such as copper. A lack of this resource could disable parts of the construction supply chain and thus endanger the ability to build homes. The Dutch building sector has a challenge to overcome. Due to technical degrading quality of the Dutch building stock, a large scale redevelopment challenge lies ahead. Ideally, a redevelopment means reusing a building as much as possible, and improving parts of the building, which we call layers. Redevelopment means changes in the façade, furniture, installations and space plan layers of the building.

This research took off with an exploration on what the application of CE principles means for the building sector. We asked ourselves the question: *What does the transition to a circular economy mean for the supply chain of the building sector, the way the sector is organized and how actors collaborate in the building process.* These questions are answered through literature study and explorative interviews with experts in the sector. As a result, we found out that Applying CE principles for a redevelopment affects multiple parties in the construction supply chain. This does not only result in technical challenges, but implies an inter-organizational collaboration challenge. This research focusses on the social aspect of applying CE principles. The exploration has also brought forward the typical way the building sector is organized. The building process is organized by, and consists of different actors, collaborating to fulfill different functions in order to construct a building.

As a result from the exploration, we adopt the main research question for this thesis: *What is the functional diversity that actors fulfill when they aim to apply the circular economy concept to the redevelopment of utility buildings?* Through literature study, we developed a framework to answer this question. The collaboration challenge in the construction supply chain can be seen as a type of innovation which actors aim to achieve. A reoccurring concept in innovation theory is diversity, on which academics agree that it influences innovation. In that sense, we asked ourselves the question, *how can we use the concept of diversity to uncover how actors collaborate in the circular building process?* Inspired by biodiversity frameworks in ecology sciences, we developed a four-level framework which is used to map the functional diversity of actors present in the circular building process. The framework is applied on four cases where circular principles have been applied in the Netherlands.

Resulting from the case studies, we established the following functional diversity.

Functional group	**Connecting through vision**	**Ideating**	**Scope broadening**	**Providing**	**Constructing**	**Ensuring**
Nature of function	Establish a vision which is leading for the redevelop-ment	Develop ideas to reuse materials and create designs	Broaden the scope of search to material streams that can be reused	Provide parties with materials to reuse	Build product elements from the found materials	Ensure the quality and safety of buildings in which materials are reused

Table 1; functional diversity obeserved in case studies

Most of the functions found are comparable to functions in the traditional building process. The connecting through vision function however needed in depth research due to two reasons; in the cases this function appeared to play a crucial role, and from the cases it was not yet clear how this function should be fulfilled. Therefore, a visionary session was organized, aiming to answer this question by inviting people who have experience with the role of connecting through vision.

From the visionary session, we concluded that the function of connecting through vision is important, because the function embodies connecting actors by finding interests together in a shared vision. Three aspects play a central role in building a vision. First, actors are involved in the vision by establishing what **values** they want to create through the project, by setting up a business case. When actors learn how they can generate value for themselves by applying CE principles, **willpower** is created which helps to disseminate the vision through other involved actors. Important is that the business case adds value for all involved actors, creating an **integrated** business case. This requires actors to step into another person's shoes and make an effort to find a win-win situation in the business case.

The functional diversity of a circular building process can be coupled to the Why, How & What structure by Sinek (2010). The "Why" refers to the value added for involved parties, enabling to create the necessary willpower. This function is ideally fulfilled by the Visionist. Afterwards, the "how" is established by exploring how the Circular Economy concept can be used to create the value added for the parties. This is done by ideating, scope broadening and ensuring. Finally, the "what" refers to the physically realized elements of the building, which is done by constructing and providing. The following image illustrates how the functional diversity relates to each other. Left are the functions, in the middle the why, how & what structure, and on the right the activities related to the functions. From top to bottom; the house represents the layers of a building which have been realized using CE principles. The middle picture represents the search for how material loops are closed and the bottom picture represents the connecting through vision function.

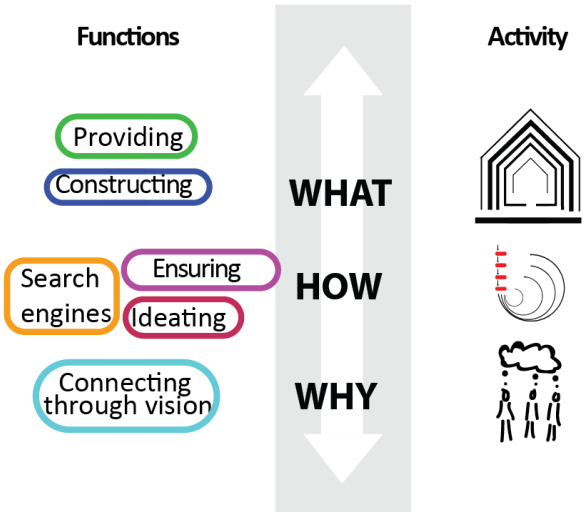

Figure 1; Functional diversity of the circular building process coupled to the why, how & what structure adopted from Sinek (2010)

Finally, we conclude that the system of actors applying CE principles can strongly benefit from the involvement of persons who have the characteristics that make the connecting through vision function easier.

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ABBREVIATIONS

TBP	-	*Traditional Building Process*
CBP	-	*Circular Building Process*
CE	-	*Circular Economy*
DSA	-	*DoepelStrijkersArchitecten*
B&vE	-	*Boele & van Eesteren*
IS	-	*Industrial Symbiosis*
IE	-	*Industrial Ecology*
BP	-	*Building Process*

Figures without a reference are the authors own graphs.

1:

OUTLINE OF THIS THESIS & RESEARCH QUESTIONS

The outline of this thesis can be structured according to the why, how and what theory by Sinek, (2010). In the beginning of this research, the exact problem was not yet defined. A preliminary research was necessary to find the "why" of this research, presented in chapters 2 & 3. We start with an elaboration on the CE concept in chapter 2; what it is and why it is relevant. In chapter 3 we explore what a circular economy would mean for the building sector. This is done through **sub-research question 1**: *What does the transition to a circular economy mean for:*

A. *The supply chain of the building sector*
B. *How the building sector is organized*
C. *How actors collaborate in the building process*

From the preliminary research we established that applying CE principles results in collaboration barriers in the building process. Since it is not clear what materials can be used in a circular building process, actors have trouble with fulfilling their functions. For example, the architect does not exactly know how his design will look like, and the contractor does not know when materials will be delivered for construction. This resulted in the **main research question for this research:**

What is the functional diversity that actors fulfill when they aim to apply the circular economy concept to the redevelopment of utility buildings?

Now that the "why" is found, chapters 4 & 5 present how the main research question will be answered. In these chapters we elaborate on innovation theory, and adopt the idea that diversity influences innovation. Building on this, chapter 5 explains how we are going to use the diversity concept to analyze building processes where actors applied circular principles. **By then, we have answered sub-research question 2**:
What theoretical framework can be used to analyze empirical cases of circular building processes?

This is followed by sub-research question 3 which is answered in chapter 5**:**
What method can be used to apply the theoretical framework?

Having established what we are going to research, and how the research will be conducted, the "what" embodies the results and conclusions of this research. Chapter 6 & 7 is the result of applying the framework to the cases and analyzing the acquired data. These chapters give answers to **sub-research question 4**. *What functional diversity of actors is observed in current circular building processes*? This question is coupled to the theoretical framework, resulting in the following division:

A. *What system of actors produced circular outcomes in the building process?*
B. *What functions where necessary to produce circular outcomes in the building process?*
C. *What characteristics/tasks can be distinguished which occurred to fulfill the functions?*
D. *What social structures did actors draw upon?*

After this is done, we are able to answer the main research question in chapter 8 by drawing conclusions.

Finally, we discuss the results, reflect on the boundaries and limitations of this research and bring forward managerial and academic recommendations in chapter 9.

2:

THE CIRCULAR ECONOMY

This chapter starts with sketching the context and problem motivation for this thesis. We argue what has led to the uprising of the CE, after which we give a definition to the CE for this thesis. This is followed by an exploration of the Dutch building sector and its resource use, to give the reader an idea of the current way of resource consumption by this sector. We end the chapter by exploring what the transition to a CE means for the sector, and why this is such a challenge. This brings us to the motivation for this research. In appendix L, the result of explorative interviews can be found and what meetings have been attended to explore the market.

Circular economy; the need for a regenerative economy

The enthusiasm surrounding the circular economy concept departs from two aspects: environmental and economic concerns. First, the circular economy is believed to relieve pressure on finite resources and second the CE is believed to decrease our dependence from these finite resources as economic competition for these resources increases. This paragraph starts by elaborating on how resource scarcity arises, and then explores the problems related to resource scarcity.

In 2016, planet earth gives home to 6 billion humans and this number is growing exponentially: in 2025 it is estimated that this number will grow to 8 billion (WorldBank, 2015). In order for our society to sustain itself we have to overcome certain challenges regarding energy, water and material resource use. The demand for minerals is expected to increase with 1% a year, which results in a 60% higher rate of resource extraction in 2050 than in 2007 (Kesler, 2007). As with other societies the world has seen, ours cannot function without the extraction of resources from the environment. Inevitably, a society growing at such pace goes hand in hand with a comparable increasing rate of resource extraction. Past societies have shown this to be a regular pattern: In order to feed the hungry mouths, agriculture expanded to produce more food. When this expansion grows in a way that cannot sustain itself, consequences are clear; populations have suffered from starvation, war and disease, to finally collapse (Diamond, 2005). Tainter (1988) argues as well that the cause of collapse of many societies was their inability to solve problems related to resource supply.

One can imagine that not the shortage of resources itself will be the cause of our society to collapse, but the scarcity could lead to political or humanitarian problems endangering society. The EU expresses its concerns about resource constraints as “strongly conditioning the EU’s competitiveness and the quality of life of individuals” (EC, 2015), which could be interpreted as competitiveness towards other political entities, competing for the same resource. Another possibility is that the scarcity of only a few minerals, could inhibit the production of a wide range of products which are all strongly dependent on this one mineral. This could disturb a society in many ways, consider for example what a scarcity of copper would mean for how transport of electricity is organized.

The origin of the Circular Economy dates back to 1976. Architect Walter Stahel was intrigued by the amount of energy required to delve virgin materials that fuel production processes of society. He found that in the assembly of materials to products only took 1/3 of the energy required to extract these materials from the earth. As an architect he was responsible for the extraction of mainly steel and concrete, and he started wondering; if we start focusing on transforming and re- using steel and concrete, we can save significant amounts of energy and costs, while at the same time creating jobs for craftsman in repairing and reconditioning activities (Stahel, 1981). Eventually, this observation led to the birth of the performance economy concept. The performance economy proposes a system in

which people no longer pay for goods, but for the performance of these goods. From this perspective, an economy emerges driven by quality: value/kg material. To manage performance of time, jobs are created focused on extending the service life of goods (Stahel, 2010). This concept is further developed and elaborated on under differing names, from service economy (1986), functional economy (1997) and ultimately, the recently popularized Circular Economy (CE) (Ellen MacArthur Foundation (EMF), 2013).

The Circular Economy (CE) promotes the closing of material loops, in order to come towards a system where raw material extraction is minimized. An important aspect of the concept, which draws the attention from businesses, is the financial potential embedded in the rise of markets focused on re-cycling, re-manufacturing, re-distribution and re-use. This is reflected by the many national and international initiatives that aim to drive the CE to a next level, such as the CE100 (EMF, 2016), a platform that brings together companies such as Philips, H&M, Google & Renault, all sharing certain ambitions that support a circular economy. Next to the commercial attention the concept has drawn, governments have been occupied by uncovering enabling conditions for a circular economy and strengthening these in policy measures and financial support, as revealed by the European Commission's CE package, launched in December 2015. As the mentioned support for a transition to a circular economy is expressed, activities in different sectors arise that can be seen as the first applications of a circular economy. An example is the building sector, where not only the first projects have been realized that claim to be "circular"[1], but companies engage in collaborations to promote and initiate more circular initiatives in the sector such as the "Green deal Circulaire gebouwen"(2015).

Defining the circular economy

There is no official definition for the Circular Economy. Thus in this paragraph some recent definitions of the concept are presented and these are used as inspiration for forming a definition of the CE that is adopted in this thesis. The first to be presented is also the one that is mostly referred to in general: the Ellen MacArthur Foundation (2013): the circular economy proposes the closing of material loops in order to come to a system that is regenerative by nature. In 2013, the CE gained great popularity after EMF published "Towards the Circular Economy, Opportunities for the Consumer Goods Sector (Vol. 2)"[2]. This publication is currently used in most cases as reference to define CE. There is no official standard, however companies, students & professionals mostly refer to the EMF work. The EMF(2013) defines CE as "an industrial economy that is restorative by intention; aims to rely on renewable energy; minimizes, tracks, and eliminates the use of toxic chemicals; and eradicates waste through careful design". These principles form the basis for CE:

- Design out waste
- Build resilience through diversity
- Rely on energy from renewable sources
- Think in systems
- Waste is food

The following illustration (EMF,2013) is used in a remarkable amount of articles, blogs, thesis's and articles.

[1] The term "circular" is adopted in this thesis. It is used as an adjective, which is defined in this thesis as something that has been, or is being realized, in line with the concept of the Circular Economy.

[2] Searching Google Trends for "Circular Economy" shows strong increase of popularity after EMF published "Towards the Circular Economy, Vo. 2".

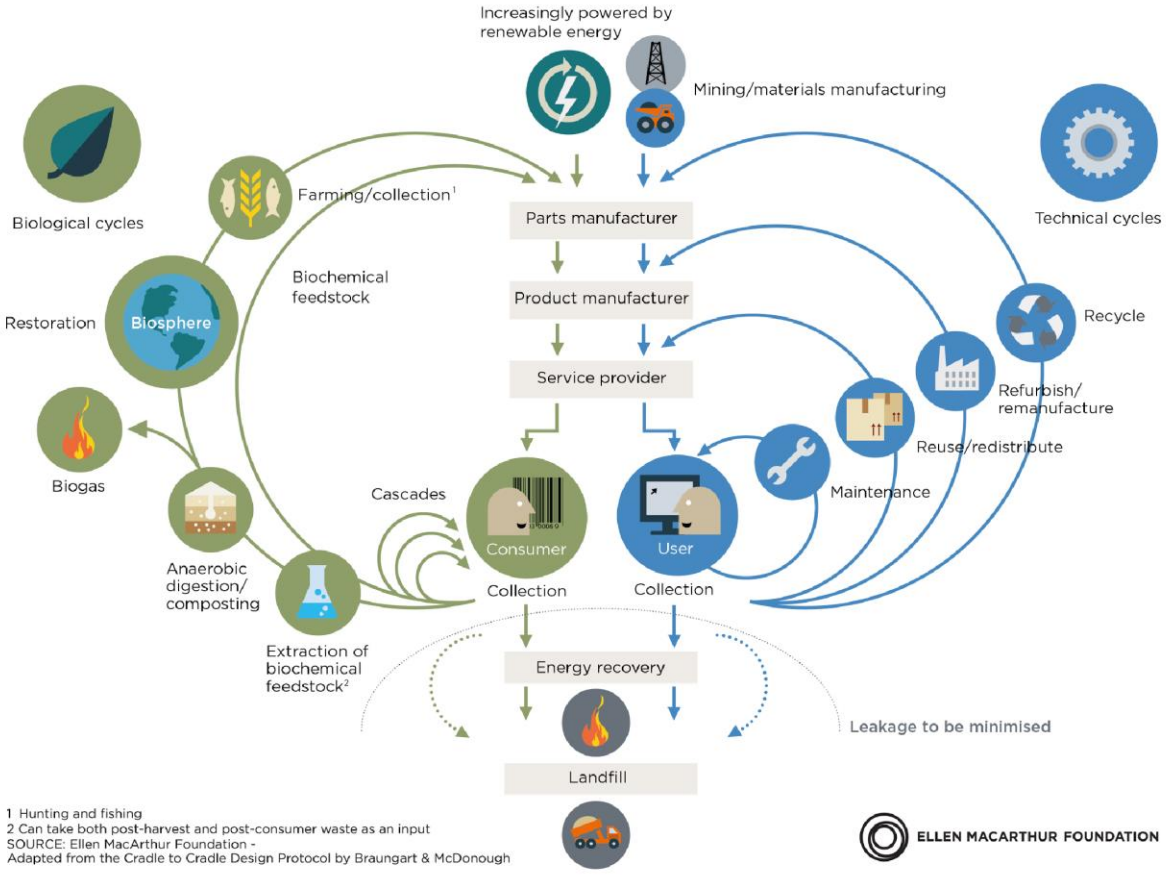

Figure 2; EMF (2013) The circular Economy

Figure 2 illustrates the linear production chain as we know it in the middle, from virgin material extraction to consumption and finally either incineration or landfill. The arrows on the right side illustrate the possible loops that can be created in order to close the material cycle: maintenance, reuse/redistribute, refurbish/remanufacture and recycling. The Circular Economy concept strives for a self-sustaining system that minimizes input flows from outside of the system. In order to achieve this, we need to perform a transition from our current, linear economy, towards a circular economy (EMF, 2013). TNO (2014) adds a bit more detail to the EMF definition: The Circular Economy is an economic and industrial system which enhances the re-usability of products and materials, while minimalizing de-valuation in the system and strives for addition of value in each link of the system. Stegeman (2015), adopts a similar definition originating from Braungart & McDonough (2002). He states that the goal of the CE is to enable the reuse of products and materials as much as possible, while preventing loss of their value.

It seems that most definitions touch upon the closing of material loops in order to prevent raw material extraction from the finite earth. Also, a strong link is made to systems thinking. Most authors endorse the adoption of a systems perspective when looking at supply chains and the way resource move through them. In order to gain a better understanding on what the circular economy is, we adopt a systems perspective as well. The following model proposed by Tukker et al. (2007) can be used to classify circular initiatives. They propose different levels of system change, linked to the possible environmental performance that the system change is aimed to achieve.

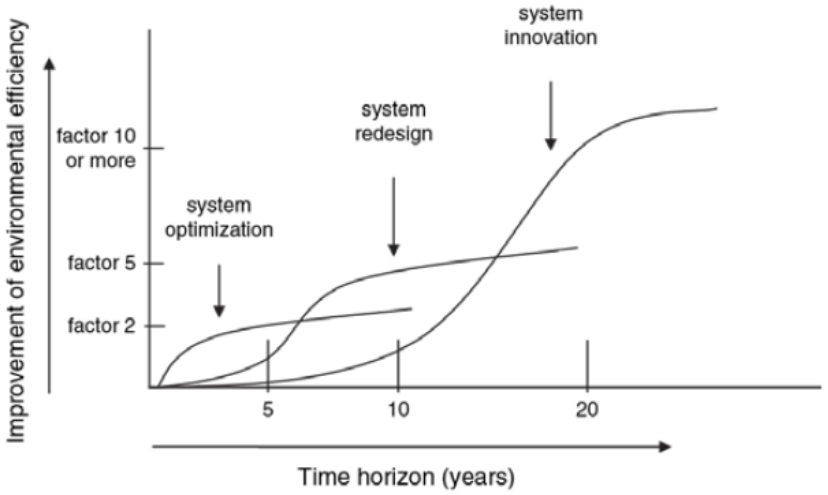

Figure 3; Potential of system optimization, redesign and innovation for environmental efficiency (Tukker & Butter,2007)

The first level, system optimization, leads to some reduction percentages of fossil fuel use. This can be compared to making a power plant more energy efficient. System redesign (e.g. implementing a recycling system of resources captured from power plants' flue gases) has more potential impact than system optimization. System innovation can create such a large scope for change that radically impacts the environmental effects of human activities. Such innovations start by questioning our societal needs. For example, the construction of a building is aimed to facilitate working places for employees of a company. However, if the employees are able to do their work at home and interact digitally, there would not even be a need to construct a new building. Consequentially, this leads to the need for a well-performing digital communication infrastructure.

The figure relates three classes of system change to improvement of environmental effectiveness. As argued by Tukker et al. (2007), system redesign creates more environmental efficiency than system optimization. This however depends. Many other factors contribute to the environmental efficiency of a system. First, setting the system boundary that dictates the focus of analysis (e.g. LCA) can influence the outcome of environmental performance assessments. Second, what has exactly been redesigned? If a system is redesigned by choosing an alternative material stream as input, but this material harms the environment in other (unforeseen) ways, we are unable to conclude that system redesign is per sé better than system optimization, in sustainability terms. Thus, the figure has to be read bearing in mind that it concerns a potential environmental improvement.

Using the classification by Tukker et al. (2007), where can we classify circular economy intiatives? The following table adopts some circular business initiatives summarized in Rabobank's "The potential of the Circular Economy" (Stegeman, 2015). The initiatives have been categorized according to Tukker's model.

Company	**Business description**	**System change category**
Nova Lignum	Company that delivers façade coverings from purely plant materials. They are recyclable and reusable.	**System optimization**; product remains a façade covering, same type of production process & business case however with different material flowing through.
Schmitz Cargobull	Realized a new business model by demolishing used truck trailers and using the freed resources for new trailers, but also connecting to FREITAG, who creates bags from old trailer parts	**System redesign**; The production process of bags has been redesigned by connecting to the truck demolishing system.
Repair Café	A meetingplace for people that have skills in reparing devices with people who are less skilled. Only condition to this free service is that people repair the	**System redesign**; products reused and repaired, instead of sending products back to the regular supply chain, local skills are used

	products together, aiming to transfer skills to unskilled persons.	
Siso	Together with Royal Haskoning DHV, Siso developed a managing program for the recycling of infrastructure owned by IT companies.	**System redesign**; a new system is connected to the old system that increases recycling.
Desso	Desso, an international carpet producer designs carpets in a way that they can be removed from buildings safely and recycled. They offer a leasing form of business, where Desso remains owner of the product and the client leases the product.	**System redesign**; The production process has not essentially changed, however a system redesign has been performed in the business model by taking back used carpets.

Table 2; Circular business initiatives classified according to type of system change

As we can see, circular initiatives are either a system optimization or system redesign. Whether a single initiative can be categorized as system innovation is difficult to say. As the graph mentions, system innovations take more time to develop (several decades) and can be seen as a transition. Thus, probably none of these initiatives could ever be seen as a system innovation by themselves, but are probably part of a transition-pathway as so called singular innovations (tukker et al., 2007). To illustrate this; Internet as we know it did not pop up out of nowhere. It started in 1969 with the conception of a network of 4 computers stationed at American universities (Computerhistory.org). If one would have applied Tukker's model at that time, the conclusion would probably be that a system redesign was performed, adding a node to a network. These where the first of many nodes connected in a network, eventually growing to the current scale of internet. This puts the development of circular economy in perspective; **the transition to a circular economy may start with system optimizations and -redesigns, or singular innovations.**

For this thesis, the following definition of the circular economy is obtained: **The circular economy is an economy where material loops are closed in order to minimize raw material extraction from the earth**. We acknowledge as well that the circular economy aims to prevent de-valuation of materials and this will be elaborated on in a later paragraph; *the circular economy applied to the building sector.* The first circular initiatives can be recognized as system optimizations or system redesigns, as potential first steps in a transition to a CE.

Limitations and considerations

The transition to a circular economy goes paired with many ideas on why the current system does not work. Some nuance however is appropriate to bear in mind, as well as some nuance would be appropriate when speaking of a perfect, circular economy. This paragraph introduces these nuances by shedding some critical light on the circular economy. We argue that a fully linear economy has never existed, and that a fully circular economy will never be reached.

When speaking of a circular economy, we tend to think of our own economy as a linear one, a so called "take, make & waste" system (MVO Nederland, 2012). We have to understand however, that our current resource economy is far from linear. Many businesses do realize that certain materials are valuable to others, for example energy utility companies who extract the sulfur from their flue gases and sell this to gypsum board producers. Next to that, some recycling systems in the Netherlands deliver a large share of resources to production processes. Wood and paper industries for example, produce their products with 79% being secondary, recycled material (CBS, 2013). Thus, our economy is not completely linear and has never been. However, not every sector has such a high degree of recycling processes, for example material flows of mineral used in construction only consists of 6% secondary materials. The next paragraph will go into more detail on the construction sector and resource use.

The principles of the CE are sometimes stretched to an extent that an idealism is created of a fully circular economy. The EMF (2013) calls this "a system which is fully restorative by nature". When thinking of a completely closed, circular economy, there are limitations. First, we live in a growing society. This drives consumption rates and therefore there will remain, at least for now, a demand for material inputs to our consumption system. Second, a fully self-sustaining consumption system implies zero loss of materials. This is practically impossible due to the fact that we will lose certain materials due to leaching (e.g. corroding steel due to rain) and since materials degrade after time (material fatigue). As for the 79% of fiber recycling in the wood and paper industry, a 100% recycling system will be impossible since the strength of the fibers will degrade over time.

Circular economy and sustainability

The EMF (2013) presents the CE as a concept that aims for sustainable development. There is however discussion going on whether or not CE is truly a sustainability initiative. Is it part of sustainability? To enter this discussion, we first need to understand what sustainable development is. According to Boons et al. (2012), sustainable development aims to rebalance social, ecological and economic values. This is broadly understood as the triple P values; People, Planet & Profit. In his thesis, Mentink (2014) assessed how the goals and interests of actors that pursue a CE align with the triple P values of sustainability (see figure below).

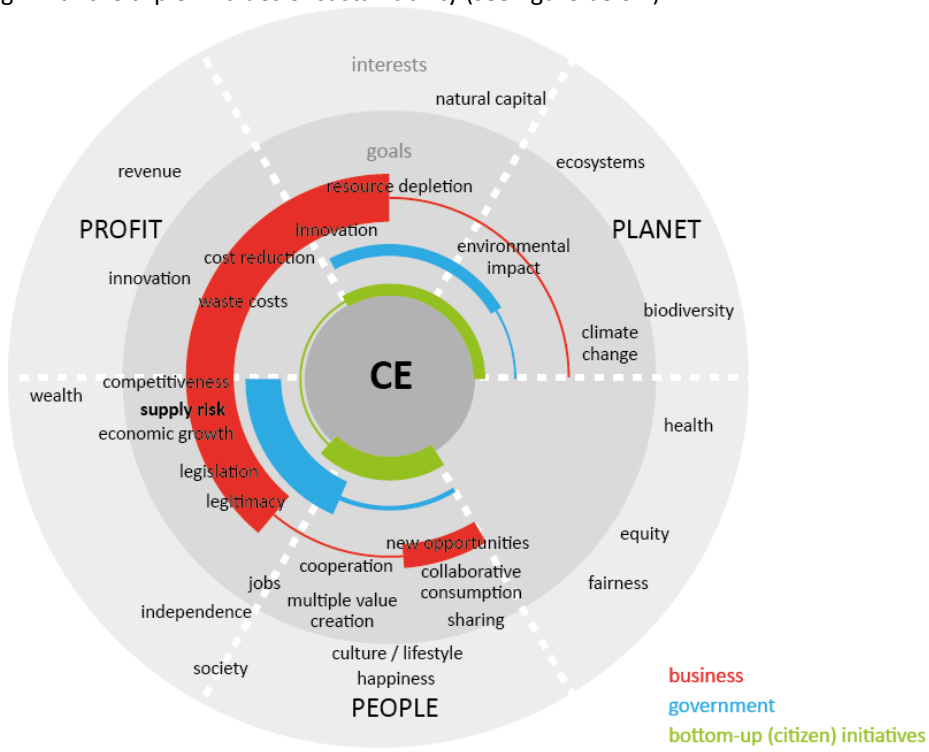

Figure 4; Goals and interests of actors engaging in CE (Mentink, 2014)

From the figure, we see that the circular economy is mainly associated with profit, some attention goes out to the people aspect and surprisingly little motivation is with the planet aspect. The graph gives the impression that a CE initiative is not in line with sustainable development, since there does not seem to be a balance between the People-Planet-Profit aspects. However, the source does not state which initiatives have been assessed (products? Industrial systems?) and when the initiatives took place. Thus, we refrain from concluding that the CE is not in line with sustainable development.

The circular economy is surrounded by another ambiguity: the reduction of CO_2 emissions. This is an important aspect of the Planet aspect of sustainable development since CO_2 emissions are related to climate change. The EMF(2013) mentions CO_2 emissions strictly in examples where these emissions are captured and fed to a process for which CO_2 is considered a resource; an industrial symbiosis. However, nothing is said about the reduction of CO_2 emissions in general. Of course, when CO_2 emissions are captured from an industrial process and for example used in a greenhouse to grow plants, the greenhouse acts as a sink and in that sense a CE would contribute to CO_2 emission reduction, in line with sustainable development. However, the report does not mention how CE relates to CO_2 reduction in context of sustainable development. At the same time, the report does argue for the adoption of a CE in business practices because the take-make-dispose principle fits in with “green business” initiatives. Thus, inexplicitly the EMF does link CE to sustainable development, but CO_2 reduction specifically is in their definition not related to the concept.

3:

THE CIRCULAR ECONOMY APPLIED IN THE BUILDING SECTOR

As we have explored the topic of CE in general, we now zoom in and explore what the transition to a CE would mean for the building sector. This is the result of preliminary research which was necessary to get a grip on what obstacles, or issues seem to prevent the transition from happening. When this is clearer, we can set workable and relevant boundaries for the continuation of this research. The exploration is divided in four paragraphs: first, we explore why a circular economy would be beneficial for the building sector. Second, we elaborate on how the transition would affect the building sectors' supply chain. Third: what would this transition mean for how the building sector is organized? And fourth, we elaborate on what would happen to how humans collaborate. As conclusion we summarize the boundaries we set to conduct the research.

Buildings and CE; why?

First of all; having a house which protects you from the climate in Holland is essential. Knowing that a linear economy could endanger supply of resources from which we construct our own housing. If this is true, the CE would be of support of our health. Even with a stagnating Dutch population; houses (or materials) degrade and need to be upgraded. Having said that, which materials are we dependent on, and how much?

Looking at global resource extraction, the construction sector takes a large share. We see that construction minerals are 1/3rd of total resources extracted, in terms of weight (about 18 billion metric tons, including infrastructural and offshore.)

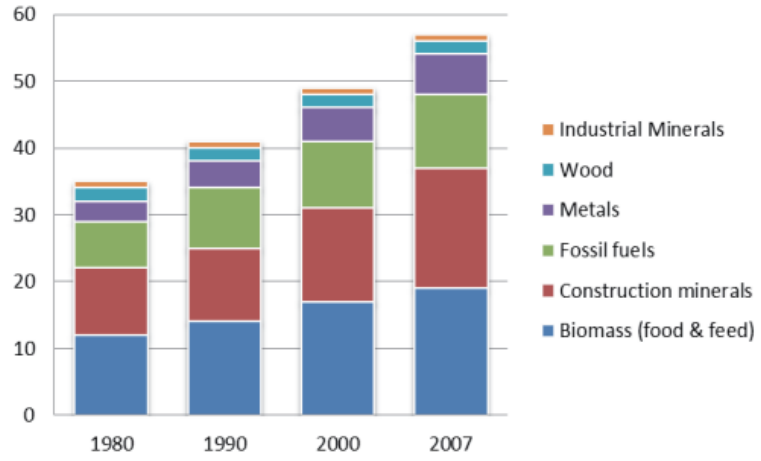

*Figure 5; Global resource extraction in billions of metric tons, 1980-2007 (**OECD, 2008**)*

In Holland 2010, the construction sector (not just buildings, also infrastructural and offshore) used 260 Mton of construction materials (CE Delft, 2014), which is 0,000014% of the world total. 200 Mton is used for filling sand, which is mostly used in infrastructure, so an estimation of 60 Mton for the building sector would be more plausible. The 60 Mton consists of the following materials and amounts.

TYPE OF MATERIAL	AMOUNT	UNIT
SAND	202.400	Kton

GRAVEL	4.400	Kton
CONCRETE	14.000	M^3
ASPHALT	9.500	Kton
GLASS	3.960	Kton
BRICK	1.728	Kton
WOOD	3,0	$X10^6$ m^3
CONSTRUCTION STEEL	890	Kton
REBAR STEEL	546	Kton
PLASTICS	290	Kton
ROOF COVERINGS	73	Kton
ALUMINUM	25	Kton
COPPER	50	Kton

Table 3; Materials used by Dutch construction sector (based on CE Delft, 2014)

Most of the resources we import, such as sand and gravel (in terms of Kg) will not be subject to depletion in the near future (CBS et al., 2014), the world is basically made of those materials. Scarcity of these materials could however arise due to limited recoverability of these materials since raw material extraction is dependent on other materials which are more prone to deplete in the near future.

There is another reason that a circular economy would be beneficial. The CE for the construction sector could help in reducing these emissions. According to CE Delft (2014), the construction sector is responsible for 5% of the total Dutch climate impact. This is caused mostly by extraction of materials which the CE aims to prevent. Another emission contribution is caused by transportation of construction materials. 18% of total transport on Dutch roads (Kg * km) is due to construction materials. Not only does this have impact on our climate directly; think of the space that would be available on the highways if transport of construction material would be eliminated, causing less traffic jams, shorter travel times, etc.

Considering the climate impact of the building sector, this could become much higher in the coming decades. TNO (2015) reports that 15% of Dutch housing will reach the age of 50 in the coming years, meaning the end for their technical lifetime. As the Dutch government aims to reduce national energy consumption by 100 PJ, large scale intervention in housing is necessary: each year 300.000 homes will need to move two places up the energy label scale[3], and from 2020 on newly built homes should be energy neutral (TNO, 2015). The large scale intervention at hand indicates that the 60Mton may increase, and the climate impact of construction as well.

In summary, a circular economy for the building sector could make us less dependent on foreign material supply. A CE would decrease the emission of greenhouse gases thus lowering climate impact. Knowing the large scale intervention in Dutch housing, a CE could help in decreasing emissions.

A circular economy; effect on the supply chain

To understand how the CE would change the supply chain of the construction industry, we apply the feedback loops of the concept to the supply chain. To do this, we use the system boundaries of CE Delft (2014), used in their assessment of the construction supply chain impact on our climate. This supply chain starts with the extraction of raw materials, and ends the incineration, recycling and landfill of material streams. We adopt this perspective and use it to explore the impact of the CE on the supply chain's activities in the following paragraph. For each supply chain activity, we indicated how recycling, refurbishing, redistribution and maintenance of the building will affect the supply chain for the construction sector. The supply chain is summarized in the following figure.

[3] The Netherlands labels houses from F to A++, F being the worst on the scale of energy efficiency.

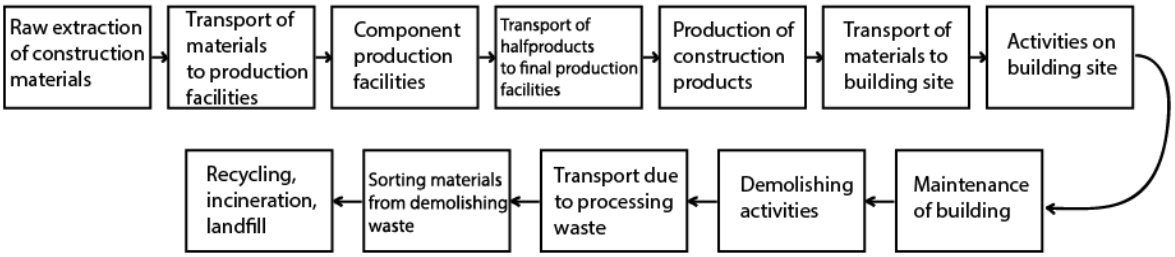

Figure 6; Supply chain for construction sector. Adopted from CE Delft (2014)

The table above shows the activities of the building supply chain, including demolishing activities. The last element of the chain (recycling, incineration & landfill) is split into recycling, and incineration & landfill. This is due to the fact that a CE promotes the reuse of materials as much as possible. Landfill and incineration are seen as activities that cause leakage of materials (EMF, 2013), for which the consequence is the extraction of raw materials to compensate for the loss of material due to leakage. Recycling however is a form of reusing material and therefore should be treated separately.

Raw extraction of construction materials
Basically the essence of the Circular Economy is to minimize extraction of raw materials. So all ways of loop closing defined by the EMF(2013), recycling, refurbishing, redistribution and maintaining should decrease demand for raw materials, since these are substituted by materials already available in society.

Transport of materials to production facilities
More recycling will not significantly decrease the impact of transport on the climate. Transport will have to happen since the recycled materials are still needed as input of component production facilities. Perhaps a positive effect occurs since recycling could happen locally, instead of importing materials internationally. The saved impact depends on what local mode of transport replaces the international mode of transport. Refurbishing, redistribution and maintenance should decrease the need for raw materials transport, since materials are re-used that are already embedded into products. Perhaps, an increase in materials needed for refurbishing, redistribution and maintenance processes will require a need for new machinery or tools. Then the question occurs; will a CE already be established for this manufacturing sector? This reveals the dependence of different sectors: the construction sector with the industrial machinery sector.

Component production facilities
Assuming that recycling dominates in the building sector, and no refurbishing, redistribution or maintenance, then component production will remain necessary since we keep destroying existing components into separate materials streams, and recycling these into new components. However, with refurbishing, redistribution and maintenance of building elements, this should decrease.

Transport of half products to final production facilities
In a building sector with a high recycling or high refurbishment scenario, transport of half products remains necessary. It could be that, due to refurbishment, a market for half-products is established which could shorten distances traveled. A building sector with a high redistribution or high maintenance scenario should decrease the transport of half products, since products are not anymore dismantled but reused directly.

Production of construction products
In a building sector with a high recycling or high refurbishment scenario, production of construction products will remain the same. However due to redistribution and maintenance, production of new construction products should decrease, since used products are being redistributed or maintained.

Transport of materials to building site

For a recycling, refurbishing or redistribution scenario, transport of materials to the building site would still be necessary, since these come out of the final production facilities (recycling & refurbishing) or from other buildings / demolishing projects (redistribution). Only maintenance of buildings and thus direct reuse should decrease transport of materials to the building site.

Activities on the building site & maintenance of building

In all four scenario's, activities on the building site remain, as well as maintenance of a building. However, maintaining a building will probably result in less activities, or less intensity of activities, compared to a high recycling scenario. This is due to the fact that recycling involves using products that come out of a factory, which means dismantling an old product, moving it away from the building site and replacing it with a product made from recycled materials. In a maintenance scenario, it seems more likely that that the products/elements of a building will remain in their position and repaired on site. This is less intensity of activity on the building site compared to when new products have to be installed.

Demolishing activities

Answering how a CE would affect this building sector activity, depends on how demolishing is done. Demolishing activities as traditionally known are mainly done to create materials streams that fit the recycling scenario of a CE. Buildings are stripped using heavy machinery, meaning that many building elements are destroyed into separate material streams that are being sold/brought to a recycler. Demolishing therefore seems an appropriate name for this activity. A recycling scenario will not affect demolishing activities. A refurbishment/redistribution scenario embodies the careful dismantling of building products/elements (Geyer et al., 2004), into building components/products that can be reused and avoiding recycling. Maintaining buildings and its components/products should decrease demolishing activities as well, since buildings are not taken apart anymore. Reasons for demolishing instead of carful dismantling and not destroying components/products are due to deconstruction barriers (safety on the demolishing site), re-fabrication barriers (elements not designed for dismantling) and limited & unpredictable market demand for re-fabricated sections which is perceived as risk (Geyer et al., 2014). The following picture shows how a demolishing activities typically look like.

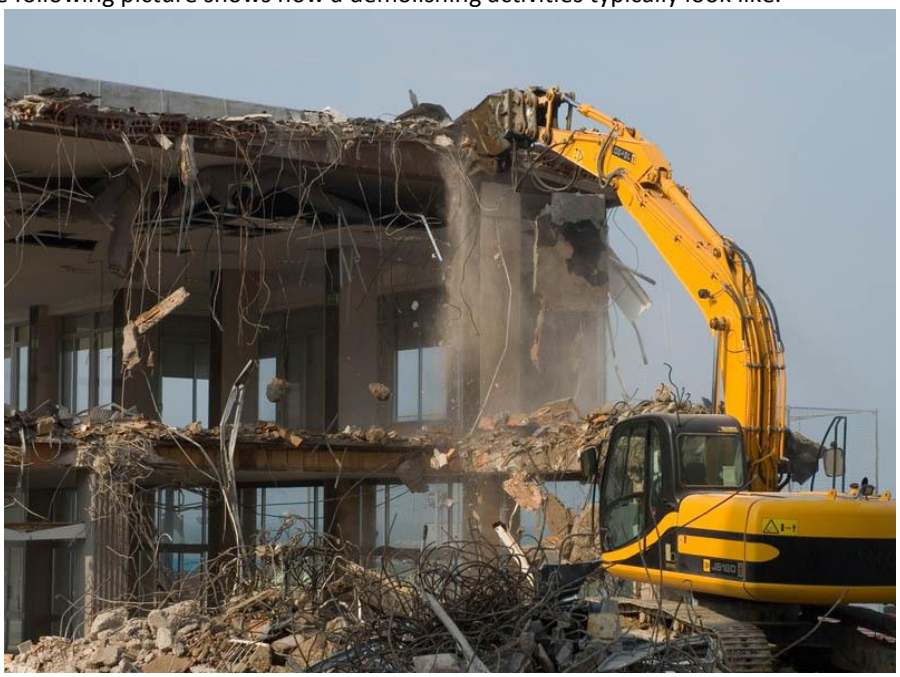

Figure 7; demolishing activities (http://www.detrez-grondwerken.be/media/images/gallery/20/big/23.jpg

Transport due to processing waste

A recycling scenario would not affect this activity by increasing or decreasing it. Refurbishment will still require (half) products to be transported to a refurbishing facility/industry. Redistribution will still require the transport of products to other buildings. Maintaining buildings should result in a decrease of transport of waste due to avoiding waste. It depends however, whether or not maintaining a building will increase other activities, for example transport of facility engineers that have to travel to buildings to execute maintenance.

Sorting materials from demolishing waste
This activity will not be influenced in a recycling scenario, since sorting materials from waste streams will still be necessary to sell different materials to different buyers. A refurbishment scenario still requires careful sorting, since building elements/components should end up in the designated refurbishing industry. Maintaining a building will result in a decrease of sorting activities.

Recycling
As the word implies, a recycling scenario would still require recycling activities. The other scenario's cause recycling activities to decrease, since materials will remain in products or half products and will be applied in new products or directly re-used.

Incineration and landfill
Before starting this exploration, it has been mentioned that the purpose of the CE is to minimize raw materials extraction, for which leakage of materials due to incineration and landfill are some of the causes (EMF, 2013). This should be the same for waste streams of the building sector, thus incineration and landfill activities should drop due to the CE. Incineration is one of the ways electricity and heat is being generated in the Netherlands which is about 2% of the total amount of electricity generated (CBS, 2014). A CE for the construction sector would not result in a strong decrease of waste to burn, little mass from the sector is used for incineration (CE Delft, 2014).

The exploration shows us that maintenance causes the most direct positive effects in terms of resource use and transport activities in first parts of the chain, and last parts of the chain. Refurbishment and redistribution still requires activities from parts of the chain, such as production of construction products due to refurbishing, and transport of materials to building site due to redistribution. Main point is that there is a hierarchy in loop closing; most preferred is direct reuse/maintenance and least preferred is recycling. This is what TNO (2013) refers to when they speak of minimizing de-valuation. As a product is created, energy has been invested in order to increase the value of the product, to a level that it is more valuable than the sum of its components. This has to be the case, if not the company would not profit from their business. When buildings are demolished, products (windows frames, constructions, etc.) are destroyed and with it the value which was initially added. That being said, dismantling a building in order for re-use to be easy, should be less of a problem. This also refers to de Ridder (2013), who promotes the so-called LEGOlization of the building sector. He argues that designing buildings and the elements they are made of the same way as LEGO elements, results in a building sector where buildings are easily dismantled, reused, or renovated.

After exploring what a CE for the building sector could mean for the supply chain of the construction sector, we also see how changes in the construction supply chain will affect other sectors. We mentioned the connectedness with electricity production from incineration, which a CE for the construction sector will not result in much harm, however if a major contributing sector becomes circular, it could mean a strong increase of importing waste internationally. It is of importance to keep incineration ovens running, since these still have to earn their investment back (NRC, 2013), unless the government is willing to pay for these ovens to close. Another example is how a refurbishment scenario would increase activities for manufacturing industry activities and a shift in transport related to recycling industries, to the manufacturing industries. Thus, a CE for the construction sector, or any sector alone will not be an answer to the problems the CE aims to tackle. It requires a complete change in all sectors, on global scale.

As for recycling, the construction sector is not completely linear. The graph below shows that a part of materials used in construction is already secondary material. This however is mainly covered through the asphalt materials cycle, which is for a large part already a closed loop (CE Delft, 2014). A small part is concrete granulate, which is re-used in concrete for new buildings.

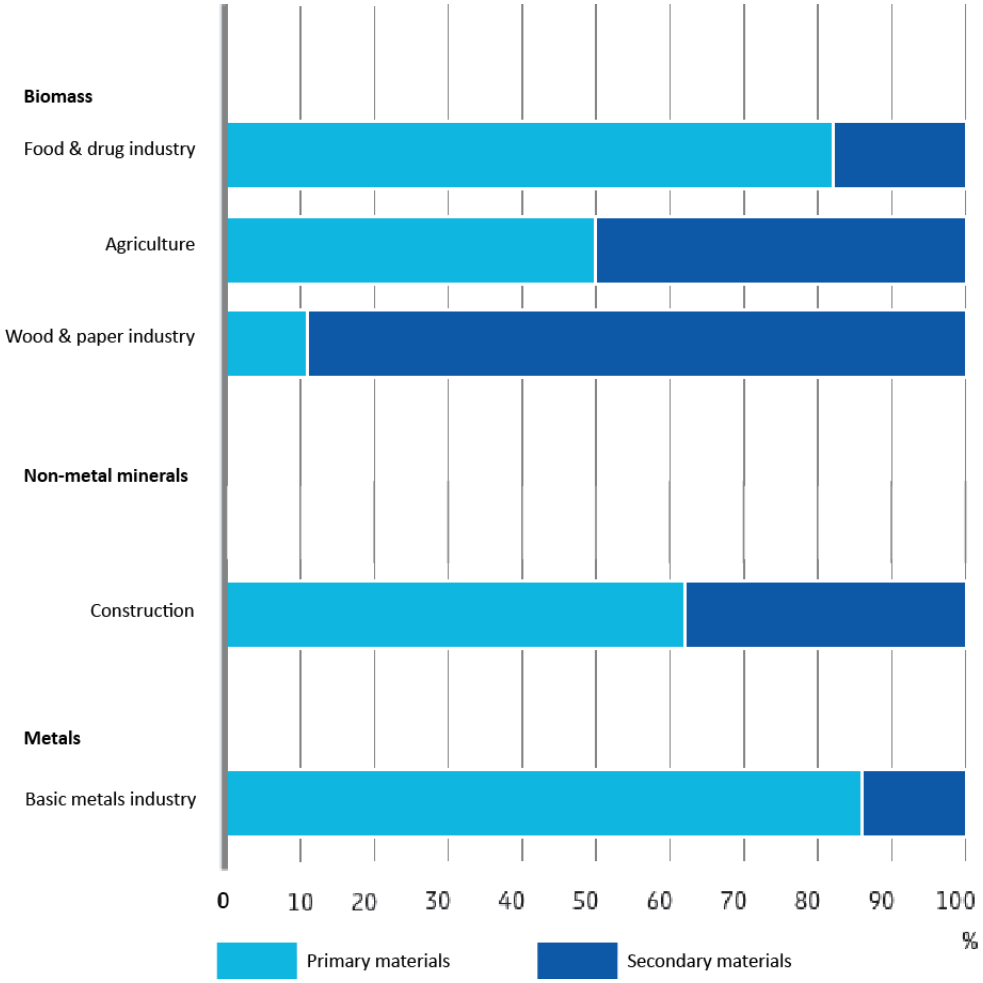

Figure 8; ratio primary & secondary material used in Dutch sectors (Bhageloe-Datadin et al., 2013)

Interesting to mention, is that 95% of building materials is re-used in other sectors, namely road construction where concrete and gravel are re-used as foundation (CE Delft, 2014). These numbers are impressive, however little positive impact on the climate results; the materials replaced by streams from the building sector, already had low impact on the climate (CE Delft, 2014).

Based on the table above, it would be good to promote direct re-use by properly maintaining buildings as much as possible, in order to minimize devaluation and move to a CE with the most positive effects. However, as said before, there are limitations that have to be considered. Materials corrode, which need to be replaced in the end. Next to that, this scheme does not take into account the jobs lost in for example the recycling industry, when moving to a high re-use economy. Both TNO (2013) and McKinsey & Company (2015) report on more employment due to a transition to a CE, due to an increase in GDP (7% for Europe, according to McKinsey, 2015) resulting in more consumption. However, we do not know if these jobs will be available for the persons who lost their job, and what it takes to re-educate these people for new jobs. From a sustainable development perspective, this causes issues in the balance between economical (profit) and social (people) aspects. This means that when a transition will really take off, a challenge lies in guarding the balance between social and economic aspects.

After exploring what a CE would mean for the supply chain of the building sector, we can conclude that re-use and maintenance of buildings would ideally be stimulated as much as possible. **Therefore, this research focusses on the direct reuse of building materials, elements and other materials.**

A Circular economy; effect on how the building sector is organized

What would a transition to the circular economy mean for how the building sector is organized? As defined in the paragraph "defining the CE", the CE causes actors to perform a system optimization or system redesign in such a way, that the use of virgin materials is minimized. However, the building sector is now organized in such a way that raw materials are mostly used. This way of organizing tells us that the transition to a CE does not only imply technical barriers, but also barriers related to collaboration. This is explained below.

Traditionally the building sector works with a supply chain that knows a high degree of segregated activities. In other words, different companies are connected through relations based on economic transactions, for which they exchange products, instead of a supply chain which is mostly vertically integrated under one company, for example in the automobile industry. The following image represents the typical supply chain of buildings. From the upper left to the right information flows towards the contractor. These information flows can for example be design drawings. The main contractor then hires sub-contractors and manages the building process of different sub-contractors (Vrijhoef et al., 2000). The following image shows this supply chain. The red circles indicate the place where materials are inserted in the supply chain when speaking of a system optimization. The materials inserted are for example re-used materials, or materials bought on a leasing contract with suppliers, which is in line with the CE concept.

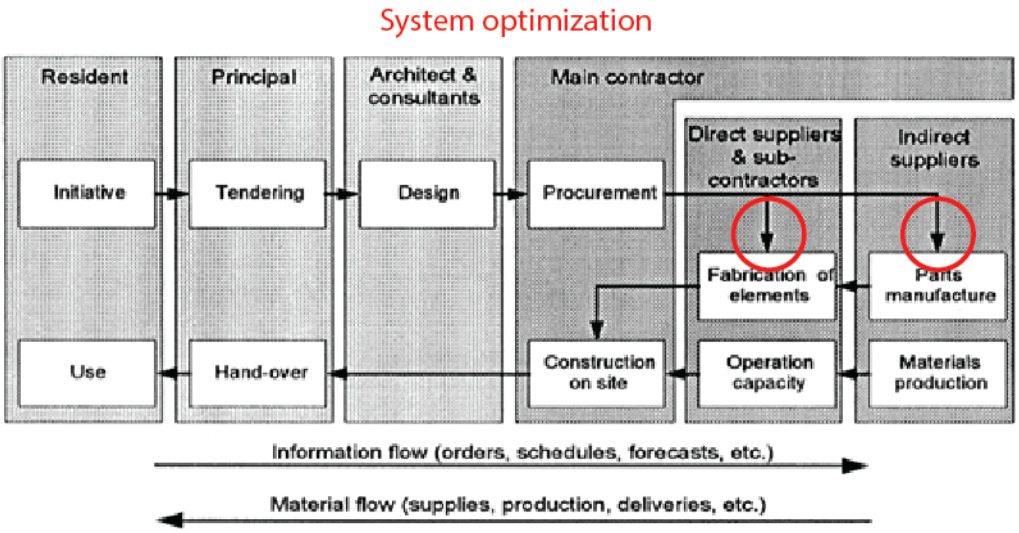

Figure 9; Traditional construction supply chain and system optimization. Based on Vrijhoef et al., 2000

It could also be plausible that completely different suppliers are found that offer circular materials. For example, a second hand building materials market place could become a supplier. This is an example of a system redesign: complete components of a system are replaced by other components in order to deliver the desired result. The following image sketches the system redesign.

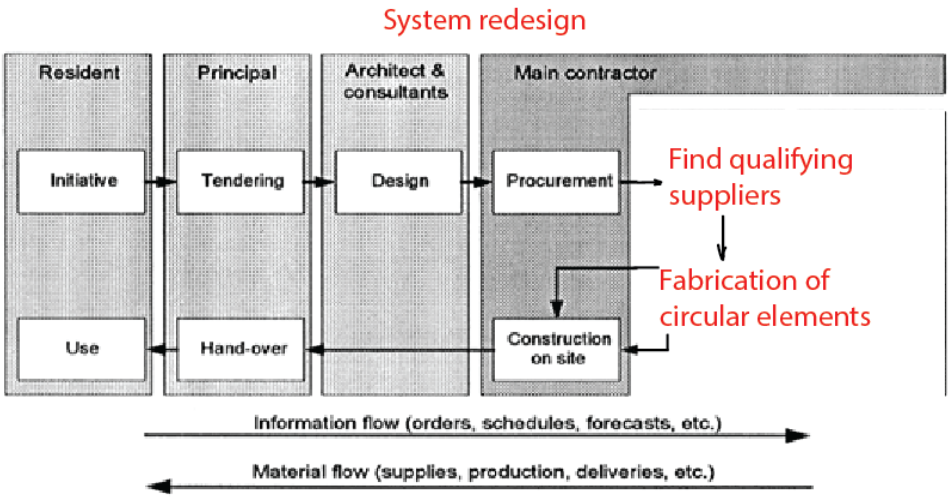

Figure 10; System redesign of the building process (based on Vrijhoef et al., 2000)

From the system optimization and the system redesign images above, we can see how a change in one part of the supply chain can influence parts that are connected to it. A different configuration in the supplier area of the chain, will influence the type of information that flows from resident to main contractor as the arrows in the figure indicate. Reason for this is that the resident is paying for these materials and has to agree with the design, the architect has to make decision on what materials to use, and the (sub)contractor has to know which materials are available at what time, in order to plan the construction process. In addition, during use phase working with different materials could influence how the building should be maintained. This indicates that changing one link in the system, causes issues for other links in the system. Thus the application of CE principles in the construction supply affects the whole supply chain and its involved actors.

What has to be considered when speaking of a system redesign or optimization in the building sector, is that a single project cannot be a system redesign in the way Tukker & Butter (2007) mention it. They speak of a system redesign, which remains in that state after the system has been redesigned. This is possible in for example the industrial sector when performing an Industrial Symbiosis: two facilities connect by a pipe, for example, which forms a new system that remains, at least for some time. In the building sector however, the redesign means another way in which actors collaborate in the supply chain in order create a circular building process. This is a temporary redesign of an organizational configuration, which vanishes after the project is delivered. Some developments in the building sector contradict this statement, for example uprising contract forms where the contractor remains responsible for maintenance of the building after delivering it[4]. These contract forms are however not yet the standard. Perhaps this is also why the building sector is so difficult to innovate, since innovative collaborations vanish and have to be built up again from scratch in other organizational configurations.

From an industrial ecology perspective, it is already said that sustainability issues require coordination focused on the relationship between organizations, rather than within organizations (Boons & Baas, 1997). As said before, the construction supply chain is rather segregated, compared to for example the more vertically integrated automobile sector. One reason for companies in general, mentioned by Boons & Baas (1997) is the increased rate of technological change, causing companies to prefer operating more autonomously since this makes them more flexible in keeping up with the pace of technological change. We do not know if this is specifically the path chosen by companies in the construction sector. It does pose the question, is coordination towards a more circular organization of the construction supply chain possible without vertical integration to compensate for the temporary character of inter-organizational collaborations in the building sector?

[4] DBMO contracts; A party will be responsible for the design, build (construction), maintenance and operation of a building.

As said before, a large scale renovation, or redevelopment of buildings is awaiting the Dutch building sector. What exactly does this redevelopment entail? Buildings can be seen as a collection of 6 layers that are connected to function conform the desires of its users. (Brand, 1994. See figure below). When re-using a building, we preferably like to keep all layers as they are so they can be of service for new users. However, these users have certain preferences that can differ from former users and thus require changes in some of the layers. Remøy (2010) studied the user preferences of office buildings: image (aesthetical) of the building turns out to be one of the most important aspects for a user to choose to rent an office. In order to for an office building to remain interesting for future tenants, the structure has to be strong enough to be re-used, the space plan has to be able to be flexibly used and the façade needs to be maintainable and replaceable.

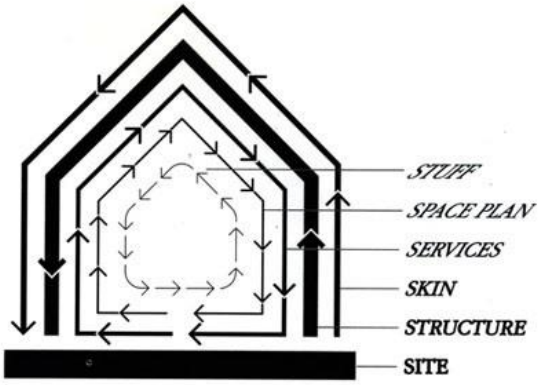

Figure 11; Layers of change (Brand, 1994)

When translating these preferences to Brand's (1994) model, transformation projects mainly affect the stuff, space plan, services and skin layer. The structure will mostly be re-used as it is. The site is difficult to replace for another site, however it is possible to redesign some characteristics of the site to match certain users' preferences.

This research will focus on the stuff, space plan, services and skin layers as these are most probable to undergo change during redevelopment due to the preferences of new tenants. A description of what the different layers are is provided in the table below.

Layer	Description
Site	Geographical setting, urban location, boundaries formed by streets.
Structure	Foundation and skeleton of the building. The structure carries the weight of the building to the ground
Skin	Exterior surface that is protective to outside weather conditions
Services	Wiring (communicational & electrical), heating, cooling & ventilating installations, elevators and escalators.
Space Plan	Interior design of the floors.
Stuff	Chairs, phones, desks, lamps etc.

Table 4; building layers (Brand, 1994)

In this paragraph we have explored what the application of CE principles could mean for the construction supply chain. We saw that both system optimization and system redesign requires other actors in the supply chain to react to this. Thus, transforming buildings in line with CE does not only imply technical changes in terms of what materials can be used, but also changes in how actors collaborate in the supply chain. This poses questions, such as; what (unique) actors are typically included in a CE project? Does the change in the supply chain require actors to change behavior? Should actors be added to the chain? **It shows us that the CE does not only induce technical challenges, but the transition also exposes the sector to inter-organizational collaboration related challenges.**

Applying the CE in the building sector; what does this mean for actors?

Actors engaging in a circular project, one of the singular innovations in the early transition, have to perform a system optimization or system redesign. However, the existing system seems to be strongly embedded in the practice of

the building sector. The sector is very good at maintaining the dominant design of the way actors work together and optimizing the dominant design to more efficient processes. This is explained below.

Often the building sector is labelled as the lagging little brother of other sectors, for example in comparison to the automobile industry. It has even been said that innovation in the building sector is a mere response to external needs. Gann (2000) argues that a change in design and construction of buildings in the transition from the 19th to the 20th century was a response to the replacement of steam power by electrical power. Whether or not it holds true that dynamics in the building sector are solely the result of external dynamics; when it comes down to innovation in the construction sector, there is a unanimous agreement over the stiffness of the way the building sector is organized and responds to changing contexts (Naim & Barlow, 2003; Childerhouse, 2002; Green et al., 2005;), to name a few. Why is it so difficult to change the building sector?

One approach to this problem is the idea that the development of buildings is overruled by a dominant design. The dominant design is "…a specific path, along an industry's design hierarchy, which establishes dominance among competing design paths" (Suarez et al., 1995, p. 416). The dominant design emerges at the same time a certain sector reaches its population peak. Difficulties arise to deviate from the dominant design as for example economies of scale come into play. Next to this, incremental improvements such as LEAN[5] or JIT[6] optimize and strengthen the dominant design even further. The dominant design of the construction process can be seen in figure 8. These incremental improvements are believed to make a system even less easy to perform a system redesign in context of the CE, let alone a radical change in the way of working (Loorbach, 2016). The difference between these incremental innovations (e.g. LEAN & JIT) and the system redesign can be explained by to what extent the innovation requires other actors in the supply chain to collaborate on the innovation. JIT requires careful tuning between contractor and supplier, in order to lower costs in the construction process. This however does not require the architect, or investor to collaborate in this innovation (Pheng et al., 2001). One could imagine that the system redesign due to applying the CE concept, which influences all actors in the supply chain, could interfere with the incremental innovation on the agendas of the supplier and contractor.

Cultural characteristics of the building sector are mentioned to inhibit innovation as well. First, the sector is seen as a highly competitive sector which is dominated by adversarial attitudes and that the sector is suffering from a built-in cultural resistance to change which expresses itself in aspects such as leadership, structure and mentality of the organization's (Green et al., 2005; van Veldhuizen, 2015). One indication of this is the notion made by Haak & Heurkens (2015) stating that in the commercial real estate sector, not much research has been done surrounding innovation. The idea within commercial real estate remains that there is no demand for innovation from the market. A second barrier to change the building sector is how clients set the environment for contractors to do this. Whether or not a client gives a contractor the resources and the correct environment is a determining incentive for a contractor to engage in innovations (Green et al., 2005). As part of the preliminary research, exploratory interviews have been conducted with actors from the building sector. The statements have been collected and can be found in appendix A.

Despite the negative attitude displayed so far towards innovation in the construction sector, some innovations do seem to flourish (Haak & Heurkens, 2015). Building Information Modelling[7] seems to gain popularity and there are currently pioneers who take the first steps in using the software as supportive tool in the building process, also striving to stimulate integration in the building process (Stallen, 2015). Additionally the building process has become object of study, aiming to come to an integrated process where the barriers due to segregation are avoided. An integrated building process (IBP) aims to involve most of the actors (architect, developer, contractor, installation advisor) in an early stage in the process, instead of first an architect making a design and when finishing, handing it over to the contractor, who then has to build what the architect has drawn. The advantage of an IBP is believed to be the gain in costs of time and due to avoiding errors along the building process (Meijer, 2010). This is the result of

[5] The LEAN principle originates from the Japanese car industry, aiming to improve the flow of products through the production process by eliminating variation as much as possible (Krafcik, 1988).
[6] Just In Time is a logistical method of optimizing the timing of delivery of products to a customer to when they need the product. This is especially useful in construction due to saving space on the building site (Pheng et al., 2001)
[7] BIM is a computer-based tool that represents the physical and functional characteristics of a building (Stallen, 2015).

actors working parallel, making communication easier, and avoiding errors made due to segregated design activities in each discipline. With the TBP, actors fulfill their function successively, resulting in a focus on their own work, and not the work of others, since these activities take place at another point in time. The following image sketches the result of this.

Figure 12; result of segregated working activities (nieuwsneus.nl)

If the lamp installer and the road constructer worker had been working in an integrated process, or at least the designers of this public space, they probably would have come across this collision between different functions, and would have taken action to not let this happen. Next to this, an IBP is believed to reduce failing costs and increase functional value of the building (Meijer, 2010). Since the IBP aims to stimulate parallel collaboration between different parties in the construction sector, this is probably applicable to a building process where actors apply the CE principles. As described in the previous paragraph, we have seen that the CE affects all actors in the supply chain in information flows and materials outcomes. This should cause actors to communicate more with different links in the supply chain, which connects to the idea of an IBP. It can thus be expected that an IBP would be necessary when applying the CE principles. The building process is also the context in which the collaboration between actors in the supply chain takes place. Thus, we will focus on the collaboration in the building process.

In this paragraph we have explored how the application of CE principles could affect actors in the building sector. We have seen how the culture of the building sector seems to be perceived as rigid, and not very easy to innovate. The sector is highly financial driven, and the idea is that without a commissioner who has an ambition to innovate, actors are less likely to engage in an innovative building process because this is perceived as more expensive. In addition, incremental innovations make connections between actors less flexible to other innovations. At the same time, the sector is trying to adopt innovations such as BIM and move towards an IBP. The IBP seems to connect with a situation in which actors apply the CE principles.

Boundaries of this research

The aim of this chapter was to explore what a transition to the CE would mean for the building sector, and is the result of preliminary research of this thesis. We reviewed why a CE would be desirable for the sector, after which an indication is given to what a transition would mean for the supply chain, how the sector is organized and how actors would be influenced in their collaboration. From this exploration, the boundaries have been set for this thesis. Here, we summarize this focus.

A transition to a CE could make the building sector less dependent from international resource flows to construct buildings. Additionally, the CE for construction can be related to reducing Dutch impact on the climate. Due to degrading technical quality of Dutch housing, a large scale renovation challenge lies ahead, not only in housing, as well as offices. Therefore, this thesis focusses on the stuff, space plan, services and skin layers of buildings, in terms of making them ‘circular’; meaning direct reuse of materials/components/products as much as possible. We acknowledge that this does not only imply technical challenges, but influences all actors in the supply chain, making

it an inter-organizational collaboration related challenge. In the next chapter, literature study is presented concerning innovation, indicating that the transition to a CE will require other ways of collaboration. In that sense, this research will take a more social approach to the transition. The building process is the context in which collaboration of actors take place, and thus we will focus on the building process.

4:

A CONCEPTUAL FRAMEWORK; DIVERSITY, ECOLOGY AND STRUCTURATION THEORY

Now that we have set the boundaries for the circular economy and what this means for the building sector, a theoretical framework is formed in order to analyze CBP's. The framework draws on innovation theory, in which the idea of actors engaging in a system redesign is embedded. Innovation literature, both in general and in context of Industrial Symbiosis, brings forward that network diversity fosters innovation. We build a diversity framework adopted from ecology theory. In addition we use structuration theory to add a dimension of human behavior to the framework.

Innovation & diversity

The system-redesign that is performed in context of CE results in new connections between supply chains and actors that are connected to those supply chains. The term innovation is used in much of the literature when speaking of making new connections (Johansson, 2004; Boons, 2008; Mirata, 2005; Stirling, 1998). There are however many different contexts described for these new connections. Johansson (2004) mentions connecting novel idea's and the application of this results in innovation. Boons (2008) describes innovation as "a set of actors that are involved in developing new technologies, the (networks of) relationships between these actors, and the rules (institutions) that guide their behavior" (p. 2). Mirata (2005) argues that innovation occurs when the search for solutions shifts from traditional collaborations to the intersection of sectoral connections. Stirling (1998) describes innovation as "fostering linkages between heterogeneous technological and institutional actors". These definitions differ slightly from each other, however it can be concluded that innovation has to do with diverting from the traditional, or established way of doing, by connecting actors, idea's or technologies to each other and applying this novelty in a system. And thus**, we adopt the term innovation in this thesis to describe activities by actors who aim to develop a system redesign in the building process due to the CE.**

In order to develop a conceptual framework, we first explore the concept of innovation, which is generally brought in relation to diversity. We then elaborate on diversity in context of general economic innovation and in context of Industrial Symbiosis, to give a better understanding of how it influences innovation.

The framework developed for this thesis is brought forward by the driving question: what is needed for innovation to occur? The main concept we adopt as an answer to this question is **diversity.** This term has come forward from studying more general literature on economic innovation, and innovation in context of Industrial Symbiosis (IS). IS has come forward from the science of Industrial Ecology, which is defined as a "systems-based, multidisciplinary discourse that seeks to understand emergent behavior of complex integrated human/natural systems" (Allenby, 2006). Due to its focus on flows of material through economic regions, this science gives an interesting perspective to the development of CE.

In more general theory on innovation, diversity is brought forward as an influential factor. Interactions in networks are performed by actors in order to give themselves access to resources and opportunities that exist in a network (Granovetter, 1973). The amount of resources and opportunities available in a network is generally accepted in literature to depend on the degree of diversity of actors in a network (Harty, 2010; Stirling, 1998; Newman et al.,

2004;). This is also described as “cross-fertilization of disparate disciplines or traditions” (Kuhn, 1970). This brings forward the question; does the diversity of actors in a building process also influence their capacity to innovation? Is there a certain leverage of diversity, resulting in more resources that are used to build in line with the CE concept?

A comparison can be made with Industrial symbiosis theory, which studies the effects of diversity in Industrial Symbiosis initiatives. In context of IS, Mirata (2005) explains that diversity increases when inter-sectoral connections are made. An actor from the car glass industry that started a symbiosis with an actor from the printer manufacturing industry performs an inter-sectoral connection. Nieto et al. (2007) reveal that diversity in collaborative networks favors innovation more than collaboration with the same types of partners. Heterogeneous networks therefor provide more resources and information for innovation activities than homogenous networks. However, access to information seems to be not enough to propel innovation. Bektas (2013) treats information as a basis for knowledge. She argues that information is merely an object. Actors interpret the object, trying to discover the purpose of the information. When the meaning of the information is exchanged, knowledge is created. She therefor stresses the importance of conversation and communication. This leads to possible barriers that could inhibit innovation. Several observations made by researchers show that a larger diversity is not always better.

One explanation to this can be made through the idea of cognitive distance (Nooteboom et al, 2007), which states that people interpret the world in different ways due to different life paths, experiences, etc. This causes a cognitive distance between people, which influences the innovative performance a group of people has. A certain cognitive distance is necessary to combine a diversity of knowledge through interaction, enabling actors to learn. However, as cognitive distance increases, mutual understanding may be threatened to a point that it negatively influences innovative performance. Mutual understanding is necessary, for example being able to trust each other. Nooteboom (2007) proposes an inverted U-shaped relation between cognitive distance and learning, as pictured below.

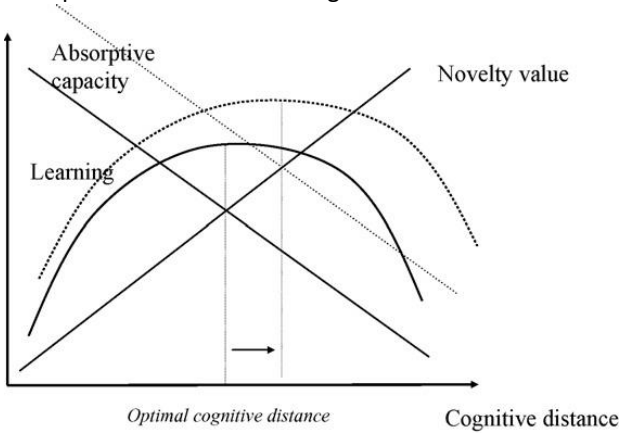

Figure 13; Inverted U shaped relation between cognitive distance and leaning (Nooteboom et al., 2007)

The curve shows that an optimal cognitive distance results in high learning. Placing this idea in the context of actors aiming to apply CE principles for a building, how does cognitive distance influence them? Does introducing an actor who is not familiar to the building’s sector culture cause less innovative performance? These are relevant questions when studying diversity, and should be taken into account.

Boons (2011) argues that increasing network diversity could inhibit IS development due to conflicting interests, causing problems when collaborating. Next to that, conflict can arise due to the many present interests and objectives (Korhonen, 2005). This is part of the reason that coordinating activities in IS development are a reoccurring theme in IS theory. Coordinating activities have been present in Industrial Symbiosis development projects with the aim to steer the development towards an outcome where companies form new symbioses and benefit from each other. One could say, coordinating activities have been necessary to keep diversity from “backfiring” into negative outcomes. It is not clear when coordinating activities are necessary: in large projects, they can be very helpful due to the networks size and diversity. In smaller projects, actors may be able to self-organize

due to the lower level of complexity (Spekkink, 2015). Mirata (2005) proposes three features that should be integrated in coordinating activities:

1. Collective problem definition is key in innovation processes. If the problem is not defined collectively with all parties involved, it would be impossible to find the correct solution, since the solution must address the problem as perceived by all actors. Without a collective problem definition, people become unaware of the range of potential solutions. This causes the incentive to innovate to decrease.
2. Innovation occurs when the search for solutions shifts from traditional collaborations to the intersection of sectoral connections. It is therefore desirable to steer partiers towards the interfaces of sectors when expanding networks.
3. Inter-organizational diffusion of knowledge stimulates innovation processes. The rate of diffusion is related to the geographical scale of the boundary conditions: face-to-face direct communication promotes quick knowledge diffusion, however this works better the smaller the region. The coordinating party can facilitate the diffusion of information. This is also referred to as learning (Posch, 2010).

As the practice and science of Industrial Symbiosis shows us, too much diversity can lead to negative influences on innovation. They propose solutions in the form of coordination. The question is whether an actor is involved in the building process that also takes on this coordinative role. And how does this role relate to the other roles in an innovation process? In other words; the literature shows us that diversity has to do with the type of actors involved in the innovation process (e.g. a specific mix of cognitive distances), and how these actors interact with each other. In order to use the diversity concept for this research, it is necessary to have a framework on how to measure diversity. In the next chapter we develop a framework which can be used to map and understand the diversity of actors in a building process, based on the science of Ecology.

Ecology and diversity

Innovation studies is not the only science which adopts the concept of diversity as a leading theme. In Ecological sciences, diversity is mostly used in terms of biodiversity, or a specific combination of organisms that together provide a service that keeps a certain ecosystem stable. The theoretical framework used in this research is inspired by frameworks used in ecology to map the biodiversity of ecosystem functions. This is done by uncovering what functions are present that keep the ecological service intact. In this paragraph we elaborate on how this is done in ecology, from which we adopt this principle to develop a framework which can be applied to the empirical part of this research.

The concept of diversity is used in ecological context. This is mostly done when speaking of biodiversity of an ecosystem, which delivers a certain function or service that we as humans profit from. For example Opdam(2006, p322) states that in order for "*landscapes to be ecologically sustainable, the landscape structure should support those ecological processes required for the landscape to deliver biodiversity functions for present and future generations*". With these functions is meant the emergent properties of an ecosystem which are interesting for humans because they support our wellbeing or deliver resources, for example an ecosystem delivering passionfruit. To deliver this function, a certain biodiversity is necessary to keep the system's function intact. To deliver passionfruit, male and female plants are needed, plus pollinators such as bees who fertilize plants that eventually will grow passionfruit. We already mentioned three organisms that form the biodiversity to keep the function of delivering the fruit intact, probably a lot more organisms are necessary to keep the ecosystem functioning (e.g. soil bacteria).

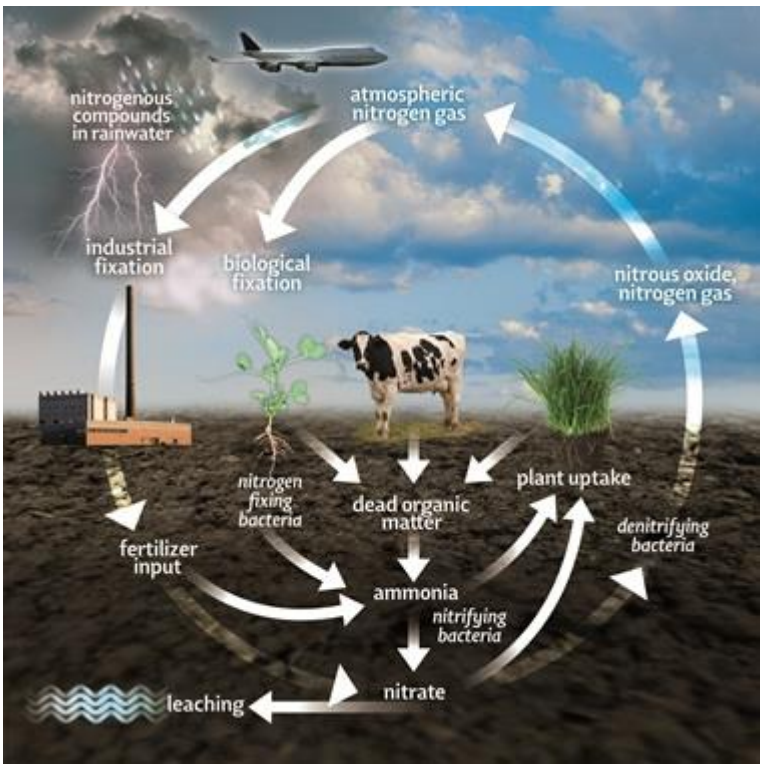

Figure 14; Biodiversity in soil ecology (http://www.rothamsted.ac.uk/soil-microbial-ecology)

We can adopt a similar view to actors applying CE principles to the redevelopment of a building. We could establish that actors together form an ecosystem, with a certain biodiversity, that work in order to produce a system function which should be a circular outcome in the stuff, space plan, skin & services layers of a building. The reason this is interesting can be explained through the application of biodiversity analysis in soil ecology (Bengston, 1998). He relates functional groups or species to the performance of an ecosystem. For example, how the diversity of species or functional groups of decomposers and soil animals affects the rate of decomposition. If we need a certain ecosystem's decomposition rates to increase, we could assess what diversity of species or functional groups cause higher decomposition rates. This could fulfill a higher purpose, for example the purification of an area of land from unwanted substances. This perspective is interesting in our case. If we map the diversity of a circular building process, we can see what actors matter to the functioning of the system (delivering circular building elements), and why they matter. This could provide us with insights on where to tweak in the building process, in order to make the system redesign/optimization easier for actors, or perhaps with more or better circular outcome.

Inspired by ecological research methods, a framework is built to analyze what is necessary for a system to deliver desired outcomes, based on diversity. The framework consists of 4 levels; system function, the system itself, functional groups (consisting of organisms) and characteristics. The following paragraph elaborates on these 4 aspects, to understand why they are important. To illustrate the framework, the example of an agricultural production system is used, which produces passionfruit. We immediately show how this framework translates to the built environment.

System function / Circular Outcomes

The system function is what the system delivers which is of interest to humans. In terms of growing passionfruit, we grow this type because we need to feed ourselves. The passionfruit delivers the necessary minerals and vitamins to feed the processes in the human body that sustain our functioning. As we need more passionfruit than nature can provide, we set up agricultural production systems to provide us with enough fruit. Quite comparable, we need buildings to protect us from the climate we live in (at least in Holland), and thus we have a socio-technical system which in the end delivers us buildings to live in. For the theoretical framework we adopt the term circular outcomes, indicating that we are interested in outcomes of a system that produces circular building products or elements.

System

The ecological system is a network of linked organisms (Bengston, 1998), that due to their linkages provide the emergent service intended (passionfruit in this case). Passionfruit male and female plants are grown and nurtured properly, so that they deliver the passionfruit. Sometimes we need other organisms in the system, such as bees to increase pollination between males and female plants. Translating this to the building process, this can also be seen

as a system that consists of interlinked actors, collaborating to construct a building. In order to fully understand the system and its outcomes, we need to understand the bigger picture by mapping the system. Only network diversity is not enough, since actors are always acting in a context and are influenced by the context. More on this in the next paragraph on structuration theory.

Functional groups

Tilman (2001) found that between the years 2000 – 2005, scholars have conducted research concerning the value and range of those species characteristics that influence ecosystem functioning, defined by Petchey et al., (2006) as Functional Diversity. Functional groups are categorized in order to uncover the functional diversity. An example of a functional group in ecology is the transformers group, which are bacteria breaking down nutrients into other nutrients, which are then consumed by plants. In the building process, functional groups can also be defined. For example, the contractor is an actor that fulfills the functional group which plans the construction of buildings. To know what people/organisms belong to a functional group, and why, we need to assess what characteristics they poses.

Characteristics & behavior

In order to find the characteristics, a simple statement is followed, which Petchey (2006) also draws upon: the characteristics to focus upon are those that are important for the function of interest. We are interested in finding functional groups in a system, so we look at what organisms do, that makes them important. Looking at the bees, their function of pollination depends on their characteristics of being able to fly, and their taste for pollen and nectar. We will use both characteristics (having wings) and behavior (flying from female to male flower) to describe a functional group. In the building process, the functional group contractor consists of people who have a background and experience in construction and are skillful planners (very simplified). Not only in Ecology, but also in paleontology, archaeology and economics, characteristics of species are defined in order to establish the disparity between species (Stirling, 1998). Disparity is the measure by which the inequality of characteristics that are under comparison is established. For Example: the disparity of a group of Dutch and Chinese people is higher, than a group of Dutch and German people. Disparity helps to make a distinction between different categories of species, which is useful when modelling complex ecosystems or economic systems, where many different species of life occur (Petchey, 2006). Thus, characteristics of one functional group must show differences from another functional group. If not, the disparity is not high enough, making the distinctions between functional groups too vague.

To summarize, the framework is pictured in the following figure:

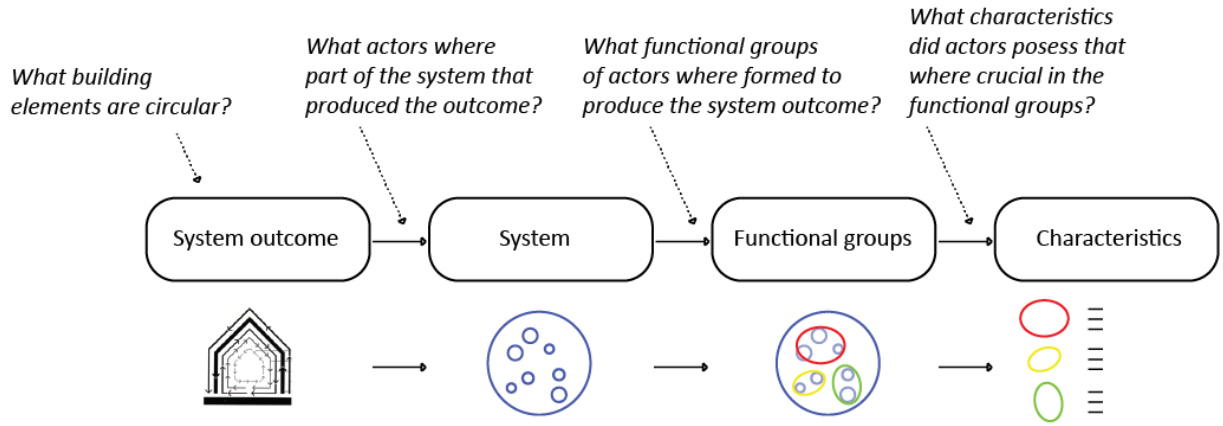

Figure 15; four level diversity framework

This four level framework gives us the possibility to understand what diversity of actors is needed for a system to deliver a desired outcome. We will use this framework to do a qualitative research. This is different from ecological science and economic science, where mostly diversity is identified, through quantitative methods (Petchey et al., 2004; Petchey et al., 2006; Queirós et al., 2014; Stirling, 1998). The following two observations confirm this. First; the studies mentioned in the references apply to large quantities of "samples". For example, ecologists acquire data

spread over a large part of a certain species' population to measure genetic compositions to investigate how certain policy measures have influenced this population over time. Economic studies of diversity also use quantitative methods to perform research covering for example the diversity of companies in multiple sectors. Second; the economic & ecological diversity studies mentioned measure a certain system that at that moment is more or less stable. Of course, parts of a system undergo change, (e.g. bankruptcy of companies or death of animals), however the number of samples in these studies are large and therefore these changes would not have major effect on outcomes. Once whole parts of sectors or populations diminish, it would affect the stability of these systems. Given these two reasons (large amount of samples and stability of systems), we divert from quantitative research methods, because (1) there are not many samples (I.E. CE redevelopment utility projects) to measure in the entire building sector due to only recent popularization of the CE concept, and (2) these samples can be seen as networks of actors that are unstable. We have seen that each link in the construction supply chain is affected, and in that sense the system of the supply chain becomes unstable. This makes a snapshot of the diversity unreliable since the composition of the system could change over time due to instability. It therefor becomes more interesting to use a qualitative method, since this gives more explanation to the instability of a system (why a specific actor is added, why another is left out?).

The four-level diversity framework not only gives us insight in the diversity of a building process. By identifying the 4 levels, we can understand why actors are active in the building process and what function they fulfil. **However, understanding the diversity purely by analyzing the process through actor diversity is not enough**. We need to understand the context in which the building process takes place. How this is done is presented in the next paragraph.

Human behavior in the building process

Analyzing the cases purely by mapping the actor diversity is not enough to understand the way they interact. It is necessary to understand the bigger picture, to understand how building processes unfolded as they have. Unlike other animals, we humans are economic, calculating creatures (Kiers, 2014). An organism like a bacterium will eat whatever he likes, whenever it crosses his path. He will not consider whether the same food may be available for him tomorrow at a lower energetic investment to consume the food. To attempt a complete analysis – as much as possible – an element is added of social structure, which actors use to legitimize their action, but are also influenced by in their actions. This is explained below through structuration theory.

Structuration theory is written at an abstract level, which makes it so applicable on human behavior in many different contexts. While drawing on structuration theory we try to establish some focus by placing it in context of this research.

Giddens (1984) states that behavior is shaped by social structures and at the same time, behavior creates and re-creates social structure. This is called "the duality of structure". This means that when confronted with situations that are new to people, they will refer to existing social structures on how to respond. Behavior is defined as agency, which merely refers to "doing". Thus, agency is shaped by structure. At the same time, the agency re-creates the structure and thus confirms its existence. Doing takes on the notion that actors can do something, and it can have both intended and unintended outcomes. Agency is done to achieve intended incomes, while at the same time unintended (from perspective of the actor who "does") outcomes can occur as well.

The theory is interesting for this thesis because the system redesign or optimization causes actors to wind up in unfamiliar situations in the construction supply chain. According to Giddens (1984), actors would then rely on social structures to shape their agency, enabling to explain why they acted as they have, to other actors. This gives further meaning to what we speak of when saying that humans are calculating, economic creatures. In the circular building process, a group of people aim to apply CE principles, which for them would be an intended outcome. The question then occurs, does their agency also result in unintended outcomes, from their perspective and perhaps from the perspective of other actors as well? In addition, Giddens highlights the idea of perverse effects, where a series of actions individually lead to desired outcomes, but accumulate to an unintended outcome for the entire system.

Giddens (1984) introduced three analytical dimensions of structure:

- Signification (eg. Culture/tradition/language)
  An actor could draw upon a social structure such as a specific belief, or habit, originating for example from a specific culture amongst that an actor is part of. In a company a certain culture may be apparent which influences agency, for example in the way people dress (suit or no suit?), or what kind of language is used.
- Legitimation (eg. rules, laws)
  Actors are able to draw upon social structures in the form of laws. They would explain their agency by referring to a certain law that applies in their situation and that if not acting according law, sanctions will follow with unwanted outcomes.
- Domination (eg. hierarchy (status, expertise), capital (labor, money))
  A third social structure indicates that an actor's agency could be explained because of dependence to a form of power executed through different forms of media, such as hierarchy, labor or money (e.g. "my boss expects results of this kind").

These dimensions of structure are used to build cognitive schemes, which actors draw upon to make sense of their actions and that of others (Walsham, 1993). The three dimensions of structure illustrate how actors rationalize their action. For example, a project leader will make sure he can proof the fire safety of a building since the fire department will assess the fire safety of the building. The relevant structure here is legitimization.

For this research, we use structuration theory to understand how people act, and to refer to structures which justify their behavior.

Conceptual framework

From literature studies on innovation, diversity and structuration, the following framework is composed which is used for this thesis. With this, research sub-research question 2 can be answered: *What theoretical framework can be used to analyze empirical cases of circular building processes?*

Figure 16; Schematic illustration of the conceptual framework

During the analysis of the cases, this framework will be used to get an understanding of the circular building process. As we have set the boundaries in the previous chapter, we now have the ingredients to present how this research will be conducted. One thing has to be clarified: in the system boundaries, we have established that we are taking a social perspective to innovation, focusing more on this than technologies. However, we have as well established that we will identify certain outcomes, in the form of circular building elements, which are elements of technology. The idea is, that by identifying the elements of interest, we map the diversity of actors necessary to create these elements. We are not asking which technologies were necessary to create these elements. However, if technologies appeared to be necessary for the outcomes, we will include these in the system of involved actors.

5:

METHODOLOGY

This chapter elaborates on the methodology used to answer the research questions of this thesis. In the graph below, the structure of how this research is conducted is pictured. The preliminary research has already been presented, as well as the literature study. In this chapter we will elaborate on the selected cases, the data collection method for the cases and the visionary session.

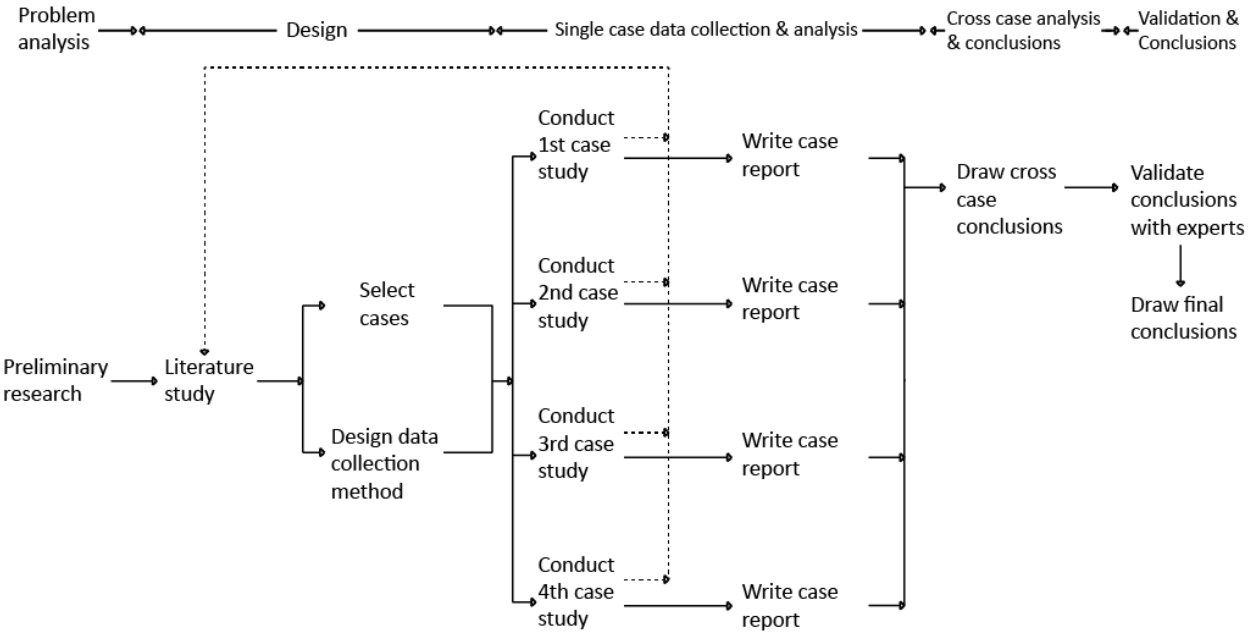

Figure 17; Methodology flow sheet

Case study research; motivation and limitations

From the preliminary research, we established that the system redesign/optimization affects all parties in the supply chain. The collaboration in the supply chain is realized in the building process. Thus in order to establish the diversity in the building process, we have to take a look at already realized projects and uncover what diversity was necessary to apply the CE principles in the building process. Therefor the main idea for this research is to use a method based on case studies. A case study is a way to collect, analyze, compare and draw lessons from research data. It is broadly used in urban planning and management studies to examine how certain projects unfold in real life (Heurkens, 2012). For this research specifically it is interesting, since we take a social approach on application CE principles which can be very well explained by examining relationships and a number of conditions in a specific context. For this, case studies are suitable (Yin, 2003). Choosing a method does appose certain limitations or issues for a research, which will be briefly discussed here.

One problem to case studies is the idea that the researcher may be biased in what results he writes down, and what results are ignored. A researcher always has a gut feeling of what results are interesting to uncover and may try harder to uncover these results than others which matter equally (Vernay, 2013). On the other hand, it is said that case studies leave researchers to revise their preconceived assumptions more often in comparison to other methods (Heurkens, 2012). In this research, we deal with bias by doing multiple case studies, leaving room for the researcher to adjust its view on certain issue along the course of the data collection. In addition, we speak with two persons for each case, in which the 2nd interviewee also acts as validation of ready obtained results.

Second, there is discussion around the validity of case studies due to data generated in a context dependent situation, basically meaning that actors are always influenced by their context and that it is impossible to generalize certain phenomena over multiple case studies, especially when a small number of cases is researched (Heurkens, 2012). This could be a weak spot in this research, since only 4 cases have been used for data collection. Therefor a reflection on the method and how it could possibly have influenced the results is made at the end of this thesis. We aim to tackle the problem of low number of cases used for this research by validating the data with experts who have not been directly involved with the cases, giving them at least less of a bias then the interviewees.

Four cases have been identified to study; Recycling centre Houten, Alliander office Duiven, Haka building Rotterdam and 100 Watt tower Amsterdam. The following pictures introduce the cases that have been selected and provide general information. It also states who has been interviewed for the cases.

General information

Location:	De Brug 13, 3991 LN Houten
Function:	Recycling center for products
Delivered:	2012
Size:	1400 m2
Interviewee 1:	Han Eijbergen (Project leader Arcadis)
Interviewee 2:	Jeroen Eulderink (Architect Arcadis)

Circular outcomes

Skin:	Wood from dismanteled pallets (Remanufacturing / recycling) Concrete slabs (Redistribution)
Space plan:	-
Services:	-
Stuff:	-

General information

Location:	James Wattstraat 100, 1097 DM Amsterdam (8th floor)
Function:	Office
Delivered:	2011
Size:	629 m2
Interviewee 1:	Dirk Bijl de Vroe (Employee Copper8)
Interviewee 2:	Auguste van Oppen (Architect)

Circular outcomes

Skin:	-
Space plan:	Ceiling insulation (recycling), seperation walls (remanufacturing), Carpet (recycling/reuse)
Services:	-
Stuff:	Furniture (reuse)

Figure 18; Introduction of cases

General information

Location:	Vierhavensstraat 38, 3029 BE Rotterdam
Function:	Public space, office
Delivered:	2011
Size:	12.000 m2
Interviewee 1:	Reinder de Vries (Project leader Vestia)
Interviewee 2:	Eline Strijkers (Architect DoepelStrijkersArchitecten (DSA))

Circular outcomes

Skin:	Re-use of as many facade elements as possible (reuse)
Space plan:	Seperation walls from cloathing (Recycling / reuse)
Services:	-
Stuff:	Furniture (Recycling / reuse)

General information

Location:	Dijkgraaf 4. 6921RL, Duiven
Function:	Office
Delivered:	2015
Size:	25.500 m2
Interviewee 1:	Eugenie Knaap (Project leader Alliander)
Interviewee 2:	Frans Wielemaker (Projectg leader Boele & van Eesteren)

Circular outcomes

Skin:	Wood from dismanteled pallets (Remanufacturing / recycling)
	Insulation from cloathing (Recycling)
Space plan:	-
Services:	-
Stuff:	Toilets, furniture (Direct reuse)

Figure 19; introduction of cases

Based on the boundaries of this research, cases are selected which meet the following requirements; it has to be a redevelopment project, and material loops have to be closed in at least one of the skin, stuff, space plan and services layers (brand 1994). In order to map the diversity which was necessary to create those elements, actors who were involved in the project are interviewed. All cases are redevelopments of utility buildings, except for the Recycling centre, which is a newly constructed building. The reason the case is included, is because information about this project was easy to access since Arcadis has designed and built it. This research is conducted in collaboration with this company. Therefor the architect and project manager could be easily contacted.

Data collection method

Based on the focus established from the problem analysis, we selected cases that suit the boundaries of this research. Next to that, an appropriate way of data collection is developed. For this we draw upon the backward analysis approach (Boons et al., 2014). The backward analysis approach is used to study industrial symbioses

processes. This method is based on social theory, concerning sequences of causes and effects, which are connected through social mechanisms, resulting in a specific outcome (Mayntz, 2004). Specifically interesting for this research is the notion that from a recurrent process, mechanisms can be extracted which are generalizable, in turn enabling the researcher to identify what social mechanisms are recurring. Using this approach, an outcome of interest is selected and research is done to what events where preceding to this outcome. Actors are selected who were involved before the start of the building process (BP), during the entire BP, and preferably still involved with the project after the BP. From each case, two actors are interviewed. The first actor has to meet the criteria set above. The second interview is mainly for validation of first results, clarification of clouded memories and addition of missing aspects. In addition, the interviewer is also biased in what he hears. Thus, interviews are summarized and sent to the interviewees for validation.

In order to collect the data from the cases, the following structure is followed during interviews. The structure is based on the backward analysis approach (Boons et al., 2014). For the interviews, one hour was usually enough time to collect the data. The interview started with getting acquainted. From getting acquainted, we gradually flow into the following structure.

- *Identification of circular outcomes (outcomes of interest, see "circular outcomes" in fact sheets).*
  In order to identify what the outcomes of interest are, we first establish a shared idea on the Circular Economy. The interviewees share their ideas, followed by my idea of the CE. I give a very simplified definition of the CE, focusing on the closing of material loops, since these are the outcomes I take as a starting point for the interview. Afterwards, I asked the interviewee what elements of the building they have been involved with fit my definition of the CE. These elements where written on separate post-its (eg. "Separation wall").
- *Mapping actors involved for this outcome; their functions and characteristics -> write actors on separate post-its.* After circular outcomes have been identified, the interviewee is asked to write down what actors where necessary to create the circular outcomes.
- *With each actor, asses why they were necessary (uncovering functional diversity) -> add on post-it of actor.* After the system of relevant actors have been mapped, the interviewee is asked to explain why a certain actor was necessary for creating the circular outcomes. The interviewee explained what he/she contributed. During the interview, I tried to uncover relative issues in the building process by repeatedly asking "why?" For example; the construction of the separation wall required the fire proofing of the wall. An impregnating company was necessary for this. I then ask "why" again, in order to uncover that the wall was checked on fire safety by the fire department (adding another actor). Asking "why" again, which results in the statement that the fire department has to operate under the building regulations. Asking "why" again, results in the idea that the culture/regulations of buildings is organized in such a way that each building we enter, is safe and has a certain comfort.
- *For each actor, I assessed what made them suitable to fulfill their function aiming to uncover characteristics.* I asked questions specifically about characteristics of actors, mostly personal ones, or characteristics of the company the actor works for. I asked why specifically this actor could fulfill this function. As a follow up, I test the importance of the characteristics by asking if this function could have been fulfilled by someone else.
- *Identify the dynamics between structure and actors.*
  The dynamics between structure and agency is uncovered by asking follow-up questions related to why actors behaved as they did. Mostly, these dynamics are uncovered already under question three, asking why these actors where necessary.

As support, post-its were used for the interviewees to write down the actors, why they were necessary, and their characteristics on the same post it. To make sure nothing is missed in the interview, a voice recorder was used. A summary of the interview was made and sent to the interviewee's and asked for validation. The cases are analyzed separately by summarizing remarkable features of the building process, by describing remarkable events which are particular to a CBP. Next to that, an analysis is made of what functions different actors perform, and how they are related to each other.

Visionary session

So far, this research has been more of a descriptive nature. In addition to this, a normative part is added. This part aims to answer the research question; *in an ideal transition to a CE, how would actors fulfill the functional diversity in a CBP?* To answer this question, a visionary session is organized. The session has two goals:

1. Validation of the functional diversity found in cases
2. Establish the ideal functional diversity of circular projects

These questions are answered in order to provide researchers and professionals who support a transition to the CE with possible next steps that could be made. The transition has to do with a societal change, and the CE, just like sustainable development, is of normative character (Quist, 2012). Quist mentions three different ways of looking to the future: exploring the possible futures, develop the most probably future, and develop the most desirable future. The latter is of relevance for the visionary session, since we are looking for possible next steps towards an ideal CE for the building sector. From the desirable future, it is possible to work backwards in time, to steps that can be taken now. This allows to put the current CBP in perspective; if we know which steps are preferred, and you know which steps are taken now, it becomes clear whether there is a gap between practice, and norm. We call this the synthesis. Quist (2007, p.232) has developed a method for an interactive back casting study. The method is divided in five steps (see figure below). Going through this method entirely is beyond the scope of this visionary session; this research covers step 1, step 2 & step 3. Step 1, the strategic problem orientation, is done by exploring what applying the CE would mean for the construction supply chain. During the visionary session we will generate the future vision, which is step 2. Step 3 is done by analyzing the results of the visionary session. The vision is created with ideas that are developed and discussed during the session (Quist, 2012).

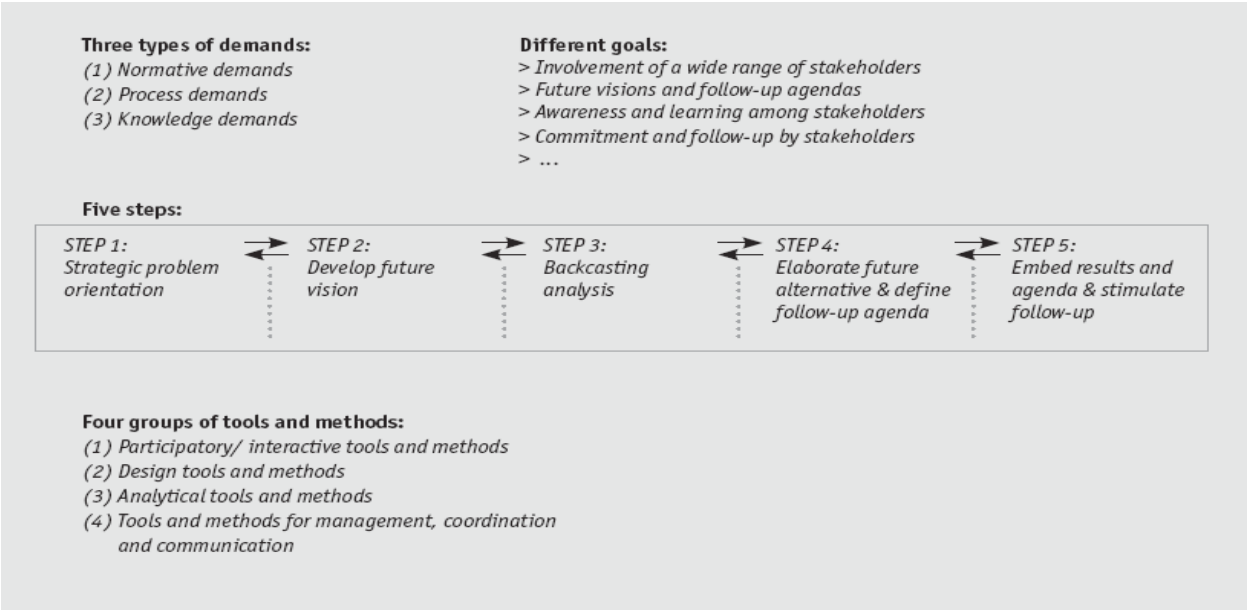

Figure 20: method for interactive backcasting (Quist, 2007, p.232).

For the synthesis, it is important that the ideas for the vision can connect to different societal domains (Quist, 2012), such as government, education, businesses, etc. This makes it easier to develop a follow-up agenda (steps that could be taken tomorrow) since specific actors can be coupled to the follow-up agenda. As a cause of lack of time, it was not possible to specifically generate idea's under each societal domain separately, however in order to inspire participants the folowing domains have been highlighted on the poster which is used to write ideas on (see appendix E). Economic, ecological, political, social, technological and juridical. These are adopted from the PESTEL analysis (Yuksel, 20120), used in backcasting methods as well.

In order for the session to be successful, the diversity of participants has to match the goals. This is done by selecting relevant stakeholders. According to Cuppen (2012), stakeholders are actors who are involved, affected by, knowledgeable of, or having relevant expertise or experience with the problem or the sector. Next to that, the diversity of actors is said to be an important element of the design of sessions like these. The goal of this session is to develop an ideal for the circular building process, and particularly to create a vision with the stakeholders, formed by combining their input to how an ideal CE for the building sector would look like in the future. In order to get to a vision, actors have to be able to fantasize about an ideal CE. Therefore, the participants should at least support the idea of a transition to a CE for the building sector. This should ensure engagement of participants in the session.
The selected participants are as followed:

Participant	Profession	Relevance
Marije Vos	Senior advisor Arcadis	Has extensive experience in the building sector, namely in sustainable development and circular economy. Supports the idea of a CE, and is able to think in a visionary way about the concept
Eefje Cuppen	Assistant Professor TU Delft	Has experience in multi-stakeholder dialogues, in context of transitions in mainly the energy sector. Is used to "thinking in systems", and able to put projects in a broader context of a transition. Next to that, she is supervisor of this thesis, and brings valuable support to preparation, execution and analysis of this session
Woud Jansen	Consultant Alba Concepts	Has extensive experience in the building sector and currently focusing on circular redevelopment in his work. Is able to take a visionary role. Is supervising another student on CE as well, focused on Circular KPI's.
Yvette Govaart	Founder Blue City010	Has experience with circular building processes. Is able to take a visionary role.
Stefan Maatman	Consultant at CFP	Has experience as initiator of the Green Deal Circular buildings. He knows how to translate CE principles in projects with clients
Anne Wernand	Behavioral Specialist at Mapiq	Behavioral specialist, use phase of building life cycle. Mapiq is a digital platform that maps functions in buildings, so the users can optimally use the building. Is able to think visionary.

Table 5; visionary session participants selection

As support, Dewi Wessleman has helped with structuring the session. She has experience as creative facilitator. Next to that, a live illustrator (Lars Hartnack) has visualized main aspects discussed in the session. The following structure for the session is used. For details, see the full timetable of the session in appendix F.

- Introduction of research & presentation results (used posters in appendix C, G & H to present these)
- Feedback on results; Do you recognize the functions found from empirical cases? Is there a function missing? (Experts could stick post-its with their comments to the posters)
- Visionary part: how would an ideal CE for the building sector look like in 2030? (Post-its with ideas for the ideal CE where put in the poster in appendix E)
- Discuss the vision plenary
- Synthesis; considering the path the sector is taking now, should we adjust course? How?

A summary of the session is made and sent back to the participants to validate interpretations. The data collected form the visionary session is presented in chapter 6. First however, data has to be collected from the cases, to be validated in the visionary session. This is done in the next chapter; uncovering the diversity in case studies.

6:

UNCOVERING THE DIVERSITY IN CASESTUDIES

In this chapter, we present each case using the diversity structure of the theoretical framework developed in chapter three. This structure is presented below. First, we introduce each case by explaining what happened before and during the building process. Then, for each case we present respectively; system outcomes, system of actors, functional diversity & characteristics of actors. These can be seen as the data acquired from the interviewee's. Afterwards we picture the system of actors, related to material flows and information flows. Schemes are made to first map the system of necessary actors for circular outcomes. Finally, the cross case analysis provides generalized analysis, based on comparable recurrent mechanisms in the cases. In appendix J, the interviews are presented in more detail.

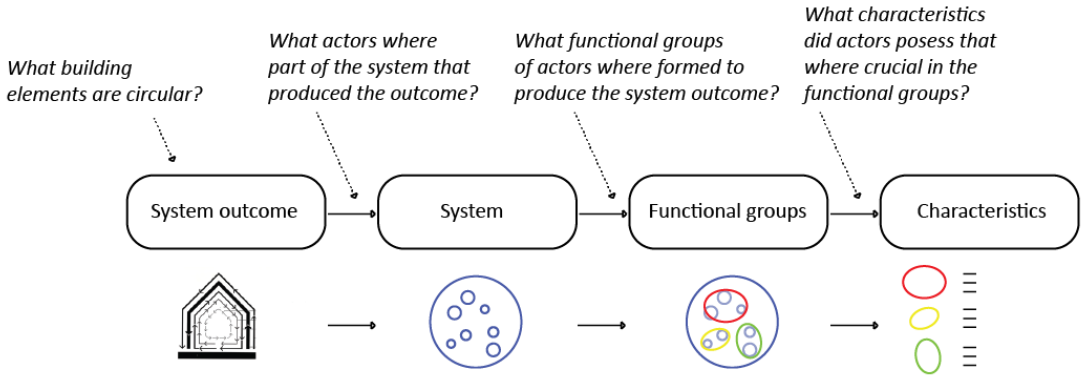

Figure 21; Diversity framework used to collect and analyze data

Kringloopcentrum Houten

"After returning home from work, I had the idea to scan Marktplaats.nl for materials to reuse. This is where I found large amounts of good quality second hand wood." ***Project manager Arcadis (2015)***

Introduction

The old recycling center of Houten did not function properly anymore. A new location was chosen next to the main recycling center of the municipality of Houten. The municipality had asked the market to offer their approach through a tender. Arcadis responded to this tender with a concept design, led by an Arcadis' architect. The team was then formed; Jeroen Eulderink (architect) and Han Eijbergen(project manager) from Arcadis, a project manager from the municipality joined the team and a contractor was selected based on its experience and will to take the risk with

reused materials. The concept embodied the reuse of materials, for which ideas where developed for reuse of plastic bottles in the façade and insulation material from clothing. With this concept, Arcadis had won the tender for both the design and construction management of the project. For the project, sustainability ambitions where set, as well as the reuse of materials. The sustainability criteria where mainly met through isolation demands, a heat pump and cold-heat storage in the ground. The first ideas for reuse of materials did not pass. The reuse of clothing for isolation did not meet the Rc-value necessary for the sustainability criteria. The plastic bottles where too challenging for this project. Thus, the team had to search for other materials to reuse. The architect went to the municipalities recycling center (milieustraat) to search for wood to clad the façade with. However, the wood was in such bad shape, it could not be used. The Arcadis project manager then searched for used wood on marktplaats.nl, from which he found wood regained from used pallets, dismantled by people who are re-integrating into society. The wood was stored at the contractor's site. With people from re-integration, the wood was cut to the design of the architect. This wood was then attached to the façade. The project manager from the municipality found concrete slabs from a demolished school in Houten, which could be used for the façade as well. Knowledge concerning water remittance from the wooden façade was needed to ensure the quality and safety, which was retrieved internally from Arcadis. Next to that, the facility manager of the recycling center was willing to take the risk with the reused wood, by possible extra maintenance for the building.

Figure 22; Recycling center Houten, with reused wood and concrete slabs (Bouwwereld.nl)

Circular outcomes

• The wooden planks which cover the façade are sourced from old pallets, which were dismantled and mounted on the façade of the building.
• Concrete slabs in the lower part of the façade are taken from a school in Houten which was being demolished. These are directly reused as outer covering of the façade.

System of actors

Actors involved	**Contribution to circular outcome**
Architect (Arcadis)	• Responsible for the concept design which own the tender of the municipality. • Searching for solutions to close material loops; he came up with ideas such as plastic bottles as façade material, clothing as insulation materials, and reused wood as façade coverings
Project manager (Arcadis)	• Finding wood for façade on marktplaats.nl
Project manager (Municipality Houten)	• He had connections within the municipality of Houten to find the concrete slabs from a school demolishing project, which was used in the façade of the recycling center.
De Zeeuw (contractor)	• Willingness to work with reused materials

	• Guiding people with distance to the job market in preparing and mounting wood on façade
Triade	• Hiring labor to dismantle pallets in to separate wooden planks • Selling the wooden planks on Marktplaats.nl
Fermwerk (provides labor consisting of people with distance to the job market)	• Fermwerk provided people with basic experience in small scale construction (carpenting) who mounted the wood to the façade.
Marktplaats.nl	• Online trading platform. The dismanteled pallet wood was offered on marktplaats by Triade, which made it possible for Han Eijbergen to find the wood
Facility manager recycling center	• Willingness to take risk with reused wood in the exploitation of the building.
Building technology specialist (Arcadis)	• He provided Arcadis' architect & project manager with knowledge concerning water remittance and the reused wood in the façade.
Alderman (Municipality Houten)	• Willingness to take risk with using reused wood in the façade of the building.
Owner of the recycling center	• Willingness to take risk with the reused materials

Table 6; System of actors in the recycling center case

Functional groups

1. *Setting a vision for the project: Architect (Arcadis), Project manager (Arcadis), Project manager (Municipality Houten)*

Before construction took off, it was necessary for actors to create a vision which allowed them to create a design that fit their ideas. Part of this vision building was done through the tender, which allowed parties to propose a vision which fits the function of the building. Since the building would become a recycling center, and considering the sustainability ambitions of the municipality, the vision was to create an energy efficient building with as much reuse of materials as possible, for a low price per m2. Another part of this vision building was communicating the vision with people who are project stakeholders now, and at a later moment of the buildings life cycle (e.g. The alderman and the facility manager of the recycling center)

2. *Finding materials to reuse in the building: Architect (Arcadis), Project manager (Arcadis), Project manager (municipality Houten).*

After the vision was set, it was necessary for actors to find materials to reuse. This required several attempts. The architect visited the waste recycling center of the municipality but could not find enough materials with good quality. Within Arcadis colleagues had been asked for ideas. The Arcadis project manager helped with the search, and was able to find wood through Marktplaats.nl, which he was scanning in the evening at home. The municipalities' project manager knew of a demolishing project and was able to secure some concrete slabs to reuse.

3. *Search engines that bring together offer and demand: Marktplaats.nl*

It turned out to be quite difficult to find large amounts of good quality materials in the direct environment of the searching actor to reuse for the building. By using search engines such as Marktplaats.nl, the scope of the search could be increased and offer and demand is brought together.

4. *Developing knowledge on quality and safety of reuse of materials: Building technology specialist (Arcadis), Municipality Houten*

Working with reused materials brings along risks concerning quality and safety of the materials. The quality of the materials was ensured by consulting a construction technology expert from Arcadis. At the same time, the municipality (as commissioner of this project) had the ability to set it's criteria concerning safety and quality of materials. Since they would be responsible for maintenance of the building, they were willing to take a risk concerning the quality of the reused wood (e.g. wood falling of the façade).

5. Finding the correct labor to construct the façade with reused materials: de Zeeuw (contractor) & Fermwerk
Constructing the façade with wood from pallets meant working with wooden planks that are not yet in the correct shape to fit the façade as the architect drew it. Time needed to be put into sawing the wooden planks in the correct measures, after which the planks had to be mounted one by one on the façade of the building. This was relatively repetitive work, for which a regular carpenter / construction worker would be too expensive. De Zeeuw found Fermwerk, who provides people with a distance to the job market with work. They could be deployed on a temporary basis, for a lower hourly pay. De Zeeuw had delivered important work by guiding the less experienced employees to deliver good work.

6. Providing materials to reuse; Triade & demolisher of the school in Houten.
For the closing of materials loops it was required to find owners of materials streams that were able to sell, or donate materials to other actors. Triade aims to create labor for people with a distance to the job market, which is done in this case by dismantling pallets from wood, and selling the wood afterwards. This turned out to be a suitable source of second hand materials. From a demolishing site in Houten, concrete slabs could be taken. This was relatively easy to organize, since the municipality had a leading role in the demolishing, and could therefore easily claim the materials and transport them to the building site of the recycling center.

Characteristics/tasks/agency

1. *Setting a vision for the project*

• Have a hierarchical status, or supported by someone with authority. The vision influences the result of the project. This means decisions are made by actors that have high impact on the outcome of the project. Usually these decisions then have to be authorized by someone higher in the organization. It makes it easier, and perhaps necessary for a vision on circularity to become leading when this vision is supported by an authority. This can be done in two ways; either the visioning person is someone with authority, or the visioning person has gained the support of an authority.
• Creativity. Setting a vision means coming up with ideas that fit the client's ambition, in this case the municipality. The first concept design, which embodied the vision Arcadis had on the project, connected with the municipalities' ambitions regarding sustainability. The ideas by the architect convinced the municipality that Arcadis shares their vision. This connects with a social structure of signification. The idea of a tender is that applicants try to connect with the ideas or culture which the potential client connects with.

2. *Finding materials to reuse*

• Creativity. This function mainly required the actor's creativity to search for ways to close materials loops, for example visiting a waste recycling center. The social structure of signification can be identified here, since the vision is set by the actors and these form the criteria for the materials to be found.
• Involve surroundings. By involving colleagues or other people in the environment, actors were able to increase their scope of search.

3. Bringing together offer and demand

• Not human actors per sé. Online platform like Marktplaats.nl where people can sell & buy products.

4. *Developing knowledge on quality and safety of reuse of materials*

• Being schooled and experienced in construction materials designs.
• Having influence in decisions concerning safety and quality of materials used in a building. This is an example where the duality of structure comes forward; the municipality is both constrained by laws which indicate a certain criteria for quality of materials, however the municipality also has the power to decide on how strict safety of materials has

to be guaranteed, since they are the ones responsible for enforcing actors to abide the law. So they both recreate the social structure, and are influenced by it.

5. *Finding the correct labor to construct the façade with reused materials.*

• Flexibly deployable employees with low hourly pay. The deployment of this labor relates to the social structure of domination, with the intention to save money, since this is seen as positive results by the bosses of the people who manage the project.

• Being able to guide unexperienced employees. This requires knowledge and experience of construction.

The diversity of actors and functions in the Alliander circular supply chain is illustrated in the following figure. Functions inside the circle can be seen as activities that are typical for the traditional building process as well. Outside the circle show activities that are specifically the result of a circular building process and would most likely not be found in a traditional building process. The figure can best be read by starting with the functions of vision establishing in the upper middle part of the figure. The arrows indicate flows of information and materials, and connect functions in chronological order.

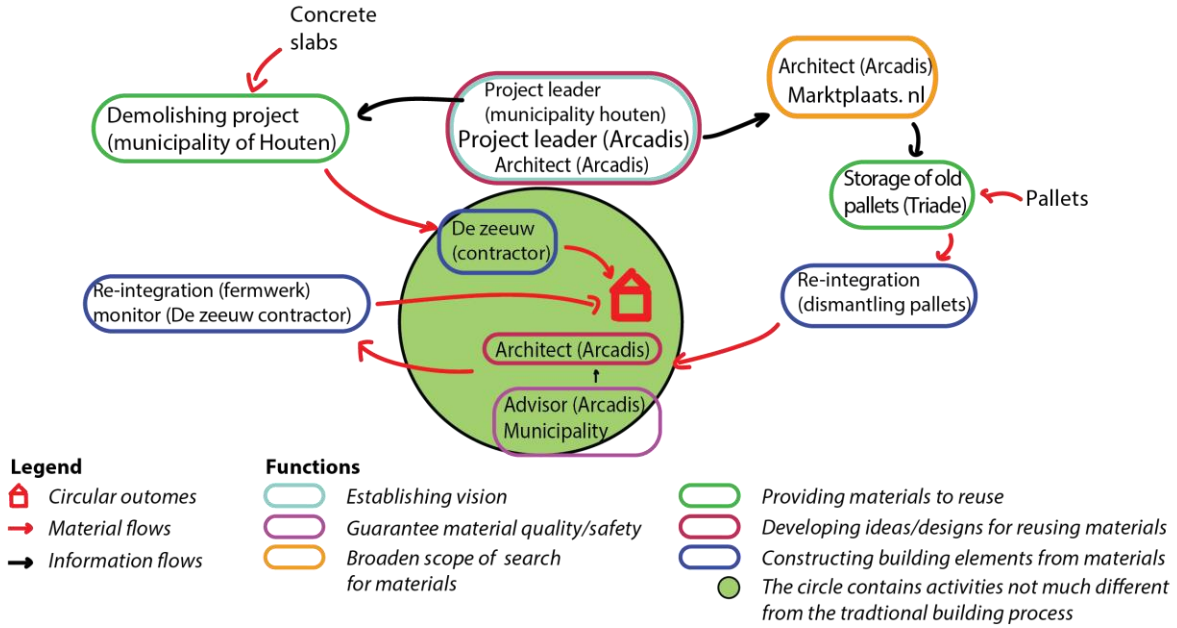

Figure 23; The circular construction supply chain of kringloopwinkel Houten

Alliander office Duiven

"*Everything changed when we were asked: what drives you? What do you stand for?"* ***Facility manager Alliander (2015)***

Introduction

Alliander, network service provider in the Netherlands, was dealing with 5 aged buildings that didn't meet the functional criteria of Alliander anymore. This resulted in the wish to develop a new office. From the start of the project, Eugenie Knaap, facility manager at Alliander, was managing this project. Initially, a new office seemed like the most logical solution to Allianders wish for a better working space for its employees. At the same time, Alliander is a company that operates in the context of the energy sector, which is now under pressure due to climate change issues. Therefore, Alliander has decided that sustainability should play a role in their operations. Next to that, building a new building and leaving an empty one may lead to public critics, as was the case with KPMG moving to a new building in Amstelveen, leaving an entire building behind empty. Advisor copper8 had been involved who acknowledged these problems. As a result, they asked the question; is a new building per sé the solution to create a better working place? Why not redevelop the existing building? Combining this with sustainability criteria led to an ambition consisting of five parts:

1. Applying CE principles for the building, terrain and building process
2. Become energy positive
3. Future-proof functionality based working spaces
4. Involve context with the redevelopment; green alliance
5. Integrality of the 4 points above

The last point is important, since a lot of solutions were developed due to their positive outcomes on multiple ambitions. Next to that, the aim was to not conduct a traditional, segregated building process, but an integrated one. This was stimulated by demanding the market to apply to the tender in a consortium. The winning consortium was Boele & van Eesteren, VolkerWessels vastgoed and RAU architects, who won based on their vision concerning sustainability. This made these parties already involved in the beginning of the project.

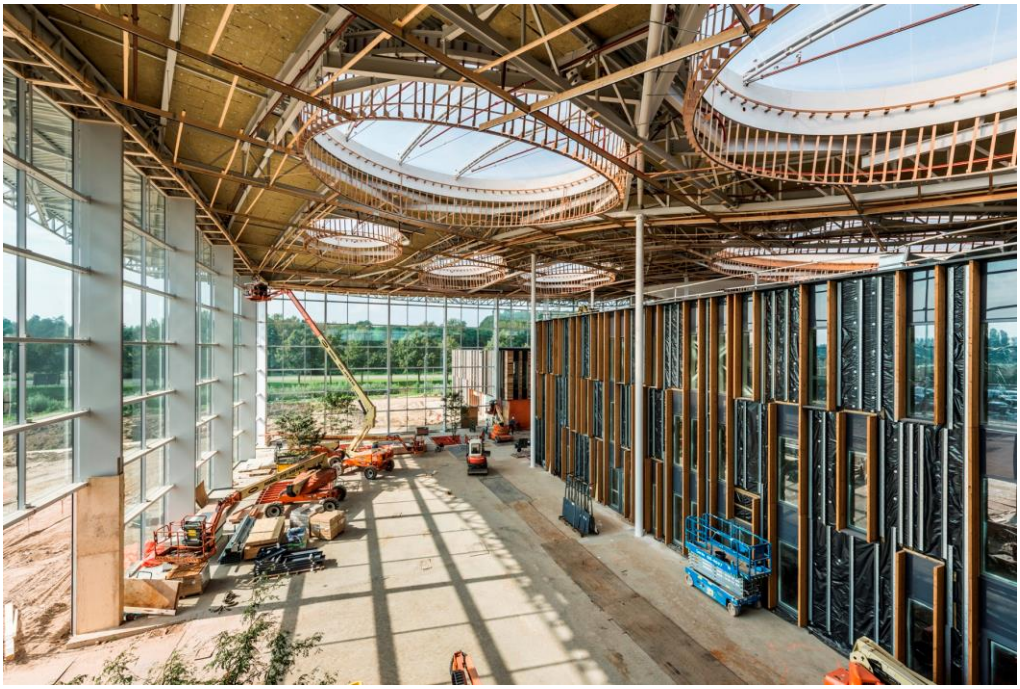

Figure 24; Construction of the roof over the original buildings. The facade on the right is covered with reused wood and insulated with clothing material (Boele.nl)

Concerning the CE ambition, the ambition of 80% reuse of materials was set. The largest contribution to this goal was the reuse of the existing buildings. Bricks from outdoor road space between the buildings where reused in the new parking lot. Toilets where temporarily stored in one of the buildings that was undergoing renovation, after which they were re-installed again. The facades of the old buildings where given new insulation, which is made from old work-clothing from Alliander employees. The coverings for the facades are made for a part of re-used wood from pallets, and for another part of "new" wood, which has been certified. A roof has been constructed which connects the separate buildings in a newly created indoor space. This was made out of steel, from which a large part is recycled steel, and has been constructed for easy dismantling in the future.
The primary ideas for reuse of materials came from RAU architects. They proposed to use the wood from large wooden reels which Alliander uses in their primary process. However, Alliander needs those in their process so they were not able to use those. A team of Alliander employees had been formed to come up with ideas for materials to recycle. They came up with the idea to check Sita's recycling center where Alliander brings their waste for reusable materials. They found great amounts of pallet wood. One of Sita's employees was asked for the amounts that they could deliver. This was enough for the facades of the buildings that where covered by the newly constructed roof. The reused wood would end up under the newly built rood, which resulted in less strict quality demands on the wood. could. This is also the reason for not re-using wood in the outside parts of the building. Re-integration was used to dismantle the pallets and cut them to correct size for the façade. Carpenter De Groot & Vroomshoop then mounted the planks on prefab façade elements, which were afterwards mounted to the buildings. For the insulation, clothing was sent to Metisse, an insulation producer, who used the fabric as input source for their production process, delivering ready to go insulation for Boele & van Eesteren to fill the walls with.

Circular outcomes

- Scrap wood mounted on the facades of the buildings under the roof.
- Insulation made from Alliander's working clothing.

System of actors

Actors involved	Contribution to circular outcome
Facility manager (Alliander)	• Was involved with setting the vision for the project • Creating a tender based on vision/ambition • Searching for solutions to close material loops.
Corporate social responsibility manager (Alliander)	• Inviting Copper8 to talk about the ambition of the new Alliander office. Concept of CE entered conversations here.
Sustainability advisor (Copper8)	• Copper8 was able to couple the vision of the project to the vision of Alliander
Municipality Duiven	• Co-operate in guarding safety and quality of reused materials
Contractor (Boele & van Eesteren)	• Make the vision concrete by establishing total reuse of 80% materials in the new building which won the Alliander's tender • Hiring labor to dismantle pallets in to separate wooden planks from 2 Switch • Ensuring quality and safety of reused wood
Architect (RAU)	• Collaborate in the tender to connect to the vision of Alliander • Came up with the first idea to reuse waste wood from Alliander's own processes.
Employees Alliander	• An expert team of Alliander employees came up with the idea to visit Sita's recycling center in order to find possible materials to reuse.
Re-integration (2Switch)	• Dismantled pallets and cut the wood for the carpenter to reuse.
Waste depot (Sita)	• Providing information on how much wood would be available for reuse
Materials quality advisor (DGMR)	• Perform fire safety tests on the façade constructed with reused wood
Carpenter (De groot & Vroomshoop)	• Create façade elements with the wood delivered by the persons from 2Switch. • Guarantee quality and safety of reused wood.
Insulation manufacturer (Metisse)	• Produce insulation materials from the clothing delivered by Alliander.
Developer (VolkerWessels)	• Collaborated on winning the tender

Table 7; System of actors in the Alliander case

Functional groups

1. *Setting the vision for the project: Architect (RAU), Contractor (Boele & van Eesteren), developer (VolkerWessels), facility manager (Alliander), corporate social responsibility manager (Alliander), Sustainability advisor (Copper8).*

The process of creating a vision under which all parties can work took some iterations. First thoughts went out to building a new building next to the old one. This idea was swept from the table when Copper8 got involved, who

connected this project to the vision of Alliander's managers. That's when redeveloping became the vision to work with. Afterwards, the vision was made more concrete through the consortiums response on Alliander's tender. In the end, the leading concept of the project was formed through the five ambitions described above. This could be recognized as the vision for this project. Interestingly, the consortium was interviewed by Copper8 to test their intrinsic motivation to work under the vision which was set. Apparently, it was important for Alliander to be ensured of a project team in which participants where all true towards the vision, requiring parties to be able to emphasize with other parties. This is also what Boele & van Eesteren(B&vE) mentioned about the interviews; "it is important to be able to understand what other parties want, and why they want this, instead of only focusing on your own tasks"

2. Generate idea's to close materials loops: Architect (RAU), facility manager (Alliander), Expert team (Alliander)
After the vision was set, it was necessary to find ways to close material loops. First, RAU came up with the idea to reuse wooden reels from Alliander, which gave Alliander an idea to look at waste streams from their own organization. Setting up an Expert team consisting of Alliander employees made it easier to find waste streams, they came up with ideas for this. The facility manager took part in these brainstorms, and also judged whether or not the ideas fit the vision.

3. Providing information on quantities of incoming materials for the recycling center (Sita)
Sita was contacted by Alliander to inform about what their waste streams are, and what the quantities of potential reusable materials were. Small quantities of materials could not be used due to the scale of the project, next to the fact that materials needed to be in at least a certain shape to be reused.

4. Construct building elements from materials
The pallets provided through Sita had to be dismantled in order to be reused in the Alliander building. The contractor had not been able to provide suitable labor for this work in terms of skills but also a low price of labor / hour, since dismantling the pallets was a time intensive job, as can be seen in the figure below. A solution to this was looking for other labor, for which 2Switch was found, a company who provides labor by people who are re-integrating into society. The contractor had already used 2Switch's services before. For the insulation, the clothing was sent to Metisse in France, who has a factory that produces insulation materials. The clothing could be used as an input.

Figure 25; Re-integration dismantling pallets (duurzaamgebouwd.nl)

5. Guarantee the safety & quality of reused material: (B&vE, de Groot & Vroomshoop, VolkerWessels, DGRM, Municipality.
Concerning the quality of reused materials, it is interesting to see that first the municipality and fire department where involved in the beginning of the process, in order to not encounter unwanted surprise while the process is at full speed. This is an example of where agency can be explained by structure (legitimation). The structure is the building regulations we have in Holland, to which Alliander refers when involving the municipality and fire department. Before making design related decisions, they were consulted what should be done to ensure (fire) safety of the materials. DGRM was hired who tested the façade on fire safety. The contractor was aware that

applying reused wood was a risk. Parts could fall off and hit people. They were able to cope with the risk, due to the fact the B&vE, De groot & Vroomshoop and VolkerWessels, are actually integrated under one board of supervisors; basically they are the same company. As a result, the risk could be shared amongst these parties and if something would happen, there would be enough resources to solve the problem. Next to that, B&vE will maintain the building the next 15 years as well, so they are the ones to solve issues related to materials quality anyway.

6. Provide materials to reuse (Alliander)
In the end, Alliander become its own provider of materials, by reusing as much of the organization's waste streams as possible.

Characteristics/tasks/agency

1. Setting a vision for the project
• It took people to review their morale to decide what vision is set for the project. This can be seen as an example of the structure of signification, where people explain their behavior through their own philosophy.
• Communicating the vision to the consortium and testing their intrinsic motivation for the project was necessary to collaborate in an honest way with each other.
• The tender could only be replied to through a consortium. This required actors in the consortium to emphasize with other parties. This was also stimulate through the integrated approach of the project.

2. Generating ideas for materials to reuse.
• Creative methods were used to come up with ideas for materials, such as brainstorming.
• Ideas where tested whether or not they support the vision. This sometimes went combined with the Visionist function. For example; the clothing for insulation was sent to a factory in France. This causes CO_2 emissions and therefore could be seen as unsustainable. This caused Alliander's project manager to adopt the idea that closing material loops from inside the organization was more important as a vision, and justified the transport CO_2 costs. This can be seen as an example of structuration, in the sense that referring to the social structure of significance gave meaning to the agency by referring to the vision set for the project.

3. Providing information on quantities of incoming materials for the recycling center
• Have data on materials streams.

4. Construct building elements from materials
• Labor did not require much training and was low cost
• Little guidance was needed by the contractor

5. Guarantee safety & quality of reused materials
• Have a tight network of trusted parties to collaborate with: the carpenter could produce the facades with reused wood because B&vE and VolkerWessels carry the risk of possible extra expenditures due to degrading façade quality. This behavior can be explained through the legitimation structure, since Dutch building regulations dictate certain norms on material safety.
• A constructing and maintaining contract gives the constructing party more control on the risks, because they design the façade which they are going to maintain later.
• Have knowledge on how to test materials on quality and safety.

6. Provide materials to reuse
• Have storage space to be able to separate materials which will be reused

The following figure pictures how the circular supply chain of Alliander looked like, in terms of actors and functional groups. The figure can best be read by starting with the light blue functions of visioning, following the arrows towards the end, which is the realization of the Alliander office.

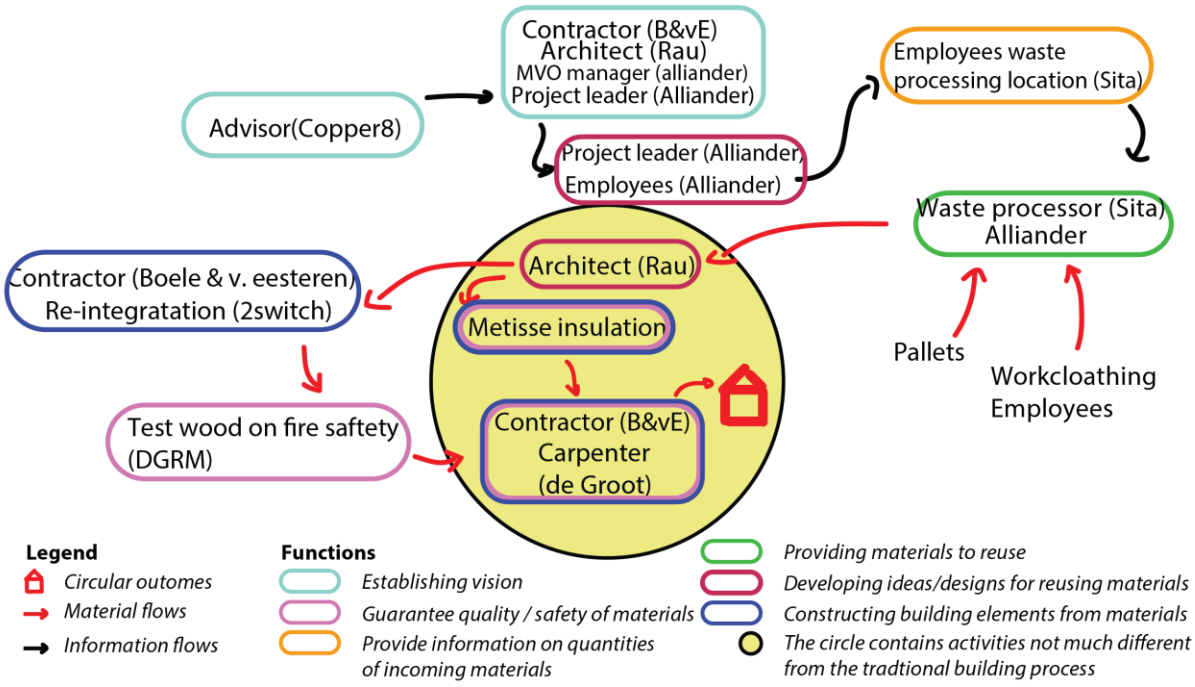

Figure 26; The circular construction supply chain of Alliander

HAKA building Rotterdam

"We could not have successfully disseminated the vision across involved actors without the intrinsic enthusiasm of Vestia's project manager"
Colleague of Vestia's project manager (2015)

Introduction

Vestia, a Dutch housing corporation, had bought the monumental HAKA building in the Merwe Vier Havens (M4H) of Rotterdam, to redevelop this in a mixed function building, both public and office. This choice was strategic; not only did they intend to exploit the building after redevelopment, but redeveloping the building should give them a higher level of involvement in the redevelopment of the M4H area, meaning possibilities for the organization to expand activities in this area (Rijksoverheid, 2012). For this building, it meant looking for ways to have activity in the building as soon as possible, in order to embed it in the social fabric of the M4H.

Two project managers from Vestia were put on the project. The architect became DoepelStrijkers Architecten (DSA) and had been involved early in the project. Reason for this, was the fact that they already have a lot ideas on how the M4H should be developed, now that industrial activities are moving away, which provides opportunities for redevelopment. With their knowledge of the area, they would come up with ideas that strengthen the use of the building. Before the building process, the Dutch public body which ensures correct handling of monumental buildings (the Dutch name is "monumentenzorg", which will be used from now on in this thesis) had communicated specific demands on how the redevelopment should be done. Most important was that the original aesthetics of the monument remained as they were initially built. For example, all the windows and frames of the building had to be reused as much as possible. Broken windows had to be replaced by ones that resemble the original designs as much as possible. Specific window designs as these are very costly, therefore reuse of existing windows and any other building elements was stimulated as much as possible.

The concept of reuse opposed on the team by Monumentenzorg triggered the idea to reuse as much as possible of materials found in the building, and in the area of the building, and make mostly furniture out of these materials. This required different labor than typical construction workers: it required working with materials coming in different qualities, from which different products had to be made. A typical construction worker was too expensive for this, and not trained as well. The Vestia project leader had a contact from which they could employ re-integration workers to do this job (named by Vestia klusteam, further named working team in this theis). They were housed on the ground floor of the building; giving Vestia both the social activity and suitable labor they needed.

Figure 27; Interior of the HAKA building (DoepelStrijkersArchitects)

Most of the products needed where chairs, a stage, closets and separation walls. The latter was made from second hand clothing and the others were made by reusing wood. For the separation wall, DSA had contacted a nearby clothing depot, where bulks of discarded clothes are collected. The architect together with his employees had folded the clothes in an attractive pattern, which was then put on a self-built installation by the workingteam. In addition, an impregnating company had to process the clothing to make them fireproof, due to building regulations. The rest of the products was constructed in the following way; from mostly demolishing projects of Vestia's own portfolio in Rotterdam, scrap wood was collected. The demolishers where willing to separate usable materials from the waste stream, however they did charge extra for this, since this "waste" is their revenue. From the usable materials, designs were made by DSA for chairs, closets and other products. The designs where made in such a way, that connections between materials where as repetitive as possible, making it easier for the workingteam to build the products and improving their working pace. Next to that, a supervisor guided the team in making the products. He was experienced in the building sector and could translate the drawings of the architect in workable instructions for the workingteam. For the podium, thick wood from a brick manufacturing factory was obtained. Materials were also found through online search engines.

In the end, exploitation of the building was not possible anymore. Vestia had been accused of risky financial management and the government forced them to sell the building, since the public character of the building was too large for the core business of Vestia. After finishing most of the interior elements, Vestia had been excluded from the project.

Circular outcomes

- Separation wall in the interior from reused wood and clothing
- Several furniture products (chairs, doors, podium)

System of actors

Actors involved	Contribution to circular outcome
Project manager1 (Vestia, commisioner)	• Established the vision of embedding the HAKA building in its context by generating social activity in the building • Testing the ideas of DSA to the vision and feasibility • Providing materials from Vestia's demolishing projects
Project manager2 (Vestia, commisioner)	• Having the connections to find the working team • Providing materials from Vestia's demolishing projects • Disseminate vision across involved actors
Architect (Doepel Strijkers Architecten)	• Establish the vision of reusing materials found in Rotterdam area • Generate ideas and designs for reusing materials
Working team (people from re-integration)	• Be flexibly deployable • Low hourly rate
Supervisor working team	• Being able to translate drawings from architect to practical instructions for working team • Finding materials to reuse for the podium
Municipality Rotterdam (government)	• Demanding guarantee of safety of materials
Dutch monuments preservation (government)	• Demanding Vestia to reuse as much of the building as possible. This was one of the reasons to start reusing materials
Impregnating company	• Providing Vesta with the necessary guarantee of fire safety for the separation wall of clothing
Demolisher of projects "de burgen, Rotterdam"	• Separate usable waste streams for DSA to make designs with
Depot second hand building materials	• Deliver higher quality wood for the separation wall
Depot second hand clothing	• Deliver second hand clothing for the separation wall

Table 8; System of actors in the HAKA case

Functional groups

1. *Setting the vision for the project: Architect (DSA), Project manager (Vestia), Dutch monument preservation (government)*

This functional group worked to establish a vison for the project, and tuning the vision to the wishes of other parties. The project commenced in a search for how to get social activity in the building as soon as possible, as a means to embed Vestia in the redevelopment of M4H. Next to that, monumentenzorg had forced the reuse of the building as much as possible. These two requirements resulted in a workable concept; reuse of materials was achieved by hiring the working team, which at the same time fulfilled Vestia's interest of bringing social activity to the building. Interestingly, the commissioner was not driven by intrinsic motivation to reuse materials, this was an external

structure (legitimacy) which was drawn upon to decide on the reuse of materials. However, DSA was intrinsically driven, and they made the expansion of the concept to also start looking for materials locally and reusing them. Next to that, they coupled the criterion that CO_2 emissions had to be minimized while searching for the materials. It was in sustainability terms not profitable to collect wood from a distant location and transport it back to Rotterdam.

2. Searching for materials to reuse: Architect (DSA), Project manager (Vestia), Supervisor of working team
It was necessary to generate ideas for what materials could be reused for different kind of products in the building. In the process, DSA generated many ideas to reuse materials. It was Vestia's role to keep unrealistic ideas from happening, but at the same time filtering the ideas which are usable. This was a challenging role for Vestia, since they valued DSA for their creativity and ambitions but ideas needed to be feasible both practical and financial.

3. Broadening the search of materials (google.nl)
Due to the diversity or products that had to be made, Vestia's demolition projects did not deliver enough different materials. By searching online, other material streams where found such as the second hand building materials and clothing.

4. Providing materials: demolisher, second hand construction materials depot and second hand clothing depot
Depots for materials such as second hand clothing and materials became providers for the HAKA building. Next to that, the demolisher of Vestia's projects became a provider by separating usable materials from less usable ones.

5. Making products from materials: Working team, supervisor of the working team
The providers deliver materials that still need to be produced into usable products. The working team delivered this labor, under guidance of an experienced supervisor.

6. Ensuring the quality and safety of materials: impregnating company
Another consequence of getting materials from untraditional suppliers is the lack of guarantee of safety and quality of materials. For example, the separation wall required to be impregnated with fire retarding chemicals by a company. The Rotterdam municipality required an official letter from this company guaranteeing the fire proofing on clothing.

Characteristics/tasks/agency

1. Setting a vision for the project
• Multiple parties where involved to set the vision, different social structures where at play. Monument preservation more or less forced Vestia to reuse as much of the building as possible, which can be seen as the structure of legitimation. DSA expanded the concept of reuse by drawing on the structure of signification, since it is in their company philosophy to apply circular economy principles, as they have done in other projects
• Disseminating the vision through the involved actors was necessary to give them the right boundaries to work with. Intrinsic enthusiasm for reusing materials helps in communicating the concept, since this enthusiasm works contagiously. Vestia's project manager himself was a hobbyist who likes to work with his hands. For example, he restored old Citroëns himself, so this way of working appealed to him. His enthusiasm spread out over the team, and was crucial to a positive collaboration between Vestia and the working team.

2. Searching for materials to reuse
• Creativity is an important characteristic for this function, since it requires out of the box ideas on how to reuse materials in product designs for the building.
• Being able to work with uncertainties is key. The architect does not know which materials will be coming in next week to work with, this makes functional specification of designs necessary, until materials are known which allows for more detailed design. This also requires the commissioner to let go of detailed control in the design.

3. Broadening the search for materials
• This function is fulfilled by a technology, bringing offer and demand together online.

4. Providing materials

• An important aspect of being able to provide materials was having storage space, such as the depots. This makes storage of materials possible.
• For the demolisher it required to communicate to the workers on the demolishing site the wishes of Vestia to reuse materials.

5. Making products from materials

• Low hourly pay
• Flexibly deployable
• Need supervisor who is experienced in construction (I.E. can read technical drawings, understand the wish of the commissioner).

6. Ensuring quality of materials

• Have the experience to guarantee safety after impregnating clothes

The following image shows the construction supply chain of the HAKA building in terms of information flows and material flows. The figure is best read starting from the top, establishing the vision, downwards to the circular outcomes

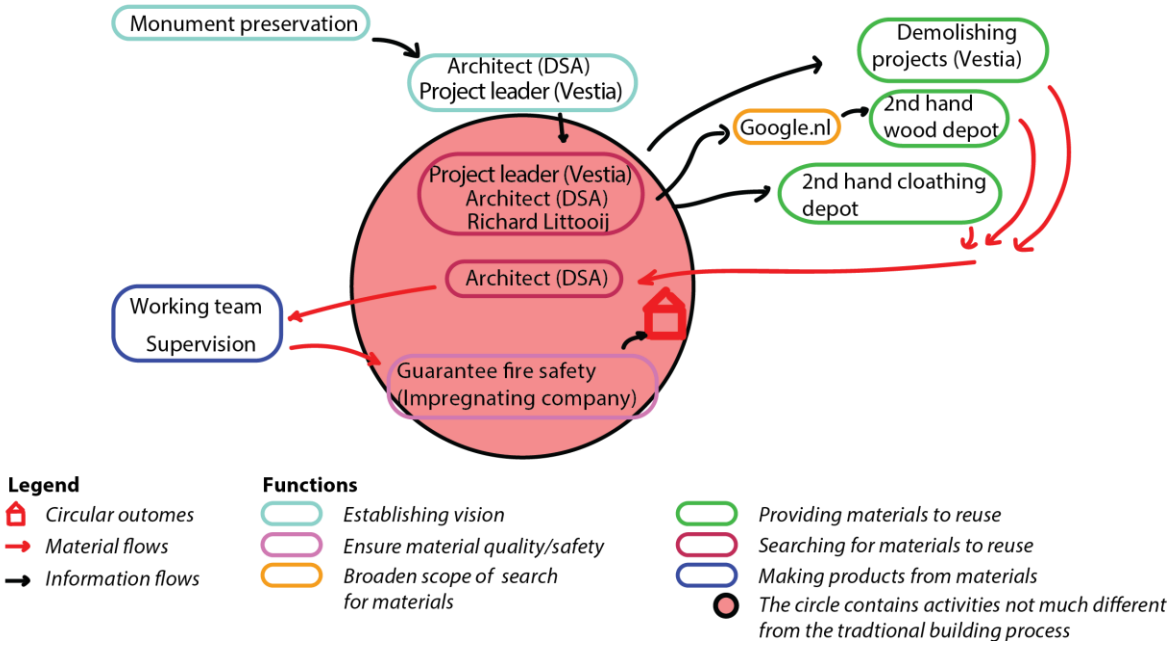

Figure 28; The circular construction supply chain of HAKA building

100 watt tower, Amsterdam

"We found a shared interest in collaborating together. A win-win situation, where the success of the tenant will also become the success of the landlord" ***Copper8, (2015)***

Introduction

Copper8, a consultancy purely focused on sustainability, was forced to leave their office due to renovation works. They grabbed this opportunity to find an office that better suits their profile in terms of sustainability. They ended up finding the 100 watt tower, which at that time was mostly vacant. This gave Copper8 the opportunity to build an entire office floor in line with their philosophy: sustainable and circular. First talks with the landlord, Cocon, where mainly needed to establish a cooperation based on mutual interest. The price Cocon asked per m2 was too high for copper8. In the end, a rental price could be established because of two reasons: first, Copper8 was able to convince Cocon that the way they will develop the office floor completely circular and sustainable, giving the interior a design that stands out. This made the parties collaborate under the vision of an office space which will be different, and stand out from other office spaces. Second, a rental price was established based on the amount of FTE Copper8 houses. For the time Copper8 remains small, a low rental price is agreed. However, when Copper8 suddenly grows, the rental price will increase as well, even above the original price Cocon had set for the space. This is based on the idea that when Copper8 is doing well, Cocon is doing well. The architect is the brother of Copper8's director. He knew the philosophy of copper8 and was therefore quick to understand the vision which was set. His main task was to make a design for the space plan. This was however tricky, since no materials where yet available to design with. Thus, a functional design was made, solely indicating what function was located where, until materials where found.

Waste processor Sita did not have enough good quality materials to work with. Another idea to collect as many used Billy cases from Ikea to make a design with also didn't make it due to fear of becoming a chaotic design. This is when the architect called Cocon, asking if they had materials from demolishing projects in their portfolio. These where available, and so the architects intern started riding his bike around Amsterdam, visiting demolishing projects and making pictures of materials, to discuss with the architect whether they are usable or not. In the end, separation walls for the entire floor of the building were made out of used wooden frames and glass separation walls from two demolishing projects.

Construction of the separation walls was done by hiring a craftsman, specialized in furniture making. The reason for this, was the fact that the contractor charged heavily for working with reused materials. This brings along risks, and a contractor charges increase of risks back to the client. Thus, the architect found the craftsman in his personal network. He made a mock-up model of the separation wall, calculating the time he needed for that part, which was then extrapolated to the total amount of meters he had to build. This resulted in a much more acceptable price for building the separation wall. The construction went parallel with the installations contractor. Not much adjustment between the craftsman and contractor was needed. The project was small and therefor the two parties could work parallel without losing overview.

The project leader of Copper8 purchased insulation for the ceilings, made of old archive paper, reused and re-usable carpets from Interface and furniture (Cradle-to-cradle certified & from scrap wood) was bought on a lease construction so that the supplier (Gispen) will take them back after use. The following figure indicates the flows of materials and information between the actors involved.

Circular outcomes

- Separation wall from reused wood and glass panels
- Several furniture products (chairs, tables)
- Carpet
- Ceiling insulation

System of actors

Actors involved	Contribution to circular outcome
Project manager & commissioner (Copper8)	• Set vision on circularity for the project • Engage in conversation with landlord to find common interest in the vision • Set up business case with Gispen

Landlord (Cocon)	• Finding the interest to create a fully circular office floor • Providing materials from Cocon's demolishing projects
Architect (BETA)	• Make a design for the office floor on functional specifiactions • Generate ideas and designs for reusing materials
Furniture craftsman	• Able to work on a realistic cost estimate for the separation walls • Work with reused materials and guarding aesthetic quality • Find furniture craftsman in personal network
Demolisher of Cocon's projects	• Separate usable materials from waste streams
Intern (BETA)	• Broaden the search for materials by visiting demolishing projects throughout Amsterdam
Circular material suppliers (Gispen, Interface, Warmteplan)	• Providing Copper8 with materials sold under circular business models

Table 9; System of actors in the 100WATT tower case

Functional groups

1. Setting up a shared vision between Cocon and Copper8

The project commenced with setting up a shared vision under which Copper8 and Cocon could collaborate. Both parties found value in the idea of delivering a fully circular office floor which stands out, in combination with a rental price based on the number of FTE's Copper8 has. Interestingly, it was tough to create this collaboration with Cocon, an actor who doesn't share the ideology of Copper8. Cocon however was dealing with an entire office being vacant. Copper8 was the first to show interest in renting a floor, bringing activity to the office. With Gispen, less talks where necessary to find a way to collaborate under the same vision, since they were not new to circular business models.

2. Coming up with ideas for closing materials loops: Copper8 & BETA

When the vision was set, it was necessary to find ways to close material loops. Where normally the architect is responsible for the materialization of the design, in this case Copper8's project leader had decided over the furniture, carpet and ceiling insulation. This was something remarkable for the architect, since he usually has the role to guard the aesthetical coherence of materials, now this function was competing with the need for materials that fit the vision of a circular office. Copper8 found the ceiling insulation, carpet and furniture. BETA was mainly responsible for the functional layout of the office floor and the separation walls.

3. Visiting demolishing projects to find materials: BETA intern

It was necessary to expand the search to multiple demolishing projects of Cocon. The intern was able to ride his/her bike through Amsterdam and take pictures of materials, sending them to the architect while he could quickly decide whether these where useful or not. The flexibility of the intern was important, and also costs less.

4. Separating usable materials from waste streams: Demolisher

The demolisher had to separate usable materials for the intern to photograph and communicate to the architect. This required the demolisher to temporarily store some materials, so the architect could decide on them. However, the demolishers could not give them much time, since this stalled their operations, not to mention that it was basically their revenue being taken away from them. This situation put pressure on both the architect and demolisher.

5. Make products from reused materials: Furniture craftsman

From the panels found at the demolishing projects, new separation walls could be made. A contractor was asked to make a cost estimate based on the functional design by BETA architects. However, the contractor mainly saw

working with already used materials as a risk and calculated this in his cost estimate, resulting in an unacceptable price for Copper8. Thus, the architect consulted his personal network for someone who could work with these materials and found a furniture craftsman. He made a realistic cost estimate by building a small part of the total design, extrapolating costs to a total for the whole floor.

Characteristics/tasks/agency

1. *Setting up a shared vision between Cocon and Copper8*

• Experience in finding the win-win situation between parties
• Finding a win-win situation required parties to emphasize with the interests of other parties.
• The urgency of empty office space helped the two parties establishing a win-win situation, since Cocon wanted parties to rent the floor as soon as possible. This connects to the structure of domination, where a shortage of resources urged Cocon to invest more energy in finding a tenant for the office.

2. *Coming up with ideas for closing material loops*

• Be creative to think of parties to contact, and places in the city to search for materials

3. *Visiting demolishing projects to find materials*

• A flexible person was needed who had the time to drive around the city visiting demolishing sites
• The fact that the intern has a low hourly pay made this function easier to fulfill. Otherwise, in the interview it was made clear that the architect himself would have visited the sites.

4. *Separating usable materials from waste streams*

• requires storage space of separated waste streams. This was however difficult to find in the dense city of Amsterdam, resulting in a tough situation for the demolisher, which could cost him money
• Emphasizing with other parties would have made this function easier to fulfill, however at this point time was always running short since the materials where stripped and it was at that moment that the architect would get a call, resulting in not much time for communication between the architect and demolisher.

5. *Make products from reused materials*

• Flexibility in calculating the cost estimate
• Experienced in working with unique designs

In this project, quality and safety of the materials was not such an issue. Except for the separation walls, the supplier could guarantee the quality. For the separation walls, the furniture craftsman used his experience to safely construct them. Next to that, the project was on such a small scale, that no fire safety tests needed to be conducted. The following figure shows the circular construction supply chain for the 100 WATT case. The figure is best read by starting at the visioning on top, and following the arrows to the circular outcomes.

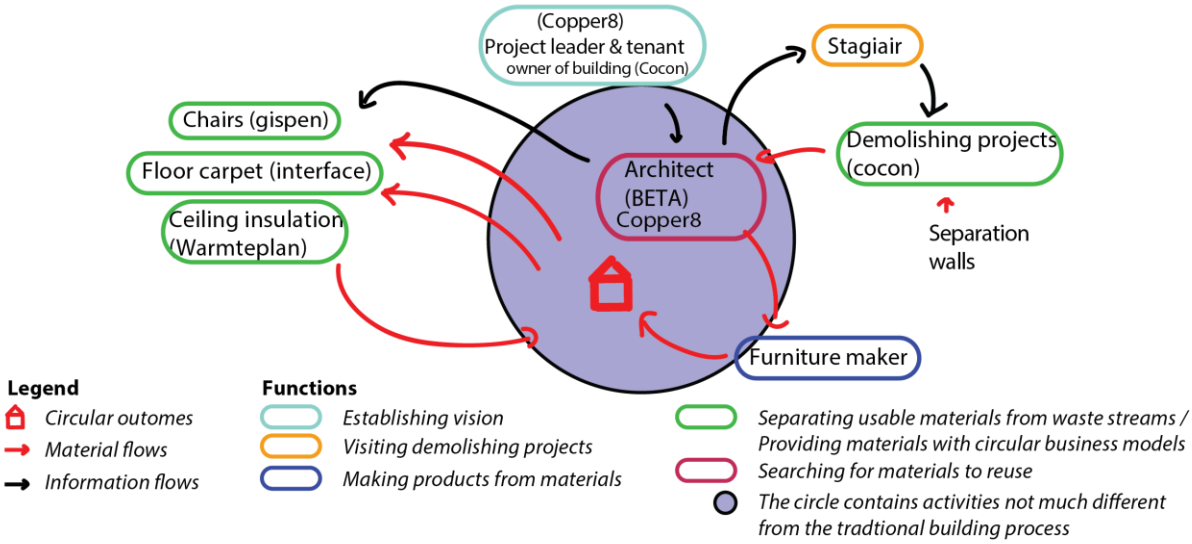

Figure 29; The circular construction supply chain of the 100 Watt Tower

Cross case analysis

For each case, we established the functional diversity. In this paragraph, the research question "*What diversity of actors is observed in current circular building processes?"* is answered. We develop cross case conclusions according to the framework we have developed on diversity and structuration theory. The following table explains how the cases show recurrent functions. Based on the functions seen in each case, we integrate these into a functional diversity which can, for most part, be applied to all cases. The functions have been given names, describing the nature of their function: Connecting through vision, Ideating, Search engines, Providing, Building & Ensuring. The definitions of the functions, plus the characteristics & tasks actors require to fulfill the functions are described as well. The names have been altered over the course of this research, as a result from discussion with supervisors and other persons. We elaborate on this process as well.

Functional group	**Connecting through vision**	**Ideating**	**Scope broadening**	**Providing**	**Constructing**	**Ensuring**
Nature of function	Establish a vision which is leading for the redevelop-ment	Develop ideas to reuse materials and create designs	Broaden the scope of search to material streams that can be reused	Provide parties with materials to reuse	Build product elements from the found materials	Ensure the quality and safety of buildings in which materials are reused
Characteristics /tasks	Be able to emphasize with other parties and find common interests in the vision on circularity	Use creativity to come up with ideas for material loop closing. Ask around, look in own organization for material streams	Bring together offer and demand. Can be done by using online search engines, visit depots yourself	Separate reusable material streams. Temporar y storage is needed.	Be flexibly deployable and able to work with 2nd life materials.	Have the ability to do research on materials safety. Or ensure safety by taking responsibility for any future maintenance.

Table 10; Functional diversity as observed in cases

The functions are based on reoccurring patters in the role actors fulfill in the CBP. A more elaborate explanation on the functions and how these have been established are given below. The names have been altered throughout this research, due to reflecting on them with supervisors and other involved persons. Per function we shortly explain what other names have preceded the finally chosen name for the function. This also helps in explaining the essence of the function. In general, all names chosen for functions initially sounded more like a role, instead of a function (Provider & Ideator, instead of the current Providing and Ideating). The names now sound like a function, which emphasizes that these are not people, but functions necessary in the cases observed.

Connecting through vision

In each of the cases a reoccurring pattern can be recognized which has to do with establishing a vision before initiating the building process. The vision is established by actors who have a hierarchical status, for example the commissioner of a project and the project leader of the contracting party. The vision is then disseminated through other parts of involved organizations. Building a vision is necessary since it gives actors direction in choices they make. Since use of virgin material is avoided, setting a vision helps in what materials are desired, and where to look for these materials. This function connects actors in the building process. For example, Alliander had the ambition to close material cycles locally, with materials already present at the building site, but also material flows present in their own organization, which led them to re-use the workers clothing. The first name chosen for this function was "Visionists". In order to emphasize the connecting character of this function, the function is named "connecting through vision".

Ideating

The functional group of Ideators is responsible for creating ideas on how material loops can be closed in line with the pre-established vision, and create designs in which these materials can be used as a building element, or product. Thus it can be seen as translating the vision into practical ideas to close material loops. It requires actors to try and find materials by asking around, for example in their direct environment. When materials are found it requires them to be able to imagine how the materials can be re-used in a building, and whether this idea fits the vision. This functional group also embodies the role of creating a design with the materials found. Due to the creative nature of this function, it is called Ideating. The initial name was Ideator.

Constructing

The function of this group is to physically construct products or building elements according to the designs made by the Ideators with specific materials. This group has to find new solutions on how to build, to save costs in the construction process. Many hours of labor is needed in this group, since the materials are not pre constructed by suppliers. The materials have to be prepared and constructed to products. Thus, actors have to find ways to create the products with other forms of labor than the traditional contractor / construction worker. Since this function embodies the reuse of materials in new products, the name constructing is chosen, indicating that people use materials to construct something. First name for this function was "recyclers". However this name was too suggestive that we are strictly talking about recycling, which embodies the destruction of value to basic material streams. However in some cases materials have been directly reused. Constructing is therefore chosen, because this can still be recycling, reusing, or refurbishing.

Ensuring

Working with reused materials requires extra effort to ensure safety and quality of materials. This functional group consists of people who can guarantee quality and safety. This can be done by for example testing the materials by doing research, or by sharing the risk with other parties on a basis of trust, or a tight network. Usually the fire department or municipality requires this guarantee. Therefor the Ensuring function requires interaction with these parties. From the cases it appeared that the earlier these parties are involved, the ensuring process brings along less issues. When projects become smaller, such as the 100 Watt tower case in Amsterdam, ensuring will probably take less time. The term ensuring is chosen, since materials that are given a second life do not come with a guarantee from the supplier with data safety of materials. Therefore, the materials have to be "ensured", so actors working in

the building sector can assess the quality and safety. Initially, translators was chosen, but this was confusing since the ideating function is related to translating the vision into ideas for the closing of materials loops.

Providing
This functional can be fulfilled by anyone who owns a materials stream which can be reused in a project. Providers are mostly found through ideation, and can easier be found by scope broadening, as described above. This function embodies two challenges; storage of materials is needed in most cases, since the materials need to be picked up by people who are going to reuse them. Finding the space can be a challenge, especially when working in urban areas. A second challenge is planning for the time materials need to be stored. Since storage space is mostly not at hand, the longer providers have to wait for materials to be picked up, the less likely they will be to save the materials for someone, since this requires extra effort from providers. The name providers is chosen, since this function merely provides access to material streams. This is unlike a supplier, who in most cases also offers extra services like installing the materials/products in the building, and being able to guarantee safety and quality of materials. The first name of this function was Provider.

Scope broadening
This functional group can consist of humans, but also certain artefacts/technologies, like online search engines. Search engines enable actors to broaden their scope of search for materials to reuse. The architect can fulfill this function by for example visiting recycling centers and looking for materials, or the function can be fulfilled by using online search engines such as Google, or Marktplaats.nl. The name scope broadening is chosen since this refers to search related activities through less typical media known in the construction supply chain. The first name of this function was “search engine”, which fits with the idea that an online marketplace can be a search engine, but also a person visiting demolishing projects looking for materials. In the end, scope broadening is chosen since this sounds more like a function, instead of search engine which is more a tool.

The established functions helps us to develop the general functional diversity necessary for the cases that have been studied. We have looked for reoccurring situations where actors execute certain tasks, based on this the functions are established. Table 7 & 8 can be used to see what actors fulfilled which functions.

Cases	***Alliander***	***Recycling center***	***HAKA***	***100 WATT***
Circular outcomes	Wooden façade (Skin layer) Isolation (Skin layer) Reused toilets (Services)	Wooden façade (Skin layer) Concrete slabs (Skin layer)	Chairs, podium etc. (Stuff layer) Separation walls (Space plan)	Chairs & tables (Stuff layer) Separation walls (Space plan) Carpet (Space plan)

Table 11; Circular outcomes of cases

Cases *Functional groups*	**Alliander**	**Recycling center**	**HAKA**	**100 WATT**
Connecting through vision	• Project leader (Alliander) • MVO Manager (Alliander) • Architect (RAU) • Advisor (Copper8) • Contractor (B&vE)	• Project leader (municipality Houten) • Project leader (Arcadis) • Architect (Arcadis)	• Monument preservation • Architect (DSA) • Project leader (Vestia)	• Project leader (Copper8) • Landlord (Cocon)
Ideating	• Employees (Alliander) • Project leader (Alliander)	• Architect (Arcadis) • Project leader (Arcadis)	• Project leader (Vestia) • Workingteam supervisor	• Commisioner (Copper 8) • Architect (BETA)

	• Architect (RAU)	• Project leader (municipality of Houten)	• Architect (DSA)	
Providing	• Waste recycling center (Sita) • Alliander	• Triade (Delivering wooden pallets) • Demolishing project (Municipality pf houten	• Brick factory (wood for podium) • Demolishing projects (Vestia) • 2nd hand clothing depot	• Demolishing projects (Cocon) • Chairs (gispen) • Carpet (interface) • Ceiling insulation (warmteplan)
Scope broadening	• Employees waste processeing location (Sita)	• Marktplaats.nl • Architect (Arcadis)	• Google.nl	• Architect's intern
Ensuring	• Contractor (B&vE) • Carpenter (De groot & Vroomshoop) • DGRM	• Advisor (Arcadis) • Muicipality was willing to take responsibility for degrading wood quality	• Impregnating company	*Scale of project was small, no ensuring was necessary*
Constructing	• Re-integration (2Switch) • Monitor & planner (B&vE)	• Re-integration 2x (Triade & Fermwerk) • Monitor & Planner (De zeeuw contractor)	• Working team • Supervisor	• Furniture craftsman

Table 12; Overview for each case, functions and what actors fulfilled these functions.

Interestingly, most of the functions have been identified because they show actors choosing alternative ways of fulfilling the function in situations where actors cannot fall back on traditional solutions. We highlight this per function below.

Constructing: constructing the products or building elements requires specific labor. Usually, labor is provided through sub-contractors, who employ construction workers that are trained for typical building activities, such as brick stapling or constructing separation walls. In the cases however, the materials needed specific preparation or handling prior to making products out of them. For example; dismantling wooden pallets was necessary before they could be made into façade coverings. Usually, the supplier delivers this wood ready-to-go, in the dimensions asked for, so construction workers can mount them on facades. Now however, there was no supplier who could prepare the wood, so this had be done under watch of the contractor or project leader. Typical construction workers are too expensive for this; it is time consuming work, which requires different skills. In three of the four cases, re-integration was chosen since they have a low hourly pay, and their skills match the job at hand. The 4th case (100 Watt tower) was a small scale project, and required a more complex task. For this, the furniture craftsman was a good option due to his experience with complex carpentry.

Scope broadening: Contractors and architects choose their materials from suppliers who offer their products specifically to the building sector. These are mostly virgin materials, and found through preferred or known suppliers. Now that actors in the CBP cannot fall back on these suppliers, they have to broaden their search activities, using search engines that are not typically used in the building sector, such as marktplaats.nl or visiting demolishing project to look for materials.

Ideating: Where usually the architect could provide renders of how a design will look like once it is finished, this becomes difficult, simply because the search for materials has not given an answer yet. This resulted in different communication between the architect and the commissioner. The architect can now only functionally specify what designs will look like (eg. Showing where a meeting room will be constructed, not how it looks like). This requires the commissioner to be flexible, and accept a certain loss of control over this design aspect.

Ensuring: normally, suppliers would deliver their materials with the necessary safety and quality specifications such as insulating performance, fire proofing, life-span, etc. In a CBP, actors cannot profit from this comfort because waste does not come with these specifications. In some way, actors have to establish how this risk is carried. There are different possibilities for this, either through doing research, providing the necessary specifications, or making specific agreements based on trust.

Connecting through vision: Traditionally, the Visionist function is not recognizable in the building process. Some traditional activities do touch upon the Visionist role. The commissioner decides on how many square meters have to be realized, wat functions have to be present in the building, perhaps what type of aesthetical appearance the commissioner prefers (Wamelink, 2009). Usually, this is done together with the designer of the building. The specifications by the commissioner can be seen as a "vision" for the project, although mainly in the form of specific demands (amount of working places, m2, etc.). Applying CE principles does not restrict actors to fall back in traditional patterns. Regardless of applying CE principles, the commissioner could still specify a certain amount of m2 and working places to be realized. However, more than this is happening. The way the Connecting Visionist function is fulfilled during the process show some interesting dynamics. For example in the Alliander case, the architect had its main contribution in setting the vision on circularity. However in the end, he did not contribute to the design, as an architect normally does. This was the contractor's task, showing a shift in who fulfills what roles here. Next to that, the commissioner (Alliander) became active in setting the vision, coming up with ideas on how to close materials loops, and in the end become a supplier of materials as well. Usually; the commissioner would only invite companies to reply on a tender for a design that matches its wishes, but is not very active in the vision behind the design (this is traditionally the architect's role). At this point it is unclear what exactly happens in the visionary function. The visionary session in the next chapter will shed light on this.

Providers: Actors who deliver materials in the cases observed are new to the building process. The function is not new, but actors from outside the building sector fulfill this function, thus falling back to traditional solutions is not applicable to actors fulfilling this functions.

From the cross case analysis we see that the functions found, are also recognizable in the traditional building process. The following table shows what traditional actors fulfill the functions, including the ambiguity around the Connecting through vision function. The table shows that some functions are recognizable in the traditional building process as well. Two functions however are new, connecting through vision and scope broadening.

Functions (Traditional BP)	Connecting through vision	Ideating	Constructing	Ensuring	Providing	Scope broadening
Actors fulfilling functions						
Project leader/ commisioner						
Architect		✓				
Contractor			✓	✓		
Suppliers				✓	✓	
Advising company				✓		
						Search engines are cata-logs or supplier websites

Table 13; Traditional functional diversity in relation actors, based on Wamelink, 2009

Considering the process, in all cases the process was a more integrated one than the traditional, segregated process. For example, when materials where provided, the architect filled in the details of the functional specified design he had already made. Thus, designing certain building elements could happen at the same time as other elements where already being constructed.

So far we have mainly made observations on how actors fulfill roles in current CBP's. The observation sketched how the building sector currently applies the CE principles. A second aim of this research is to assess whether these first attempts align with how ideally the CE should be applied in the building sector. Have they been doing the right thing? Could they have done something different, in order to obtain better results? Next to that, the cross case analysis brought forward that the role of the Connecting Visionist seems in some way fulfilled differently than traditionally, but it is unclear what this difference is. In order to add this normative aspect to the research, the observations are discussed in a visionary session with experts, giving them the opportunity to add their vision to what happened in the cases. We will also focus on the Visionist function, since it is still unclear what exactly the nature of this function is.

7:

THE VISIONARY SESSION

From the case studies, we have established the functional diversity currently observed in circular building processes. Based on these observations, the question arises if these first attempts are in line with how the CE principles should ideally be applied in the building sector? Next to that, a key question remains; what exactly is the function of connecting through vision? These two questions are answered in this chapter, which is done by organizing a visionary session. With visionary is meant, a type of person who is involved with the function of visioning in context of circular buildings. The idea is that these persons can provide the details on what how actors are precisely connected through a vision. The basic structure for the session consisted of three parts. This structure will also be used in this chapter to elaborate on the outcomes of the session. We started with validating the results found so far. Afterwards we established a future vision on what a perfect CE would look like in 2030. Finally, a synthesis is made between the ideal future, and the current observations in the building sector. This should give a clear indication of what should happen, or change in the building sector to move towards the dream on a perfect CE. The data collected in the session is analyzed and put into perspective of the Connecting Visionist function in the final paragraph of this chapter called Visionary session; analysis. See appendix I for the posters including the post-its and ideas added during the session.

Validation of functional diversity

The functional diversity as presented in the cross case analysis was presented to the participants in the following format. The meaning of the functions is explained through a presentation on the research, and details on the functions were handed out to the participants as well.

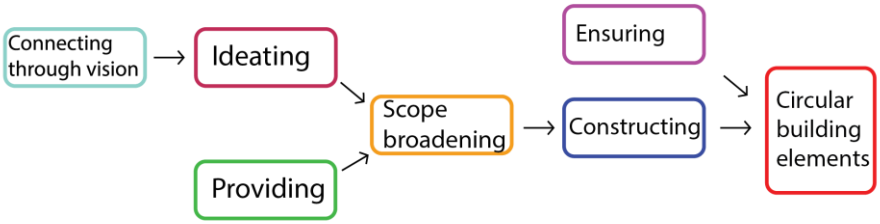

Figure 30; Functional diversity as presented in the visionary session

The experts said they could recognize the functions. They acknowledged the activities and tasks that are related to each function. There were two remarks which were leading in the discussion on the functional diversity: the participants remarked that the relation between the functions was presented in a linear way. They believed however, that it is much more of an integrated process. Second, they missed some reflection on the financial component to the projects. This is related to the way business cases are formed between actors. We will elaborate on the two issues below.

Linear vs. integral relation between functions

The participants believed that the way the functions are presented, sequentially and in a linear way, does not represent the reality. The relation between the functions is much more integral. This means that the function of the

constructer, can be performed at the same time as someone performing the role connecting actors through a vision. It is true that visioning occurs more intensive in the beginning of a building process, but visioning can also be necessary when a new actor is involved in the building process, with whom the vision should be communicated and perhaps even altered. The Alliander case showed that visioning is done throughout the whole process, for example when establishing that producing insulation in France instead of Holland is fine in sustainability terms as defined by Alliander.

Business case in circular projects
The functional diversity does not give much detail on the financial component of circular projects, which cannot be ignored. Ultimately, people are driven by financial incentives. A project cannot be realized if not profit is gained through the project. Based on the presentation, the role of the Connecting Visionist touches upon the financial aspect slightly, but not enough. In the end, it should be all parties that gain a certain value from a circular project. In the end, we are speaking of a Circular Economy, so how do parties establish this economy in their project? The discussion on this topic already took off during this part of the visionary session, however parts were discussed at the end of the session as well. We will discuss the circular business case at the Synthesis part of this chapter.

Future vision

"In a perfect Circular Economy, people have reconnected with nature. Nature will take a seat at the board room table." Yvette Govaart (2016)

What would the ideal Circular Economy look like in 2030? This was the driving question participants generated ideas on. Idea's varied greatly, touching upon digitalization of the construction sector, to social matters, such as the type of work people will be doing. The vision was constructed by generating ideas on post-its, which have been collected in appendix B. The ideas where discussed in the group. The ideas and discussion is explained below.

The idea's fueling the future vision varied greatly. From a **technological perspective**, there was clear consensus that the building stock in 2030 will be registered digitally into detail. Any information which anyone wants to obtain about materials of a building is collected. This is the basis for a grand market of second hand building materials. However, not much material exchange will be needed since all buildings will be easily transformable to suit a new habitant or tenant's needs. It was also clear that a CE in 2030 is not just about materials, but also energy. In the future, buildings will become small power plants, and in the end by intelligently connecting buildings, a collection of buildings will become at least energy neutral by exchanging energy.

Also more **social aspects** where mentioned. For example, a perfect CE results in a situation where everyone feels responsible for the building they use. People automatically guard the value of a building, and destruction of value will be seen as "not done". Constructing a building is done by companies who have integrated most functions of a building process, which allows for people to work together on multiple buildings, and establish unique ways of working not only through trust, but become acquainted with someone and people will be able to work with friends on projects. This also results in a society where working actually becomes the core of what people love to do in their life. People can do what they are good at, and everybody can be what they want to be. In 2030, the contractor has a different role. He no longer manages material supplies. Also, laws and regulations in the building sector will be much more flexible then they are now. Due to certain regulations, some business cases cannot be exploited, as was the case with Brummen. Also, in 2030 Individualism will be something of the past. The individualism has led to huge amounts of depression, fear and burn-outs, it will cost society too much.

Other ideas revolved around **perception of value**. In a perfect circular future, we can easily assess how certain added natural or social value will benefit a specific community or ecosystem. This gives commissioners/developers clear insight in what their investment will deliver. In the coming years, closed stock projects will make their entry, where profit is not only recognized in financial terms. Value will be embedded in other things than money. In the end, in the transition we need to become one with nature again and understand that we are part of an ecological system. We keep relying so much on high tech solutions, however we humans are essentially part of nature. This will also

result in a system where people do what they are essentially good at. Due to digitalization, production chains can become much smaller and people can manage materials themselves. The contractor could become a manager of values, instead of materials. He could help in managing the integrated business case

The following picture shows the results of the visionary brainstorm.

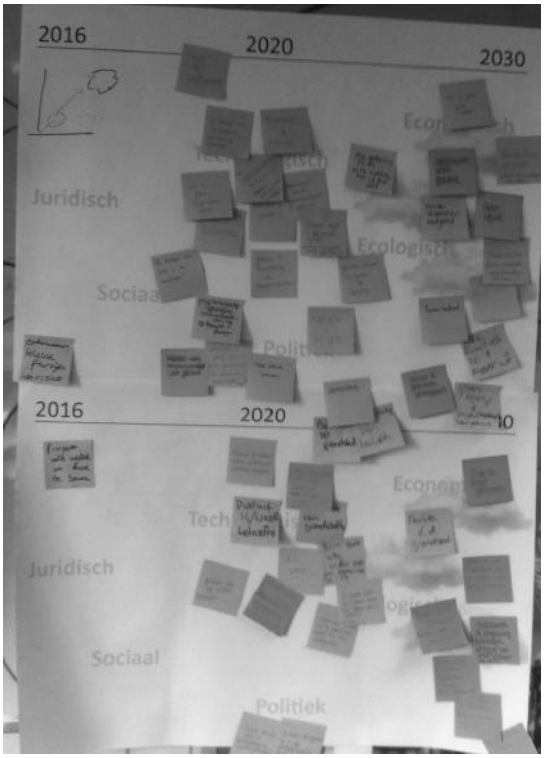

Figure 31; visionary brainstorm result

Synthesis

"In the end, we need people who understand that a change of course is necessary: people with a different mindset and morale." ***Yvette Govaart & Woud Jansen (2016)***

After sketching the ideal vision, participants where asked whether they experience, in their practice, a path of the building sector which leads towards the vision. This was difficult for the participants to answer. Going from an ideal vision in 2030, to where we are now, is an enormous step, considering the rate of change of our society. However, some remarks could be made on the transition pathway the sector is taking now.

At the moment people in the sector are working to develop a model which can be used to assess the circularity of projects. Such an assessment tool contributes in the transition to a CE on multiple levels. One is the fact that an assessment model gives people who apply the CE principles more guidance on what ambition they could set for a project. Secondly, an assessment tool helps investors to rate companies on their circular performance, which helps them in their choice for investment. The adoption of a generalized assessment tool can be seen as a contribution to institutionalization of the CE concept.

Digitalization is also thought to start playing a role now in the transition to a CE. The sector shows signs of experimenting with Building Information Modeling based databases of resource passports, showing the exact material contents of a building. Having this information could bring users of buildings much closer to the producers of materials, making parts of the supply chain much more accessible. Next to that, digitalization could give users of buildings the chance to become involved with the exploitation of the building, or even responsible for this. Users could for example easily decide on selling furniture or separation walls to other users who are in need of them, when offer and demand is digitally matched.

Considering the setting the business case in the beginning of the project, people have to design business cases that stretch over a longer part of the exploitation phase. This is due to the idea that values created through circular principles are sometimes paying off in a later stage of the life cycle. For example, the roof constructed over the Alliander office buildings is easy to dismantle in the future. For now, this does not directly generate money, but in the future this could save Alliander a lot of demolishing costs and ideally even generate revenue, for example by selling it to someone who wants to build it at another location, or reuse directly. This goes for the 100WATT tower as well, where investing in a circular office floor that stands out pays back at later moments. The owner of the 100WATT tower now plans his meetings in the circular floor, showing off his creation. This could help him in establishing new collaborations, by impressing his invitees. In addition, the business case has to connect to the primary process of involved parties. This is how people find value in a certain project, because they as a company are able to improve their primary process as a result from the project. Alliander's primary process is facilitating consumers in their living by connecting them to the power grid. By investing in their image through this ambitious project, they aim to reach out to their clients.

Finally, a remark was made concerning the users of the building. Nowadays, users of buildings are not involved in the design of buildings, and they are also not able to give their opinion on how the building functions. Ideally buildings contribute to the primary process of all users. In Tropicana (Rotterdam), the ambition is to develop an ecosystem of tenants which share a certain interest in sustainability, and their primary processes complement one another. So tenants are selected on how they add value to the whole ecosystem. Ideally a tenant profits from sharing the building with other parties because of their network/activities, and the other parties can profit of the new tenant.

In order to move this transition to a CE, we have to relate financial aspects to social and natural aspects. People will have to start realizing that, social and natural values can enrich a business case. This way, organizations will realize that a higher initial investment will also pay itself back later in higher and more financial, natural an social values. Next to that, the transition will become much easier if the profits mentioned (financial, social and natural) where able to be quantified, functioning as proof for people who are not yet convinced.
Another important aspect of the transition is learning between different organizations and different projects. For example Brummen, where some parts have succeeded, but others have failed, namely the business case part. This is a great lesson for future projects.

Visuals of the visionary session

During the session, a live illustrator interpreted what has been said and translated speech into image, by drawing on the spot. This resulted in the following image. The image is a representation of different themes which have been discussed during the session. We discuss three parts of the image which have been highlighted by red circles. Starting in the top middle, we see a group of people sitting on a table marked by a euro sign, which represents people as connecting Visionists by discussing a business case, and finding interests for all involved parties. Below in the circle is written "other perspective on ownership", referring to adopting different business models based on service or lease. Perhaps more important is the fact that everything in the drawing revolves around the visioning. Other parties mentioned like the contractor and the advisor are all connected through this visioning function. In addition, the bottom left mentions the aspect "learning from nature", which refers to the idea that we as humans should treat a building and it's users as an ecosystem in which we should find the combination of humans and materials that results in the best value gained for the system.

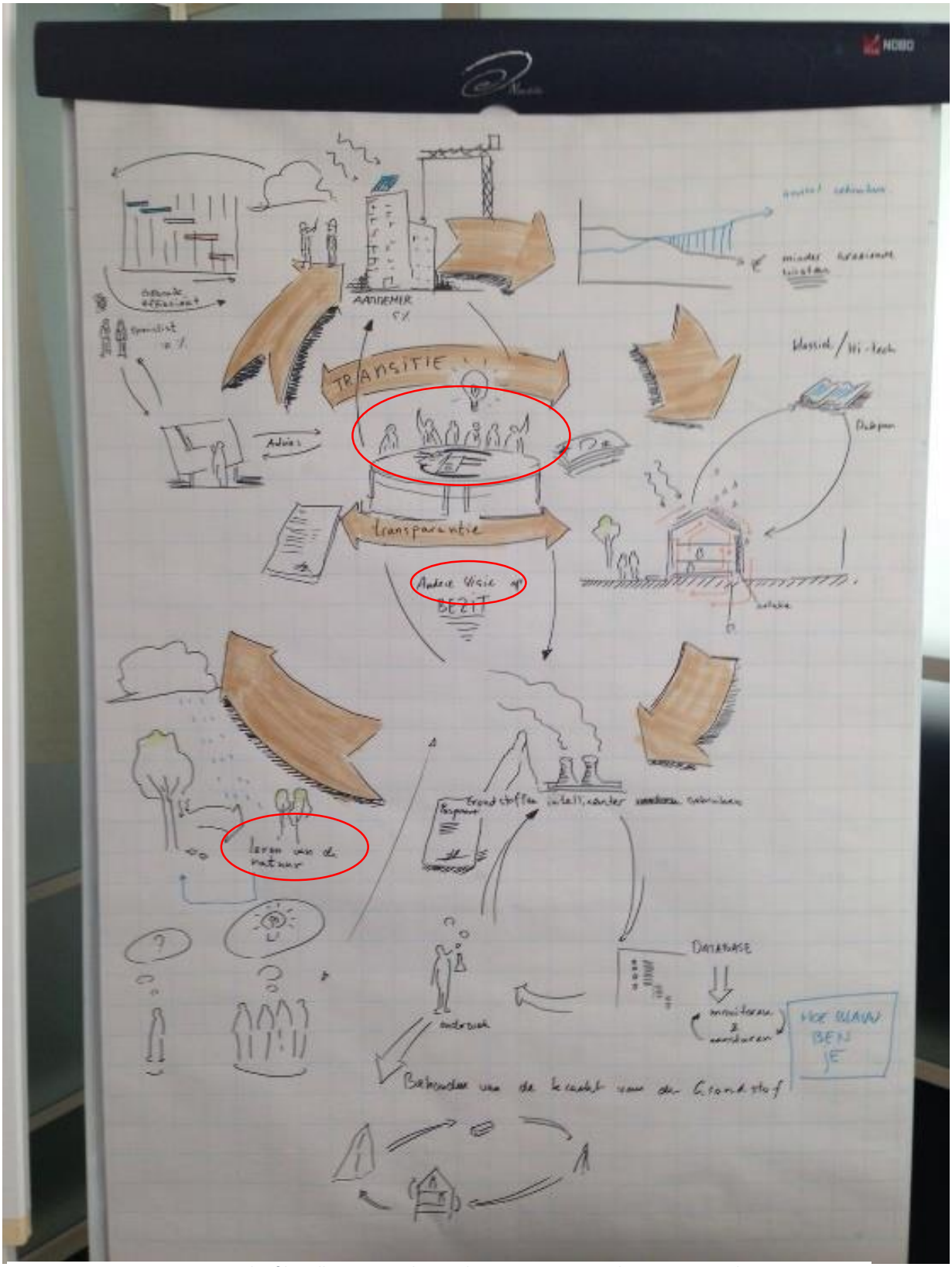

Figure 32; result of live illustrations during the visionary session by Lars Hartnack

Visionary session; analysis

Now that we have collected the data from the visionary session, it is possible to give more detail to what a connecting visionist actually does. Most of the ambiguity around the function is vanished since we have gained insights in how the visionist connects actors by working on business cases that provide added value for involved actors. The business case become a strongly re-occurring theme during the session. This is not entirely surprising. The EMF (2013) stresses the importance of adoption of new business models in a Circular Economy. Mentink's thesis (2014) also shows the importance of business model innovation in context of a CE. In the visionary session, we touched upon business model innovation for the construction sector. Three aspects were leading in the discussion concerning business cases; value, willpower and integrality. These are interrelated and will therefore be discussed sequentially below.

Value

A business case revolves around adding value. This brings the crucial question forward; what is the added value that the client needs? This refers to the client's primary process, its core activities. How can the project deliver value which can be used to strengthen, or improve the client's primary process? Asking this question is crucial, because it sets the scope for the project. From the cases and the visionary session, we can see that value can be created through the idea that a project will become profitable for this person's organization and/or because this person has an intrinsic motivation to apply the CE principles, which gives him/her the drive to take the role of visionist and connect actors under the shared vision. When it is clear what values should be added through the business case, a crucial element is created amongst involved parties for the success of the project: willpower.

Willpower

Without willpower, a project is unlikely to succeed. Willpower has to be created amongst the relevant people. These people are usually higher up in the organization, or these are the people who need to clarify their action to someone with authority. These are also the people most likely to be involved in the early phase of the creation of a business case, since they have the hierarchy to either stay in conversation, or pull out. However, not everyone "high up the ladder" has the willpower. This is what makes a Visionist: the willpower to perform a system redesign instead of relying on established routines,, using a different mindset, based on morale. Only though willpower, actors can engage in collaboration on a circular business case, requiring also some transparence in communication of the business models of their own organization. This brings us to the next point; integrality.

Integrality

A business model where all parties involved in the end should benefit from is what drives a circular building process. Integrality is key in the conception of the business model. It has been said before that a CBP requires actors to step out of their role and be able to emphasize with other actors and their roles. This is true, for both the business case conception phase and in the building process. For example, suppliers have to be involved in the business case conception, since it is necessary that they adopt a different business model then they traditionally benefit from (e.g. engaging in lease constructions, discounts due to take-back of materials, etc. instead of "linear" business models). Again, their participation also depends on whether or not the business case adds value for them, creating the willpower.

There is a certain minimum amount of people needed to perform the Visionist function: the larger a project becomes, different parties need to deliver someone to fulfill this function. The connecting capacity of one Visionist is not enough in large projects. Preferably each party is represented by a Visionist. In small projects one Visionist may have enough connecting capacity, as shown in the 100 Watt tower.

With the data acquired from the visionary session, we can update the function of the Connecting Visionist. This is pictured in the following figure.

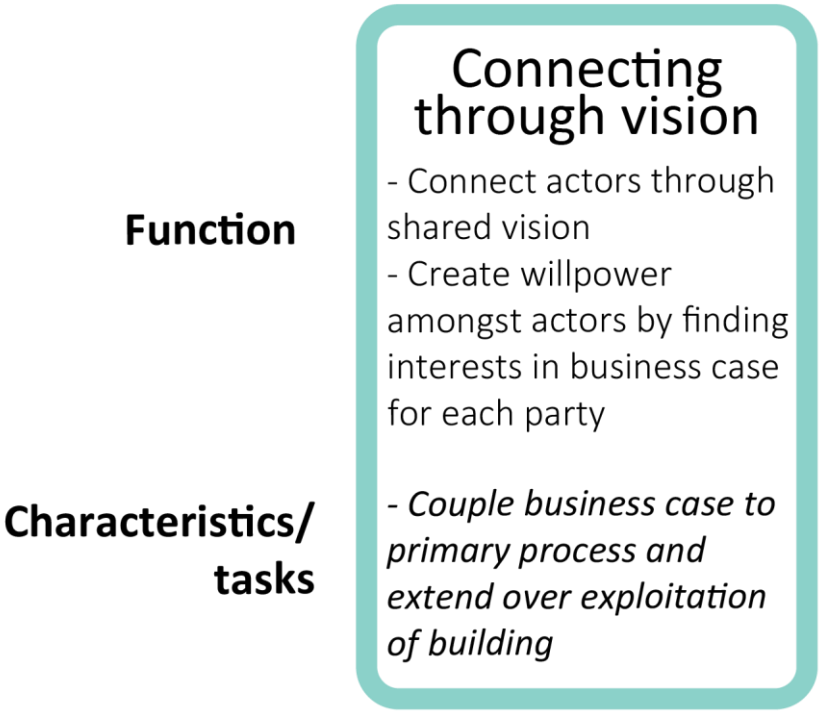

Figure 33; Updated function of connecting visionist

In closing remarks, it was mentioned that the cases studied are all part of the transition towards the circular economy. Perhaps they are not perfect in terms of what has been discussed during the session, but in the transition these projects are crucial since we can learn from what went wrong and from what worked well.

8:

CONCLUSIONS

In the beginning of this thesis, we established that applying CE principles in the redevelopment of utility buildings results in a system redesign/optimization of the construction sector supply chain. In order to find out how this influences actors, we mapped the diversity of recent circular projects. We then tested this diversity by sketching what a CE for the building sector would look like ideally. In addition we zoomed in on the nature of the Visionist function. This allows us to answer the main research question: *What is the functional diversity that actors fulfill when they aim to apply the circular economy concept to the redevelopment of utility buildings?* This question is answered by first elaborating on the functional diversity as observed in the cases, followed by zooming in on the function of the Visionist. Finally, we adopt the ecologists' perspective from the conceptual framework and conclude about how the functional diversity relates to the performance of the system to provide the desired system outcomes.

Functional diversity

As a result from the analysis of case studies, we identified the functional diversity, what actors fulfilled these functions, and what characteristics they possessed to fulfill these functions. The following table illustrates the functional diversity present as observed in the circular building process. The names of the functions have been chosen in a way that they correspond with the nature of the function.

Functional group	**Connecting through vision**	**Ideating**	**Scope broadening**	**Providing**	**Constructing**	**Ensuring**
Nature of function	Connect actors through shared vision & find interest for involved parties	Develop ideas to reuse materials and create designs	Broaden the scope of search to outside the building sector	Provide parties with materials to reuse	Build product elements from the found materials	Ensure the quality and safety of buildings in which materials are reused
Characteristics /tasks	Couple business case to primary process and extend over exploitation of building	Use creativity to come up with ideas for material loop closing. Ask around, look in own organization for material streams	Bring together offer and demand. Can be done by using online search engines, visit depots yourself	Separate reusable material streams. Temporar y storage is needed.	Be flexibly deployable and able to work with 2nd life materials.	Have the ability to do research on materials safety. Or ensure safety by taking responsibility for any future maintenance.

Table 14; Functional diversity of the circular building process found in case studies

In order to conclude more about the functional diversity, we have to make a comparison to the diversity of the traditional building process. The relationship of the functions and actors in the traditional building process is already made in the cross case analysis. Below this comparison is made.

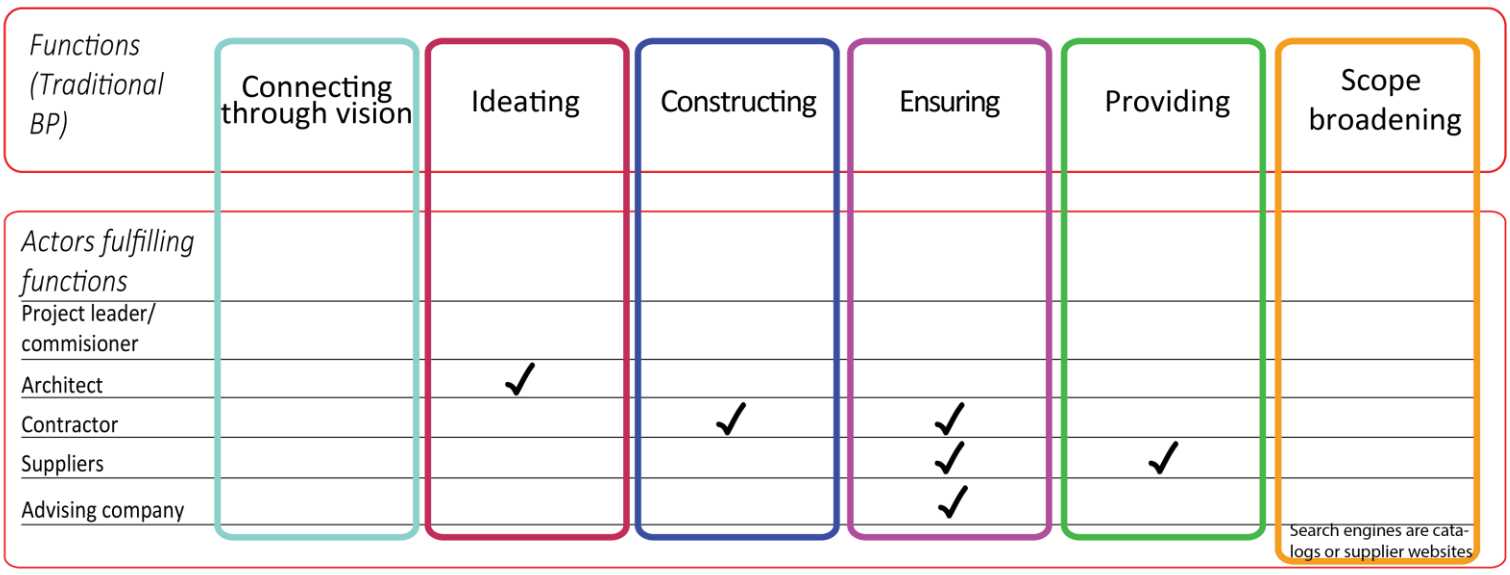

Figure 34; Comparison of functional diversity. Traditional vs. circular building process

As the figures show, **actors fulfill more functions in the circular building process, then in a traditional building process**. The average number of functions fulfilled by actors traditionally is 1.5, while in the circular BP, this average is 2.6. The number of functions fulfilled by one actor in the TBP is not tested through cases as has been for the CBP, so this number is less scientifically viable. However, it does represent the common notion that the TBP is still a strongly segregated process. The number shows us that a CBP requires actors to step out of their own role, and be able to emphasize with other functions in the process. Sometimes, this even means fulfilling other functions, e.g. one person fulfilling the role of connecting through vison, and at another times being an Ideator and even a Provider at some point. The following table is assessed whether the functions have a completely different nature from functions in the TBP, meaning a new function is created, or the nature remains the same but the tasks in the function are different. The TBP column is mostly based on Wamelink (2009) and the findings on the construction supply chain in chapter 2.

Function	*Traditional building process*	*Circular building process*
Connecting through vision	- Not present in TBP	In the circular building process, the role of the Visionist is to connect involved actors in the supply chain through a shared vision. The Visionist must disseminate the vision of the project amongst the actors involved. When projects become larger, more people are needed to fulfill this function to increase connective capacity of the role. This function is new to the building process and will be elaborated on below.
Ideating	The role of the Ideator is traditionally most comparable to an architect looking for materials to use in their design.	The role of the Ideator can be fulfilled by anyone involved in the building process or in the surroundings of the involved actors. When the vision is broadly supported, most team members fulfill the role of the Ideator, since it has become a shared interest to look for materials to reuse. The nature of this function remains the same, establishing what materials to reuse, but the way the function is fulfilled is different, since it requires a different way of looking for materials (E.g. asking around in organization, or broadening the scope)
Providing	Providers traditionally are suppliers of materials, producing building elements or products.	Providers are no longer typical suppliers, but this function is fulfilled by owners of material (waste) streams, for example from demolishing projects. Anyone can become a provider; as long as the material provided is given a second life now or in the future. The nature of this function does not change, though the function is fulfilled in different ways, mainly by parties less usual to the building sector.
Scope broadening	- Not present in TBP	The scope of search for materials has to be broadened to find less traditional suppliers of materials in the building sector. Resulting from the ideating function, it becomes clear what kind

		of materials have to be found and what function they need to fulfill. Scope broadening became a recurrent function in the cases. This requires the use of for example online marketplaces as marktplaats.nl. An architect visiting a recycling center for wood (Houten recycling center case), or the intern visiting demolition sites (100WATT case) can be seen as acts of scope broadening.
Constructing	The constructor is typically the contractor, along with sub-contractors. They plan their building process on existing knowledge from previous projects. They secure their planning and risks in contracts.	This function is fulfilled by different people in a different way compared to a TBP. Contractors have to operate in the boundaries of the vision. In that sense, they have to be flexible and can in some cases not rely on previous experiences in their planning. They have to look for other ways to remain competitive in their costs, while still working with unknown situations. Sometimes they are able to organize this (using re-integration), however sometimes they cannot and other actors fulfill this role, such as a craftsman for furniture as seen in the 100WATT tower. The nature of this function has not changed, but is fulfilled in different ways.
Ensuring	This function is mostly fulfilled by suppliers and research agencies who can guarantee/test the quality and safety of materials.	In essence not much different from tradition. This function is mostly fulfilled by suppliers, contractors and research agencies who can test the quality and safety of materials. In some cases ensuring is done a bit differently. Lower quality of materials is accepted and parties take responsibility for it, accounting for possible extra costs of ownership. The nature of the function stays the same, and is sometimes fulfilled in a different way.

Table 15; TBP compared to CBP in terms of functions and which actors fulfill them. The TBP column is mostly based on Wamelink (2009) and the findings on the construction supply chain in chapter 2.

As we have learnt from the functional diversity analysis, we can make the following conclusions.

The functions providing, ensuring, constructing & ideating seen in the circular building process are mostly comparable to the functions in the traditional building process. The nature of these functions remain the same as seen in the traditional building process. However, the behavior and tasks in this function change. The functions show behavior of actors looking for other ways to fulfill the same function, for example when the contractor needs to dismantle wooden pallets but his usual way of working (hiring construction workers or carpenters) becomes too costly. This forces the contractor to look for other ways to dismantle the pallets, which in the cases is mostly done by people from re-integration.

The functions "Scope broadening" and "Connecting through vision" are new functions, origination due to application of CE principles. Scope broadening is required because actors cannot make use of standard suppliers in the construction chain. Instead, parties are found that usually do not supply materials for a redevelopment project, such as demolishers and waste processors. Scope broadening is necessary to find these parties. The connecting

through vision function is necessary to connect actors in a network with a different structure than in a traditional, linear supply chain, which is necessary to perform the system redesign/optimization.

The Connecting through vision function plays a crucial role in the building process. As we have seen, the system redesign influences the involved parties of the construction supply chain. The function of visioning means finding a vision in which all involved parties can find an interest. This gives a structure for involved parties to work with. It is used in the ideating function to assess whether certain ideas of loop closing are desirable to realize. For example, the HAKA project vision included the idea that material loop closing has to occur locally. This made loop closing with materials found outside of Rotterdam not suitable for thus project.

Studying the cases indicated that connecting actors through a vision is crucial to a circular building process. It was however not yet clear what this function exactly entails and how actors fulfill this function.

Connecting through vision: in detail

This paragraph is the result from the visionary session. Based on the input by experts, we could establish how the different functions relate to each other. The experts could recognize the functions that actors fulfill in the circular building process as presented. Most time in the session was spent discussing the function Connecting through vision, which is a new function to the building process. Here we describe how ideally the Visionists connects actors in the process.

How does the perfect Circular Economy for the building sector look like in 2030? This question was answered by experts in the visionary session. Experts answered the question much by discussing topics that go well beyond the CE. From “Nature back in the boardroom”, the in-existence of money, to the end of individualism and a society where everybody does what he/she is good at (see appendix D for results of the 2030 brainstorm session). This indicates that a transition to the circular economy is associated with much more than a system redesign/optimization of the construction supply chain; it requires a fundamental change in how we define value. This is however still a dream. Nevertheless, if the steps we can take tomorrow are towards that dream, what steps would these be?

Central to this answer was the theme business case, which parties design to creating values (Mentink, 2014). This means that a party considers starting a project, because the expectation is that the added value obtained through the project exceeds the initial investment. A construction project can be seen as the realization of a new business case. Within this theme, the aspects **value, willpower & integrality** have been discussed in chapter 6. So how do these aspects relate to the diversity of the building process? The three aspects mainly fit the role of the Visionist. It should be in his/her capacity to uncover what shared values should be created by the project (economic, social or environmental incentives), stimulating the willpower amongst involved parties, making integrality possible.

The structure why, how & what (adopted from Sinek, 2010) is used to understand the relationship between the functions. The why refers to the value the project delivers to the involved actors. It is the foundation to build willpower, which is done by “asking the right question”; this means uncovering why the project is initiated, and how the project should strengthen the primary process(es) of the involved parties. Think of the moment when Copper8 asked Alliander, “how does the project connect with your core values?” It also means thinking about the entire life cycle of the building, and including values added in the exploitation phase to the business case to make a larger investment in the start of a project feasible. For example, Alliander decided to invest in a circular building, because the social value created, improving image for the client, would pay back during exploitation of the building. Or Cocon in the 100WATT case, who was willing to invest more and earn this back in the exploitation phase financially (more income from Copper8 as tenant) and socially (better image as landlord). This is indicated under “activity” in figure 31 below with a group of persons who established a shared vision.

When the vision is set, it becomes possible to move to the “how”, which refers to how the closing of materials loops can add the wanted value for the parties involved. The circular hierarchy is of importance here; first re-use as much as possible directly, before moving to redistribute, repair, or recycle. It involves Ideating and scope broadening, looking for possible solutions to closing material loops. When these are found, it becomes possible to involve the

providers and constructors in the development of the business case. The how can also include other sustainability related criteria such as local use of materials (to save CO_2) or closing the materials loops of waste streams in the own organization, as was the case in Alliander. These criteria can create the values desired to create through the project.

From the "why" results the "how" and in turn comes the "what", which is the product/element/building to be constructed and where material loops should be closed. Here it is important that a supplier of a material, adopts a circular business model. If not, we cannot speak of a circular economy since not all parties have enjoyed an economic incentive through the closing of material loops. In the figure, Brand's (1994) model is used to represent the what. It is the material outcome of the project, where the layers are easily dismantled for future reuse.

It is important to note that the why, how & what structure does not aim to indicate that a building process can be divided in why, how and what phases. The why, how and what are inseparably connected.

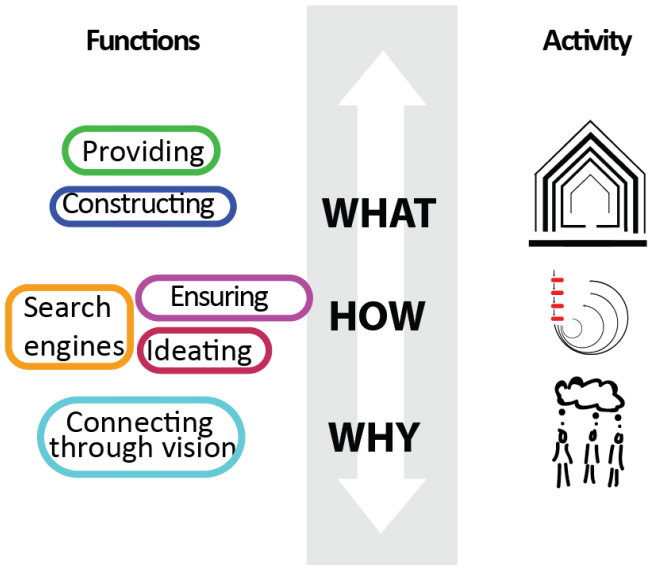

Figure 35; Functional diveristy related to the Why how what structure adopted from Sinek (2010)

The model shows that the why is decisive for how the project unfolds. The result of the project (the "what") can always be traced back to the why, and the why can always be traced back to the what. It is a coherent whole, which is indicated by the arrows behind the different levels. Next to that, the model shows that actors in a CBP should not take the CE as a goal, but as a means to work towards the vision which has been set for the project.

In this concluding remark we adopt the ecologists' perspective. We have mapped the functional diversity of actors in the CBP. How can the system be tweaked, or enriched to increase the performance of the system? We have seen that most functions are comparable to that of the traditional building process, and that traditional actors are able to fulfill these functions, but in different ways. In that sense, do we need to add new actors to fulfill these functions to enhance the circular outcomes of the system? The answer is no, except for the function of connecting through vision. As we have seen, an extra effort is required for example by emphasizing with other parties in the building process, but no new actors needed to be added to manage this. The connecting through vision function however showed that a specific kind of actor fulfills this function. These people are able to connect actors through a shared vision, in which involved actors find interests and thus the willpower to apply CE principles. We can conclude that the existence of this function is crucial for the system to produce the desired outcomes. We have seen that actors possess characteristics as enthusiasm and intrinsic motivation which helped them carry out these function. Also from the results of the visionary session we see that these characteristics matter to a successful CBP. **Thus, involving a person who carries the characteristics of a Visionist can strongly benefit the circular building process and its outcomes.**

9:

DISCUSSION, RECOMMENDATIONS & REFLECTION

The results obtained from this research trigger reactions and new questions. In this chapter, we express these reactions and elaborate on the questions that rise from the discussion. We first discuss what it means to apply the CE concept in the building sector, followed by the functional diversity found in the circular building process, discussion on the Connecting through Vison function, and discussion a possible transition to a CE. Recommendations are provided in between, since they flow gradually from the discussion. Finally, we reflect on limitations due to chosen boundaries, data collection method and theoretical framework.

Results of applying the CE in the building sector

Interestingly, all the cases found closing material loops as a means to achieve added social values. This is surprising, since we are talking about a Circular ECONOMY. This is shown in the table below.

	HAKA	KRINGLOOPCENTRUM	100 WATT TOWER	ALLIANDER
WHY	The why of this project is answered through its function in a long term strategy to be involved in the redevelopment of the Merwevierhavens in Rotterdam	Because of the function of the recycling center, the idea to close materials loops was formed as a concept for the architecture. In this case, closing materials loops became the goal, not the means.	Closing material loops became a means to contribute to a shared ambition by Cocon and Copper8 on developing an office floor that stands out.	Alliander decided that due to their public services, they took the chance to develop this project in a way that positively influences their image. Closing materials loops was an answer to this. Next to that, a dismountable building could give them financial benefits in the future.
HOW	The how was developed by combining the strategy of Vestia, with the regulations of monumentenzorg. Reuse of materials was done by locally sourcing labor in form of re-integration	By looking for used materials that could be reused, an answer could directly be given to the “why”.	This is done by setting a high ambition, for a fully circular office. Material flows were used from demolishing projects and business cases were set up with suppliers	By closing loops, Alliander could create a positive effect on their image to their clients, and contribute to a better environment.
WHAT	Recycling in space plan and stuff layers	Recycling in the skin layer of the building	Reuse in the stuff & space plan layers	Reuse/recycling in the stuff, services & skin layers

Table 16: why how & what structure applied to cases

As the table shows, the added value was mostly recognized as social values, such as image, or strategic value. The idea of a circular economy however, is that an economic incentive should lead to the reduction of materials consumption. Copper8 has set up specific business cases with its supplier, in line with creating an economic incentive for both parties. Alliander has shown that they believe a financial incentive is gained through constructing a roof that can be dismantled. However, for example in the HAKA project, economic incentives were not made through the

closing material loops. The project actually became more expensive due to the structure with the architect and the working team. The aim was to create social value, which would help Vestia get influence in the M4H area in the long run. From these results, it is the question whether a circular economy for buildings truly has to be a means for economic incentives. The examples show that actors value other things than money as well, and the CE as a means helps them to create those values. However, these parties already have some connection with society, which make a search for social value more logical. It can be expected that for most parties, economic incentives will still play a large role.

Functional Diversity

The six functions found in this research represent how actors have performed the system redesign. When comparing the nature of the functions, we see differences in how functions can be described. For example, the function of constructing is very clear; from materials, you build products or building elements. The same goes for providing, which basically means separating materials that can be reused in circular projects. The Connecting through vision function however seems different in the sense that it takes much more words to explain this function. The function is quite hard to grasp. We know that this function is about connecting actors under a shared vision on circularity, but this how this connecting takes place is hard to grasp. For example in the HAKA case, it has been mentioned that the enthusiasm of Vestia's project manager about the vision was crucial to communicating this across other parties. Also the enthusiasm of the Architect of the kringloopwinkel, who asked colleagues inside Arcadis for ideas on materials to reuse, and visited a materials recycling center to search for usable materials with his bare hands. What exactly drives him? The following quote gives some direction towards an answer.

"*If you want to build a ship, don't call in the men asking them to collect wood, and order them to build a ship. Instead, teach the men to desire the vast, endless ocean*." (Antoine de Saint-Exupéry).

All the cases have something in common, which is that they include persons who desire to do something different. Persons that take the opportunity to break out of the business as usual. And in their enthusiasm, they are able to light a spark in other actors. Perhaps it is not even the vision itself that really connects actors. It is the spark, felt by people while talking about the vision, which really connects actors. In that sense, circular economy projects allow people to think about their dreams, how in their opinion a building should be redeveloped without harming the environment. Then, we ask ourselves, what is the spark? This concept is so intangible that it is difficult to give recommendations on how to answer this question. But we might be able to answer this question by looking at what sincerely drives people. What makes people happy? How can we provide the environment enabling people to experience more sparks? This brings us to the idea brought forward in the visionary session; an ideal CE where everybody does what makes him/her happy, and what he/she is good at**. A managerial recommendation** would be to make sure that your employees are actually doing what they like, and are intrinsically motivated to perform certain task. **An academic recommendation** would be to make a connection in research with social studies, on for example the relation between happiness on the working floor and whether this makes innovations in companies easier.

Thinking in functions with regard to applying CE principles gives actors an idea of what tasks will need to be executed during the process. This also gives actors the opportunity to think about, what tasks do I like to fulfill? This leads us to the following **managerial recommendation:** Doing this together, involving parties before start of a project, gives actors the opportunity to discuss how functions and tasks influence each other. Thinking about this in advance could give actors a perspective on what could happen in a Circular building process. Going one step further, one could even imagine doing a sort of role play, enabling persons to experience the functions beforehand. Perhaps a simulation or serious game tool could be used to do this. Maybe an activity as this could already be a part of the connecting actors through vision function.

The Connecting through vision function plays a role in a large part of the building process, not only in the beginning. As we have seen, the system redesign/optimization influences the involved parties of the construction supply chain. The function of visioning means finding a vision in which all involved parties can find an interest. This causes actors to be connected through a vision, forming a network connection which is different from the typical, linear connection. The following image illustrates this.

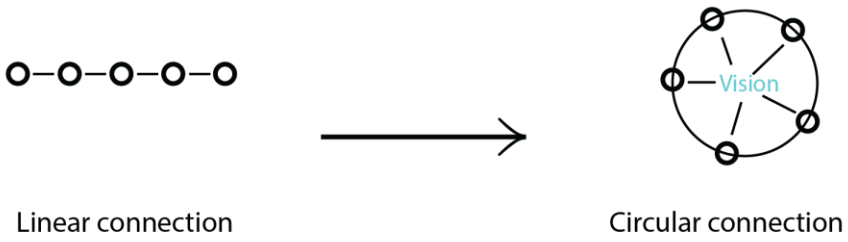

Figure 36; Connecting through vision. Unclear what exactly happens in the process

This research leaves a gap at the spot where the arrow is. **We therefore propose the following academic recommendation**: the arrow indicates a network configuration change, but we do not know how this change takes place. An answer to this can be found by relating the functional diversity, and specifically the visioning function to the building process. This could give us an idea of how the Visionist function exactly unfolds over time. For example, at what moments in the building process should the Visionist function exactly take place? How can the connecting through vision function be organized in the building process?

Finally, concerning the connecting through vision function, we see comparable results with regard to research on functions in the building process in context of sustainable development. For example, van Hal has identified a role called "Innovation Champion" (van Hal, 2000), which is a person using his charisma to further innovation, by getting all those involved enthusiastic about the project. The characteristics of this function much resemble the connecting through vision function. A comparable example is distinguished by van Doorn et al. (2012), called "the architect as inspirator". This function can be fulfilled by an architect who distinguished himself as a though leader on a certain sustainability topic. An example is McDonough, who is broadly recognized as Cradle-to-Cradle Guru, Or Thomas Rau, who increasingly plays the role of inspiratory in CE projects. The person doing this is supposed to develop support under participants to realize sustainable solutions. Interestingly, it is said that this person is not required to be involved through a contract. It is however important that this person stays involved as supervisor. How does this play out with people fulfilling the Connecting through vision function? Do they need to remain involved throughout the entire process? This leads to more process related questions that need to be answered, which can be seen as **an academic recommendation.**

Transition to a CE for the building sector

After studying the cases we can compare how in different contexts circular economy principles are applied. These are a fraction of total amount of buildings that are being redevelopment during that time; we cannot speak of a circular economy for the building sector at this moment. We have seen examples of cases that in some way had a public aspect to it, except for Copper8, however they already have a strong vision on circularity. Application of CE principles seems more difficult at the commercial side of real estate, which is also observed in context of sustainable development (Heurkens, 2016). What conditions could make a transition to a CE easier, not only in projects with a public character but also commercial real estate development? From an institutionalist view this can be discussed (Heurkens, 2016). With institutionalist view, we mean the social structures which influence decision making of actors in the building sector, such as rules, culture, habits etc. We discuss this by adopting Heurkens' structure consisting of four categories of tools that can shape institutions in such a way that incentives for parties are created to apply CE principles. These are discussed based on the findings in this research.

First, shaping tools can be used to set the context for market actions which influence decision making. As this research points out, it is crucial to adopt a vision for a project, since this is what connects actors during the building process. Thus, adopting a vision on circularity on organization level can be a first step to shape the decision environment in later situations. Perhaps more effective would be to regulate vision building for companies. For example, the government could only accept replies to tenders when companies have set a vision on resource use.

This forces companies to at least think about their stance on resource scarcity. It can even leave them to the decision to adopt a vision in which they consciously state to not strive for a CE, or support other concepts. Quite comparable is the CO_2-prestatieladder which rates companies on their CO_2 emissions. The higher a company's position on the ladder, the more discount this company receives on the tender. A possible danger is that this could result in more greenwashing. Another approach is through stimulating tools to create incentives for the application of circular principles. Since the function of Ensuring turned out to be important for the circular building process, municipalities could organize "soft-regulation" contexts for circular projects, which lowers the perceived legal risk for parties to reuse materials, for example because of degrading materials quality. The Netherlands experiments with comparable initiatives to stimulate entrepreneurship (Financieel dagblad, 2015). Additionally, considering the functions of providing and scope broadening, an increase of second hand building materials marketplaces should enable actors to operate more effectively, finding suitable materials much quicker. One example of this is oogstkaart.nl, on which anyone can offer any material to be reused. If these marketplaces are even able to specify the quality and safety of materials, actors won't have to invest time in the Ensuring function.

The ideas mentioned above apply to the idea that fulfilling functions becomes easier and therefore requires less time to invest during the building process. This is however only applicable when perhaps the most important decision is already made by a commissioner; applying CE principles. How can commercial real estate developers be attracted to make this decision? Reed & Sims (2015) mention that certified sustainable buildings attract investment due to less risk of lower rental prices. Certifications are not yet specifically available for circular projects, so this would be **an academic recommendation**, to develop Circular Key Performance Indicators (KPI's) to be able to assess circularity. This can be used by companies assess and compare circular projects. In turn, making circularity measurable for investors. A first attempt, is made by graduate Jeroen Verberne, whose report is not yet published at the time of writing. Developing the KPI's could be done in collaboration between advising organizations and for example investment rating organizations such as VBDO.nl. Advising organizations can create a business case for developing and applying circular KPI's with their clients. Investment rating organizations can influence market demands by assessing how different companies score on circular KPI's.
An academic recommendation is to develop tools to measure "soft" values, such added social value, or environmental value. The cases have shown that CE principles are used to generate social values. How can these social values be measured, or assessed, giving investors more insight in return on investment. It is necessary that these tools remain easy to use. I would recommend to develop these tools in collaboration with organizations, to make sure their interests are embedded in the tools.

We mentioned that singular innovations are the first steps in a transition pathway to the CE for the building sector. During the research, it became clear that not so much the singular innovations cause the transition, but that it is more important how a sector learns from these innovations, so that following projects can build on this. This is difficult in the building sector, since each project is executed by a temporary organization, which splits up afterwards. **A managerial recommendation** therefore would be to include reflection as a final step of the building process. A moment where the project team sits down and reflects on what happened. The reflection is a learning moment for involved actors, which could result in binging what was learned to the table in next projects.

Interestingly, the institutional conditions proposed above are based on making the functions easier to perform for actors in the building process. This leads to the idea that a system redesign of the building sector is completed when these functions have become part of tradition, meaning that when analyzing functions of a circular project in the future, the researcher would conclude: "the functions are of the same nature as usual, and fulfilled by the same actors, in the same way". This would indicate that circular building has become the norm, and that there is nothing special anymore about the connecting through vision function. At that point, perhaps another concept is leading in the building sector which requires another type of connecting function.

Reflection

In this paragraph we reflect on how choices made could have affected, or put limitations on the research. We discuss this for the theoretical framework, boundaries & scope of this research and the data collection method.

Theoretical framework

The method used for this research was based on the idea that diversity influences innovation. From ecology literature, we adopted a framework which is used in that science to observe the dynamics of an ecological system. However, since it is humans we are studying, which are calculation creatures, we added the dimension of structuration to explain behavioral dynamics. These choices had implications for how this research had unfolded, which is reflected on here.

Ecological systems are usually stable systems. The diversity framework is generally used to analyze these stable systems, where organisms fulfill their role as any other day. This is in contrast to the cases, which can be seen as unstable systems, since actors cannot rely on basic behavioral schemes to fulfill their functions. Actors try to stabilize the system by looking for unconventional ways to fulfill their functions. In a stable system, every organism fulfills a function, and the sum of the functions keeps the system stable. In the CBP however, it is rather an unstable system, which perhaps becomes stable in the end, right before the project finishes and the system collapses (the actors terminate collaboration after the project is finished). The system starts out small, and the diversity grows to a point where the sum of the functions of the actors deliver desired outcomes. And thus, a dimension of time is relevant in the CBP, which has not been adopted from the ecological diversity framework.

Another implication for the resource due to the choice of the diversity framework, is that (as far as we know) plants are emotionless, which a diversity framework does not take into account, and ours as well. This research has zoomed in on individuals and their characteristics, and how they interacted with other individuals to produce desired outcomes. An attempt is made to include social structures explaining behavior of actors in the cases. However, we have excluded what emotions could mean for collaborations. In his book “thinking fast and slow” (2011), Daniël Kahneman proves in several ways how our pre-assumptions influence behavior towards other people. For example, simply the way a name is interpreted by humans could already make them prejudiced in whether or not the person who carries that name is credible or not. Considering the normative character of how persons embrace the CE, and develop an intrinsic motivation to embrace it, could lead to decisions based on emotion, rather than rationale (as far as we even are able to be rational in our decisions, but that is another discussion).

We also drew from structuration theory to add an element of human behavior to the research. This theory is very abstract and is therefore applicable in many situations, just like the cases in this research. The threat however is that not real relevant results are produced, using a theory at such an abstract level. We managed to uncover some structures in the building sector, explaining for example the ensuring function, which is basically fulfilled since actors have to conform to the Dutch building regulations. Interesting, but not much shocking news. It would have been more interesting to flesh out the structuration theory in relation to the business case. As mentioned in the visionary session, money is what drives people in the end. This is a leading social structure, influencing agency (and vice versa). The business case is related to this, and it would be interesting to develop a more focused theory based on the relation of structuration and business cases.

Boundaries of this research

The starting point of analysis for the cases was a material one; we focused on the material outcomes of the project, from which we diverged to the more social layers of the cases by focusing on humans, and trying to uncover how they acted. This could have been the reason that at the visionary session, people felt that a financial component of the cases was missing, and yet crucial to the unfolding of the building process. During the interviews, interviewees where asked about the business cases, however they could not answer these questions in much detail. Two explanations can be given for this: first, financial subjects are sometimes difficult to talk about, since these lay at the heart of a company and this makes it a sensitive subject. Second, due to the materialistic starting point, interviewees where selected that knew at least everything about material outcomes (the Brand layers), not specifically every detail about the business cases driving the project. Third, the choice for the cases influences the results of the research. The cases all had a public character, except for copper8, but they are quire unique in their vision on sustainability. The lack of detail in answers could have been a result from this. It also shows that we are far from the ideal situation described in the visionary session, in which people expressed that it becomes necessary to be more transparent in how a business case is set up, and what values are gained by which party.

In this research, the system optimization/redesign approach is adopted. This resulted in a more inter-organizational focus, we did not take into account specific dynamics inside organizations. In that sense, we may have missed aspects of the redevelopment that played a role in organizations internally. For example, the municipality of Houten had already adopted a vision on sustainability and reuse of materials. We don't know what lead them to this, and how they formed the vision. These where intra-organizational activities that have not been taken into account.

We have also made some statements on innovations, in a more general sense. First, this research shows that not per se a radical change in diversity is needed to cause the innovation in the circular building process. Innovation can also occur by actors stepping out of their own role and emphasizing with other parties. This may be an interesting point for future research: in many businesses, people don't have the time to think and try to be in the shoes of another party. What if people got more time to do so? **An academic recommendation** would be to test the innovative capacity of companies who give their employees a fixed amount of time to occupy themselves with innovation related matters. Second, we stated that incremental innovations in the building sector are inhibiting the system redesign/system optimization. From the cases however, we have seen no clear signs that incremental innovations such as JIT or LEAN become inhibiting for the CBP. This could be explained through the idea that every building project is executed by a new organization, with a different mix of parties. Between these parties, it is not likely that they strive to pursue specific appointments made before start of the project, in different contexts. On the contrary, in some of the cases the control over the supply chain was high, for example in the Alliander case where they could deliver their own materials as input for the building process.

We have made a comparison to how sustainability relates to the Circular Economy. We raised the following assessment by Mentink (2014) and assessed wat the EMF (2013) mentioned on sustainability and could not conclude how the CE relates to sustainability. Based on the cases, and from the visionary session, we can say that the CE has the potential to be properly used in line with sustainable development. The cases show that actors require to develop a vision on resource use, which in most of the situations was combined with sustainability criteria such as decreasing CO_2 emissions. However, one danger lurks, which is that the CE could also be a way to justify unnecessary consumption. In the end, it is consumption that leads to unsustainable practices. It is crucial that actors reconsider their actions. Is this redevelopment really necessary for my organization? Are there other ways to achieve the desired results, perhaps in non-materialistic solutions?

A concluding remark is given concerning the normative character of this research. This research was not about whether or not a Circular Economy is truly a good economy to strive for. Some thoughts have been shared on for example possible losses of jobs, but assessing the most plausible effects of a CE has been beyond the scope. The debate on normative positions is not new in the field of Industrial Ecology (IE) (boons et al., 2000). There has been discussion on the idea that most researches adopt a normative position concerning Industrial Ecology. In reflection, I believe that studying how actors aim to redesign systems should not merely be seen as a support of the CE, it should also be considered important since it teaches us about the systems we as humans have developed, and become part of. Studying how these systems can be changed, is in my opinion extremely important, because we may reach a point in the future where urgency forces humans to perform system redesigns, simply because our self-developed systems might backfire on our wellbeing.

Data collection

The ecological perspective allowed for this research to let go of thinking in the traditional roles of the construction supply chain ("the architect designs, the constructor builds"). Instead, we were able to uncover the core of what needs to happen in a Circular building process by not asking what the architect did, but asking who contributed to the circular outcomes, and what they did. This turned out to be valuable, because it resulted in a good overview of what actors fulfilled which function. However, **academics** using this framework in the future should bear in mind that there is a danger of missing elements of behavior and social structures.

One problem with case studies is said that there is always a context which influences how the case unfolds as it does. That means that generalization, as is done in this research through the cross case analysis, becomes very difficult. This is true for this research. We have only examined four cases, and the cases varied in certain ways, for example

in size. However, the cases did show very comparable functions and activities, which gave confidence in generalizing the functional diversity. Testing this functional diversity with experts also validated the generalization.

The visionary session was organized because the cross case analysis showed that most ambiguity surrounded the connecting through vision function. Also, in the interviews there was an emphasis on vision building. The session was organized with visionary people, since we wanted to clarify this function. This was a conclusion from the cross case analysis. Other functions also resulted in questions, but due to lack of time we focused on the visionary function, becoming quite decisive for the results of this research. We could have also done an ideating session, perhaps to uncover how Ideators can better shape the search for materials to reuse. However, the connecting through vision function is the basis of a project and was therefore more interesting to collect data on.

A final point I'd like to share, is about the comparison with the traditional building process made in this thesis. In some way, the traditional building process has very recognizable elements to it, and on the other hand each building process is unique, executed in a different context and thus one could develop the notion that the traditional building process does not exist. I have seen other graduates struggle with this as well. In some of the interviews I asked interviewees what for them was different in this process than from their usual experiences. They were very capable of answering this question, **so an academic recommendation** would be to ask this question in interviews because the answers are given by the same person who has been interviewed on this special building process. This way, the comparison can be made on the spot.

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APPENDICES

Appendix A

Statements from actors in the building sector, collected form unstructured explorative interviews. The statements are not always made by someone who actually has that function at the moment, but he did once have this position, or has a lot of experience working with the actors from the table.

Actor	Perspective
Developer	"Participating in innovation such as circular economy poses too much risk and generates too little financial benefits to compensate for this (Adriaanse, 2015; Van Geenhuizen, 2015)". "Financial models do not suit the new, required systems-thinking approach to projects. True value due to innovation is not incorporated in the investors and developers excel sheets" (van Geenhuizen, 2015).
Contractor	"Contractors have the time nor capital to invest in innovations such as the CE. They operate in a highly competitive market, where the clients wish is determinant (Veldhuizen, 2015). "Contractors have only recently found a way to give meaning to the sustainability in their activities. Now, a new concept like CE comes knocking on their door. It is not realistic to expect contractors to find a way to work with this concept easily" (Veldhuizen, 2015).
Investor/owner	"Higher risk in projects poses threats on our yield. Investors are responsible for capital owned by others, it is critical to keep uncertainty to a minimum (Adriaanse, 2015)". "Financial models do not suit the new, required systems-thinking approach to projects. True value due to innovation is not incorporated in the investors and developers excel sheets" (van Geenhuizen, 2015). "The investor, or owner, is seen as the highest on the hierarchical ladder. The contractor points towards the owner when it comes to a lack of innovation. The owner then points towards the government for a lack in regulatory activities, resulting in a circle of blame." (Veldhuizen, 2015).
Architect	"The architect used to have an almost sovereign role in construction processes as advisor. This has changed, the power has shifted towards the contractor partly due to new forms of contracts in the construction sector (Veldhuizen, 2015).
User	The commercial user is mainly concerned about three things when looking for space; location, aesthetics and pricing. Sustainability is not considered an extra. In contrary, when a building is perceived as not sustainable, the building is discounted" (Remoy, 2015).
Consultant	"Trust and commitment are crucial to the necessary collaboration required for innovation processes. Practices have learned that parties have to work their way up from distrust, to collaboration based on trust." (Adriaanse, 2015). "Consultants are often required to take a role as neutral third party, to structure and guide the process towards successful collaboration. Trust and commitment seem to be great barriers in circular economy projects". (van Akoleyen, 2015).
Material supplier	"The circular economy is a way of thinking that does not yet prove any value to us yet. Typical forms of circular business models cause our investments to freeze and result in more transaction costs, not to mention juridical difficulties". (Barendsz, 2015).

Appendix B

Visionary brainstorm.

Results Vision 2030: an ideal circular economy in the building sector

Use of building
- Clever use building
- Buildings ultra-flexible
- Each building intelligently transformable to users wishes
- Sensors
- Big data
- Bim with any information about any material in buildings
- Sensors
- Database of raw materials
- BIM including all materials embedded in buildings

Ownership vs. Use
- Less property owners
- Everyone feels responsible for building
- Supply Industry is bought as a service
- You pay for the service and not for the raw material
- There is no property more
- Property -> Use
- Users are owners of their surroundings
- Product will need

Energy
- Building is housing in power
- Trias Energetica not leading; electrcicteitsproductie is no longer a limitation
- Buildings in setting exchange energy with each other
- 0 on the meter buildings
- Buildings as part of electricity system; production, storage etc.

value Creation
- People, planet and profit value creation
- Balance between individual and collective balance between PPP
- Measuring is knowing; also from social and natural values
- Nature at the table in the boardroom
- closed stock projects, value is embedded in other things than money
- Money does not exist anymore

Policy & resources
- Heavy tax on resources
- Politics is mainly about resource allocation
- Consumption is taxed
- Universal database of resources
- Finite resources are not necessary anymore; we only use renewable materials.

Roles & functions
- Contractor becomes materials scout
- Architect becomes curator
- All functions in one company (ie. Automobile sector)
- Industry becomes supplier of services, not products

- everybody can do what he is good at
- Everybody can be what he wants to be

Notes concerning the ideas above
In order to move this transition to a CE, we have to relate the financial aspects to social and natural aspects. People will have to start realizing that values as money, social and natural can enrich a business case. This way, organizations will realize that a higher initial investment will also pay itself later in higher and more values generated, financial, natural and social ones.

Another important aspect of the transition is learning between different organizations and different projects. For example Brummen, a great example, where some parts have succeeded, but others have failed, namely the business case part. This is a great lesson for others.

Next to that, the transition will become much easier if the profits mentioned (financial, social and natural) where able to be quantified, functioning as proof for people who are not yet convinced.

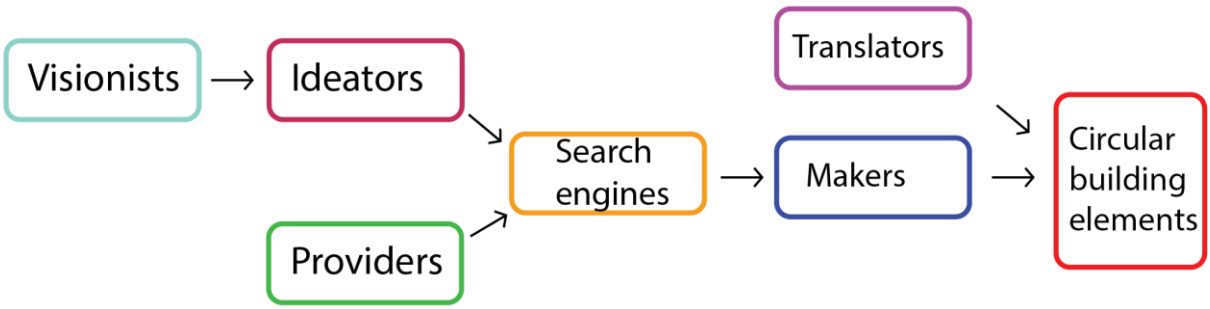
In the end, in the transition we need to become one with nature again and understand that we are part of an ecological system. We keep relying so much on high tech solutions, however we humans are essentially part of nature. This will also result in a system where people do what they are essentially good at. Also, in 2030 Individualism will be something of the past. The individualism has led to huge amounts of depression, fear and burn-outs, it will cost society too much.

In 2030, the contractor has a different role. He no longer manages material supplies. Due to digitalization, production chains can become much smaller and people can manage materials themselves. The contractor could become a manager of values, instead of materials. He could help in managing the integrated business case.

Also, laws and regulations in the building sector will be much more flexible then they are now. Due to certain regulations, some business cases cannot be exploited, as was the case with Brummen.

Appendix C

Functional diversity as presented to participants of the visionary session.



Appendix D

Results Vision 2030: an ideal circular economy in the building sector
Use of building
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- Product will need

Energy
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value Creation
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Policy & resources
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- Politics is mainly about resource allocation
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Roles & functions
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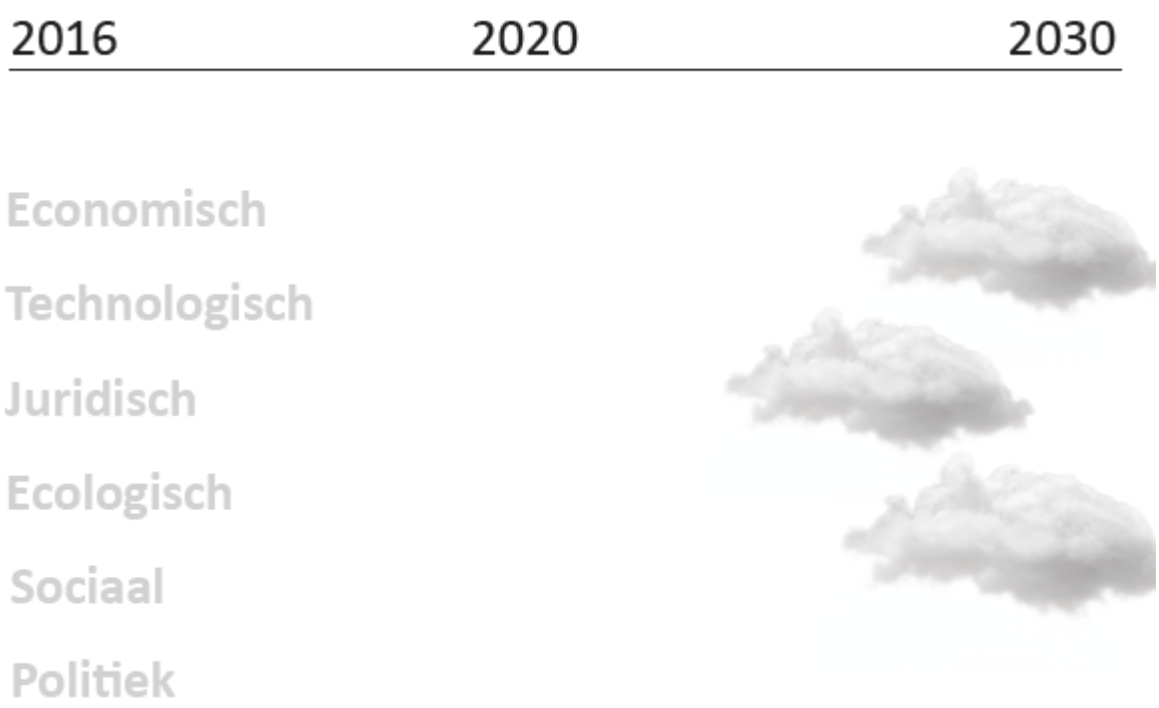
- Industry becomes supplier of services, not products
- Everybody does what he/she is good at

Appendix E

Poster used for participants to write ideas on.



Appendix F

Timetable & preparation visionary session

Preparation:
- put posters on wall. Actors & functions (appendix G), Functions in process (Appendix C), visionary canvas (appendix E), Analysis of cases (appendix H)
- Lunch was arranged
- Enough markers & post-its available
- Telephone with camera
- Voice recorder
- Live illustrator who illustrates some of the ideas discussed (see result in appendix I)

10:00 Welcome by Marije Vos
10:10 Introduction research + results (functional diversity from cases)
10:25 Icebreaker; which of the functions do you fulfill during work, or personal life? Short introduction on people present.
10:40 Validation functional diversity. Do you recognize the functions, are there functions missing?
- Experts were asked to write remarks/thoughts on post-its and put these on posters
- Discussion about remarks

11:10 Break
11:20 Visionary brainstorm; put post it's on visionary canvas with ideas on how the ideal CE would look like in 2030
11:35 Discuss ideas in group; what steps could be taken tomorrow to go towards the vision?
11:50 Break (lunch)
12:10 Synthesis; Considering the results of the vision, are we going the right way? Should we adjust/steer? How?
12:30 Closing remarks

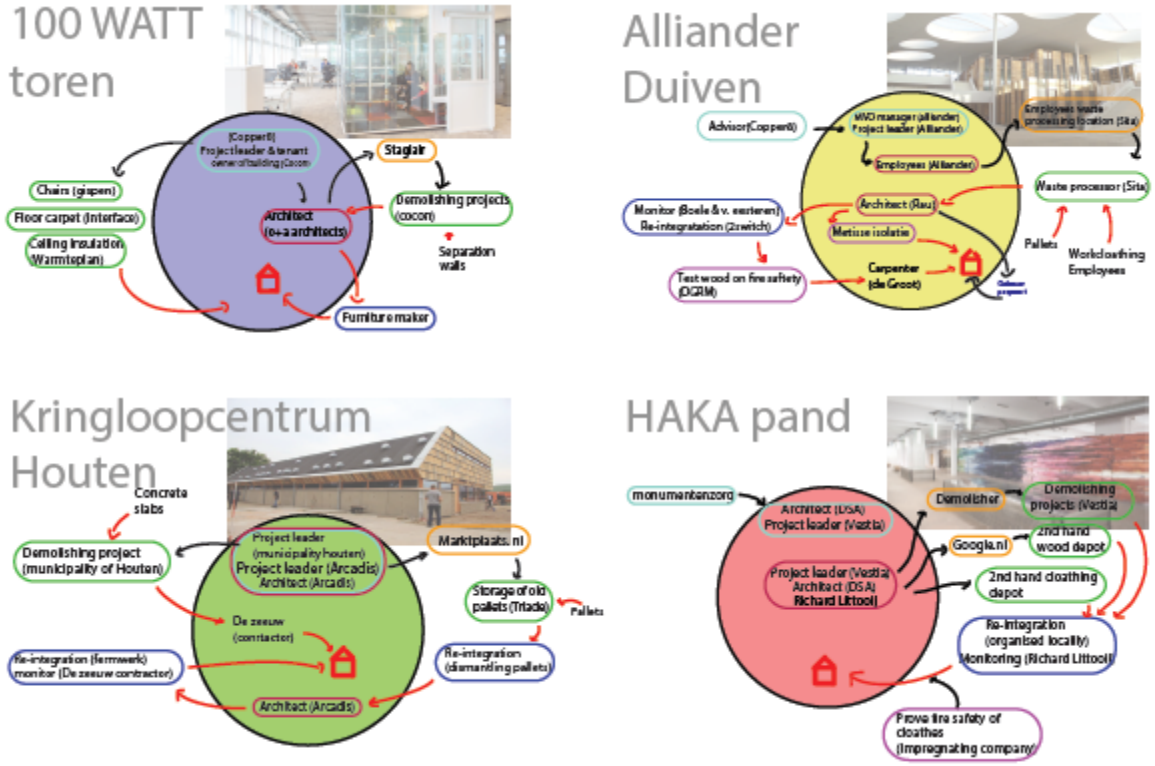
Appendix G

Poster “actors & functions” used in visionary session

Functions	Visionists - Set ambition, lead & motivate team	Ideators - Find materials and design products using these materials	Recyclers - Make usable products from materials	Translators - Translate foreign materials to the language of buildings	Providers - Provide materials to recycle	Search engines - Bring together offer and demand
Actors fulfilling functions						
Project leider	✓	✓			✓	
Architect	✓	✓				✓
Aannemer			✓	✓		
Andere collega's binnen bedrijf		✓				
Leveranciers				✓	✓	
Adviesbureaus	✓			✓		
Minder traditionele actoren						
Her-integratie			✓			
Afval verwerkers					✓	
Stagiar						✓
zoekmachines (eg. marktplaats)						✓
Meubelmaker			✓			

Appendix H

Poster for visionary session: cases and flows of materials & information



Appendix I

Results and posters used in the visionary session

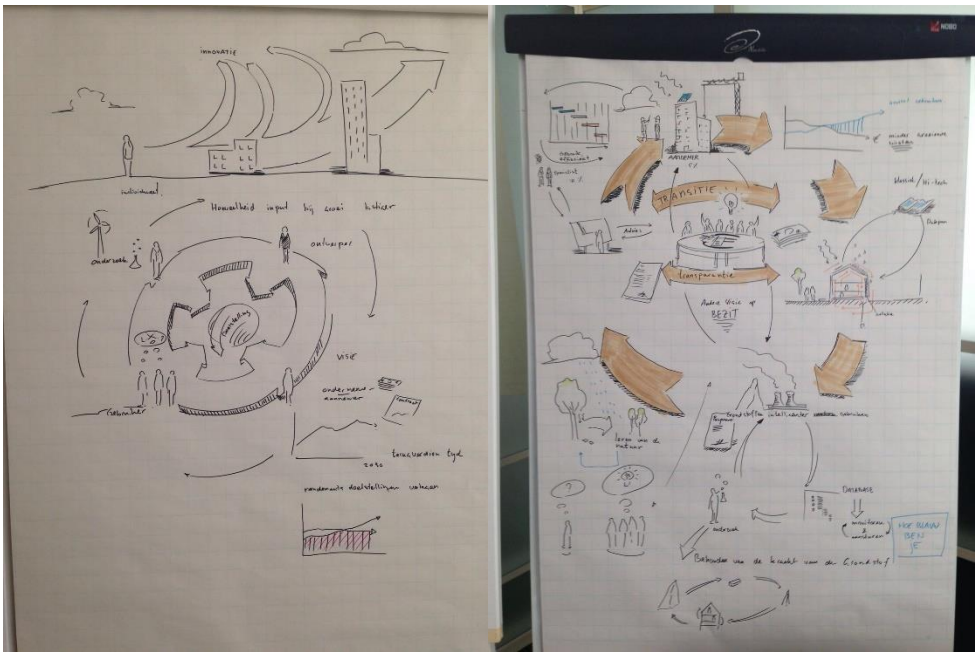


Figure 37: result from live illustrations

Figure 38: Poster functional diversity with comments of participants

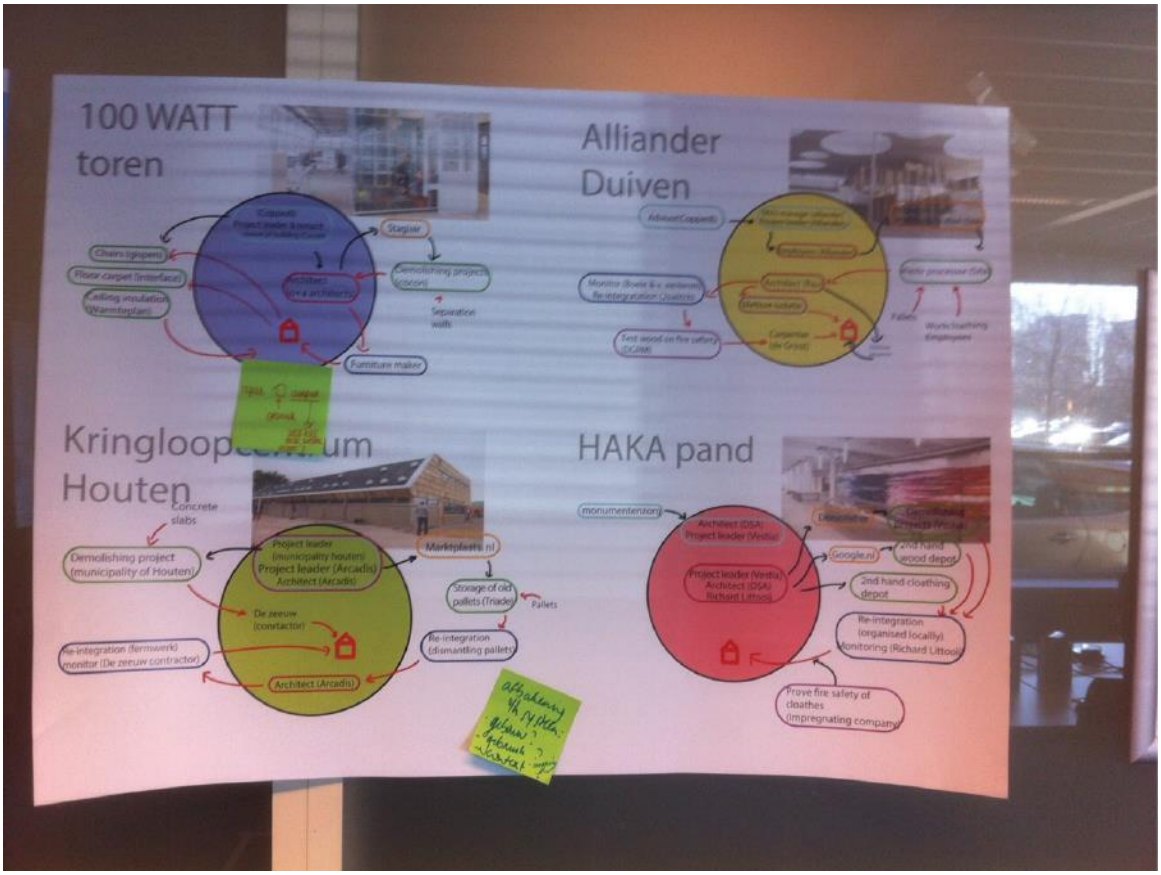


Figure 39; poster cases and supply chains as used in visionary session.

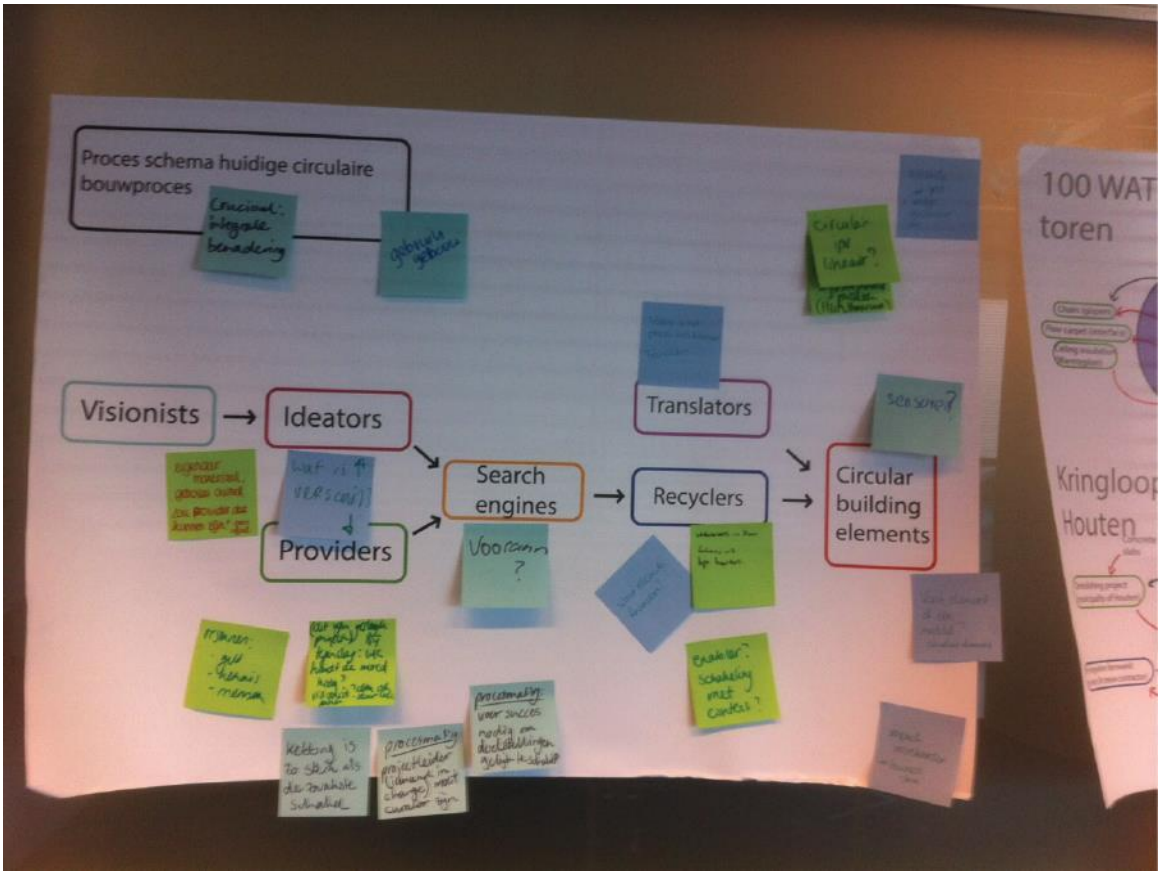


Figure 40; poster functional diversity as used in visionary session.

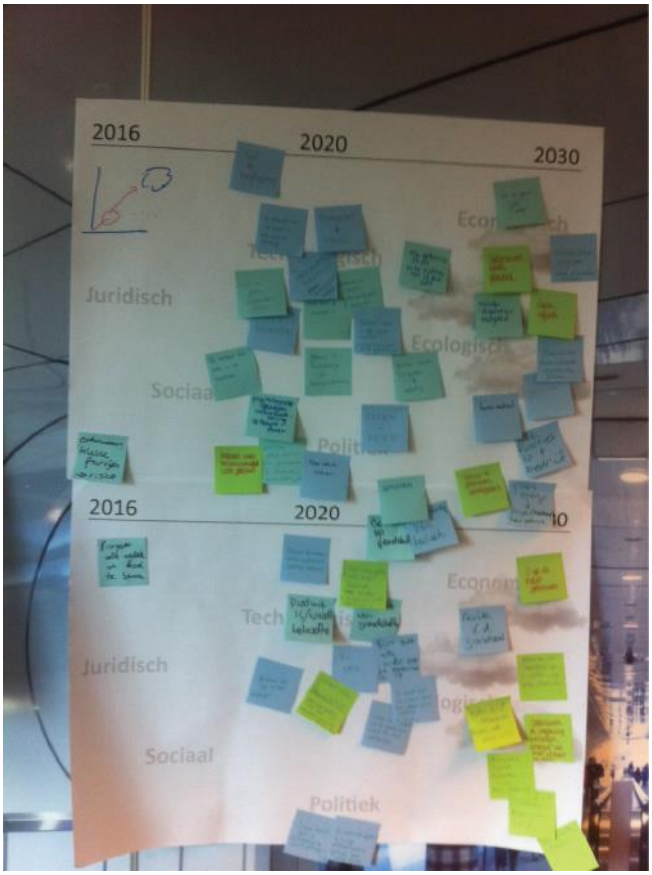


Figure 41: Poster used for visionary brainstorm

Appendix J

Interview report, 100 watt tower with Architect Gus van open, BETA

The architect was consulted for the first time at the moment that the ambition for the circular floorspace had already been established. The architect was asked for his ideas on how to achieve this.

In the process, multiple attempts were made to give materials a second life.

A first attempt was done by collecting as much used IKEA billy bookcases as possible and use these to make a design for storage space. This idea was dismissed by Copper8 because they feared it would a bit of a messy design. Next to that, the functional design for the office space changed, so storage in this way was not necessary anymore.

Talks with Sita where not satisfying, since they could not deliver enough quality materials. Most of it was in a devalued form, such as shredded wood.

After phoning with Cocon, it turned out that they had some demolishing projects going on, from which it was possible to collect materials. The architect's intern got access to the projects and went on site to assess whether or not there would be usable materials. The intern played an important role, since he had the knowledge to asses whether or not certain materials would be good to construct with. The demolisher did not offer much time for storage of materials before they were transported to be recycled. In the end, through this search the separation walls for the office were found.

There was not much interaction necessary between the installation conctractor and the architect. The finishing touches of the project and the installations were quite separated. Except for some hooks in the ceiling, activities did not collide with each other.

A Circular building process requires a different way of working from the parties involved than traditional. Usually, actors can fall back on the known pathways and parties get more flexibility and freedom in choice of materials. However this is different in the Circular process. Parties have to step out of their comfort zone. An example is financial insecurity, what the final costs will look like, but also the role that you play as an architect. Working with used materials creates uncertainties on how the result will look in the end. This requires extra effort to try and visualize the result. Next to that, certain tasks were not in the hands of the architect anymore. For example, choosing the floor covering was done by Copper8, which usually would have been discussed with the architect to mnake sure the entire aesthetics of the floor are guarded. However there was no time for detailed communication due to the pace the project took, next to that the floor covering fits copper8's vision.

However also a contractor will need to be able to step in the shoes of other parties. Traditionally, when a project seems challenging, a contractor will adopt the position; whats never done, will be very expensive to do, or we don't do it. Parties need to avoid this by working under the same goal/ambition. For example realizing a circular office floor, and willing to invest extra under this ambition.

In this project, the contractor also charged a high price for constructing a separation wall with used materials. In order to solve this, a furniture craftsman was hired who made a part of the wall, inventarised the costs for this part, and extrapolated this to indicate a total cost for the separation wall. This turned out to be much lower than what the contractor had calculated. This shows how rarities are directly translated into extra costs by the contractor.

Interview copper8 – Dirk Bijl de Vroe – circulaire inrichting verdieping 8 100WATT toren Amsterdam.

Since their old office location was renovated, Copper8 had to move out and search for a new office. In first instance, they were looking for a ready-to-go office floor. Then they came across the 100 WATT tower in Amsterdam, which was not yet furnished and basically needed carpet, separation walls, services, storage space, furniture and ceiling insulation. This appealed to Copper8, since they could develop the office floor in line with their stance on sustainability and circular economy: everything they do has to be in line with CE and sustainability. When advising clients on sustainability, sometimes you are limited on how far you can push your ambition with the client. Redeveloping the floor you plan to rent makes you your commissioner, so we could go as far as we wanted with our ambitions.

Vision & ambition.

The project started with setting an ambition for the project and setting up a collaboration with other actors under this ambition. The main actor to set up this collaboration with was Cocon, landlord of the 100 Watt tower. Initially, the price Cocon wanted per m2 was too high for Copper8. However, by finding a common interest in the ambition by copper8 had set, they could work towards a win-win situation for both parties. First, Cocon was missing revenue from this vacant office tower. Copper8 wanted to rent this office space, so they found a common interest in this. The price as Cocon had wanted per m2 was too high for copper8. So they needed a solution for this. In the end, a win-win situation was found where the rental price was based on the amount of FTE copper8 employs. If Copper8 grows, they are doing well. Meaning they increase their revenue, which offers them more financial resources for rent. So when the FTE of Copper8 grows, the rental price increases as well. Even

more than Cocon had initially wanted per m2. This results in a win-win situation; when Copper8 is doing well, Cocon is doing well.

Arriving to this win-win situation was initially not easy since the conversations with Cocon started financially driven. Parties tend to think from the existing structures and ways of doing business. Key is to, in these structures, find how they think about other interests then financial ones and how these can be earned. In these talks, Copper8 maintains balance between content, process and finances. When a system is financially not working, it cannot be maintained. Thus, in the end a situation needs to be created where all parties financially benefit from, but it should not be the starting point for conversation. In the end, they found a situation where Copper8 & Cocon could profit from a circular and sustainable, and a financial sitiuation which was acceptable for each party.

Materials

The separation walls are composed out of waste coming from demolishing projects out of Cocon's portfolio. The floor is covered with carpet from Interface (Patchworks; used pieces of carpet put together in a new pattern & Networks; carpet made from discarded fishing nets). The ceiling is covered with pulp from old archive material. The furniture from Gispen is leased, and made out of scrap wood. All the furniture is C2C certified.

The seperation walls are where more difficult to realize since they are not offered ready-to-go by a supplier, as is with Interface for example. The architect needed to find materials to build with. He made use of online search engines, however these did not deliver materials in the quality he was looking for. In the end, he had his intern ride his bike visiting the demolishing projects of Cocon to find materials that could be reused. A difficult situation occurred, since the demolisher did not want to store the materials for a long time. He wanted to know quickly if the materials would be used by the architect. That's why it was of importance that the intern could make a correct estimation of the usability of these materials.

A check for fire safety was not necessary. The stuff used for the separation wall had already been used as a separation wall in the former buildings, and the project was so small that it was not very relevant to check for fire safety.

Copper8 tried also to procure their lights based on the concept "light as a service". This means paying for the light, not for the lightbulbs and structural elements holding the lightbulb. This creates an incentive for the supplier to use materials in such a way that they maintain their value as long as possible. However this turned out to be too complex to realize, since for example payment for electricity was already included in the rent. It was difficult to find out what part of this was consumed through light. Next to that, Cocon already has contracts with the energy service organization. So redesigning this system would take so many stakeholders, it may be too much effort to get this done. Also because most people think, light is light, you hit a switch and it's on. What's wrong with the current system?

Collaboration

The collaboration in a project small as this one was less complex. It is necessary to have the proper communication, for example between architect and installations contractor. They need to be informed about each other's activities. However, it is not necessary to initiate a large scale program concerning integrality/collaboration, not like with Alliander's Duiven office.

Another factor of influence in the collaboration was that the architect is copper8's director's brother. He shares her positions on sustainability and circular economy. Therefor it was not difficult to collaborate under this ambition. They know each other well, which perhaps makes collaboration more natural.

HAKA building, interview Reinder the Vries, project leader from Vestia

Multiple interests where related to the redevelopment of the HAKA building. Next to our own interest to develop the building, monumentenzorg had forced us to reuse as much as possible of the fount materials in the building, in the new design. This means tiles, waterhoses, steel windowframes, etc. Broken windowframes are usually replaced by new once, in stead of fixing the broken frame. However, due to the aesthetical demands, repairing became cheaper then ordering a window frame that is

designed the same as the original design. The design is so specific, that this will become a very costly procedure. We even needed to reproduce errors made in the original details of the building. This was one of the instructions by Monumentenzor*g.* It had to be just like it was designed.

We also had to deal with the municipality, next to monumentenzorg. These are both governmental organizations, but they don't communicate with each other. My role as Vestia's project manager was to satisfy both parties in their wishes. Sometimes building regulations where conflicting with the instructions of monumentenzorg. This causes time delay.

The contractor was Dura Vermeer.

The architect was DoepelStrijkersArchitecten (DSA). They took care of the design of the interior. They had a very clear image of how the design had to be realized. This meant that sometimes they were the ones to do practical work, such as folding the clothing themselves for the separation wall.

On the ground floor of the HAKA building we housed a working team. These were people with a distance from the job market and from probation. This working team needs a different guidance compared to a construction worker. These people have a different way of working, and we found someone able to work in this situation. We hired a superviserr, who guided the team and could help them with interpreting drawings for example. The working team were given materials to reuse, and the drawings of the architect, so they could make products out of the materials.

A satellite organization had been set up that was the contact point for this project. This was due to the different nature of this project from what Vestia is usually doing. We hired external people to man this organization. They handeled exploitation of the HAKA building and the branding.

The working team was also installed through the satellite organization, a person worked there who had the connections to arrange this team. This fulfilled our desire to have the social activity as quick as possible in the building. These people where already working in the area of the Merwe4Havens (M4H), but they did not have a stable office. These people did not pay rent, on the contrary, this was employment so Vestia had to pay the people since they worked (indirectly) for Vestia.

The labor provided by the working team was probably two times as expensive compared to when we would have just acquired new products. This was not anticipated on by Vestia in advance. The costs amounted gradually, and thus you would not notice the total sum in the beginning. However half way through, you realize the amount of money this way of working wil cost and this raises doubt on whether or not things could not have been handled differently. There was no way back; we communicated quite some information about the project publicly through media, so we were stuck the way we were.

Not only the working team contributed to the exceeding costs, also the collaboration with DSA was costly. They had put a lot of work in generating ideas for reusing materials, for which hours where calculated which Vestia had to pay for. The architect is a creative person, sometimes living in the clouds. For example; the architect sees a door and thinks, we can make a bench from the door. However a door is built for vertical forces, not horizontal ones. The architect then spends two weeks, making drawings for these doors as benches, only to find out later that the doors are not strong enough to sit on. This became costly. However, Vestia never expected the project to be profitable.

If we would have ordered regular furniture, which is made in amounts of 1000's at the time, this would have been much cheaper due to the economy of scale. We set up our own production process, from which the production was low. You create some value, but not enough to cover the costs.

Concerning the collaboration with DSA, sometimes this was more tricky then other times. It was difficult to steer DSA towards the right direction. Not only due to their focus on creativity and innovation, but also due to organization from our side. We had multiple people from Vestia working on this and establishing a vision for the project was already difficult enough. If the vision is not clear, it is as well difficult to deliver a clear communication to DSA. Once per week, we had a meeting with DSA, which is more than in usual projects. They would show their ideas and it was up to me to give approval for execution. Unfortunately, disapproval was mostly the case, which did not feel right. You feel as if you block the architect's creativity.

The vision was established by DSA in the beginning. They had the idea to use the materials coming from demolishing projects from Vestia in Rotterdam. Also concerning CO_2 emissions there were certain demands, for example to source materials close by, avoiding CO_2 emissions due to transport.

There was also contact with the satellite organization which was set up for the HAKA project. The contact went via the supervisor. At some moment, we put some more pressure on the working team. We started setting deadlines, saying we need to have product X finished by a set date.

Contractor Dura Vermeer and installations contractor Imtech were also working in the building during the activities of the working team. Every now and then there would be contact between the working team and these contractors. The contractors would bother with the working team when they saw that they were doing some things the wrong way, for example when they were using a faulty screw for a piece of furniture. They would teach the working team what to do. Sometimes the contractors would even lend equipment to the working team. This was then used, however sometimes not properly given back to the contractors, after which they needed to look for these tools. This caused minor conflicts but where not a barrier for the process. The contractors also gave materials to the working team. For example they would order pieces of pipe, but they needed a specific size of pipe, which meant cutting off part of it and leaving a piece behind. This was then given to the working team.

The wood for the furniture came from demolishing projects of Vestia in Rotterdam, from an area called de Burgen. A whole neighborhood was being demolished over there. During a meeting, someone from Vestia had the idea to contact the demolisher and retrieve materials. The demolisher was willing to work with us and put aside an extra container with materials we could reuse.

The wood for the podium came from a brickfactory, which was found by the working team supervisor

The seperartion wall required larger pieces of wood which were more difficult to find from demolishing projects. DSA found someone in Rotterdam who runs a second hand depot for building materials, which is where the good pieces of wood where found.

The clothing for the separation wall were found at a second hand clothing depot in the M4H. This was an idea of DSA. They were looking for a solution to improve the acoustics of the building. Textile is a good solution for this. DSA presented the idea and this was approved by Vestia.

Availability of materials has not really been a problem, there were not a lot of moments that we had to wait for new materials to be delivered.

The municipality had caused some delays. They would check the separation wall for fire safety. In order to do this, you would need to impregnate the clothing with fire trading substances. This was not enough for the municipality; they wanted to have the guarantee that the substance was also tested on clothing. Eventually we had to ask the company who makes the impregnating substance to send a letter, confirming that it had been tested properly on clothing, so that the municipality was guaranteed of fire safety.

The municipality has a document which displays combinations of frequently occurring building materials which are pre-checked for fire safety. If one of the materials found in the HAKA building were not displayed in the book, then the whole element or product this materials is part of, is not approved. Because of this, we had a time consuming process of getting materials approved by the municipality. Even if you look at the type of material and know that it will not cause major issues, if the material is not in the book, they would not approve.

Concerning the working team; we needed to have cheap and flexible labor. A construction worker would have never been suitable for this job. He is too expensive, around 45€ per hour and is used to work fast and efficiently, which does not match this labor which embodied many deviations in design and flexibility. The working team cost about 10-15€ per person per hour. They would however take 4x longer on one chair, compared to an experienced person. The fact that we had the working team supervisor to steer the team is of importance, without him it would probably even been a slower process. He knew that he should pay attention to how a materials would be used for a design. Working with material with different qualities from a new material requires special attention, since you have to be critical in what can be used, and what materials cant be used.

The core team was Project manager 1 (Vestia), Project manager 2 (Vestia), DSA & working team supervisor of the sattelite organisation. Everyone had his own vision to the project which in the end was melted into one vision working best for the whole team. In our weekly meetings we spoke about Dura Vermeer, Imtech and the working team. We had to settle small issues between the teams. The contractors took a flexible position in this.

We also had some ideas that where failed. A part of the building could be used or energy storage, in an old silo. This was too much of an investment and too much risk. We also had to discard plans of DSA, for example using old doors for a podium, which cannot carry the load.

In the end we all worked under the same ambition, which was realizing a beautiful ground floor. We had a diverse team with different backgrounds and experiences. One person was specifically focused on technical quality of constructional aspects such as the ground floor and the façade. Project manager 1 was mainly steering the process and guarding the quality of this process. However without guarding the quality it seemed to work fine as well. Project manager 2 was Crucial, he was very compelled to the project and could transfer his vision to others in the team. He was very convinced of the added value of working with reused materials, and this enthusiasm spread over the team. There was no other person in Vestia who could handle this job the way Bas could.

A couple of lessons learned by Reinder de Vries:

- Involve the municipality in your plans, from the beginning. The role of the municipality turned out to be focused on looking for unsafe things in the building and everything that seemed unusual was marked unsafe. Involving the municipality in the process could have helped.
- Coordinating three teams (Dura Vermeer, Imtech and the working team), is a tiring process. If possible, steer the teams from the location. Not decentralized.
- Coordinating the people from the working team needs to be done by someone who knows how to inspire, possess technical knowledge and drive to help unskilled people out. Patience is obliged while doing this.
- Designs have to be functionally specified. You need a design for which the materials still need to be found.

Interview HAKA building with Eline Strijkers, DoepeStrijkersArchitecten

Vestia had contacted us about our ideas concerning the HAKA building. We already had many ideas on the building and how it could connect with the context. Next to this, we try to adopt circular principles in all of our project, as well as the HAKA building.

Vestia wanted to redevelop the building as quick as possible, and we came up with the idea of reusing as many materials as possible, both found inside the building and in the MerweVierHaven area. We wanted to combine the CE though with sustainability. This meant that we were only going to reuse materials that were found locally. Driving too far for reusing materials is not usefull, since you will be putting pressure on the environment anyway.

Vestia had set up a working team that over the course of two years, had made products our of reused materials, for which we made the designs. The team was not very skilled and thus we made designs as simple and repetitive as possible.

We as an architect were struggling with communication how the project would look like in the end to Vestia. Of course, they wanted some sort of idea of how the office would look like in the end. This is however very difficult, if you have no idea of what materials will be used in the end. This requires flexibility from both the commissioner and the architect.

Interview Alliander with Frans Wielemaker, project leader at Boele & van Eesteren (contractor).

Frans Wielemaker is project leader at Boele & van Eesteren (B&vE). He has been responsible for the redevelopment of the Alliander office from the contractors perspective.

B&vE was part of the winning consortium of the Tender published by Alliander. We were able to distinguish ourselves from the rest since we had an impressive ambition of 80% reuse of materials. This ambition connects to the image that Alliander wants to expose to it’s clients. They connect with societal values and that is what Alliander wants to invest in. The consortium has tactically responded to this. Copper8 has conducted interviews with the winners of the tender to zoom in on their personal motivations concerning working on adding societal value. For me it was not an issue to be interviewed. I believe I can step in to someone else’s shoes and imagine what counts for someone else.

The 80% reuse could be reached by reusing the existing buildings. The waste materials coming from the existing offices were stored on building site to be reused in the new building. The location was suitable for this, there was enough space for storage of materials.

A condition to the success of this building process was the collaboration with decision makers of other working groups. Good collaboration is not for sale, you need to work on this to establish it. The integral approach of this project was necessary to shorten the duration of the building process. Different parties could work on different parts of the construction, without winding up in unforeseen situations. For example, Alliander would focus on the furniture of the building in terms of reuse, while B&vE focused on the reuse of materials in the construction of the building. This was possible because we were working as a team, under the same vision.

The role of the contractor is not much different in the process than usually. You follow the known paths as much as possible to get things done. Important is that once good ideas come to table that support the vision, we were able to quickly execute these ideas. This was possible in the consortium: VolkerWessels and B&vE basically work as one company. We have all disciplines of the building process under one roof, from project development to carpentry. The lines are short, we do not have many organizational layers and decision making is not conflicting with for example shareholders. This is different to for example BAM and Heijmans, where the organizational layers work a bit more muting.

The following factors were of influence on the success of reusing materials:

- The original building was well maintained, which gave a push forward to reuse materials.
- (inner façade wood) Using the labor of 2switch (people from re-integration) gave us the possibility to establish a low price per m2 façade constructed: €20 compared to the €60 per m2 for the newly constructed wood on the outside façade.
- We could guarantee quality of the reused wood on the façade due to the fact that we are also responsible for the maintenance of the building. If a wooden board falls from the façade, we go to the recycling center and grab new wood.
- The fire department was early involved with the building process. This made it possible to look for fire safety solutions together. Doing this prevented ending up in unforeseen situations.
- We were able to set up our own production process of the façade. This way it was easier for us to ensure the quality of the wooden façade, since we developed the façade from sourcing materials, to mounting it to the façade.

Concluding; the most important of a CE project is a commissioner who supports the ambition.

Interview Alliander, with Eugenie Knaap (project leader, Alliander)

This interview is a summary. It focusses on the reuse of materials, which was an ambition for the redevelopment of the Alliander office in Duiven. An important remark is that the integrality of this building process was key. Reusing materials was not the only ambition and its success is due to its connectivity to other ambitions.

Five ambitions were set for the redevelopment:

1. Circular economy; for the building, building process and terrain.
2. Energy positive; minimalize energy use, smart applications of energy generation.
3. Future-proof and function specific working places.
4. Setting up alliances with the surrounding organizations. By collaborating with the neighbors, you can achieve more than by yourself.
5. The integrality of the upper four.

From the beginning we wanted to avoid a segregated building process which marks the traditional way of building. Integrality opens doors when it comes down to circularity. This was realized by publishing a tender, on which parties could only react through forming a consortium. The tender was not very detailed. It mainly consisted out of Alliander's vision on a building project. The winning consortium was RAU, Boele & van Eesteren (B&vE) and VolkerWessels.

An example of integrality result is the roof over the reused buildings. Since this roof functions as a protection to climate, it allowed us to reuse wood in the façade under this roof, due to lower quality demands.

To generate ideas for reusing materials we set up an expert team consisting of Alliander employees. They were responsible for the idea of visiting the recycling center of SITA and looking for materials which could possibly be reused. This is when we realized that a lot of waste is coming from our own primary process, such as a lot of used pallets, which were sent for incineration by Sita. We could prevent these CO_2 emissions by giving this wood a second life in the building,.

Now that we know what materials we want to reuse, the contractor has to work with this. This is difficult, because he is used to ordering wood directly from a supplier. Now, there was an enormous pile of wood pallets that needed to be dismantled. This was done by making use of a service called 2Switch, who deliver labor consisting of people who are re-integrating in society. Under instructions of B&vE, these people have dismantled the pallets and cut them in a usable length for the façade. In the end, carpenter De Groot & Vroomshoop mounted this wood to façade elements. This was difficult for the carpenter since he could normally guarantee a certain material quality. They are not used to their commissioner also becoming their supplier.

The wood on the facade also needed to be fire proof. Due to this unusual situation of reusing materials, we included the municipality and fire department from the beginning, not just for the wooden façade but also other aspects related to the redevelopment. In addition we hired DGRM to test the fire safety of the façade. By doing this we eventually succeeded in doing what we wanted; closing material loops.

We didnt just want to invest in a new building, we wanted to do something which is smart considering the future. From this perspective, it does not really matter what financially happens after one year of exploitation. By anticipating to the future, which we did by constructing a building that can be dismantled after 15 years, we will be cheaper off in the end. This gives flexibility to the consortium to look at the financial aspects from a different angle.

Another important aspect was the mindset which people had when collaborating in a project like this. Sustainability has become a buzzword and people have given their own definitions to it. One idea may be sustainable according to one person, but the same idea may be perceived as completely unsustainable according to another. Thar's why it is important to establish a shared mindset in the beginning of the project with the consortium. What do we agree is good, and what do we agree is unsustainable. Parties where selected based on how they replied to our vision, so this helped in generating a shared mindset.

Next to reusing wood for the facade, we recycled working clothing of our employees in order to product insulation material. This was applied to the middle building under the roof, since this offered better climatic conditions which made the lower RC value not an issue. Acoustic demands where made, but it would not have conformed to lower outdoor temperature demands. Using these working clothing we wanted to tell a story. We wanted to show how material from your own primary process can become a source of materials for your building. Applying this is an interesting example of closing materials loops. We did not have enough for all buildings. At some point you have to say, this is enough and we go further. Telling the story was more important here.

Concerning sustainability, we encountered an interesting issue when we were aiming to build according to BREEAM excellent. One of their criteria, is to use watersaving toilets. But we reused toilets from the old buildings, which weren't water saving. We however find it better to reuse the toilets instead of buying new, water saving ones. This is an example of where the structures of BREEAM collide with applying CE princpiples. This was also a reason to ask ourselves, should we go for BREEAM? In the end we developed our own ambition.

Concerning the roof, which can be dismantled in the future, what matters most is that you give people the opportunity to do something with the materials in the future. Because we used specific nails for the roof, it can be taken apart easily. Then people can do with the materials what they want. We are not deciding on this now, because this also closes off other possibilities.

An important moment in time was when copper8 had asked us, how does the proejct connect to your vision, your conviction of how it should be? Is a new building the solution to this? This is when we realized we have responsibility to show the good example to our clients. Idea's for a new office tower where swept away from the table and we started looking at other ways to create the environment we need for our employees.

Finally, it turned out to be essential that there where enough people involved with an intrinsic motivation which connects to the way the rest of the team feels about sustainability. In advance, people had ideas concerning the opportunities the project had to offer, and we were all convinced that this was something special. This motivation is the basis needed for a succesfull project. In contrary to an ambition resting on a list of points that have to be dealt with.

Details from interview Houten, with Han Eijbergen and Jeroen Eulderink (project leader and architect Arcadis). This was written on the post-its

Actor	Contribution
Gemeentewerf	Hout mocht gezocht worden(veldonderzoek)
Contractor (de Zeeuw)	Bereidheid werken met hout
	Inzet mensen werkvoorziening begeleiden
Ferm Werk	Arbeid aanbieden voor hout op gevel brengen
Hoofd beheer Gem. Houten	Bereid risico te nemen in beheer/onderhoud
Project manager municipality	Connecties voor 2e hands materialen verzorgd
Alderman Municipality	Willingness to take risk
Architect Arcadis	Ideeën voor materialen om te hergebruiken
	Onderzoek naar locaties voor materiaal
Triade	Sloophout van pallets leveren voor gevel
	Arbeid leveren voor het bouwklaar maken van materiaal
Projectmanager	Vinden van hout op marktplaats
Marktplaats	Aanbieden van hout op marktplaats
Construction specialist (Arcadis)	Kennis hout en waterafdracht
Facility manager recycling center	Bereidheid risico te nemen

Appendix K

Summary visonary session

Business case

The business case as we know it has to be made in a different way; it has to be designed over a longer period. When making the business case, we consider the following things (in context of Tropicana):

- Entrepreneurs should share the same value's (Blue entrepeneurs)
- The owner of the building is not only the owner of the materials, but also owner of the concept behind the redevelopment. Thus; the activities of several companies in the building will enrich each other.

This way, a system is created where flows of people, information and materials fit together, making it easier to exchange these flows and generate value for each other. A new role is needed; this is the role of someone who clarifies this for actors in the building process.

In addition, an increase of collaborative strategies are being created amongst parties before the building process. A collective vision is needed in order to realize a collaboration like this. Therefore, each participant in this vision building needs to be a Visionist. Unless someone has enough hierarchy or another form of power to push certain ideas through. Another way to establish this, is if users collectively wish for certain values to be adopted in their building.

These collective strategies require that the eventual users (blue users) become responsible for the exploitation of the building. This way, the business case becomes an integral business case for several users in the building. This stimulates innovation as well, since the business case is shared, the diversity of people involved can come up with ideas to strengthen the business case.

This integral business case requires an integrated building process, not like a traditional building process. Actors have to be able to step out of their role to deal for example with recycled materials. Additionally, transparency on the business model intended by organizations when going for an integral business case is necessary. And it has to be clear what the profit for the parties will be, and how this profit will be shared, both financial, social and natural profits (better environment for example). This requires a different mindset of actors involved. It requires a broader perspective, covering at least the whole life cycle of a building.

We need to get rid of the old “chain-thinking”, where organizations don’t realize they are part of a larger production chain, each influencing each other. Instead of only thinking of your organizations performance, think if the common performance of the chain as a whole. This would change the perspective radically.

Visionary thinking (2030)
In order to move this transition to a CE, we have to relate the financial aspects to social and natural aspects. People will have to start realizing that values as money, social and natural can enrich a business case. This way, organizations will realize that a higher initial investment will also pay itself later in higher and more values generated, financial, natural and social ones.

Another important aspect of the transition is learning between different organizations and different projects. For example Brummen, a great example, where some parts have succeeded, but others have failed, namely the business case part. This is a great lesson for others.

Next to that, the transition will become much easier if the profits mentioned (financial, social and natural) where able to be quantified, functioning as proof for people who are not yet convinced.

In the end, in the transition we need to become one with nature again and understand that we are part of an ecological system. We keep relying so much on high tech solutions, however we humans are essentially part of nature. This will also result in a system where people do what they are essentially good at. Also, in 2030 Individualism will be something of the past. The individualism has led to huge amounts of depression, fear and burn-outs, it will cost society too much.

In 2030, the contractor has a different role. He no longer manages material supplies. Due to digitalization, production chains can become much smaller and people can manage materials themselves. The contractor could become a manager of values, instead of materials. He could help in managing the integrated business case.

Also, laws and regulations in the building sector will be much more flexible then they are now. Due to certain regulations, some business cases cannot be exploited, as was the case with Brummen.

Appendix L

Explorative activities

In order to explore the market in CE context, several events have been attended. The aim of attending these events consists of two parts; one is to explore how people in practice regard the implementation of CE in their business and what barriers they run into. Second is to gain contacts that could be of value during the rest of this research and afterwards. The connections made could be used in order to find suitable case studies.

1. 07 – 09 – 2015

Trough Arcadis, I joined the Green Deal Circular Buildings. The aim of the green deal is to analyze 6 pilot-cases on how they could be made more circular. Each case has a case-holder and a team of experts joined the green deal in order to finally aim to successfully apply the CE concept to the case. I have been assigned to the case of ABN-Amro, which wants to make their Eindhoven office circular.

Result; Found a contact at Alliander who could help me finding the right people to interview concerning the Alliander office transformation in Duiven.
Result; Experienced by own eyes how difficult it is to work together with different parties on a topic that is so broad as CE.

2. 23 – 09 – 2015; **Minuting the round-table expert meeting at Circle Economy**
   For the non-profit organization Circle Economy (http://www.circle-economy.com/?lang=nl) I have joined round-table meetings with key-figures in the industries that are required to take action to implement CE. My role was to record the meetings and report this back to Circle Economy. This meeting was focused on the infrastructure sector of Holland. The Port of Rotterdam facilitated this meeting by lending a boat and explore the harbor of Rotterdam, while discussing about the CE.

3. 07 – 10 – 2015; **Minuting the round-table expert meeting at Circle Economy**
   For the non-profit organization Circle Economy (http://www.circle-economy.com/?lang=nl) I have joined round-table meetings with key-figures in the industries that are required to take action to implement CE. My role was to record the meetings and report this back to Circle Economy. This meeting was focused on the built environment and was held in Amsterdam.

   Result; gained contacts with the municipality of Amsterdam and have set a meeting to get to know each other and talk about my research and how this could help the municipality of Amsterdam

4. 09 – 10 – 2015; **Inspirational session organized by Copper 8**
   Inspirational morning session at Copper 8 (http://www.copper8.com/ in honor of the "day of the sustainability". Copper 8 is involved with several CE projects, including the Alliander office in Duiven and they have transformed their own office according to CE principles.

   Result; found their office as a suitable case to study for this research. I am now exploring the possibilities to use their office as a case study

5. 01 – 09 – 2015 - still running; **Help setting up a CE product for Arcadis**
   Within Arcadis I have been involved in setting up a product for municipalities that aims to support them in the transition to a circular economy, as well as in the industry as in buildings. Together with colleagues from Arcadis Belgium and Holland, we have improved the product that we offer.

   Result; was able to use knowledge on Industrial Symbiosis as inspiration for setting up this product. This turned out to be an opportunity to couple scientific knowledge to practical solutions.

6. 01 – 11 – 2015; **Set up a blog**
   Set up a blog during this research. The goal is threefold; To keep the people updated about this research that have helped me with information gathering on the CE topic; To be able to translate some of the scientific writing to a style of writing that connects more to the practical, business side of the CE; To be able to critically reflect on practical examples in the market regarding the CE, for which there is sometimes no room in the research itself.

7. 29 – 10 – 2015. **Facilitate a brainstorm on the sustainable transformation of the Arcadis Office**
   Within Arcadis, I have offered to guide a brainstorm on the transformation of the Arcadis office in Amersfoort. A group of 15 sustainability experts will try and come up with the best ideas to sustainably

transform the office. I will use this to explore the possibilities of implementing the CE concept in the transformation of the office.

Explorative interviews

Below are summaries of interviews held with The interviews have been heavily condensed. There may be information given in the interviews, which is not written down here. This information is mostly used to explore how stakeholders regard the CE in the RED sector and get a feeling for what people think are the barriers to implementing CE.

Wouter Spekkink, 02-09-2015

Coordinating activities become more part of IS these days. In harbor activities in Rotterdam for example, some IS developments took place due to a public party that was responsible for the administration of the activities of industries in the harbor. It was a small extra step for the public party to assess whether some of the activities in the harbor could be combined to form IS. They facilitated conversations between companies that could be possible future partners. It is important however that these parties take the leading role. If the facilitating party becomes leading, the companies could miss the incentive to continue together. The coordinating activities are usually applied at larger geographical regions, or larger IS development programs. This to compensate for the complexity of the network. It is however unclear if with smaller IS programs coordinating activities are necessary. Perhaps these companies can do it by themselves. Or maybe coordinating activities could speed up or smoothen the process.

Bob Adriaans, 02-09-2015

A common problem in the real estate sector is to organize collaborations between different parties. It seems an enourmous challenge to guide companies from a relationship of distrust, to a collaboration based on trust. This often fails when only one company in the group chooses to go for own profit instead of collective profit.

Erik van Veldhuizen, 04-09-2015

Contractors operate in an extremely competitive environment. This gives them very little room for innovation. They are usually not the one to be able to set the ambitions of the project, this is done by the commissioner. Therefore, contractors point at commissioners that they are responsible for innovations as CE, however the commissioners then blame the government for not enforcing rules. Architects used to lead a construction process. They were seen as "building process masters". However these days have changed. Now the contractor has more influence on the design. Contractors have just gotten used to the sustainability concept. They finally found a way to deal with this and maybe even be able to use it in their advantage. And now a new, broad and difficult to understand concept as CE comes around. They are not in the position yet to act on this concept.

Niels van Geenhuizen, 04-09-2015

The circular economy offers a great potential for companies to be innovative in their resource use. However, the financial values of CE are hard to grasp. They are not yet visible. And if there is no financial gain, there is no reason for companies to innovate on a this theme. A solution could be to design a financial model of building valorization, which could be integrated with the CE principle. In that way, values that can be created through CE, can actually be made visible in the real estate developers excel sheets.