Circular Economy in Business Modeling: An investigation into the Danish Building Industry

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Abstract in English

This master thesis explores the current applications of sustainability within buildings. The findings assists in developing transition strategies for businesses and their networks moving towards meaningful circular economic practices. These applications and strategies are necessary for Denmark and other nations in transitioning toward achieving the Paris Agreement goals in combating climate change. Denmark's goals to reduce greenhouse gases emissions by 20% by 2020 are on track [Svendsen and Tang, 2018]. However, as a global spearhead of sustainability Denmark has great potential in also leading the world into the circular economic movement by pushing the envelope on what's possible and exhibiting how it's possible, why not when Danish companies are already internationally at the forefront of innovation for circular methods in construction [State of Green, 2019b].

Theoretical concepts of sense making theory and actor-network theory are used to assist in understanding the current market and in creating recommendations for development to circular economy within the industry. This involved collecting possible solutions between stakeholders within the industry through empirical data collection (interviews and gamification) at the Aarhus Building Green Conference 2019. Data was analyzed to gauging the depth of understanding, eagerness, wariness and approach-ability to sustainable applications within the industry. The result of the empirical data collection created the framework of feasibility in encouraging sustainability and circular economy transitions within business models makeovers as a strategy for change.

Acknowledgments

Thank you first and foremost to ***Arne Remmen*** our supervisor. His unending supply of interesting literature, critical observation and flexibility made the thesis writing experience rewarding. We could not have accomplished this without his knowledge, direction and thoughtfulness.

Additionally, we would like to thank all of the interviewees at Building Green for being amazing participants and open-minded to playing games with us. Without their contribution there would be no substance to the results of this work.

A special thanks is extended to Jesper Sørensen from Rexcon who providing the case for the CEBM modeling and was very engaged with our process and questioning.

Abstract in Danish

Dette kandidatspeciale er skrevet som afslutning på masteren Environmental Management and Sustainability Science.

Dette speciale har til formål at undersøge nuværende initiativer af bæredygtighed inden for den danske byggeindustri. Resultaterne assisterer udviklingen af for cirkulær udviklingsstrategier til danske virksomheder og deres netværk. Disse initiativer og strategier er nødvendige for, at Danmark kan opfylde klimamålene fra Paris-aftalen i bekæmpelsen af klimaændringerne. Danmarks mål om at reducere drivhusgasser emissioner med 20% inden 2020 er godt på vej [Svendsen and Tang, 2018]. Men som en af verdenens førende indenfor bæredygtighed har Danmark stort potentiale for ligeledes at sætte et eksempel ved at skabe en cirkulær økonomisk bevægelse der skubber grænserne for, hvad der er muligt og hvordan det skal gøres. Og hvorfor ikke når danske virksomheder allerede internationalt er på forkant med innovation af cirkulære metoder i byggeriet [State of Green, 2019b].

I nærværende speciale anvendes teoretiske koncepter i form af teorierne sense-making teori og actor-network til at forstå det nuværende marked i den danske byggeindustri, samt skabe anbefalinger til udvikling af cirkulær økonomi inden for branchen. Dette involverer dataindsamling af bæredygtige og cirkulære løsninger fra interessenter i branchen gennem interviews og gamification på Aarhus Building Green Conference 2019. Data analyseres for at undersøge industriens forståelse, iver og modtagelighed for bæredygtige iniiativer inden for branchen. Resultatet af den empiriske dataindsamling vil derefter skabe rammerne for fremmelsen af udviklingen inden for cirkulære forretningsmodellerne som strategi for forandring.

Preface

Disrupting industry, a human responsibility

The need to disrupt linearly directed industry and address climate change is evident. The American Meteorological Society published a report that showed of 131 climate change papers investigated 65% of them concluded human activity was the key factor in contributing to the relative climate change under study [Heering, 2018]. What promotes humans to industrialize in a linear instead of circular way? Theories suggest this is the result of human detachment from ecological contexts and that a more ecological hermeneutics approach to the use of technology could be a solution [Keller, 2019]. The extent of human influence on the planet has scientists debating whether it is time to move from the Holocene era into the Anthropocene era due to the geological influence industrial activities are having on the planet. An epoch defined by manufactured landscapes, domesticated chickens, nuclear technologies, mass extinction and world wide plastic pollution [Carrington, 2018].

In 2018 and 2019 climate change expressed itself through a 0.4% world average temperature increase [The Copernicus Programme, 2019]. Australia experienced its hottest month on record, Canada and USA experienced dangerously low and unusually wide-spread cold [The Copernicus Programme, 2019] and in February 2019 Denmark recorded the highest-ever winter temperature since 1873 [The Local, 2019]. The earth is experiencing prolonged intense heat leading to intense wildfires in some locations and heavy precipitation leading to flooding in others [World Meterotological Organization, 2019]. The time to change behaviour and disrupt industry is now.

The development of cities has been most impactful in association with climate change. The extracting, processing, producing and providing of goods to satisfy human demand is unprecedented by any other single industry. PACE quantified that 92.8 billion tons of resources were being harvested a year [De Wit et al., 2019]. To illustrate this, Figure 1 shows time vs. material extraction rates. Mass of waste is measured in gigatonnes, value is measured in Gross World Product (GWP) in trillions of Euros (€Tn) and carbon emissions is measured in equivalents in gigatonnes ($GtCO_2e$). Over the last four decades all values increased and projections towards 2050 show the rate of extraction possibly accelerating, the shaded area shows a widespread possibility of where the future may lead. Carbon emissions may entirely drop and result in meeting the Paris Agreement, however, there still remains a possibility of emissions increasing.

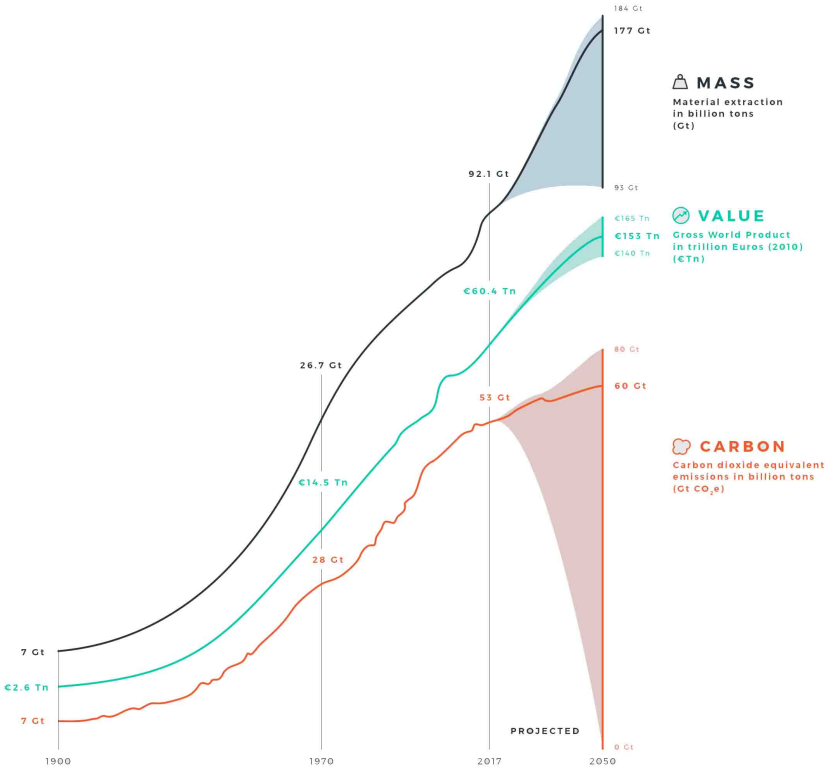

Figure 1: Development from 1900 - 2050 in terms of Mass(Gt), Value Creation (GWP) and Green House Gas Emissions ($GtCO_2e$), [De Wit et al., 2019]

In 2018, only 9% of 92.8 billion tonnes of elements, minerals and resources were being used in a circular way [De Wit et al., 2019]. One half to a staggering three quarters of the inputs harvested for use were returned to the environment within the course of a year and the reuse of secondary materials has been less than 2% [Matthews et al., 2000], tertiary uses are uncharted. Recycled content of buildings needs to increase from the current 10-13% being recorded worldwide today to help close the circularity gap [De Wit et al., 2019]. Additionally the method of supply ordering needs to be addressed, 60 Million tones of product in the UK alone were wasted due to over-ordering building materials meaning that these products were not used even once before being land-filled [Holmes, 2016].

The building industry is the primary contributor to the factors that fuel resource challenges. Here is how, the urban environment is responsible for up to 80% of global energy consumption, 75% of carbon emissions and over 75% of the worlds natural resource use [De Wit et al., 2019] and yet buildings take up only 3% of the worlds total dry surface area [Circle Economy et al., 2018]. The demands on the building industry result in almost half of all materials passing through the global economy each year and $1/5^{th}$ of total carbon emissions [State of Green, 2019a]. 85% of the buildings needed by 2050 have already been built, those buildings contribute 40% of total global energy consumption and 36% of total global CO_2 emissions [State of Green, 2019a].

By 2050 these numbers are projected to increase due to four main factors: 1) growing world population, 2) urbanization, 3) growing middle class and 4) displacement caused by environmental factors [Stern, 2006]. The UN projects world population to increase to more than one billion people within the next fifteen years and by 2050 to rise to 9.7 billion [United Nations, 1385].

Secondly as of 2019, 55% of worldwide population resides in cities, by 2050 that number is estimated to rise to 68%. This means that 2.5 billion more people could be living in cities by 2050 [Department of Economic and Social Affairs, 2018]. Thirdly, Smith [2018] states that there will be a need for two billion new homes over the next 80 years as a result of a growing middle class.

Fourthly, as climate change increases so does the need to reconstruct, reinvent and rebuild. The cost of reconstructing tripled in the US over the last decade as intense storms and natural disasters destroyed homes and increased the need to repair cities [Quartz, 2018]. Globally, this number is even larger as people are being displaced due to receding shorelines, political unrest and resources depletion leading to resettlement [Stern, 2006].

A report by Udall and Shendler [2005] stated that buildings consumed over a quarter of the worlds wood harvest, and a sixth of the worlds fresh water harvest. In one year the use of concrete in buildings accounts for 20 billion tons of aggregate, 4 billion tons of cement and a staggering 800 million tons of fresh potable water [Czarnecki and Van gemert, 2017]. Figure 2 illustrates the level of consumption of materials specifically to the building industry in gigatonnes. Notably, demand is projected to double by 2060 aggravating the above conditions if nothing changes.

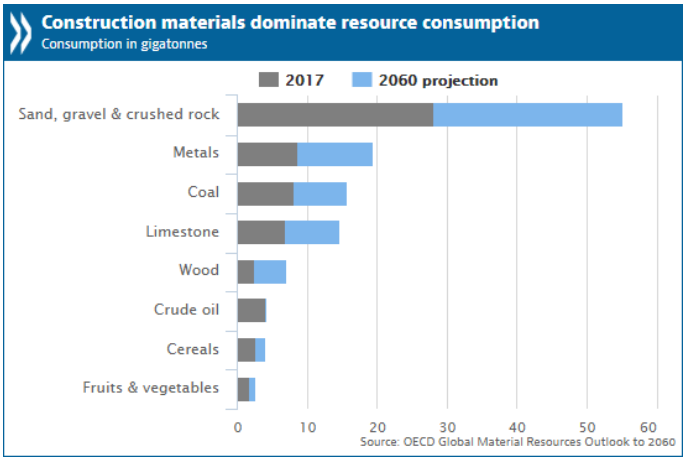

Figure 2: Buildings and Resources, [OCDE, 2018]

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As students passionate about the built environment about sustainability and about circular economy, this topic made sense as a starting point for the Masters Thesis. It is with great anticipation and pride that we hope to learn and share knowledge on the sustainable and circular economic transition towards healthier world practices for better futures.

Contents

List of Figures

Glossary

Biosphere: 'The regions of the surface and atmosphere of the earth or another planet occupied by living organisms' Oxford Dictionary [2019]

Circular Economy: "A circular economy is one that is restorative and regenerative by design and aims to keep products, components and materials at their highest utility and value at all times, distinguishing between technical and biological cycles. [Ellen MacArthur Foundation, 2015]

Circular Buildings: A circular building is the application of circular economy principles into the building of structures. [Holmes, 2016]

Framework: A basic Structure underlying a system, concept or text. [Graden, 2017]

Strategy: is the direction and scope of an organization over the long term, which achieves advantage in a changing environment through its configuration of resources and competences with the aim of fulfilling stakeholder expectations [Johnson and Henderson, 2002]

Strategic Plan: A detailed proposal for doing of achieving something. [Graden, 2017]

Sustainable (capitalized): Any pursuit to fulfill the vision of the Bruntland Report "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs"[United Nations General Assembly, 1987]

sustainable (lower case): Dealing with the biosphere and the systems within it

Value Chain: the process or activities by which a company adds value to an article, including production, marketing, and the provision of after-sales service.

Technosphere: 'The sphere or realm of human technological activity; the technologically modified environment' Oxford Dictionary [2019]

Acronyms

- ANT: Actor Network Theory
- BAU: Business as Usual
- BREEAM: Building Research Establishment Environmental Assessment Method
- CASBEE: Comprehensive Assessment System for Built Environment Efficiency
- CE: Circular Economy
- CEBM: Circular Economic Business Model
- CEBMs: Circular Economic Business Models
- C2C: Cradle-2-Cradle
- CSC: Closed Supply Chains
- DGNB: Deutsche Gesellschaft für Nachhaltiges Bauen (German Sustainable Building Council)
- EMF: Ellen MacArthur Foundation
- EPMs: Elements, Products, Materials
- Gt: Gigatonnes (Billion Tonnes)
- GCM: Global Circularity Metric
- GWP: Gross World Product
- GPP: Green Public Procurement
- GDP: Gross Domestic Product
- $GtCO_2e$: Carbon Dioxide Emissions in Billion tonnes
- IPCC: Intergovernmental Panel on Climate Change
- LEED: Leadership in Energy and Environmental Design
- MCV: Mass Carbon Value Index
- OCDE: Organization for Economic Cooperation and Development
- RL: Reverse Logistics
- WEF: World Economic Forum
- WRI: World Resource Institute
- PACE: The Platform for Accelerating the Circular Economy
- €Tn: Trillion Euros

Part I

Introduction

1 The Circular Economy

The preface provided an introduction to the current relevancy of moving the building industry towards a circular economy (CE). The introduction will now establish the scope in which CE is to be investigate in this work. This is followed by a definition CE and its relationship to Sustainability (capital case) and sustainability (lower case). This moves into frame-working the different applications of CE within the building industry by defining circular buildings and looking into applications of CE in Denmark and what challenges it faces there.

1.1 Project Scope and Objective

The building industry consists of a complex systems of stakeholders ranging from owners, consultants, engineers, contractors, architects, citizens, trades and governments. This paper investigates CE in the Danish building industry from the grass-roots level focusing on primarily trades and consultants. Additional stakeholders from outside the industry that have influence on CE such as national and EU government forces are not investigated. As this report looks to understand CE from bottom-up approach instead of a top-down approach.

1.2 What is a Circular Economy?

CE is commonly understood as the process of removing waste from economic cycles. Figure 1.1 illustrates the contrast between the linear economy that is used today and the CE. The left side of Figure 1.1 represents the current economic operating system of take-make-dispose. Primary resources are harvested (take), converted to a product (make) and sold for use/consumption and then thrown out (disposed/wasted). Briefly note that waste is a human construct that stems from this linear economic process' and can be in the form of material or energy.

The right side of Figure 1.1 illustrates the alternative to disposing products at the end of the use phase. The circular system aims to keep materials in the economic cycle indefinitely maintaining the materials value and utility throughout.

Figure 1.1: Linear vs. Circular Economy
[Riebel, 2018]

Figure 1.2 shows an additional perspective that represents one of many mid grounds between moving from a linear to a circular economy. This is one economic model being presented as CE the recycling economy. The recycling economy prolongs the need for mining of primary resources, however, it doesn't eliminate waste nor provide a solution of the ongoing problem that waste still is produced and the quality of products is continually being degraded instead of contributing back into economic systems. This intermediary ground of recycle economy, which also includes concepts such as performance economy has led to some confusion as to what direction for a circular economic transition should be taken.

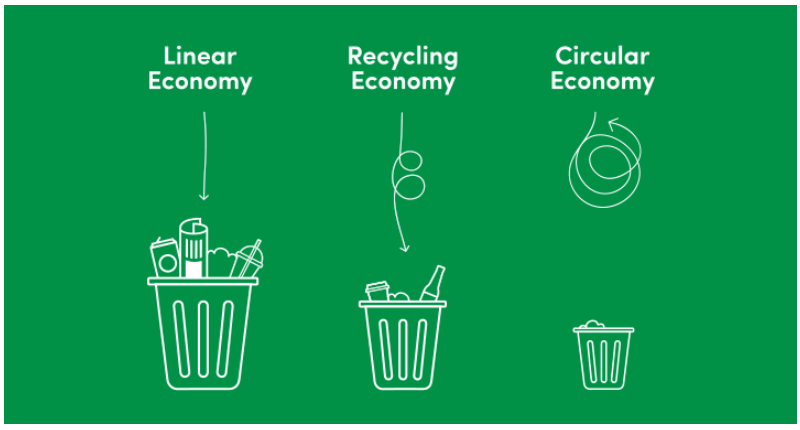

Figure 1.2: Linear, Recycle, and Circular Economy
[Wilson, 2019]

The following section looks to create a definition of CE in order to create a mutually understanding of the term for use in this work. This is first achieved by establishing the difference between sustainability and CE.

1.2.1 Circular Economy vs. Sustainability

Circularity and *sustainability* are from time to time used interchangeably with each other [U.S Chamber of Commerce Foundation, 2019]. This paper distinguishes the difference as established below in Figure 1.3. "Sustainability" (capitalized) is represented by the outer boxes of the diagram and references United Nations General Assembly [1987] vision for sustainability: "*Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs*".

"sustainability" (lower case) is distinguished as being part of the biosphere. The biosphere refers to natural systems such as the nutrient cycle, carbon cycle and water cycle. These systems embody circularity, but this is not what is meant by CE (defined below). The distinguishing element is that sustainable systems will cycle regardless of human interaction. The reason that human impact has become the defining component between sustainability and CE is because all other species on the planet evolve and learn to adapt to their environment, humans on have evolved to adapt the environment to them [Lohan, 2018]. With that power comes great responsibility and currently humans have not yet proven they are intelligent enough to manage it [Potocnik, 2014].

Circularity or circular economics refers to the technosphere which refers to human designed systems and process such as those involved in manufacturing. When the systems designed in the technosphere meet certain human established requirements to manage the impacts of those activities is called CE. The right side of Figure 1.3 illustrates how human activity attempts to mimic sustainability. To achieve this is a complex endeavour requiring considerations of countless cause and effect relationships. Additionally, it requires simultaneous achievement of the three pillars of sustainability. [Sauvé et al., 2016]

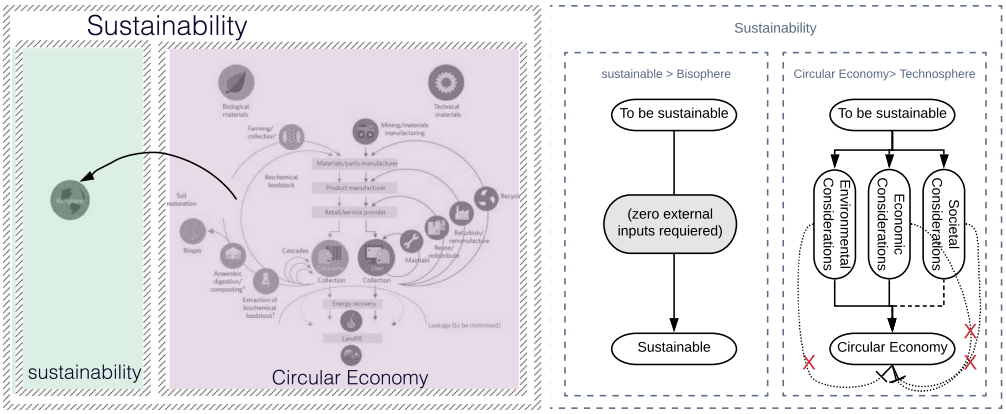

Figure 1.3: Sustainability, sustainability and circular economy, made with modifications to Circular System Diagram by The Ellen MacArthur Foundation [2019]

This practice has been encountered where one component of a company is installing a sustainable practice and calling the business sustainable. [Hoedeman, 2002] states in his

article that companies have successfully lobbied to green-wash their activities and products. This affects the needed development for solving the global environmental and social crisis. Literature shows that environmental and economic pillars are commonly addressed and the social aspect seems to be absent, this does not qualify as CE [Sauvé et al., 2016]. An independent achievement of one of the pillars towards CE should not qualify as CE, this is emphasized in Figure 1.3 by the red "X" marks over independent arrows towards CE.

1.2.2 A Definition of Circular Economy

The book 'The Economics of the Coming Spaceship Earth' written by Boulding [1966] describes the concept of the spaceman economy and identified that circular systems were unavoidable if maintaining human life on earth was to be achieved. The concept was further developed by Pearce [1990] who supported the spaceship economy with reference to the laws of Thermodynamics. The law of thermodynamics he referenced states that the entropy of a closed system will gradually increase with time and this will cause higher value energy or material to degrade [Geisendorf and Pietrulla, 2018].

Walter R. Stahel then defined CE as an economy that closes material loops, generates jobs and reduces energy consumption, material consumption and waste. Stahel is additionally known for his work in introducing the concept of performance economy. A model utilizing products or materials as a service within loops where renting, borrowing and sharing are central elements [Lewis, 2018].

Nowadays various organizations have defined CE to meet their missions and visions. The organization Circular Economy defines it this way: "A new economic model for addressing human needs and fairly distributing resources without undermining the functioning of the biosphere or crossing any planetary boundaries." [Circle Economy et al., 2018]. However, at print, Dame Ellen MacArthur's definition of CE is most commonly referenced [Geisendorf and Pietrulla, 2018]: *"A circular economy is one that is restorative and regenerative by design and aims to keep products, components and materials at their highest utility and value at all times, distinguishing between technical and biological cycles"* [Ellen MacArthur Foundation, 2015].

MacArthur experienced the meaning of 'finite' and connected the concept of the closed-loop economy while sailing solo non-stop around the world . In her sailing voyage life and death was dependant on her ability to manage the limited resources on-board. This illuminated to the then 28 year old that the global economy operating system functions on the same principles but is flawed. Moving from the linear to circular model is inevitable if humanity is to avoid our own self-impending demise [TedTalk, 2015].

However, the definition which most diligently addresses the three pillars of sustainability came from a report by ABM-AMRO and Circular Economy [2014]. Where CE is defined

by the following six principles:

1. All materials will - in theory- be infinitely recycled
2. All energy is derived from renewable or otherwise sustainable sources.
3. Human activities support and strengthen the ecosystem and are natural capital.
4. Human activities contribute to a diverse society.
5. Human activities support and strengthen health and happiness.
6. Resources will be used to create more than just financial value, for example, ecological or social value.

where; **the final goal is an economy**:

- Materials streams are efficiently managed and recycled;
- that runs entirely on the basis of renewable energy;
- without negative effects on human life or the ecosystem.

[ABM-AMRO and Circular Economy, 2014]

Related Circular Economic Concepts

In creating a framework in which to understand CE the researchers also considered familiar and related concepts. In this case many of the following concepts have been used interchangeably with CE. They include cradle-to-cradle (C2C), blue economy, regenerative design, closed supply chains (CSC), natural capitalism, industrial ecology (IE), performance ecology, bio-mimicry and reverse logistics. [Geisendorf and Pietrulla, 2018] Below is a brief investigation of these concepts:

Cradle-to-cradle (C2C): is a framework that works holistically to create efficient and sustainable systems free of waste. *Blue economy* focuses on principles that utilize mechanisms found in nature aimed at protecting the environment while also creating new jobs. *Regenerative design* focuses deeply on imitating the closed-loop input output model often reflecting bio-mimicry and limiting by all means possible transportation for production; *Closed Supply Chains (CSC's)* consider reuse as the main methods to close the loop, while also taking into consideration roles of governance and coordination in producing tools for implementation; *Natural capitalism* combines the objectives of nature and business to further encourage growth; *Industrial ecology (IE)*, refers to a industrial ecosystem. If applied globally could optimize energy and material while minimizing pollution and waste. IE focuses on the environmental aspect of new strategies not on profitability; *Performance ecology* refers to selling of services instead of material products and has three main goals: create new jobs, increase wealth, and decrease resource consumption; *Bio-mimicry* is the practice of imitating or being inspired by nature to create innovative sustainable and environmentally conscious solutions; *Reverse logistics (RL)* is a process inclusive of planning, implementing, and controlling flows, it's main focus is in the reuse

of materials and products as well as applications of return management. [Geisendorf and Pietrulla, 2018]

To create a better understanding of CE Geisendorf and Pietrulla [2018] took the above related concepts of CE and arranged them into 6 categories: 1)Motivations, 2)Proposition for waste management, 3)Guidelines and tools, 4)Economic sectors covered, 5)Economic scope, and 6)Activities (see Appendix A.3 which outlines the method of analyzing these concept characterizations). These categories led to the following definition: "In a circular economy the value of products and materials is maintained, waste is avoided and resources are kept within the economy when a product has reached the end of its life"-[Geisendorf and Pietrulla, 2018].

This report will utilize the definition and 6 principles of CE from ABM-AMRO and Circular Economy [2014]. The various application methods and categorization of related CE concepts presented above will be taken into consideration when developing the framework for the project analysis.

1.2.3 Circular Economy in Denmark

The building industry in Denmark is rethinking construction and its potential for sustainable applications. In Denmark two thirds of all minerals mined for use in the country go towards construction [The Danish Environmental Protection Agency, 2016]. Danish government and industry are focused on addressing the global climate issue and the associated environmental challenges. This includes making collaborations to accelerate the sustainable transition by influencing society to create a green growth economy which is necessary as long as the battle between business as usual (BAU), climate change and rising global temperatures continues. [State of Green, 2018b] The 'polluters pay principle' developed 30 years ago in Denmark assists in waste management by charging a fee whenever something is land-filled. As a result, Denmark's recycling rates have reached 66% in 2018, only 5% of waste is buried, the remaining waste is utilized in incinerators for energy recovery [State of Green, 2018b]. The practice although efficient is not Sustainable and, therefore, not circular.

In general the construction industry lags behind in responsible waste management where 50% of the worlds waste stems from the building industry [Omotayo and Akingbonmire, 2018] & [State of Green, 2019b]. Denmark on the the other hand recycles an estimated 87% - 90% of construction site waste [State of Green, 2018b] & [3XN/GXN, 2018b] (leaving in question, however, what the parameters or guidelines are for recycling and waste management). Denmark is among the most efficient countries at waste and resource management, as well as the largest producers of waste [State of Green, 2018a]. 3XN/GXN [2018b] recognizes that too much *value* is being lost in the recycling process. For example

when waste concrete from a building is turned into pavement the value from the original product drops 50 times. This is where Denmark can strive to innovate the market next [3XN/GXN, 2018b].

Innovation has sprouted in Denmark as Realdania hosted a Circular Construction Challenge in 2019, where the participants were asked to re-purpose or prevent the 650 million tons of construction waste that is produced worldwide every year to be wasted. The winning solutions ranged from developing mycelium based building products to businesses that build sheds entirely from old construction site materials [State of Green, 2019b]. Additionally companies all over Denmark can be seen to invest and re-brand to show their new pursuits to be sustainable. Rambøll for example relatively recently pivoted it's consulting services towards sustainability and innovation. This year the company participated with AAU Case Competition and awarded first place to a team who pitched a solution to re-brand Aalborg as the Sustainability capital of the world through leading by example with smart mobility, start-ups, post-secondary institutions and digital conferencing.

Figure 1.4: Winners, AAU Case Competition 2019
[AAU Case Competition, 2019]

1.2.4 A Definition of Circular Buildings

A circular building is the application of CE principles into the building of structures [Holmes, 2016]. Figure 1.5 by Circle Economy et al. [2018] distinguishes between CE and circular buildings. Where circular buildings are a product of a CE maintaining focus on the three pillars of Sustainability as well as the additional dimension of time. Circular buildings involve the consideration of specific industry based networks, processes, products and activities. The networks include stakeholders such as owners, developers, citizens, government, contractors and environment. The processes includes taking into consideration socially ethical practices in resource mining, health and safety on site as well

as economic well-being of those involved. Finally the activities have to be in line with international and national, environmental governmental regulations.

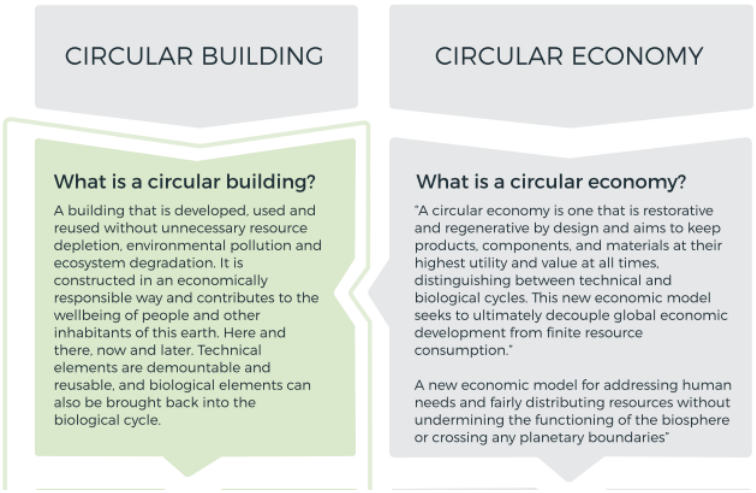

Figure 1.5: Circular Buildings
[Circle Economy et al., 2018]

Figure 1.6 mind maps relative terms to circular buildings found in literature. The center is circular buildings with synonyms of the term surrounding it in lighter green including green buildings, natural buildings, sustainable buildings and so on. On the outermost circles in the lightest green are concepts used to describe or define central terms such as design for dissasembly, resource efficiency and material passports. This investigation indicates the interpretation of circular buildings currently provides ample opportunity for application of CE tools and practices within the building industry.

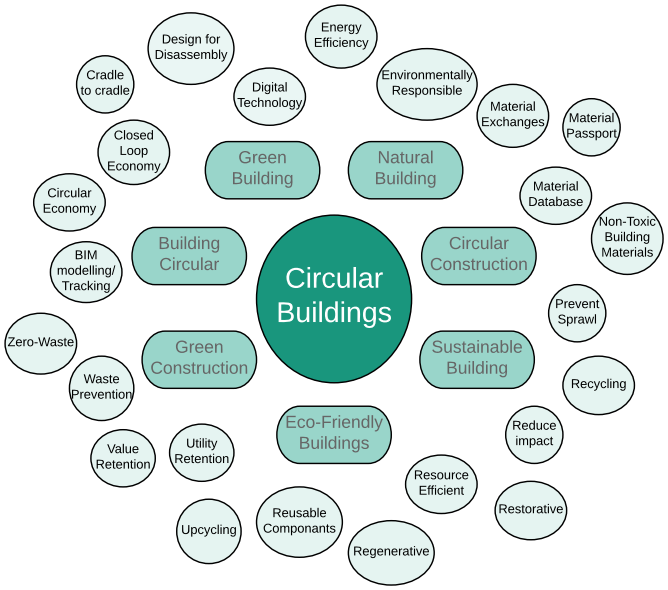

Figure 1.6: Circular Building Mind Map
[primary source]

The many different interpretations of circular buildings or green buildings represent themselves in a range of different forms. The Crystal building, Figure 1.7 in the United kingdom achieved the highest accreditation in both BREEAM and LEED categories. This building has features such as water collecting and 'so called' smart technologies managing light and temperature. It is clear, however, that the primary building materials of glass and steel come with a high material passport price. Have they been designed for dissasembly and can their value be maintained.

Figure 1.7: Crystal London
[Wright, 2015]

Another interpretation of the circular building is the off-grid earth ships. Figure 1.8 shows a building built entirely from utilization of local resources and waste materials. The building also functions separate from city infrastructures utilizing passive strategies, rainwater harvesting and clay as main components of the structures energy saving systems.

Figure 1.8: Earth Ship
[Earthships, 2019]

The range of different interpretations of sustainable buildings is vast. For a CE to be truly executed the entire life cycle of the building needs to be considered as one system where the building starts in the mining of materials and ends when those materials are mined back into the system it was taken from.

2 Research Statement

The opportunity for capitalizing on CE is growing. The business case for CE in circular buildings is presenting itself in the form of sustainable building design, sustainable construction, repair, maintenance, as well as reducing, reusing and recycling throughout the process of building development, use and demolition [European Commision, 2017]. While there are many circular building strategies in working with circular building concepts, there remains to be a representative method for master-planning projects with regards to circularity and design for disassembling [Holmes, 2016]. Transforming the industry towards circular building practice will involve the engaging the entire value chain [3XN/GXN and Lenager and Vandkunsten Architects, 2018]. The start of that value-chain reaction could start at the grass-roots level. This papers looks to investigate the current potential of small and medium level businesses in starting the transition to circular business models that embody the CE.

As a result the research statement for this project will aim to investigate the building industry within Denmark with potential to applying circular business models into SMEs (small medium enterprises) as the proponent to creating lasting and impactful change in the market.

Problem Statement How can a circular economic based business model be designed for a company exhibiting sustainability in practice?

- **Sub-questions 1:** *Which initiatives are being taken within the Danish building industry toward Sustainability?*
- **Sub-questions 2:***How do businesses in the building industry communicate and reflect CE in business models?*
- **Sub-questions 3:** *What form would CE integration take to encourage industry wide implementation?*

Part II

Research Design

3 Methodology

This chapter presents the project's research design giving the reader an overview of the project. Figure 3.1 shows the research process. The first phase was problem identification. In problem identification the researches of this group determined challenges concerning the impact of buildings on the environment and why they are relevant. This lead into the research statement and sub-questions. From here the theoretical framework and methods are set aiming to address the research statement. Once empirical findings were collected and analyzed modeling of the CE business model is presented. The last section presents reflections, a discussion and recommendations.

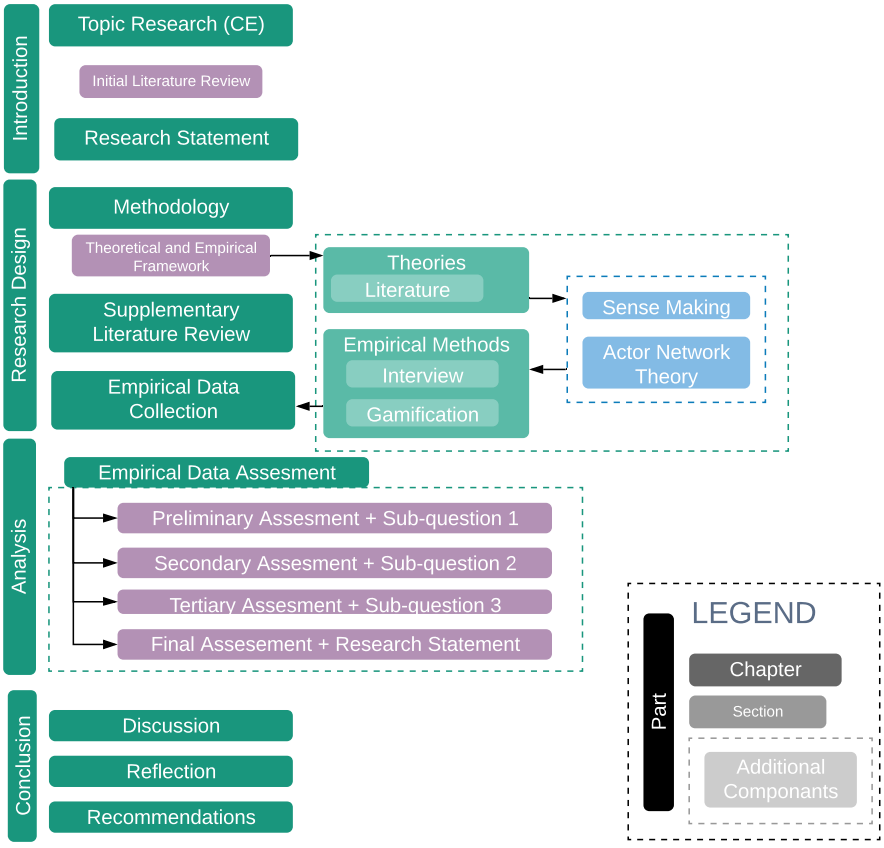

Figure 3.1: Research Design
[primary source]

3.1 Literature Review

Having determined a research statement a supplementary literature review was utilized to develop on initial research narrowing down and building up knowledge on the area of interest. The literature in both the initial analysis and supplementary analysis is collected from sources presented by the project supervisor as well as the following databases: Aalborg University Library, Google Scholar, Elsevier, JSTOR and for researching green initiatives in the Danish building industry, Google was utilized to collect manuals, find government websites, locate journal articles as well as reports and web references. Each source was evaluated for a recent publishing date, reputable author and publisher as source validation.

The following keywords were used in these searches: circular economy, buildings, construction, circular business models, Denmark. Resulting articles from keyword searches were also used to identify further relevant literature, these included: Sustainability, sustainable buildings, smart buildings, green construction and circular construction.

3.2 Theoretical Framework

This section outlines the theoretical framework composing of the theories and concepts used to qualify and explain the interpretation of literature and the methods of research used in analysis within the project. These theories are further used to anticipate development of the industry movement, and therefore, formulate a foundation for further recommendations on the circular economic business model presented in response to the problem

Actor Network Theory (ANT)

Actor network theory (ANT) will be used at high level to recognize the complexity of the business network inclusive of the human actors and the non-human actors within it: human actors such as the clients, the developers, designers, engineers, owners, architects, trades, suppliers and so forth, as well as, non-human actors such as technologies including sustainability and CE. ANT was created by science sociologists with a concern to move beyond the separation of nature from society and towards an approach that recognized their connectedness in human activity [Kurokawa et al., 2017]. This is vital in the consideration of sustainability and the research at hand. ANT will be used to explore business engagement with Sustainability and CE in the building industry aiming to understand the mechanisms with which business must engage. The system will use conceptual modelling to black box the ANT scope that will be investigated, this is further explained below.

Conceptual Modelling and IDEF0 The complex network in which circular economics

finds itself within the building network requires that the area of focus be black-boxed in order to limit the degree of investigation. This project uses conceptual modelling IDEF0 (**I**cam Integrated Computer Aided Manufacturing **DEF**inition for Function Modeling) as a tool to organize the functional context of the system. Figure 3.2 shows the template for this analysis. The center of the Figure shows the concept of investigation with *inputs, controls, outputs* and *mechanisms* showed in relation to activities that contribute, influence and results of the implementation of the method.

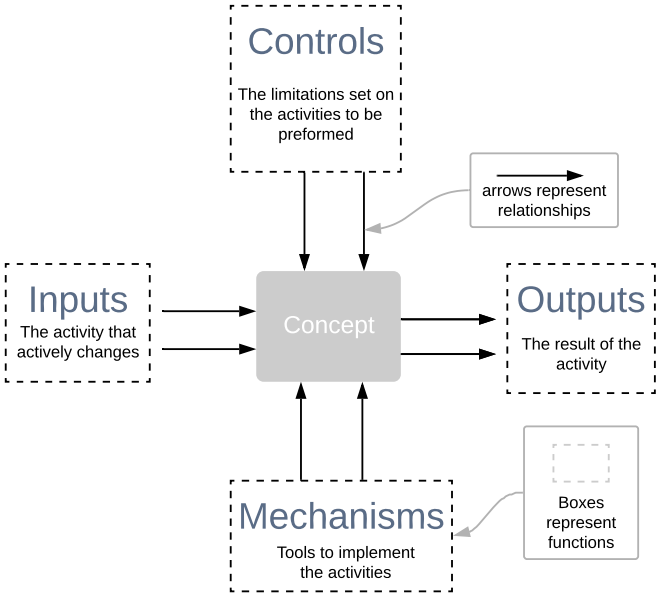

Figure 3.2: Concept Modelling Reference, made with modifications to Johnson and Henderson [2002]

Sense Making Theory

With an intention to make sense and bring structure to sustainability in business modelling it is essential that businesses understand why sustainable practices make sense from a business perspective and not just a moral perspective. Barriers to change can often be rooted to subjective frameworks and how one makes sense of circumstances this supports of inhibits change [Millar et al., 2012]. How are shifting markets, new technologies, political incentives, climate and cultural adaptation trends encouraging transition. Businesses want to reassured that changes will promote economic success. The modelling at the end of this project and coordination with business will assist in understanding what is needed to promote a sustainable transition.

Framework, Strategy and Implementation:

To undertake the challenge of interpreting the building industry network will need to be organized into a system where a *framework*, *strategy* and *implementation* process are illustrated in Figure 3.3.

Framework in this case this is where the processes are analyzed and agreed upon and goals are set it is an abstract, an *idea*, in this case it is CE. *Strategy* refers to the presentation of a plan of action designed to achieve a long term or overall aim. In this case circular buildings. Here defined goals towards meeting the framework are set, this refers to the *direction* where activities are heading and processes are defined. In order for processes to be put into action that fits the industry or company an *implementation* process has to be completed, the things that need to be done are established this is the circular business model.

As a result, *implementation* is considered the grassroots, level towards creating significant change that can spill into industry. *Implementation* refers to *action*. The process of putting a decision or plan into effect. This is a crucial aspect to consider in order to create change. It is also understood that any *implementation* practice put into place will receive some form of resistance. This is especially true in an industry like construction, where teams and collaborations are created for the duration of a project and then disassembled, thus making changes particularly difficult to actualize.

This implementation area is where the researchers see the purpose for this project. Research, practices and tools will be studied as a precursor for instilling change toward the development of a circular economic business model that will affect the company in a bottom-up approach as an implementation strategy for sustainability.

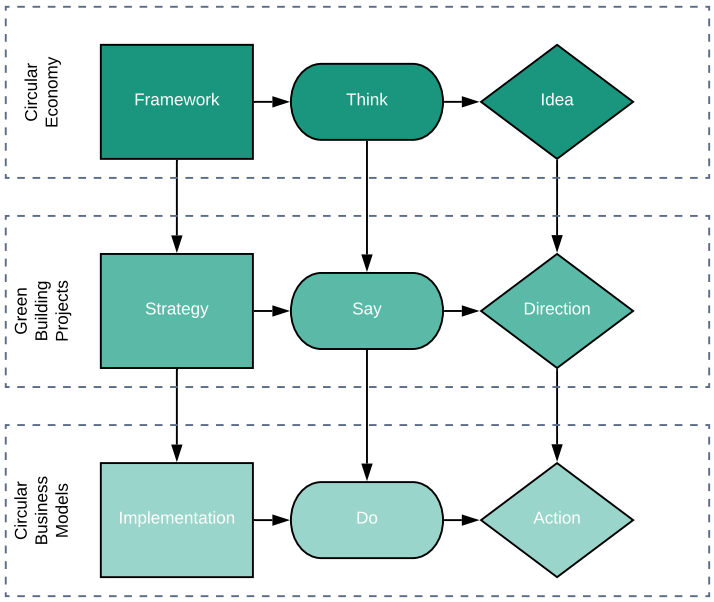

Figure 3.3: Framework, Strategy, Implementation [primary source]

3.3 Empirical Data Collection

The empirical data collected took the form of a literature reviews, semi-structured interviews and semi-structured expert interviews, gamification as well as a expert commentary on presented circular economic business modelling.

Semi-Structured Interviews

Primary data collection in this report is conducted through semi-structured interviews. This type of interviews allow the interviewee to lead the dialogue providing the opportunity for exploring areas of interest that may not have been known by the interviewer and yet may result in necessary information for the project. Open-ended questions encourage free speech of the interviewee and allows for more in-depth answers resulting in gaining valuable and relevant data.

To answer *sub-question one*, twenty-seven short semi-structured interviews from a broad representation of Danish building industry businesses were conducted at the Building Green conference in Aarhus. Responses to the interviews were analyzed and summarized in relation to the business Sustainable potential, circular economic potential and feasibility to circular business model transition. The interviewees represent a variety of the Danish building industry including manufactures, consultants, contractors etc. *Sub-question two* is answered through analysis of the results from the interviews and gameification.

To answer *sub-question three* a strategic CE business models is created by the researchers based on solutions gathered through literature review, three expert interviews are together cross referenced to see feasibility in engineering opportunities for CE applications for one business. These examples are tested on a final expert for feasibility. The results from the tests are evaluated discussions are made and a conclusion and a final recommendation is presented.

Gamification

Gamification is the "the use of game design elements in a non-game context" [Amir and Ralph, 2014]. Gamification was used as a research method to collect data regarding CE business models. This form of data collection was used to allow the participant to openly illustrate understanding of a term while leaving out any predefined expectations or loading of results. Gamification has been used to motivate and immerse the interviewee to achieve their goals. The method was additionally useful in encouraging user participation and engagement in a casual setting, many participants noted that it was *'the most fun they'd had all day'*.

3.4 Building Green Aarhus

Building Green is a conference established for sector of the construction/building industry interested in sustainable products, thoughts and solutions. It is the leading event in North Denmark to exhibit products and solutions on sustainable applications to industry that also includes a platform to present knowledge consisting of international keynotes, debates and networking. [Building Green Aahrus, 2019] In 2019 the theme for the conference was CE and buildings which made it the ideal place to speak with experts and industry. This is where empirical research has been held for this projects investigations.

Figure 3.4: Building Green Program Cover and Research Team with Augustas Sudaras, Building Green Aahrus [2019].

4 CE in construction

The introductory chapter established the meaning of Sustainability (capital case), sustainability (lower case) and CE for use in this report. This section goes into depth regarding the narrowed down subject area. This is accomplished by elaborating on the framework, strategy and implementation established in Figure 3.3. Investigating areas applicable to the building industry.

4.1 Network Framework

The building and construction industry is a complex system that involves meeting various milestones by multiple stakeholders from various businesses who collaborate and coordinate throughout to obtain a common goal while ensuring each business thrives. Which phases of construction can CE be applied? Is it in the feasibility phase, the design phase, construction phase, operation phase, reuse and refurbish phase, or demolition phase? Or does CE start within the business structure of companies, for instance within the company business model and the company vision and mission? Three stages of the building process are framed below in Figure 4.1 to assist in this data collection.

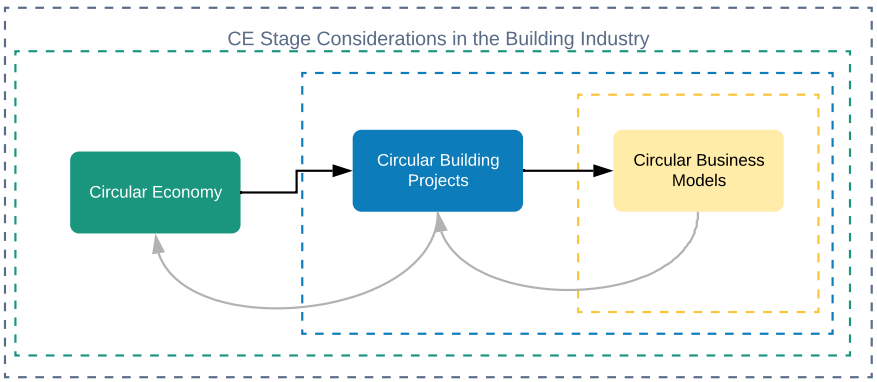

Figure 4.1: Circular Economy Analysis Framework, [primary source]

4.1.1 Circular Economy Applications

The building network that the researchers are studying is shown in Figure 4.2 *circular economy* in the center of the concept square with inputs of sense making and behaviour change. Mechanism that can assist with CE transition include innovation, holistic design, frameworks like the SDG's and those specific to CE. Controls managing these mechanisms include bureaucracy (things move slow) and monetary restrictions. If the mechanisms and controls can work together then the output of a CE would result in new revenue streams, transparency in networks, ingrained circular methods and an all round circular vision and mission.

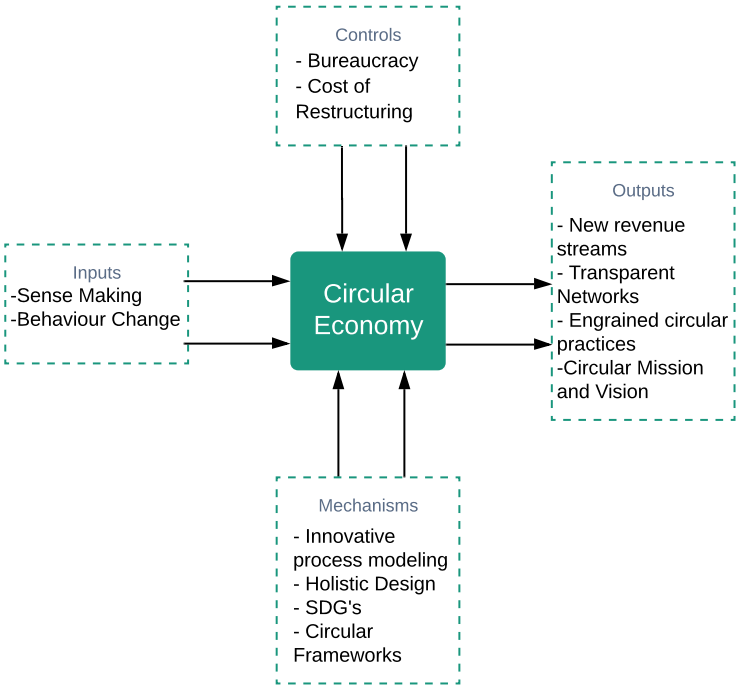

Figure 4.2: CE Process Diagram [primary source]

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Various unique CE frameworks have and are being developed by individual companies and governments aimed at collecting needed data to report and track meaningful CE integration. Below is an examples of just one CE framework presented to gain inspiration during the modelling and analyses phases. A few more methods were encountered including the EU Levels and Ellen MacArthur Frameworks. However, for the purpose of this research it is only important to understand that they exist and what form them may take. Most result in a list of priorities, principles and a theory as the one innovative one below that take into consideration the three pillars of sustainability and establish strong ties to business modelling.

The Circularity Gap

CE is looking and imagining the long-term horizon of economic impacts. The Circularity Gap indicates 4 steps that leaders can take to make change happen:

- 1. Translation global trends into national regional and commercial pathways
- 2. Develop decision metrics and a measurement framework
- 3. Facilitate peer-to-peer learning and knowledge transfer
- 4. Build a global coalition for action that is both diverse and inclusive

[De Wit et al., 2019]

DISRUPT is a CE model that assists with incorporating the dynamic processes above. Below the Acronym with its relative components are listed (See A.1 in the Appendix for full descriptions).

- **D**esign for the Future
- **I**ncorporate Digital Technology
- **S**ustain & Preserve what's Already There
- **R**ethink the Business Model
- **U**se Waste as a Resource
- **P**rioritize Regenerative Resources
- **T**eam Up to Create Joint Value

[De Wit et al., 2019]

The global economy is viewed primarily through one lens, 'financial value creation', circularity concepts encourage the global economy to take into consideration a helix of view-ports to address the challenges associated with linearity that society is experiencing today. De Wit et al. [2019] suggests a Mass-Value-Carbon (MVC) nexus to express the dynamic conceptual framework to assist with this challenge. In this way it is possible to asses global financial value, carbon emissions footprint and mass of material extraction as interlinked. This is an attempt to mimic material metabolism in economics, and therefore, progress towards closing material and energy loops. It is pivotal in understanding the wastes that are created within the process.

At the moment there is the lack of consistent measuring frameworks available across governments to make implementation of circular economic principles viable for government policy development and business strategies. There is a need to track changes over time and track with meaningful measuring units progress. The Global Circularity Metric (GCM) assists in translating a complex amount of information into a comprehensible helix of 3 elements, mass, value and carbon emissions.

4.1.2 Building Project Applications

The building project concept diagram is illustrated in Figure 4.3. This section receives the outputs of the previous level as it's inputs. The key controls here include government, laws, codes and international directives, the mechanism to achieve it include innovative concepts such as the green building schemes and iterative design. The outputs if achieved would include higher quality buildings that consume less energy, have less operation costs and create new secondary resources. This section focus mainly on green certification schemes as most mechanism exist within them.

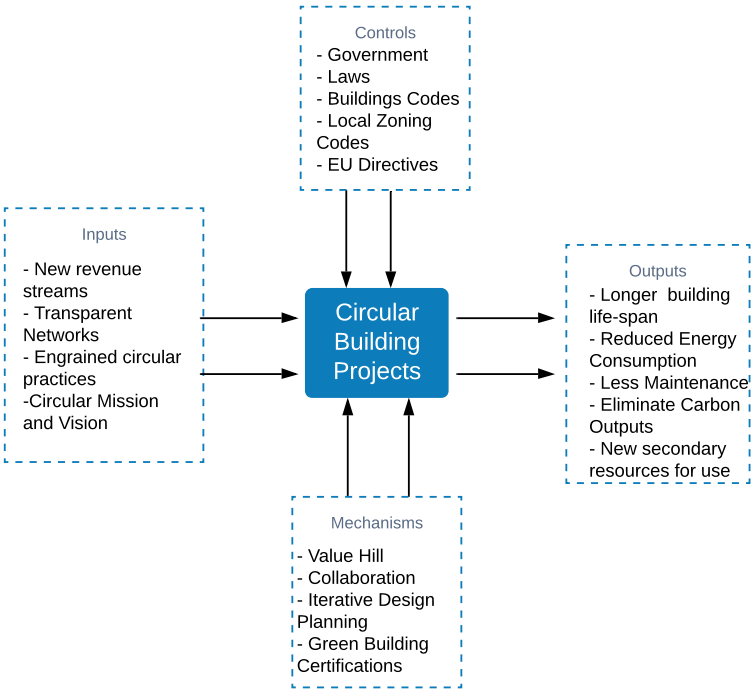

Figure 4.3: Circular Building Project Process Diagram, [primary source]

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Green Building Certification

Master-plan frameworks are certification systems that attempt to capture as many sustainability components as possible within the process of building. Green building certification programs have existed since the 90's. Figure 4.4 shows a brief time line of this phenomenons development. All the programs share the common goal of implementing strategies to improve the best practices within the industry. These strategies overlap and range from implementing team charrettes to waste sorting and responsible procurement.

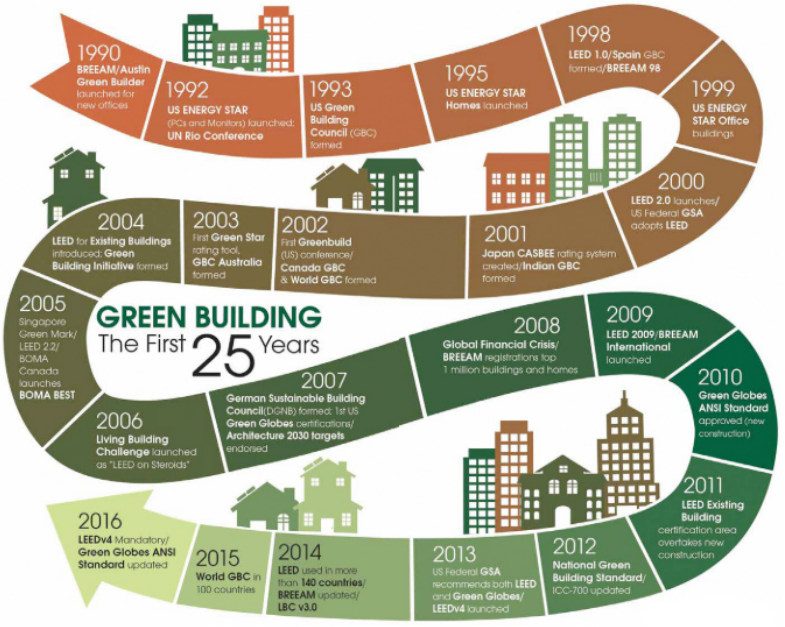

Figure 4.4: Green Building Certification Timeline, [Yudelson, 2016]

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Figure 4.4 shows that in 1990 the first attempt at standardizing a green strategy for "new office" building types was launched in Britain under BREEAM. Soon after in the U.S. the green appliance rating system Energy Star was launched followed by the formation of the U.S. Green Building Council (USGBC) which led to the U.S. version of BREEAM called LEED. In 2001 Japan created CASBEE. Since then many other countries created similar certifications adapted for their national standards and geographical locations. [Yudelson, 2016]

After 25 years many are recognizing that the system of green building certifications has not been globally effective. Obstacles standing in the way include, complexity, start-up investment costs, lack of policy and implementation from government or associations. Missing in these master-plan strategies are frameworks for implementing circular economic principles particularly on the micro [Elia et al., 2017].

Additional challenges with these schemes is lack of mutual direction across project teams and the many options for reporting that exist. Such as with Life Cycle Analysis (LCA) that measures the scope and quantities of embodied energy in the processes. LCA's are very appealing. However, a lack of set methods, (ie. standard functional units, system boundaries, life cycle inventory and common impact assessment categories) is causing discrepancies between research and making legitimacy and confidence building in this kind of research difficult. [Anand and Amor, 2017]

4.1.3 Business Model Application

The inputs required to create circular business models are shown in Figure 4.5. This is controlled by regulations, laws and customs. Mechanism that could help with restructuring include closing loops, discovering new value in supply chains and developing innovations in business model frameworks.

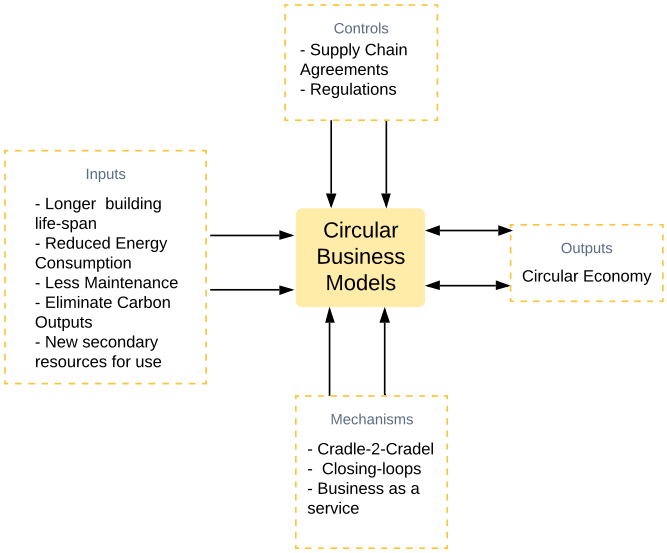

Figure 4.5: Circular Business Model [primary source]

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Circular Business Models Circular business models are models that look to integrate environment, society and business into the DNA of companies. CBMs are used to connect stakeholders in the value chain making them agents of change. The aim is to create internal frameworks for circular initiatives within companies. This section investigates the development of the circular business model as inspiration for application during the analysis. It starts with Walter R. Stahel separation of CE business models into two directions reuse and repair and recycle and retrofit [Lewis, 2018]. From these many other CBMs have taken form to promote value capture and creation.

Elia et al. [2017] shows the global trend towards exploring CE opportunities with focus on moving from linear business models to circular business models. Figure 4.6 introduces 5 such models from 3XN/GXN [2018a] 1.*Circular supply chain*: A model that encourages sourcing materials that are not scarce or destructive to the environment with preference to those that are renewable, recyclable or biodegradable. Focus is on reduced costs, increased predictability and production 2.*Recover and recycling*: Focuses on utilization of end of life materials, recovery and recycling, it emphasizes profits as well as efficiency. 3.*Product life extension*: This model aims to extend the lifespan of products utilizing resale, up-cycling, restoration and re-branding all to extend and increase value 4.*Sharing platform*: As in sharing economy focuses on renting and lending 5.*Product as a service*: Focuses on renting

whole buildings or components within. These types of models could be pivotal in hastening the transition to more sustainable construction industry.

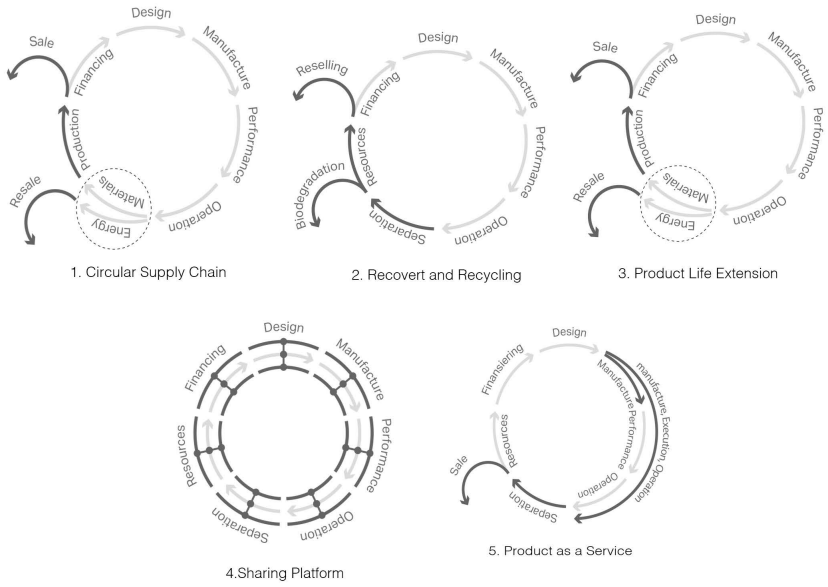

Figure 4.6: CEBM-Types [3XN/GXN, 2018a]

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The value hill assists in circular building strategizes by categorizing where to maintain the value of products within systems. The value hill (Figure 4.7) sets a framework to retain product value throughout it's lifespan. The higher on the hill the more value, the further down the hill the less value. This is distinguished in the order of value retention elements, products and materials (EPM's). The main aim is to develop modular components that can be replaced, fixed and disassemble at the highest value.

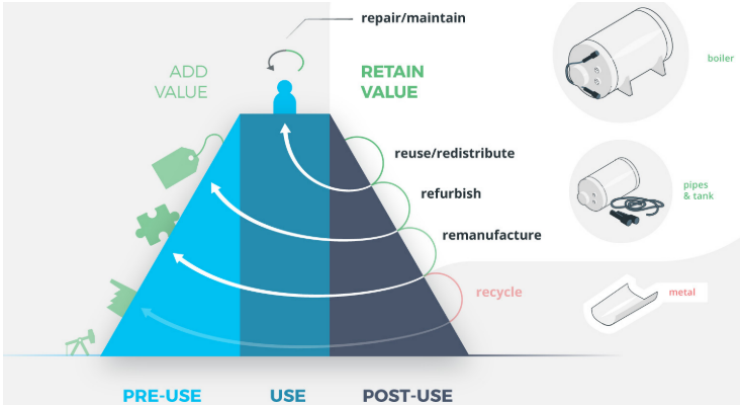

Figure 4.7: Value Hill. Adapted from Achterberg, [Circular Economy et al., 2015]

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Figure 4.8 shows a building with each smaller internal component representing a modular part of the whole with relative lifespans of those components. This diagram is extremely

helpful in establishing a framework from which to tackle CE in the building industry with consideration of new building model applications.

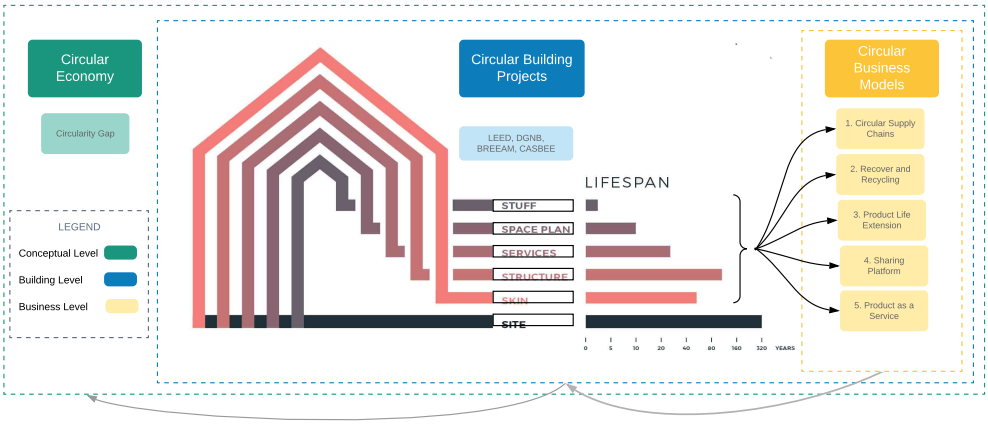

Figure 4.8: Framework Relationship Diagram [with modifications to Circular Economy et al. [2015]]

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The above conceptual diagrams have been connected in Figure 4.9 to illustrate how the system works together. Grey arrows are used throughout to indicate the reports investigation into engineering CE through the bottom up approach instead of through the conventional top down approach.

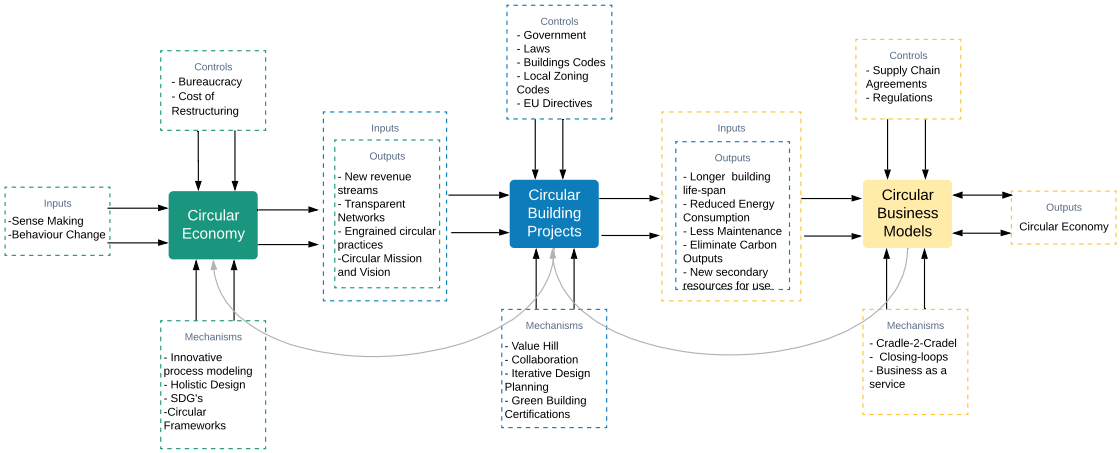

Figure 4.9: Conceptual Diagram Summary [primary source]

The list of mechanism here are not exhaustive, to achieve CE utilization of a variation of combination of tools and mechanisms listed above would be required. This exercise assists in understanding that the systems in which building and building projects exist have many controls influencing each step of progress. The last level is where the project seeks to look for potential change makers in the building industry at Green Building Aarhus.

5 Interviews and Gamification Summary

5.1 Interviews

The research methodology outlined indicated that semi-structured interviewers were to be utilized for this research. For this, two types of interview guides, one for market interviews and one for expert interviews were used. Summaries of these guides follow, full interview guides are provided in the Appendix A.4 and A.5 (full audio recordings of the interviews were submitted digitally).

Sub-questions 1: ***Which initiatives are being taken within the Danish building industry toward Sustainability?***

The aim of of this question is to identify how companies communicate **Sustainability** through their product or service. The question needed to be simple and open ended so that the interviewee, whether (s)he was the owner, sales rep or other, would be able to respond. The following two questions were used as openers to the interview.

Opening Questions:

1. What service or product does your business provide
2. What green initiative brings you to Building Green?

Sub-questions 2: ***How do businesses in the building industry communicate CE and reflect CE in business models?***

Do companies communicate CE in their understanding of their own company business model? Sub-question 2 used the gamification method to obtain data. This method is presented in the next section. Many participants chose to speak during the gaming process and this was also taken into consideration during analysis. Participants were encouraged to elaborate or explain further if valuable information could be obtained through clarification or expansion.

5.2 The Gamification Tool

The gamification exercises was designed using the five business models presented in Figure 4.6 in Chapter 4. The game presented during the interviews is illustrated in 5.1 below. The participants were given the process terms from all 5 CE business models and asked to select those which were relevant to their business.These terms were used in order to be able to make clear cross-references to the business models presented by the 3XN/GXN [2018a] report *Building a Circular Future*.

Participants were informed they could use as many or as few terms as they saw fit, or create new terms if needed, all terms are presented in 5.1. Participants were then asked to utilize the arrows or curved arrows to show process interactions and relationships with each other, ample straight and curved arrows were provided to connect all terms. The terms utilized in the game are left undefined so that the participant can define the uses as needed. When complete a photo was taken for documentation.

Table 5.1: Games Term List

Included Terms (Original)	**Added Terms (Adapted)**
Selling	Engineering
Financing	Government
Operation	Students
Reselling	Architects
Materials	Building Industry
Manufacture	Investors
Design	Competitors
Performance	Market Influence
Separation	Innovation
Resources	Environment

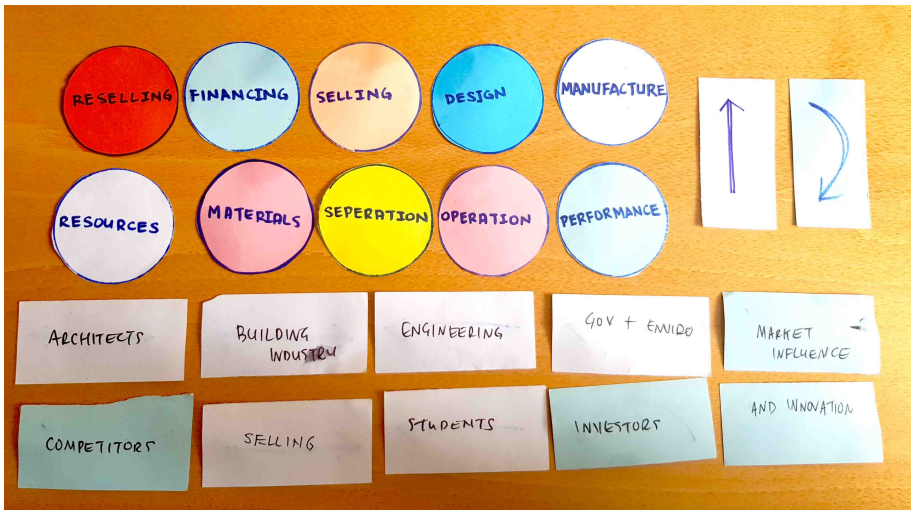

Figure 5.1: Gamification pieces with modifications [primary source]

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Sub-questions 3: ***What form would CE integration take to encourage industry wide implementation?***

Experts were interviewed to gain knowledge and understanding of trends, barriers and influencers of CE in the building industry. The key takeaways by theme are summarized below. Where needed expansion is given to the information provided to ensure the reader can understand the whole meaning out of context.

Table 5.2: Expert Interview List

	Name	**Profession**	**Company**
1.	Peter Sattrup	Architect/Consultant	Association of Architects
2.	Gerard Roemers	Sustainability Consultant	Metabolic
3.	Ditte Lysgaard Vind	Managing Partner	Lendager

Expert Interview 1: Peter Sattrup Peter Sattrup was a keynote speaker (Figure 5.2) at Building Green Aarhus, an architect with 11 years professional experience, a PhD in sustainable architectural design and a background as an associate professor teaching design methods to engineering students. Today, Sattrup is a full time lobbyist and strategist for architectural practice with the Danish Association of Architectural Firms. Sattrup's work involves articulating architect value creation and communicating architectural relevancy to society. Sattrup emphasized his key concern being making the best possible set-up for architecture, not architects; and that Architecture is the background for our lives and the framework that informs our behaviour ultimately defining how we organize as people.

Figure 5.2: Keynote with Peter Andreas Sattrup, [Building Green Aahrus, 2019]

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Industry conditions Sattrup advised that maintaining diversity and secure an open market for start-ups and smaller firms is important in the architectural profession. Consolidation into ever larger units comes with the risk of making access to market more difficult, which could possibly stifle innovation.

"Concept of value creation needs to include more dimensions on value and a much longer life-cycle perspective of value as well"- Peter Sattrup

value-creation in business models To challenge the added-value based economics, one needs to start talking about value creation in business models. It becomes important to take sustainability thinking into the industry without using words like sustainability or green, which do not currently translate directly to value within many business. Sattrup states that the key is to demonstrate long-term value and credibility that these effects will actually materialize and may help the short-term values to evolve in the long-run. If the business model makes economic sense and includes the social, environmental and economic aspects you have injected sustainability into business.

strategies Sattrup works on a project called (Arkitekt - Dokumentér din værdiskabelse, a comprehensive collection of methods used for documenting value creation) which aims to connect one-off partially used methods more widely into a coherent framework to avoid piece-meal approaches to sustainability. Collecting and providing an overall methodology of tools for sustainability within the industry assists in moving the overall industry consciousness towards more meaningful applications of Sustainability.

drivers and barriers Sattrup states that the building industry is working with short-term business models for architecture which is a long-term phenomenon. Procurement models are often only looking at construction costs, even design costs are squeezed into time lines according to what can be afforded.

"75% of the impacts are designed in the design phase. this is where you have influence and should spend time planning and designing"- Peter Sattrup

Sattrup mentions that design investments gets squeezed because of ROI-based business models. Long-term value that emerges overtime needs to be communicated and guaranteed to materialize in order to influence these short-term business models that exist today.

Tendering structure is a bit flawed. Sattrup references Bent Flyvbjerg when talking about how tendering the best design proposals. Noting that a lot of winning tenders end up with projects that over promise and under-deliver. This is the result of funding separation from stakeholder to stakeholder. If there could be a cross-communication from organization to organization in understanding between stakeholders in regards to benefits in quality improvements in the built environment then deeper applications of sustainability could be applied.

"You have one box of money for construction, and you have another box of money for maintenance, and then you have another box for lets say the kindergarten [users]"- Peter Sattrup

Sattrup mentions that recycling companies are looking for ways to work with materials as resources, but that there are a lot of rules with laws and regulations that are inhibiting the transference. There is a need to re-document the scope of the application of these standards.

"If we need to recycle materials, then we need to reinvent the way we document the material behaviors"- Peter Sattrup

aesthetic life-cycle and flexibility A Swedish research project showed a new building being retrofitted from day one, kitchens and bathrooms, walls and floors. This is happening throughout the industry. So, aesthetics life-cycles play a huge role in waste production. There is definitely a need to talk about aesthetic life-cycles beside technical life-cycles and life-spans in considering component replacement and maintenance.

"There is a very strong aesthetic dimension to life-cycle thinking and I think that it is completely underestimated in the models that we use [...] -Peter Sattrup"

decorative elements for durability Architects can play a role in designing for flexibility as well as enhancing features that contribute to user experience. Sattrup refers to Stewart Brand, who states that different layers of the building have different degrees of permanence.

"If You look at Stewart Brand book 'How buildings learn' one of the observations that he makes is that decorative pieces of architecture are usually lasting for a very long term "- Peter Sattrup

Most permanent is the structure of a building, but aspects of a building with high aesthetic value (eg. ornamentation) have high degrees of permanence as well [Brand, 1994] the decorative pieces of architecture become very long term, the things that are designed with quality and durability and refinement that tells the user that 'here you have invested something special' and these components tend to last longer in buildings.

CE influencers and networks Architects are able to make a real change and influence the uptake in circular thinking. Architect firms like Vandkunsten and Anders Lendager, CEO at the Lendager Group and with Kasper Galager of 3XN for example. They engage industry to create new products. There needs to be more engagement and creation of business models and legal frameworks. Once there is a working example that works the rest will follow. Architects have the power to set these trends.

Expert Interview 2: Gerard Roemers Dutch Sustainability consultant Gerard Roemers (Figure 5.3) works for cities and regions at Metabolic in Holland. Metabolic works in consulting for governments or corporation's, as well as acts as a think tank for academic research such as with European Unions Horizon 2020 project (the biggest

EU Research and Innovation program ever developed to ensure EU competitiveness in the world market). Additionally, Metabolic supports ventures for spin-off CE companies. The aim is to create an ecosystem of companies to establish a sustainable economy as soon as possible. Currently Roemers is working on various projects from developing CE applications for BREEEAM, with government creating policy instruments and indicators for measuring of circularity and collaborating with architects and developers on building design and applications.

Figure 5.3: Keynote with Gerard Roemers, made with modifications [Building Green Aahrus, 2019]

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circular buildings There are no explicit tendering procedures for circularity in Denmark at the moment because there isn't a market for it yet. Changes rest on asking the right people the right questions. Denmark has a national strategy on CE but nothing Gerard is quite aware of on the local level, yet.

sustainability Energy transition is progressing very well in Denmark. However, energy efficiency is only one parameter of sustainability and the circularity transition requires consideration of embedded impacts from materials as well. These considerations are just not set into regulations at the moment. There is a lot of work that needs to happen in this area.

"There are the energy transition and then there are the circular transition. Often they are describes as two different things, which is strange [...] It is really important that they are aligned" - Gerard Roemers

knowledge providers 3XN Architecture, Lendager Group and Effect Architects are the large names in CE in Denmark. Internationally Roemers recognizes EMF, Metabolic, Circular Economy as main international names in circular building. The Netherlands market is booming in terms of resource mining and the Dutch company Superuse was the first to develop a city-wide harvest map (a map which outlines where in the city resources can be taken for use in other projects). A harvest map differs from a material passport in that material passports document all the materials used in a product or construction

providing characteristics of the materials which give them value. A harvest map could be looked at as a material passport of a city. Gerard mentioned that Danish company Arup Consultants are also moving into this direction of harvest mapping.

terminology Some call themselves circular some call themselves bio-based (the bioeconomy is the study of production of renewable biological resources and the conversion of them and their waste streams into value added products such as food, feed, bio-based products and/or bioenergy [Carus, 2016])

encouraging faster transitions Roemers believes that carbon taxes could be effective in finding financial incentives to transition to CE, but such policies are currently difficult to implement.

"There are a lot of companies that yes they want to make money but they also want to do the right thing" - Gerard Roemers

implementation strategy Roemers notes that government has some responsibility for encouraging the CE movement. Companies can really make a difference, but he does not see them as capable of casing the entire market (industry) to transition. Large business have too much to lose in the business model transition so won't make the transition on their own. Thus government and market share a mutual role in showing what is needed to move towards CE. Roemers is investigating a cooperative model in his own sphere to make this work, but this is only possible if you have an established community and capacity to do it. He says that construction companies are not changing, but municipalities and commercial developers could.

"If you got a really progressive developer and combine that with a progressive government, you get a long way going. And then the rest will follow, the suppliers and contractors will follow"- Gerard Roemers

Expert Interview 3: Ditte Lysgaard Vind

Ditte Lysgaard Vind (Figure:5.4) studied political philosophy and sustainability leadership while working at Dong Energy. Today Vind runs Lendager the Circular Way. This is a project that helps the built environment transform towards circularity in their process, products and business models. Other part is taking waste from other industries and creating innovation by mapping and measuring the quality in order to sell to someone else.

Figure 5.4: Keynote with Ditte Lysgaard Vind [made with modifications [Building Green Aahrus, 2019]

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away form business as usual There is a huge movement from BAU and interest in gaining since there are some projects already completed. A lot of action is happening with resource recovery spaces.

"One thing is interest, another thing is acting and luckily we see more and more with projects with circular economy in it" - Ditte Lysgaard Vind

danish building sector Developers and entrepreneurs have not picked up on a lot of opportunities yet other than the resource recovery.

"There is way more attraction to resource recovery right now, because that is in the building going up. Where the others are end-of-life, so there is not really the same agency from the developers and contractors because it is too far out in the future" - Ditte Lysgaard Vind

drivers and barriers Demand for resources and future resource scarcity will become a driver. The main barriers are focused on stakeholders in the industry.

"One of the key barriers is culture and habit. And lack of knowledge." - Ditte Lysgaard Vind

Knowledge will become a driver to change. For a long time there was a lot of theoretical potential, today more cases are seen of that in action which is helping.

influence Municipalities have a long way to go. Right now there are a lot of requests for relaxations to rules to allow new development within industries. Vind says that it is investors who can really push entrepreneurs in the sector.

5.3 Circular Economy Expert Synthesis

From the above interviews a synthetization of the information collected was into key takeaways presented in Figure 5.5. The following text explains the assessment and recommendations given by the aforementioned experts. On the first interview, Peter Andreas Sattrup explains that the industry currently exists on a short-term framework (ie. design and construction time-lines and tendering processes), but CE requires long-term planning and that time allows the benefits of such industry to become fruitful in the long run. Sattrup points out that the current silo approach, creates issues in tendering. On the other hand, he advocates that one of the main players the propelling the paradigm shift required is architects, they can influence the industry and if their practices are successful and can also inspire others to follow. How can this be done? Sattrup presents concepts such as value creation, and encourages that social, environmental and economic factors to be included into the business model.

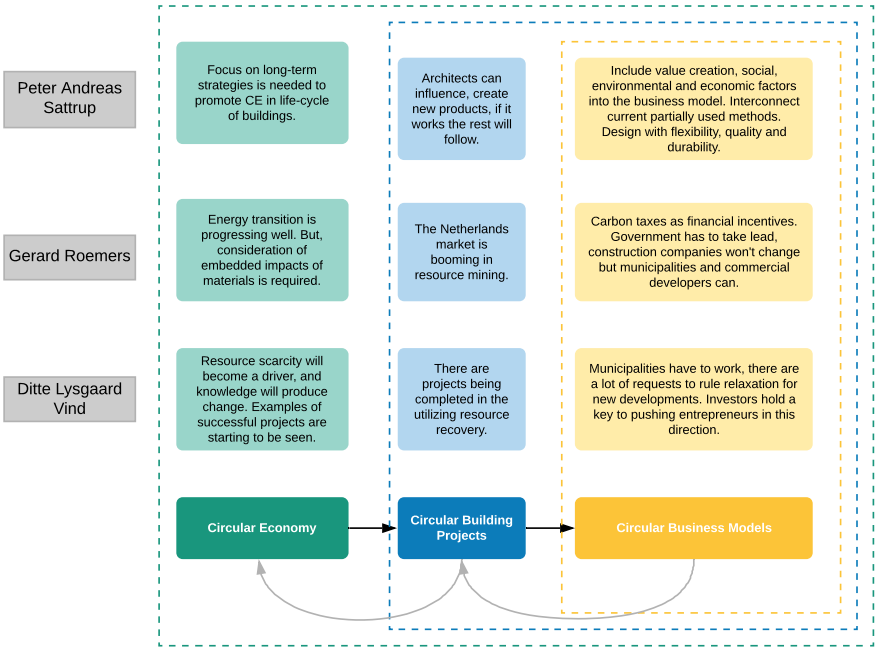

Figure 5.5: CE Expert Synthesis
[primary source]

The second interviewee, Gerard Roemers, explains that currently energy transition is prospering in Denmark, but the consideration of where the materials come from and their impact has to be further considered in the industry as a whole, this has a similar underlying tone regarding the long-term considerations in construction design and construction stated previously. Roemers suggests looking towards the Netherlands, where there is a focus on resource mining. Finally, it is believed that the implementation on carbon taxes is a plausible gateway policy that could be taken by government. He states that, construction

companies might not change, but municipalities and commercial developers can change with less resistance, thus pushing the industry towards circularity.

Finally, the third interviewee with Ditte Lysgaard Vind, focused primarily on the topic of resource scarcity that might become the key driver for the change culture required to create circular industry practices. She states that there are currently successful projects that rely on the utilization of resource recovery, they shed light on the solutions for the challenge at hand. As a proposition for such solutions, Vind indicates that municipalities have to work on the relaxation of rules that open up the industry for new practices to come to market. She also mentions that investors hold a key to stir entrepreneurs into this direction.

The information collected from the interviews above has been summarized in Figure 5.5 to be used as a tool to enhance the circular business model design that will take place in the tertiary assessment.

Part III

Analysis

6 Empirical Data Assessment

In this chapter the researchers analyze empirical findings. The process for analysis is outlined in Figure 6.1 which is explained in further detail within each section below. From the analysis of the empirical data the problem statement is addressed.

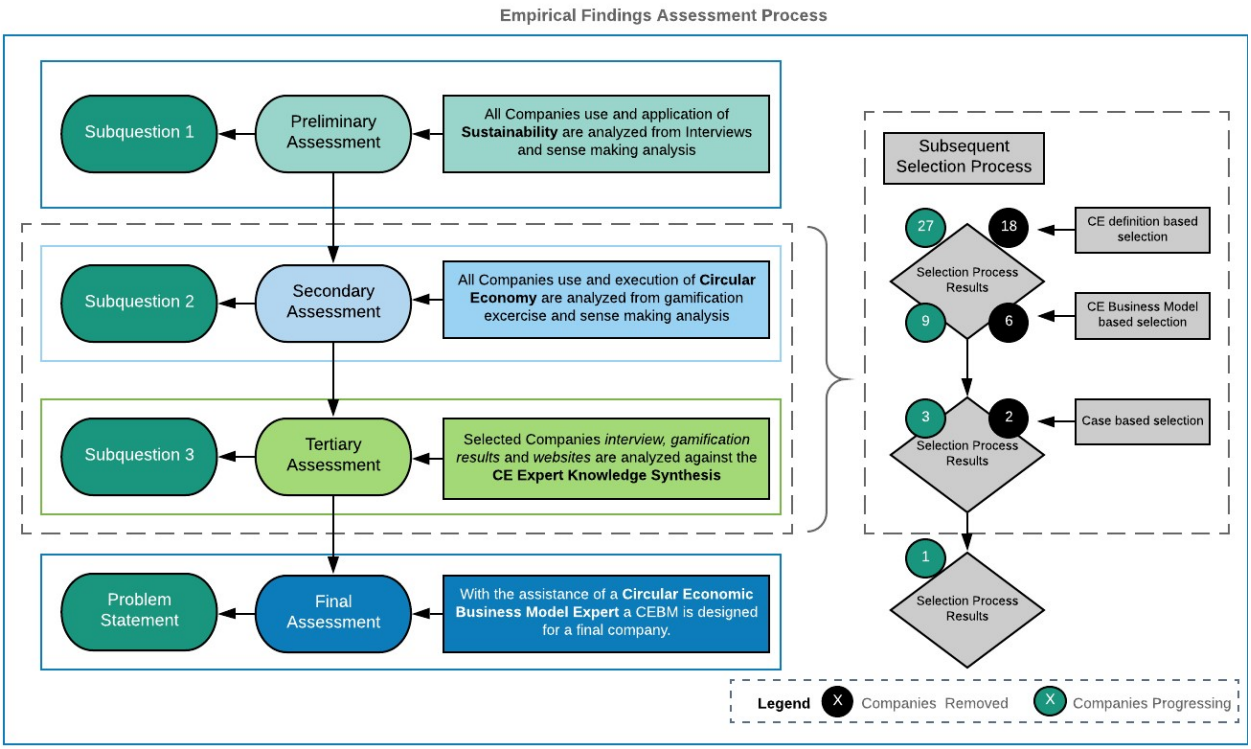

Figure 6.1: Empirical Findings Assessment Process [primary source]

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At the conference 27 companies from the Danish building industry were asked to present their products and services. Table 6.1 lists the companies interviewed, the table headers show the number of companies 1 - 27 on the left, the company name and the product/service the company provides.

The final company will be chosen as the company with the most pre-existing sustainability and circular economic practices as the pilot case to develop a circular economic business model.

Table 6.1: Interview List

	Company	**Service**
1.	Cembrit	Fiber Cement
2.	Climatic A/S	Fall Protection
3.	Cramo Adapteo	Modular Buildings
4.	DBI Dansk Brand	Fire Test/Material Cert
5.	DK Concrete Hardener	Concrete Hardener
6.	Fermacell Scandinavia	Fiber Gypsum
7.	Fire Eater	Fire Suppression
8.	Frøslev	Wood Products
9.	Gamle Mursten	Recycled Bricks
10.	GMH Måleteknik A/S	Indoor Climate EQMT
11.	Guldager A/S	Water Treatment
12.	InnoByg	Sustainable Network
13.	Milton Megatherm	Central Heating
14.	Natural Greenwalls	Green wall Systems
15.	PanelByg	Insulation
16.	Phønix Tag Materialer	Roofing Felt
17.	Scanaton	Clay Bricks
18.	Skalflex	Facade System
19.	SolarLAb	Solar Cladding
20.	Sto Design	Cladding System
21.	Thermozell	Concrete
22.	Thors Design	Upcycle Furniture
23.	Teknologisk Institut	Knowledge Sharing
24.	AirPlant	Air Purification
25.	ILuft	Tabletop ventilation
26.	KSK Group	Skylight insulation
27.	Rexcon System	Wall System

*Note that some companies interviewed were not conventional service or product based companies and were spoken to out of interest but were not considered for the enlisted subsequent select processes.

The *preliminary assessment* involves a high-level overview of the 27 companies. The findings are analyzed and weighted against the intent of Sustainability (defined through the literature review) expressed through green initiatives that respond to the three pillars of sustainability. This results in the answer to sub-question 1.

The *secondary assessment* investigated all the companies business model simulations on a high level to inquire to applications of CE in business modeling or not. companies CE definition and the study game simulation and explanations thereof were listed and 6 companies that exhibited potential for circular practices according to the definition of CE established above were selected to be analyzed more deeply in the assessment.

Subsequent to the answering of sub-question 2 in the secondary assessment a selection

process of companies takes place this is seen in the grey colored right side of Figure 6.1. The selection and process will be presented in the tertiary assessment in the form of tables showing proceeding companies that are subsequently studied in more and more detail. The subsequent selection process has 3 stages. In the first stage 18 companies are removed where selection was based on initiatives related to the definition of CE presented in the introduction, in the second stage 6 more are removed where selection was based on evidence based feasibility of the business wanting and able to practice CE. And in the final stage 2 more are removed where the selection is based on an in-depth investigation into each company to further understand the opportunities for evolving the business towards CE.

In the *tertiary assessment* a feasibility in-depth investigation was done on 3 companies. The researchers investigate first the comparability to the circular business models presented in the chapter CE in construction, then the interviews, business models and company websites against the key findings from the experts in CE (Peter Andreas Sattrup, Gerard Roemers and Ditte Lysgaard Vind) and sub-question 3 is answered. The *tertiary assessment* resulted in 2 companies being removed from the project and one proceeding onto the *final assessment*. In the *final assessment* a business model study for CE is developed.

6.1 Preliminary Assessment on Sustainability

The preliminary assessment involved interviews with 27 businesses which presented a general overview of sustainability encountered at the conference. Since the conference was based on sustainability it was expected that there would be a sustainability initiative at each business. It was unclear what the requirements were to have a booth at the conference, but it seemed reasonable that having some sort of sustainable spin on the conventional business was necessary. The interviews were analyzed one by one for green initiatives in sustainability and recorded. Initiatives have been communicated qualitatively in most cases, thus the researches have categorized and organized these initiatives into one of the three pillars of sustainability. This categorization resulted in quantitative data which could be analyzed for a high level summarization of sustainability in industry by the social, environmental and economic pillars.

The interviews resulted in 29 green initiatives mentioned 108 times by company representatives. Figure 6.2 illustrates the overview of Sustainability initiatives by pillar. By the distribution in Figure 6.2 social and environmental pillars of sustainability are representing a similar proportion of influence on the market. The economic pillar is less represented during the companies presentation of their products and services. Below each pillars green initiatives are presented.

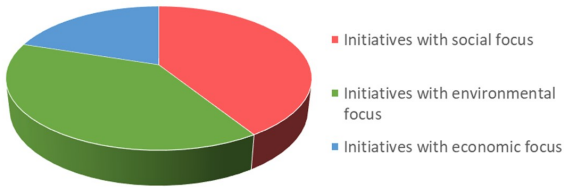

Figure 6.2: Proportion of Sustainability Initiatives by Pillars [primary source]

6.1.1 The Social Pillar

The initiatives concerning the **social pillar** of sustainability ranked very important. 39% of the 29 initiatives were related to the social pillar, where user friendly solutions, easy installation, knowledge sharing, consultation and human health were in focus. An initiative was assessed as social when the initiative positively impacted or took into consideration human well-being. Of these 10 social initiatives, 8 companies stated that flexibility was applied in the design of the product, 8 companies considered security and safety and health which is already required by law - so hardly innovative -, 7 took into consideration whether or not their product were non-toxic. The remaining green initiatives were represented by 4 or less of the companies with social strategies such as user friendliness, knowledge sharing, FSC certification and cradle-2-cradle certification of their products.

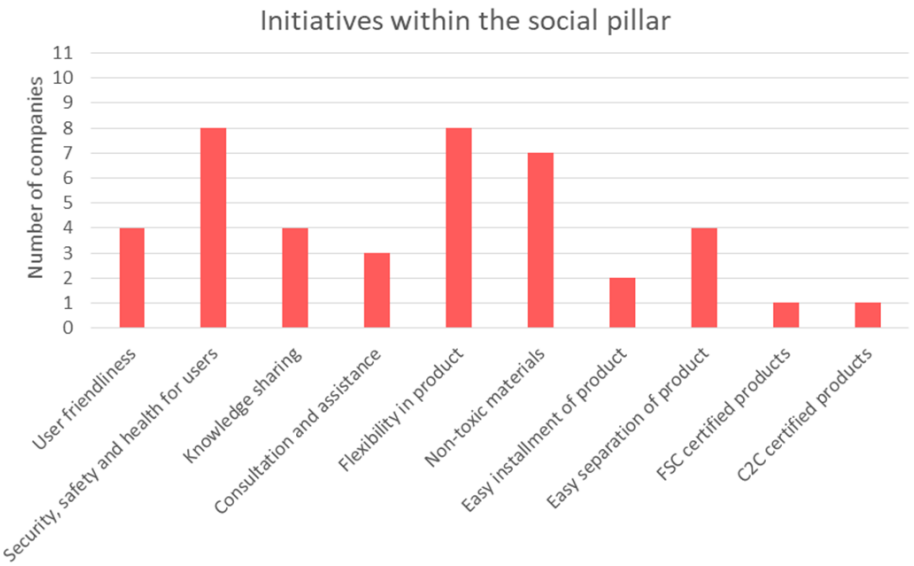

Figure 6.3: Initiatives within the social pillar communicated by companies [primary source]

Flexibility and *security, safety and health for users* were the most noted green initiative within the social pillar categorization. The use of the terminology *flexibility* varied from business to business ranging from modular building suppliers, cladding suppliers and fire suppression services. Utilization of flexibility was expressed through, flexibility of product choice to flexibility of design opportunities. Security, safety and health for users varied from security of users while working, to products improving climate in buildings or work spaces.

6.1.2 The Environmental Pillar

Initiatives regarding the **environmental pillar** presented 42% of the initiatives relating directly to the environment. The companies utilized initiatives such as responsible selection of material, design for disassembly and design for long life in products. An initiative was assessed as environmental when the primary focus was environmental well-being.

The environmental pillar was represented by 11 green initiatives. 10 companies states that long-life was considered as an environmental component of their product, none had a full closed loop. 7 companies had commitments to clean materials in their product and 6 had recycled materials in their product. 5 companies presented green initiatives focused on reuse of the product, modular design, and resilience as initiatives targeted at environmental pillar. Other initiatives supported by 2 or less companies included reuse of components, PFC wood certifications, water recycling and products made of surplus materials. These observations are presented in Figure 6.4.

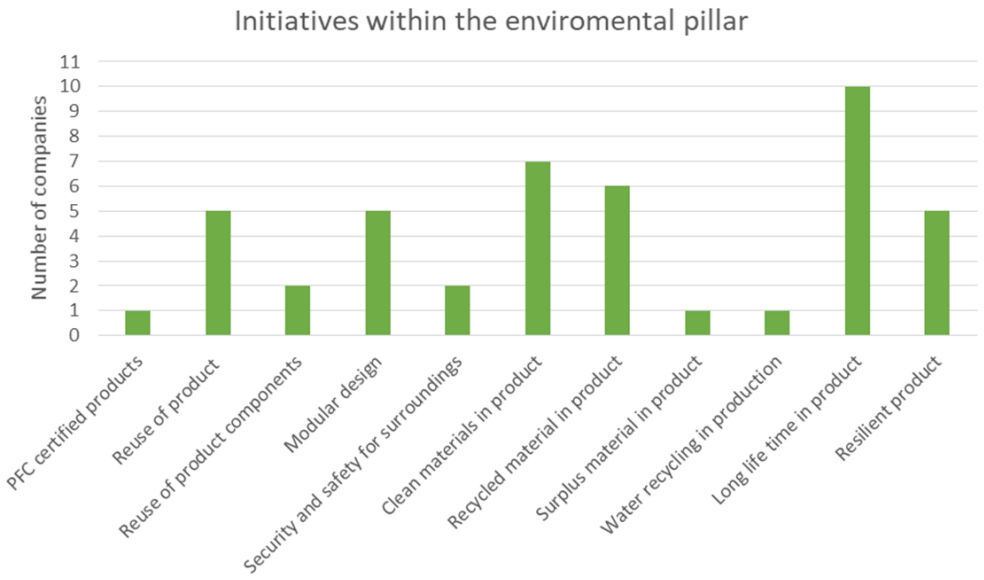

Figure 6.4: Initiatives within the environmental pillar communicated by companies [primary source]

Long-life in products and *flexibility* were the most represented initiative amongst the 27 companies. Long-life was primarily presented by suppliers to the skin and structure layers of building. This reflected the information found in the literature review on building value.

Companies were asked if *end-of-life* initiatives were considered. 6 companies said that reuse of product was a part of their business, only two had a take-back system. Seven companies saw possibilities for reuse of their product, however, this was not a focus. It was the same case for the potential recycling of product materials, where 15 mentioned the possibility, however, none of the companies applied it in practice nor had it as a focus during design. Several of the companies mentioned this was due to the short time their companies has been in business and others mentioned the long life time meant it wasn't their concern. Most companies focused mainly on their products up until the sale. Several businesses manufacture or resell products ideal for reuse and/or recycle, however, whether or not the products are reused or recycled was left up to others businesses.

6.1.3 The Economic Pillar

Initiatives related to the **economic pillar** of sustainability had a share of 19% of the 29 initiatives mentioned. Companies mentioning these initiatives focused on efficiency in end product, the building, resulting in economic savings. An initiative was assessed as economic when the main focus was business prosperity or savings in the end product. The reason for the economic pillar not being represented as much as the social and environmental may be as the focus on the build green conference primarily on those two pillars.

The economic pillar was represented by 8 green initiatives. Of these initiative 4 companies had mentioned either energy efficiency of their product or optimized design of size and weight as well as product as a service. At least 2 companies mentioned locally produced products, low energy use in production, transportation efficient and digitization of process as economic applications of sustainability. These findings are presented in Figure 6.5.

Energy efficient product and *optimized products, size and weight* were the two most presented initiatives within the economic categorization, with representatives mainly from the skin layer of the building. For companies utilizing energy efficient products focus was on creating savings on buildings energy use by insulation or energy saving or creating products. For the ones working with the initiative *optimized products* focus was on optimizing products so less product is needed and thereby creating savings. *Renting/leasing* of product and services also presented as initiatives by four companies. Utilization of the green initiatives ranged from renting fall protection for installers, green walls and furniture to renting of complete modular buildings.

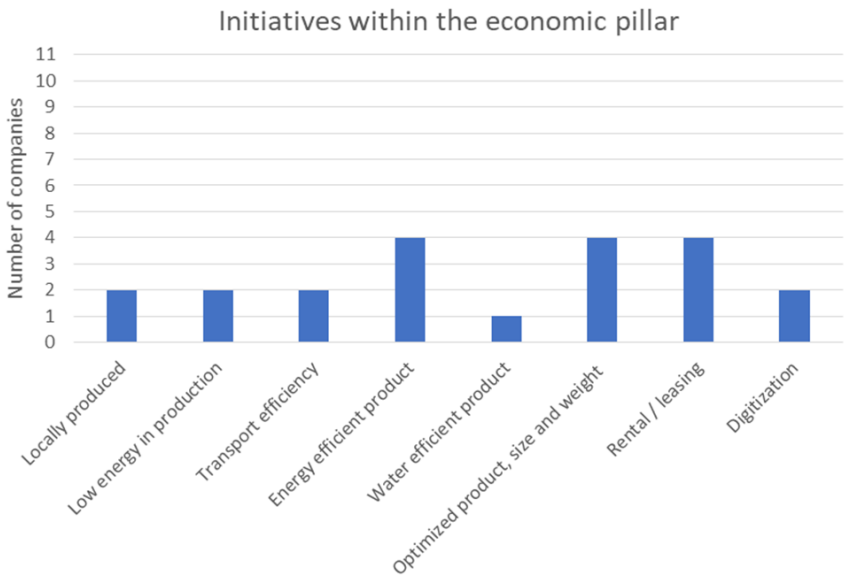

Figure 6.5: Economic Pillar Communicated by Company Initiatives

Summary of Sustainability in Industry Sustainability is expressed broadly throughout the interviews resulting in a wide variation of initiatives see Figure 6.6. This was mirrored in companies reasoning to attend the sustainability focused building conference. Initiatives ranged from including all three pillars of sustainability to only one and from embracing a broad spectrum of initiatives to integration of only one or two.

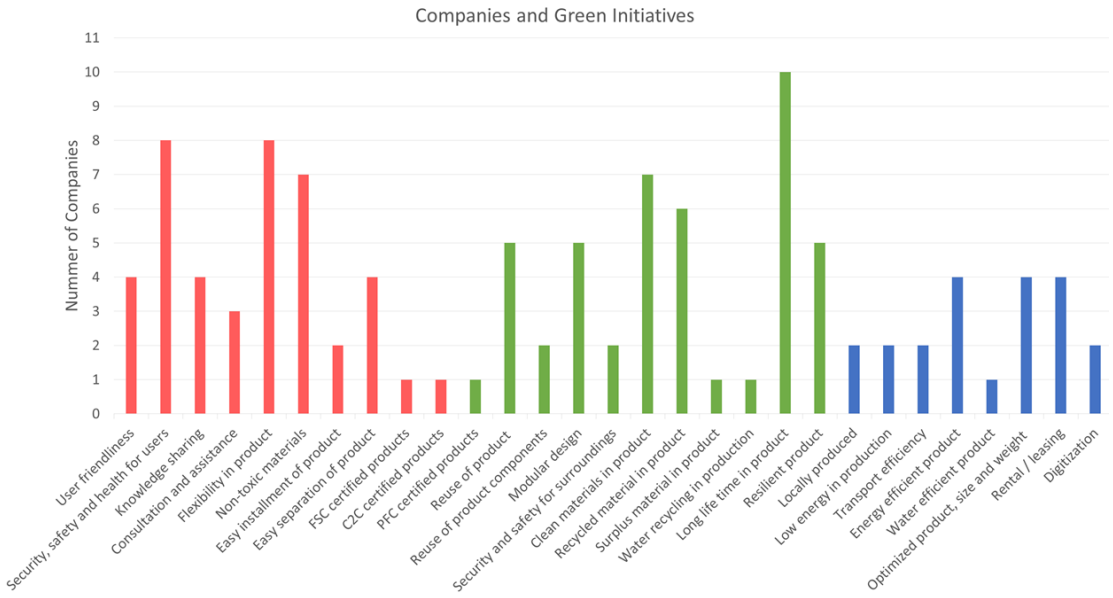

Figure 6.6: All Green Initiative Communicated by Companies [primary source]

Long life and flexibility represented the highest number of green initiatives overall.

However, the green initiative *clean and healthy products* seemed to have the biggest focus and was mentioned more frequently overall. This included green initiatives such as reducing use of toxic materials and toxic processing of materials, as well as, products that aimed to secure optimal climate for humans or assist in the safety of humans in buildings.

6.2 Secondary Assessment on Business Modelling

The secondary assessment provides an impression of how the building industry businesses communicate business models. The business models simulated using the gamification will be compared against findings in the literature review on circular business models from *Building a Circular Future* by 3XN/GXN [2018a] and analyzed in order to answer the second sub-question. Findings are listed in Table 6.2.

The gamification exercises proved both entertaining and challenging for the participants. Companies were initially compelled to visualizing their business models linearly, when additional questions were asked in reference to the interview many adjusted, sometimes recognizing that there were some circular applications at play. Most companies resulted with one or few circular initiatives being connected together, there were only a few cases in which circular loops were closed entirely and those had an intended significant focus in circularity in their business model. It was found that business models from the gamification exercises rarely directly imitated the the circular business models. Companies also seemed to have different interpretations of the included terms and so added terms.

When basing the business models on existing initiatives most of the companies could expand their business model to the three first circular business models, letting the initiatives guide the companies to further their circular progress. Eight companies worked with initiatives that would enable the opportunity to integrate the business model Circular Supply Chain, seven of the companies the business model Recover and Recycling and six companies Product Life Extension. The two last business models, Sharing Platform and Product as a service, could be integrated in a total of four companies based on the companies initiatives and focus, being the least immediate business models for the selected companies.

When questioned about the phase end-of-life, companies mentioned the potential for both reuse and recycle, sometimes adding it on to their business models even if it was not a conscious design feature or an desired initiative for the company to expand on. This resulted in divided business modes with actual initiatives on one side and potentials on the other, giving the business model an unclear focus and direction.

Table 6.2 provides an overview of the 27 interviewed companies and the circular business models the relate to, distribution in the table is based on the interviews (see Appendix

A.9-A.13 for the list of companies' green initiatives) and gamification exercise. The five business models are represented in the table as follows:

- **1. CSC**: Circular Supply Chain
- **2. RAR**: Recover and Recycling
- **3. PLE**: Product life Extension
- **4. SP**: Sharing Platform
- **5. PAS**: Product as a Service

If CE was not mentioned nor shown in the business models they were left blank.

Table 6.2: Business model relation schema to circular economic business models

	Company	**1.CSC**	**2.RAR**	**3.PLE**	**4.SP**	**5.PAS**	Total
1.	Cembrit	•		•			2
2.	**Climatic** A/S	•	•			•	**3**
3.	**Cramo Adapteo**	•	•	•		•	**4**
4.	DBI						0
5.	DK Concrete Hardener	•					1
6.	Fermacell Scandinavia	•	•				2
7.	Fire Eater	•					1
8.	Frøslev	•					1
9.	Gamle Mursten	•	•	*			2
10.	GMH Måleteknik Aps						0
11.	Guldager A/S		•		•		2
12.	InnoByg**						0
13.	**Milton Megatherm**	•	•	•			**3**
14.	**Natural Greenwalls**	•	•		•		**3**
15.	PanelByg						0
16.	Phønix Tag Materialer	•					1
17.	Scanaton	•					1
18.	Skalflex						0
19.	SolarLAb		•				1
20.	Sto Design	•	•				2
21.	Thermozell	•					1
22.	**Thors Design**	•	•	•	•		**4**
23.	Teknologisk Institut **						0
24.	AirPlant	•		•			2
25.	ILuft	•	•				2
26.	KSK Group	•					1
27.	**Rexcon System**	•	•	•			**3**

* Gamle Mursten could be considered PLE by some because they are extending the life of an existing product. However, others might argue that because within the framework of their business no PLE initiative have been taken and thus should not be considered. ** Two companies that were interviewed were not service based or product based. These companies were network based and they did not talk about circularity in their own processes.

This section looked at all the companies relationship with circularity in Table6.2. The rest of the section will take a select sample of 6 companies to study towards an answer to sub-question 2. Not all of the companies interviewed represented circularity and some represented it in theory but not in practice. The companies that will be mentioned below are **bolded** in the above table. They were selected for having the greatest relationship with circularity.

6.2.1 Circular Economic Business Models

1. Circular Supply Chain: Sourcing of materials that are renewable and/or recyclable as well as designing for consecutive material life cycles by utilizing easy separation and modular design are initiatives that characterizes the first circular business model. These initiatives were mentioned by several of companies: Climatic A/S, Cramo Adapteo, Milton Megatherm, Natural Greenwalls, Thors Design and Rexcon System. The majority of initiatives were through sourcing of non-toxic clean materials, with four companies practising these initiatives. Three companies designed for easy separation and modular design. Two companies utilized recycled materials. One aimed to use non-toxic and clean materials in addition to C2C certified products. Companies categorized under **1.CSC** illustrated within their business model resources and material consciousness even if priority of such varied. Figure 6.7 illustrates the business model presented by Milton Megatherm AS. a supplier of HVAC heating equipment. and **1.CSC** Circular Supply Chain business model framework that it has been compared to as an example.

Figure 6.7: Milton Megatherm's business model [primary source] & [3XN/GXN, 2018a]

Megatherm AS. emphasized the importance of clean materials as such it was the first input in the business model influencing design, performance and operation. The scope of the business model starts from sourcing materials then to operation, showing primarily a linear business model. However, the possibility for recycling the product and components after end-of-life were noted so potential in this area exists. Although no take-back program currently exists and it was noted by the representative that this was not a focus point and

was outside of the model scope.

The next company investigated for **1.CSC** was Thors. Thors sells wood furniture made from reused petrified wood found in the Copenhagen harbour. The wood, Azobé, from maritime bulwark is used for it's desired strength properties. An important initiatives beside the sourcing of materials was ensuring the use of clean products. The only other component in their furniture is steel brackets, both wood and metal are non-toxic and finishing coats are not-required. Thors owners emphasized the importance of resources and material procurement and that this was very central in their business model.

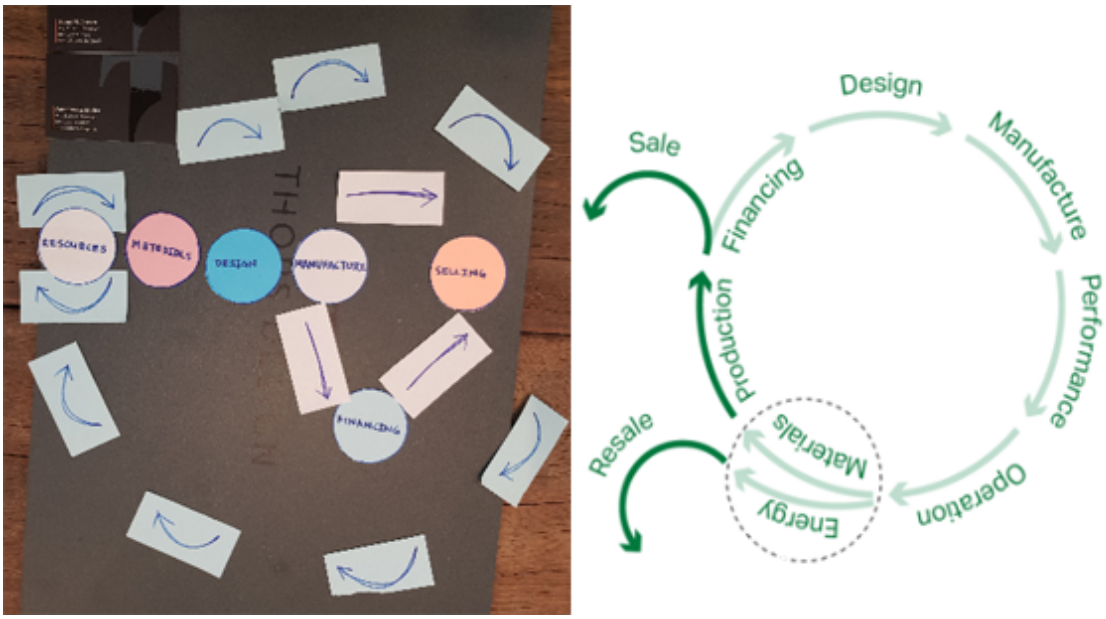

Figure 6.8: Thors Design's business model [primary source] & [3XN/GXN, 2018a]

"The wood we use are from the harbors. We take it out of the water and make furniture of it. When you close a harbor or change the tree, we take it out of the water, we use the old one for furniture[...] the wood is from Africa, it is called Azobé or iron wood" - representative from Thors Design

2. Recover and Recycling: Initiatives securing reuse and recycle of materials in products as well as design for separation and modular design are central initiatives in the recover and recycling business model. The same initiatives were communicated by six companies: Climatic A/S, Cramo Adapteo, Milton Megatherm, Natural Greenwalls, Thors Design and Rexcon System. Three of the companies mentioned direct reuse of their products or product components. Two of those companies noted design for separation and two others mentioned modular design as initiatives in their business. Two more companies mentioned producing products from recycled material with potential for reuse and recycling. All the selected companies mentioned a potential for product or product component reuse and/or material recycle.

Cramo Adapteo provides rentals of modular buildings, which they take back and refurbish before renting them out again. Reuse of their product is a central part of their business model. This business model shows reselling, see Figure 6.9, however, reuse is not shown explicitly and gives room for different interpretations of the business model as the representative chose not to indicate with arrows the relationships and verbally just noted they were connected. Initiatives within recover and recycling were not illustrated as part of the business models, however, they were mentioned during the gamification exercises.

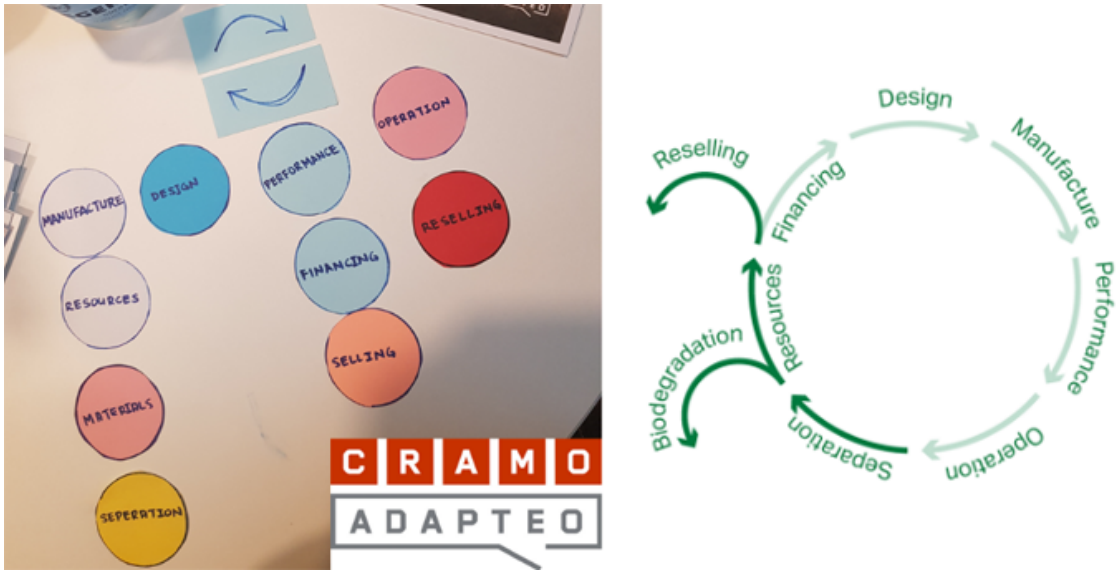

Figure 6.9: Cramo Ádapteo's business model [primary source] & [3XN/GXN, 2018a]

It was important focus to find the right material, so that it would also be green, that's why we use recycled plastic [...] It's possible to reuse the system [...] We can take everything down from one office area and go to another office area and put it up again - representative from Natural Greenwalls

Natural Greenwalls business model showed the most opportunity for separation and reselling, and although it was states that recycled material was used it was unclear how much, nor was the potential for recycling post use. The business model is linear despite the included terms being placed in a circular orientation. Additionally, Natural Greenwalls manufactures part of their products with recycled materials, however, this is not clearly identified in the business model,as shown in Figure 6.10.

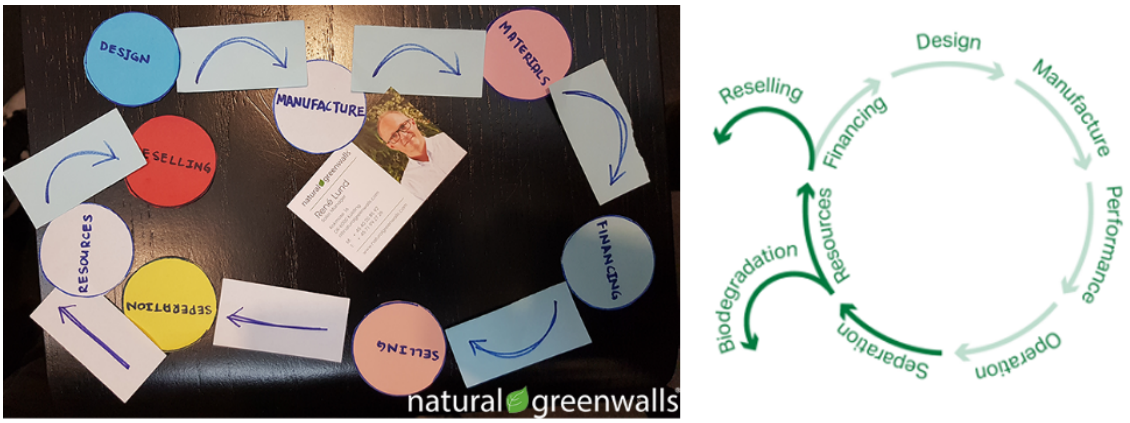

Figure 6.10: Natural Greenwalls' business model [primary source] & [3XN/GXN, 2018a]

3. Product Life Extension Resale, up-cycling, restoration and re-branding are in focus in this business model. Initiatives that fall under product life extension consisted mainly of designing for long life and the opportunity for easy product repair or components or replacement of products. Design for long life expectancy was viewed as being a very sustainable initiative and three of the selected companies mentioned it. This initiative, however, proved challenging as users often desire upgraded products after some time. This phenomenon can cause the products end-of-life to be reached sooner than it was designed for. Some companies have integrated different solutions to counteract this and out of the six companies four had actively design for easy separation and modular design, three of those also had the initiative long life time. One company utilized up cycling, restoration and re-branding of materials. The companies with initiatives related to this business model were Cramo Adapteo, Milton Megatherm, Thors Design and Rexcon System.

Thors Design focused on re-branding product history for resale utilizing story telling and tracking of products to increase their product value. The representatives from Thors Design mentioned how value increased as the products developed a nice patina and a longer history. The re-branding is only mentioned and not shown in their business model, see Figure 6.8. Reselling is illustrated with arrows leading the products from sale to resources.

You buy the history. Of course you buy a material, a table, because you need a table, but if you just need a table, you can buy any table you want. Here you buy the history, more than you buy a table. You buy the idea of what it's made of and where it from. - Representative from Thors Design

Rexcon System mentioned easy separation and installment in addition to the modular design of the product as a substantial element in the design of the product seen in Figure 6.11. This together with reuse gave the company a circular focus, which is partially illustrated in the business model with arrows ending in separation and reselling.

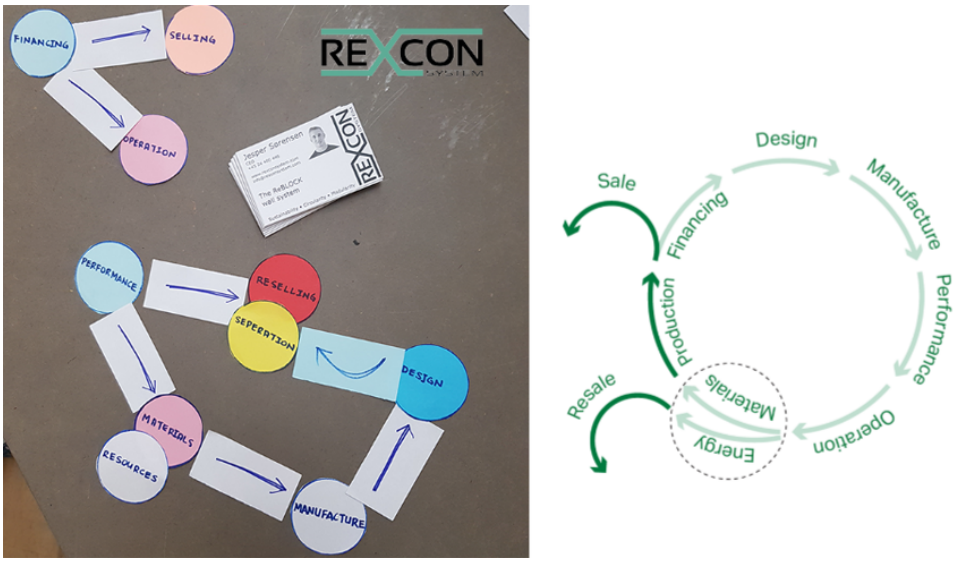

Figure 6.11: Rexcon System's business model [primary source] & [3XN/GXN, 2018a]

4. Sharing Platform One of the least explored initiatives was the sharing platform business models. This circular economic business model optimizes usage of the product by lending out or sharing the product. Among the six companies two companies, Natural Greenwalls and Thors Design, mentioned the service of renting of their products. For the two companies renting was part of their businesses, however, this service was not clearly presented in their business models, it was only explained and referred to as selling in their business models, as seen in Figure 6.10 and Figure 6.8.When end customers wish to return the product Natural Greenwalls will take it back and reuse it, which secures optimized utilization of the products.

"We have two kind of costumers, our dealers, which are our biggest costumers, that buy our systems [...] and [...] in Denmark we also have our end costumers, and some of them are renting walls, they just pay every month and if they are finished their business or move to a bigger building, they can just [...] quit"- representative from Natural Greenwalls

5. Product as a Service Two of the companies explored initiatives associated with the fifth business model, where focus is on renting out whole systems of buildings as a service. Climatic A/S delivers fall protection services. Fall protection protects workers from falling of roofs when doing work such as installing solar panels on buildings. Their business model clearly shows the reuse of their equipment in their solution based services see Figure 6.12. However, circularity was dismissed as a focus. Manufacturing of the product is placed outside of their business model scope, as they do not manufacture the products. Separation is placed further out as well as it represent potential recycling of their products instead for a service.

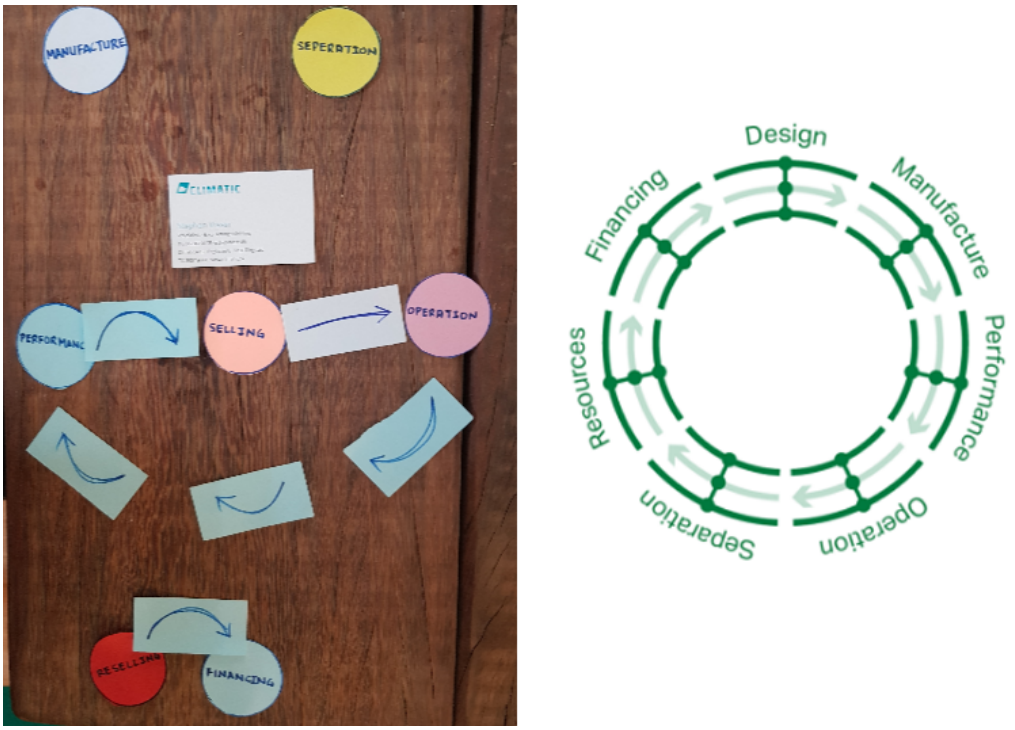

Figure 6.12: Climatic A/S's business model [primary source] & [3XN/GXN, 2018a]

Cramo Ádapteo's business model consist of four interconnected pillars and above those, two circled arrows, see Figure 6.9. This business model expressed the timeline going from the left pillar where the products are manufactured, then to design where solutions are created, on to the rental and operation of the solution and in the end the reselling. The product being a service is not illustrated explicitly, and no explanations from the company representative were provided during the gamification exercise.

We are selling temporary models for hospitals,for offices, for schools,for the farmer industry for offices in labs. We are designing and building and our buildings have a life time for 25-30 years [...] then we take it home, we refresh it and rent it [...] We are in seven countries and it is the same models in all countries [...] We need to have the same color and system because it will go around in all countries- Representative from Cramo Adapteo

6.3 Tertiary Assessment

The Tertiary assessment begins with the Subsequent Selection where the selection process is completed with a select from the 27 businesses interviewed to three for in-depth assessment.The below section shows how they have been selected.

First Subsequent Selection

The following present a explanation of the first *Subsequent Selection Process*, where nine businesses were selected for their presented initiatives to be specifically considered for the final CE design. They were selected according to their integration of circularity which they presented in the interview. The process used for this selection was a high level assessment in excel (Appendix A.7) of the companies willingness to focus and work with CE in their business's. This reflected the supplementary research by moving from companies with initiatives related to Sustainability in general to companies integrating initiatives concerning CE, see Figure 1.3 by using the six principles presented by**?** and including companies with more than one circular initiative.

Table 6.3: First Subsequent Selection Results

	Company	**Service**
1.	Cembrit A/S	Fiber Cement
2.	**Climatic A/S**	Fall Protection
3.	**Cramo Adapteo**	Modular Buildings
4.	Gamle Mursten	Recycled Bricks
5.	**Milton Megatherm**	Central Heating
6.	**Natural Greenwalls**	Green wall Systems
7.	Scanoton	Clay Bricks
8.	**Thors Design**	Upcycle Furniture
9.	**Rexcon System**	Wall System

Non circular businesses with circular initiatives The companies Cembrit A/S, Climatic A/S, Milton Megatherm and Scanoton had several initiatives that related to both circular principles and business models, however, the circularity was not the main focus in their businesses. As the researchers wish to develop a applicable circular business model for a company, these four are deselected.

The circular businesses Of the companies selected two stood out relative to circular business models. The companies Gamle Mursten and Thors Design built their business model in a was that resembled circular models. Gamle Mursten collects used bricks at building sites and sell them as reused bricks. The company will take the products back if contacted at the products end-of-life and resell the bricks that can be reused thereby creating a practically closed loop. Thors Design source material from Danish harbors and upcycle it to unique furnitures. Thors Design both sell and rent out their products and have a take-back service, which keep their products in cycle for a very long time. The relative simple and clean input of materials into the two companies products makes the material streams manageable and the circular business model more simple to maintain. These companies show good examples of circular businesses in the building industry and as the researchers of this project wishes to develop a circular business model for a company

where the impact will be bigger, these two companies are deselected.

Second Subsequent Selection

Non circular businesses with circular initiatives The companies Cembrit A/S, Climatic A/S, Milton Megatherm and Scanoton had several initiatives that related to both circular principles and business models, however, the circularity was not the main focus in their businesses. As the researchers wish to develop a applicable circular business model for a company, these four are deselected.

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The following three businesses were selected for both their progressive integration of sustainability and CE business modeling as compared to their peers: *Cramo Adapteo, Natural Greenwalls, and Rexcon System* . Cramo Adapteo was selected due to the focus on easy separation of their product, reuse of product, reuse of product components and modular design. Natural Greenwalls was selected due to their focus on recycled materials, ability to offer their product as a service, ability to reuse product components at end of life. Finally Rexon was selected for the businesses focus on ease of installation of the product, modular design, transportation of product considerations and the potential for reuse.

Table 6.4: Second Subsequent Selection Results

	Company	**Service**
1.	Cramo Adapteo	Modular Buildings
2.	Natural Greenwalls	Green wall Systems
3.	Rexcon System	Wall System

Cramo Adaptao communicated strongly various circular initiatives during the interview and showed a business model where the product became a service and were, therefor, selected for *tertiary analysis*.

Natural Greenwalls mentioned initiatives of circularity throughout the interview and expressed interest in the circular potentials of their product so they were selected for further investigations in the *tertiary analysis*.

Rexcon System articulated circularity in their interview and displayed opportunities and motivation for further circularity in their business model so was selected for *tertiary analysis*.

The completion of the preliminary and secondary analysis resulted in three businesses proceeding to the *tertiary assessment*. These businesses were selected because they had the most Sustainable green initiatives and the most circular economic applications compared to their peers. The researches have chosen to engage a selection process due to time constraints as well as the aim to strategically focus only on businesses who present demonstrated dedication to implementing sustainability strategies. These three companies will be studied in depth towards the design of a final CE business model. The researchers investigate the interviews, business models and company websites against the advice and key findings from the experts in CE (Peter Andreas Sattrup, Gerard Roemers and Ditte Lysgaard Vind) and sub-question 3 is answered. In the end of the assessment one company is selected and a applicable circular business models is developed.

Cramo Adapteo is a provider of temporary modular building solutions for use in rental, daycare, health care facilities, office space, construction sites and more. The company business model is service based. The business designs spaces, assembles them on remote sites, provides maintenance/service, and at end-of contract disassembles and removes the modular building. The company web-page reflects many sustainability initiatives such as designing for adequate light as well as designing for sensor based temperature control for energy savings [Cramo Adapteo, 2019]. Listed below are the green initiatives towards sustainability by Cramo Adapteo.

Table 6.5: Cramo Adapteo Green Initiatives Summary

	Green Initiative	**Pillar**
1.	Modular design*	ENV
2.	30-40 year lifespan of modules*	ENV
3.	Durability	ECO*
4.	Reuse, Rebuild and refurbishment of product	ENV
5.	Disassembly and reassembly of entire product	ECO
6.	Possibility for redesign	ENV
7.	25,000 models options	SOC
8.	Resell: only summer houses	ECO
9.	Design for adequate light	SOC,ENV
10.	Efficient HVAC Design	ENV, ECO
11.	Flexibility	ECO,ENV

* Note that some initiatives may overlap, however, they are not exclusive to one another

and so are listed separately.

Cramo Adapteo's business model shows four columns (Figure 6.9). The researchers were verbally informed that these elements interact and influence each other even though the business model does not show this. The first column included the terms: *manufacture, resources, materials* and *separation*. The representative explained that the manufacturing of the modular components involved the synthesis of all four components. *Design* was separated into its own category. *Performance, financing* and *selling* were designated their own category and *operation* and *reselling* were also categorized on their own. There was sparse additional explanation given during this particular exercise.

Analysis of elements shows that Cramo Adapteo embodies strong potential for circular economic applications. In reference to Figure 4.6 on Circular Economic Business Model Types, Cramo Adapteo reflected components of the first, second, third and fifth models *circular supply chain*, *recover and recycling product life extension* and *product as a service*. The inclusion of modular design allows components to be reused and are refurbished to extend the lifespan of the product, additionally the product can be resold at the end of life. Opportunities for are limited, however, due to reasons illuminated by Ditte Lysgaard Vind which involved strict laws restricting where secondary components can be used. A government level relaxation and testing procedures for approving these applications could create greater demand. If components are not reused it is understood that the remaining modules are disposed of.

There would be Sustainable benefits if Cramo Adapteo architects began designing the modules for disassembly increasing the value of hardware within the modules. This could be possible through an internal company material passport and national wide harvesting map of their products, as mentioned by Gerard Roemers. Cramo has opportunities (due to the size of the company) to employ new revenue streams if internal resource mining were applied. These new jobs could include mapping, storing and refurbishing of these components. Cramo Adapteo could further their sustainability by promoting energy efficiency within the modular operations of HVAC and lighting. Additionally the transportation of modules by utilizing electric zero-carbon trucks could reduce the companies carbon footprint. Furthermore, responsible procurement of building components could further encourage Sustainability and CE through supply chains. This could include elimination of toxic building materials and encouragement with products that have a cradle-to-cradle certification or other green building certifications.

Natural Greenwalls sells wall systems, green walls, moss walls and recycled teak walls. The business is located in Denmark where all the components are designed, produced and procured. The system presented at the conference was the green wall system. The green wall featured an internal irrigation system that runs from plant to plant in a recycled plastic housing using specially designed efficient water supply system. Gravity is the

primary energy source. Natural green walls green initiatives are listed in Table 6.6.

Table 6.6: Natural Greenwalls GI Summary

	Green Initiative	**Pillar**
1.	Partial modular design	ENV
2.	Recycled plastic materials (%unknown)	ENV
3.	Reusing products	ECO
4.	Disassembly and reassembly possible	ENV
5.	Possibility for reselling	ECO
6.	Locally produced	ENV
7.	low water-use compared to other systems	ENV
8.	Quality control considerations for durability	ENV
9.	Technology applications	ECO
10.	Possible advancement for air purification	EN
11.	Integrated and iterative design	All
12.	Specific sourcing of materials	ENV

* Note that some initiatives may overlap, however, they are not exclusive to one another and so are listed separately.

An analysis of Natural Greenwalls business model were cross references with Figure 4.6 on circular economic business model types and resulted in relationships to model three, four and five *product life extension*, *sharing platform* and *product as a service*. The company utilizes up-cycling, restoration as well as the opportunity to rent or buy it's products. Considerations of long-term planning was evident through the option of purchasing their product or renting it as a service where the product is then maintained by third party landscaping companies and eventually returned at the end of the service contract if so desired, although this is only in theory and has not yet been done. Furthermore, the consideration of resource efficiency and optimization of water during the operation of the product were taken into consideration during design.

There are opportunities to utilize architects in the promoting and use of their product and sharing the benefits of biophilic work-spaces and fresher indoor quality. Considerations need to be made in regards to how much more energy is required as a trade-off for a nice to have component. Similar applications as above could be utilized which involve the pursuit of certified components in product components and procurement.

Rexcon System provides an innovative wall system inspired by LEGO systems. The product offers full value chain benefits from significant savings relative to today's competitors, time optimization's compared to today's processes and a minimal carbon footprint relative to the competition. Rexcon was part of Building Green Aarhus conference Innovation Village, where grassroots, start-ups and students present innovative sustainable solutions to buildings [Rexcon System, 2019].

Table 6.7: Rexon GI Summary

	Green Initiative	**Pillar**
1.	Modular system design	ENV
2.	Easy use, efficient	SOC
3.	Disassembly and reassembly of product	ECO
4.	Optimizing design and packaging for transport	ENV
5.	Possibility for reuse and reselling	ECO
6.	Flat Pack	ENV
7.	FSC and PEFC certified materials	ENV
8.	Minimized transport volume	ENV
9.	Minimal operational thermal conductivity	ENV
10.	Work site reduced noise and cutting	SOC
11.	web page features 9 contributions to the SDG's	All
12.	reduced labour costs	SOC

* Note that some initiatives may overlap, however, they are not exclusive to one another and so are listed separately.

An analysis of Rexcon's resulting model from the gamification exercise were compared with Figure 4.6 on circular economic business model types and resulted in relationships to model 1, 2, and 3 *circular supply chain*, *recover and recycling* and *product life extension*. The company additionally makes commitments to nine of the 14 United Nations Sustainability Goals. As illustrated in 6.13 below.

Figure 6.13: Rexcon Sustainability Goal Commitments

The representative at Rexcon illustrated through the gamification a very obviously cyclical relationship between seven business components. Three components created their own internal connection. The product is designed with minimal material divisions and is FSC and PEFC certified. It was unclear if the components could be reclaimed after construction as many add-ons occur to the structural element during installation. However, theoretically the wood, metal brackets and screws can be recycled after use. Rexcon was the first system to identify the embedded impacts of it's product with consideration to transportation as had been identified as a growing point of importance by Gerard Roemers earlier on.

Rexcon implemented a product that can assist architects in influencing markets as Peter

Sattrup mentioned was possible. If this product works well and makes enough sense it could flow into the market easily. If more recycled materials were to be used in the manufacturing of the product, such as reused plywood, more testing and permissions would be granted but it doesn't entirely eliminate the possibility for future resource mining within cities. It is evident that Rexcon has taken steps to both certify and engage international initiatives such as the UN SDGs. Rexcon illustrates on a social level how to product saves labour costs, environmental costs and economic costs. Finally Rexcon has truly presented a new innovative product that is designed for improving that which is already available on the market.

Table 6.8: Tertiary Assessment

	Company	**GI**	**CE**	**Summary Notes**
1.	Cramo Adapteo	8	4	
2.	Natural Greenwalls	12	3	
3.	**Rexcon System**	12	3	

6.4 Final Assessment

Rexcon was selected as the final business to be utilized in exploring a design of a circular economic business model in the building industry. Rexcon was selected out of all the businesses interviewed due to the companies overall commitment to sustainability. This was demonstrated through it's communication of the three pillars of sustainability through green initiatives and through the company being able to communicate circularity within the gamification exercise. Additionally, Rexcon aligned it's product with the UN Sustainability Development Goals(SDGs) and published the information on it's web-page. The final assessment thus investigates circular business model design options for Rexcon.

The process for designing a circular economic business model for Rexcon can be seen in Figure 6.14. Here the researchers first take Rexcon systems' identified sustainability and circular economic initiates, then combine them with the 6 principles of a CE by ABM-AMRO and Circular Economy [2014] and apply them to two existing frameworks for circular economic models by 3XN/GXN [2018a] as shown with the arrows. The results are circular business models with potential to advance the processes of the businesses with the intention of creating more value throughout the supply-chain.

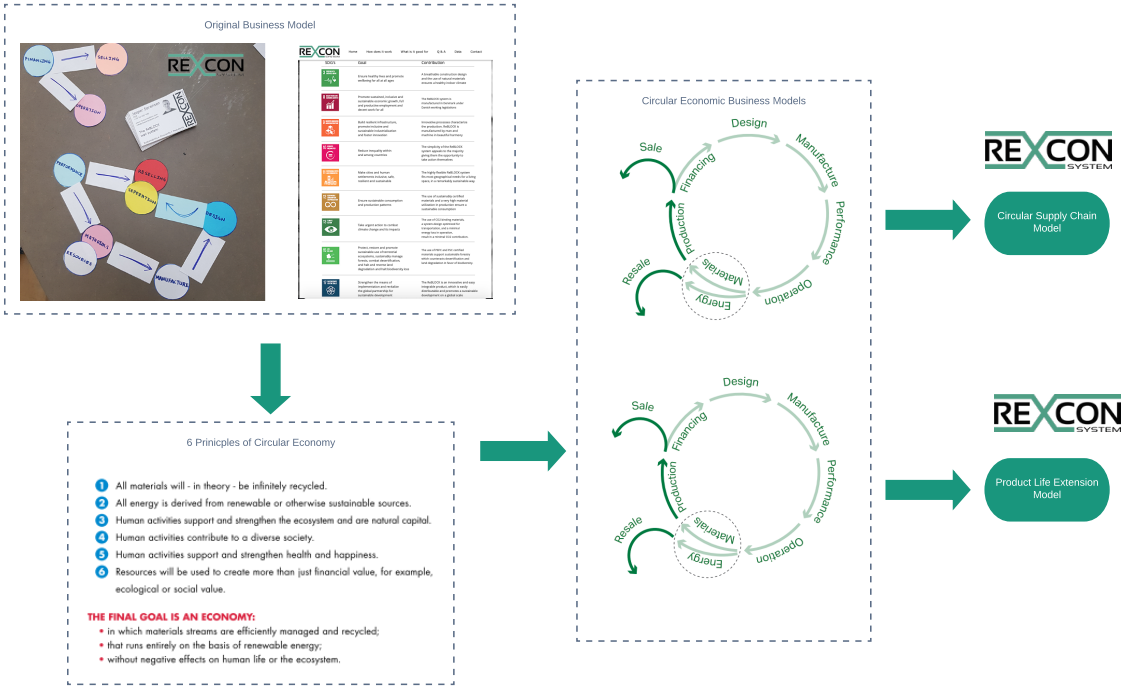

Figure 6.14: Final Assessment Design Strategy[Primary Source]

The Rexcon representative interviewed was contacted again in order to gain additional information regarding the companies product to develop these models and has committed to collaborating in interest of the research results. The two circular economic business models selected from 4.6 are as follows: The fist model is based on **1.CSC** Circular Supply Chain because it is most feasible while being able to make the biggest sustainable impact for the regular ReBlock system. This is because there was room for improvement material wise and the owner was not ready for a **SP** or **PAS** BM option yet.

"I have thought of implementing this 'take back' option to my model, but the business is not ready to handle this option yet" - Jesper Sørensen

Developing a CSC model would then reduce the impact of the product at end of life improving the model overall. **3.PLE** Product Life Extension was selected for the Basic ReBlock System because this product already posses quite a circular supply chain and for the same reasons about the business is not interested in a total shift to service based products this was the most approachable option in which sustainability could still be improved. The section below will begin with an introduction to the product and then divide into the two model presentations. The models presented identify both CE principles and sustainability development goals as part of the business model process.

6.5 Rexcon Load Bearing Wall Element

Rexcon system has designed a load bearing wall element. This component can be seen in Figure 6.15 comes in two designs "Basic" and "Regular". The element is prefabricated and suitable for a variety of construction applications. The wall is innovative offering significant savings, time optimization's and a minimal carbon footprint. The component as seen in Figure 6.17 can be transported in a flat-pack manner to it's destination, it requires two steps to unfold and lock and from there can be stacked in place, see Figure 6.17. The component is designed for a single level application for houses, garages, garden homes etc. [Rexcon System, 2019]

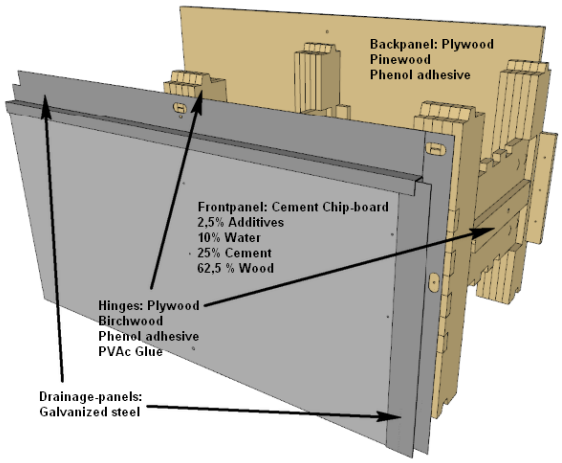

Figure 6.15: Regular ReBLOCK Structural Element [Søresen, 2019]

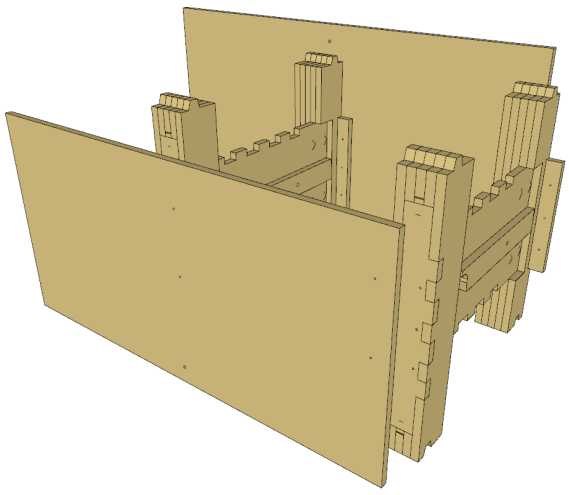

Figure 6.16: Basic ReBLOCK [Søresen, 2019]

The Rexcon company web-page states that it is all about sustainability and circularity. Five main targets are show in relation to this statement. They are *resource accountability.* Rexcon has a commitment to FSC and PEFC certified materials, *reduced emissions* because

of the products flat pack design transportation costs are lowered compared to conventional assemblies needed for structural walls, *system simplicity* the Rexcon product is easy to use and requires little training, it is fast to assemble and can be done with only the use of hand tools, *work environment* Rexcon takes into consideration the health and safety on site and notes that no heavy lifting is required, little to no noise is generated during it's installation and because it is cut in factories this reduces on site dust improving overall work conditions, finally *reusable* the block is designed for disassembly. It can be flattened again after use and theoretically applied elsewhere.

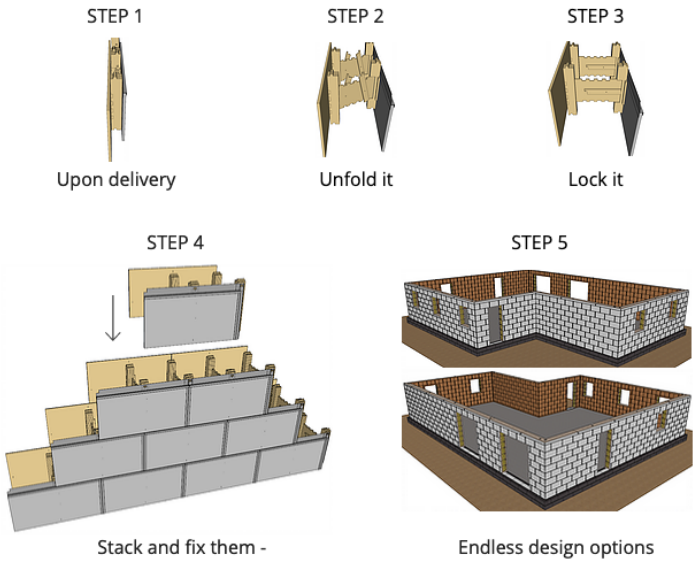

Figure 6.17: Reblock System [Søresen, 2019]

6.5.1 Circular Supply Chain Business Model

The concept behind the circular supply chain concept is that companies begin to consider the full impacts of their products. This involves making considerations regarding the products scarcity and it's environmental impact in terms of embodied energy from harvesting of materials to deconstruction. Companies looking to engage in a circular supply chain look to find materials that are socially, economically and environmentally responsible. Opportunities include bio-based materials, components that are easily transferred back into the products, refurbished at a lower cost, than if sourced from new. This method may result in new resource streams. [3XN/GXN, 2018a]

The Circular Supply Chain Business Model will cover the Regular Reblock system from Rexcon. This is a plywood, metal and hardyboard system illustrated in Figure 6.15. In Figure 6.18 the researchers design circular supply chain business model is presented. The business model distinguishes between the principles of CE Rexcon is already covering and the principles that could evolve. The business model also shows the SDGs that Rexcon is working towards and which phases can influence the SDGs targets. The text will elaborate

on the business model and the initiatives that the researchers propose for Rexcon.

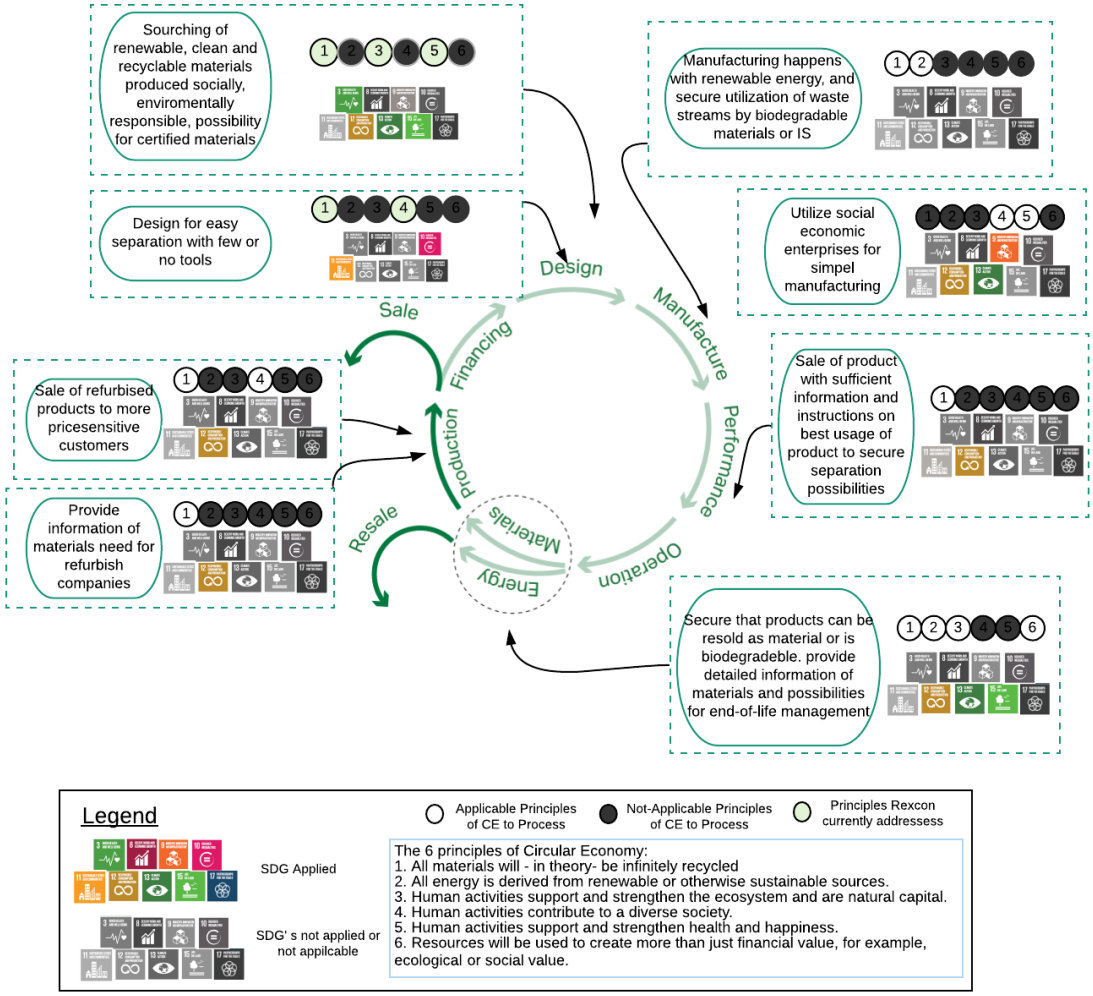

Figure 6.18: Rexcon Circular Supply Chain CEBM [primary source]

Design Process: In the design phase Recon already commits to sourcing sustainable and certified wood material for the Regular Reblock system meeting the principle 1, 3, 4 and 5 of CE with healthy materials made by companies showing social responsibility. The research recommends that Rexcon investigates alternative and renewable materials instead of the cement boards. Cement boards made with silica is known to cause respiratory problems and depending on the supplier is rated as carcinogenic to humans, additionally cement board needs to be disposed of properly as it is toxic to the environment U.S Department of Health and Human Services [2019].

Rexcon meets CE principles 1 and 3. In addition to these initiatives Rexcon can benefit from looking into biodegradable solutions that can transfer carbon back to the natural carbon cycle by composting. Thereby Rexcon is meeting principle 3, by strengthening the ecosystem. Another aspect of sourcing material is the transport of materials from supplier to Rexcon. Looking into the distance of suppliers or the sustainability focus at

the transportation companies to find the best alternatives.

In the design of the Reblock Rexcon has taken several considerations into account beside material sourcing. Designing for easy separation with few hand tools, gives the products a high usability enabling a more diverse range of users to utilize the Reblock. This meets the fourth CE principle.

Manufacturing Process: In the manufacturing process, Rexcon has the opportunity to address the second principle of CE. This is the usage of renewable energy sources. If Rexcon uses renewable energy they will meet this principle and furthering the contribution to Sustainability *Goal 13: Climate Action*, lastly the will be able to contribute to *Goal 7: clean energy.*

In the manufacturing phase Rexcon presents data on waste. In regards to the use of plywood:

> *"... there is a waste of between 5.18% - 13.62% depending on what is produced. The cement chip boards have a production waste of 9.53% in the manufacture. And the Galvanized steel profiles a waste of 3-4% depending on the type of ReBLOCK being produced." - Jesper Sørensen*

A focus on further minimizing waste production through design, contributes to CE principle 1 and development of an even stricter waste management plan could include sending cutoff materials from manufacturing back to suppliers or to recycling company.

Rexcon focuses on product development constantly improving the design through iterative design processes. Packaging of the product is also considered. To further this focus the researchers suggests the packaging of the finished products is made of recycled material, as well as take-back option of packaging upon product delivery.

Operation Process The operations phase is illustrated in Figure 6.17. The company web-page provides recommendations on how to use the product, which includes choice of insulation and reuse of the Reblock. During the sale or after, providing more information on how products stay reusable and recyclable, assist in meeting CE principle 1. The researchers recommend that further information on materials and separation methods or resale or recycling during disassembly could be developed. There has not been mention about maintenance over the long term in regards to durability and rot-prevention this could be further developed.

Overall Rexcon's current business model and system is progressive in it's circular and sustainability initiatives. There are many CE initiatives already address and the fact that the company independently spearheaded SDG applications is impressive. From this study choosing to pursue a full closed loop business model focusing on circular supply chains is feasible for Rexcon, developing value in the final adjustments could be further investigated

in additional research.

6.5.2 Product Life Extension Business Model

The main focus with the product life extension model is to find additional value in the materials that go into the product which can be improved, maintained and recovered in some way, or that the products being used for the product come from a secondary or tertiary source instead of a primary source. If the customer or the producer is the actor in accomplishing the finally step, that the processes and set-up for accomplishing this is established in the design phase. This can take the form or resale, restoration and re-branding of the existing product. The business model Product Life Extension will cover the Rexcon Basic Reblock system, product seen in Figure 6.16.

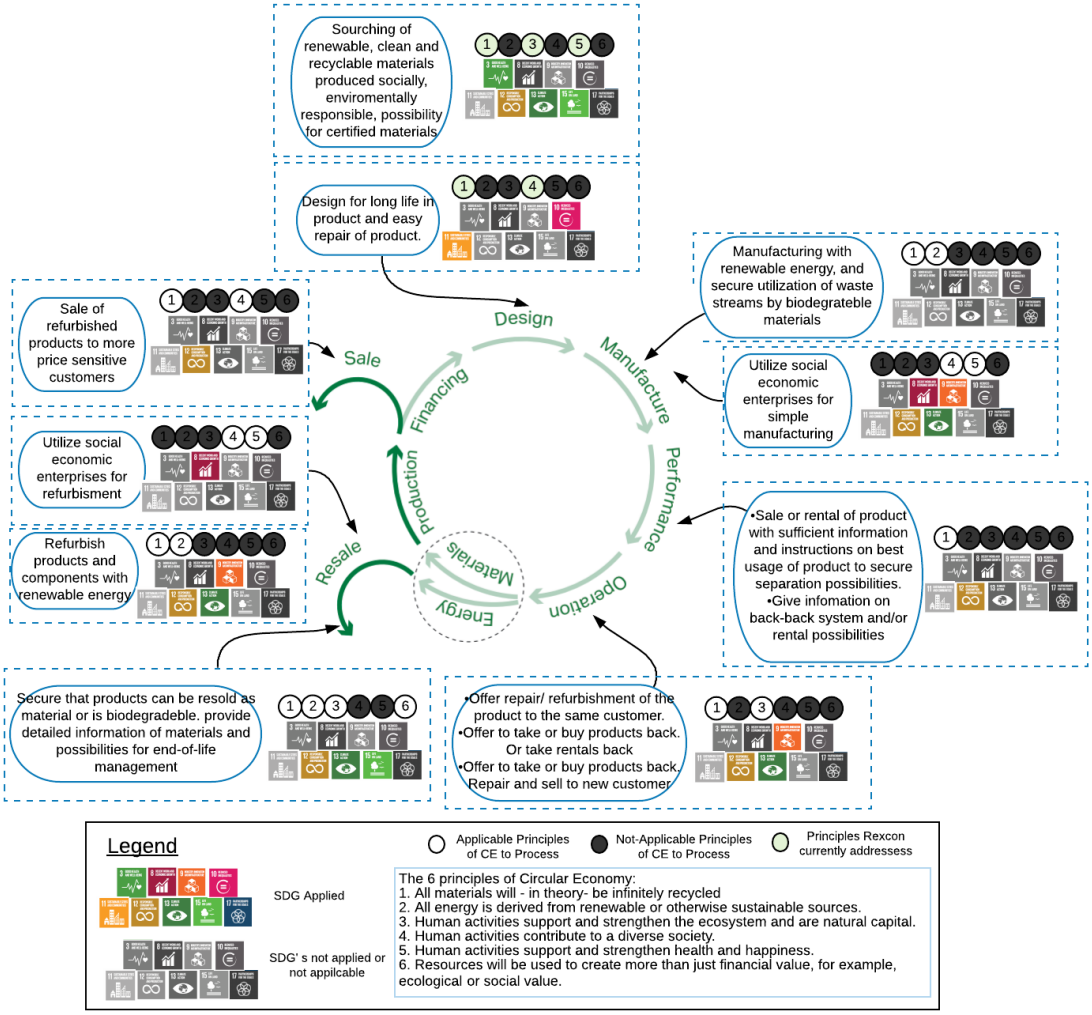

Figure 6.19: Rexcon Product Life Extension CEBM [primary source]

Design Process: As mentioned above Rexcon already engages in the sourcing of sustainable wood and this addressed CE principle 1 and 5. Further development of the

design can explore the possibilities of biodegradable materials or more durable woods such as hardwoods instead of softwoods or plywood's. The initiatives mentioned above regarding design and manufacturing are the same here with the basic Reblock system as was indicated with the regular Reblock system.

Operation process The operation of the basic block is similar to the regular block and includes the same insulation recommendations as indicated in the Reblock operation process. During sale Rexcon could provide additional information as mentioned above in regards to proper handling and recycling post-use. The researchers recommend for this circular economic model that Rexcon offers the potential for renting out their product, the framework for this kind of business model would need to be investigated but it could start with temporary structures with a set time for the rent. This would include Rexcon selling to builders who promote a full-package operations and maintenance service securing the products life time and possibilities for reuse. In the end of life phase Rexcon can offer different services depending on the scenario. If the customer wishes to expand or rebuild Rexcon can take worn out products back, refurbish them and deliver them back to the customer for a cheaper price. Rexcon offer to take back and repair before selling it at a discount to a new customer or sell the secondary material to recycling or up-cycling company. Last service would be a take-back system to secure that material at end of life is composted.

Overall Rexcon's current business model and system continues to be progressive in it's circular economic and sustainability initiatives under this circular business model. From this study choosing to pursue a full closed loop business model focusing on product life extension is feasible for Rexcon, developing value in the final adjustments could be further investigated in additional research as mentioned above.

Part IV

Conclusion

7 Conclusion

7.1 Addressing the Problem Statement

This chapter presents the results of the research findings and answers the problem statement of **How can a circular economic based business model be designed for a company exhibiting sustainability in practice?** The answering of this problem statement involved the investigation of initiatives being employed within the building industry as related to sustainability (and it's three pillars). This took place in the form of interviews at a building green conference. The problem statement required the investigation into industry awareness around the concepts of CE. This was accomplished through a gamification exercises that involved participants to communicate their company business model through process and interaction coordination. Finally, the investigation took an in-depth look into the building industry through the lens of a company. The company exhibited commitment to sustainability and CE and from this a strategic circular economic business model was designed. The results of these investigations are summarized below.

Sub-questions 1: Which initiatives are being taken within the Danish building industry toward Sustainability?

Initiatives being pursued within the danish building industry towards sustainability included a variation of sustainability pillar focuses. From the 27 companies interviewed 108 initiatives were mentioned and categorized into 29 groups. Initiatives with social and environmental focus were almost equally represented with 40% of total initiatives being focused here from each pillar, whereas initiatives with economic focus only presented 19%, due to the focus of the conference. The general industry overview showed that initiatives prolonging life time in products and flexibility were the most common. This was interesting because companies who claimed long-life in their products also claimed they didn't have to deal with end-of-life because the product would last longer than the company, or that they would not be around at the end of life of the product. Another common initiative was with addressing clean and healthy products. Most companies only focused on their products sustainability up until point of sale. Illustrating a need for circular business models to enter the industry.

Sub-questions 2: How do businesses in the building industry communicate and reflect CE in business models?

There was little buzz overall of CE through the investigations at the sustainable building conference. Few companies communicated directly applications of CE into their business although some mentioned it as a component of a single product or process. There were piecemeal applications of CE of which the most communicated initiatives were design for long life, design for disassembly, modular design, clean products as well as opportunity for recycling and reuse. The gamification exercises which attempted to simulate current business models in companies resulted in mainly linear business models with some circularity within. However, after being questioned and hearing back responses from the interview many adjusted their models, some resulting in partial circularity. Most companies understood the term circular economy and mentioned potential circular initiatives, some also mentioned intention for future potential of applications to the business models. Two companies made circularity the base of the businesses practices they were Thors and Gamle Mursten. Both companies focused on solely one product and they achieved circularity quite effectively at least on the material stream.

When looking at the analysis and cross-referencing of the models to the CEBM presented in the literature review, most companies integrated initiatives compatible with: Circular Supply Chain, Recover and Recycling and Product Life Extension. Few companies practiced initiatives related to the two last CE business models, Sharing Platform and Product as a service. Overall communication of CE was fragmented throughout the industry indicating that a standardized system for circularity could prove beneficial for meeting particular circular targets.

Sub-questions 3: What form would CE integration take to encourage industry wide implementation

In order to investigate the final sub-question and due to time limitations one company was selected for it's promising demonstrations of sustainability and verbal commitment to circularity to provide as a case for this investigation. It should be noted that two other companies were eliminated due to their already circular models this was the furniture maker Thors Design and the brick recycle business, Gamle Mursten, two others weren't considered as they were networks and their models weren't specific to the the building industry. It was discovered that in order to encourage CE in the industry it is inevitable that certain industry norms, regulations and process would need to change. A structured framework per service provider much like the one that Peter Andreas Sattrup is involved with could prove very valuable within each service or product industry. Industry wide implementation of CE would require industry wide commitments to changing the framework of the industry altogether, including it's goals and mission.

Answer to the problem statement:

In order to model circular economic business models for a company it was first important to establish that sustainability and CE are meaningful metrics in the business mission. Many businesses talked about their commitment to sustainability but only applied it to contained parts of their business. This was true with insulation providers who only measured sustainability on the potential for energy savings in the completed buildings and did not recognize the application of sustainability within the business itself or toxicity of their product assemble, nor the product's single use. Again this was evident with the providers of fall protection for workers installing solar panels. No activity was pursued for sustainability except that they found a new market to sell their service.

The exercises of modelling two circular economic business models showed that there are many opportunities for circular economic applications and that some forms are more applicable than others depending on if the business is service or product based. It also showed that from product to product the modelling can change. Applying the model as a case was challenging in that it presented countless considerations at each stage of the product process. Also establishing what metrics to use as part of the qualification process was difficult. A large amount of imagination, design and considerations is needed to identify for example the circular economic principles may be addresses at each process. This was the same for determining how the sustainability goals were to be addressed. The metrics were up to the researchers to framework and the freedom to design them were on one hand endless (because of countless possibilities in framing CE) but on the other hand inconclusive (because there is no set standard).

7.2 Discussion

In the preface we had established the importance of transitioning to a circular economy as quickly as possible. CE as a concept is gaining popularity in the Danish markets as a response to the effects of climate change. In this way CE has become relevant and important to science and society as the need to change societal behaviour to respond to pressing environmental concerns grows. The building industry was identified as the largest single contributor of carbon emissions, waste and as a result global warming making it a relevant industry of study. Distinguishing the difference between Sustainability (capital case), sustainability (lower case) and CE showed the significance between the biosphere, the technosphere and the combination of two. A concise definition of the terms were established to frame analysis of circular economic strategies within the Danish market. This was presented with an optimism that Denmark was capable of spearheading the movement and that the danish building industry has a foundation for further developing these concepts and potential for applications within the building industry. The research statement aimed to understand how a circular based business model could be designed for a company exhibiting sustainability in practice. This was done with the anticipation that

businesses could push the initiative towards CE faster than if a bottom-up approach was implemented base on a top-down standardized policy or regulation.

The investigation looked to a green building conference to collect data from businesses in the building industry, seek out a progressive business and design for them a business model. As a result 27 companies and 3 experts were interviewed. Of interest were 6 businesses that came from the innovation corner of the conference. A section of conference had a separate space dedicated to start-ups featuring a sustainability based product. However, despite the special arrangement the majority of these companies did not engage fully into Sustainability as it relates to a circular economy as a part of their communications of their products. For example, Fermacell that produced several products where only one product had a circular element of recycled paper in the gypsum fiber walls. Overall the sustainability initiatives taken at the Green Building Conference were lacking the spearheading spirit that was expected in that many tried to pass the ball to other stakeholders like government or citizens.

As a matter of fact the researchers were even more surprised to note that the business model simulation when played with the 3 experts did not clearly represent the kind of circularity presented in the literature review of circular economic business models. This leaves in question whether the theories of circularity are too ambitious or if the gamification design could have been executed differently. The findings in Figure 7.1 may also be harder to directly translate to CE as all experts interviewed were involved in consulting services as opposed to services based on a specific product or component of the building process. It appears that the complexity of designing and representing circularity goes beyond just drawing circles between business processes.

All 27 companies interviewed were able to communicate sustainability in some form or another through green initiatives. Not all communications indicated the understanding or balance of the 3 pillars of Sustainability and it was more often than not that the company defined Sustainability through only one or two sustainability initiatives without consideration of other dimensions of the business processes. Few companies were able to communicate CE, or see it in their business until questionings took place. The researchers recognize the possibility for the companies having more and/or even well connected initiatives then presented at the conference, however, most communication indicated the above mentioned.

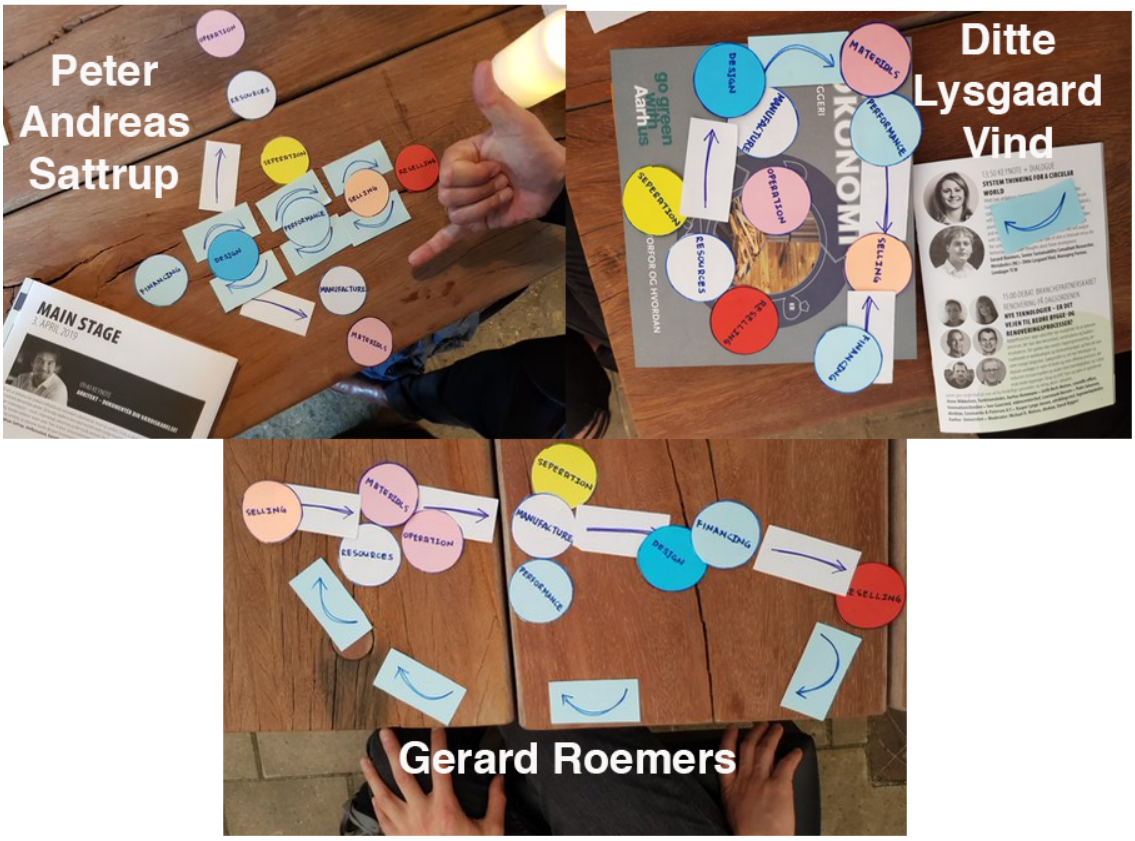

Figure 7.1: Experts Circular Economy Models [primary source]

The final business models designed for Rexcon proved to be challenging. It was difficult to track material streams and apply possible value-creation to them, this was the same when looking at energy streams. The examples of CE in literature seemed to be grossly oversimplified. It quickly becomes evident that even the most ambitious businesses with commitments and consciousness towards the environment need the help of other stakeholders and stronger partnerships to encourage CE loops to close.

The engagement of CE within the building industry requires an industry wide involvement which would require management accounting, operations management and innovation management. With the organization and systematic understanding of the partnerships within the industry to bring the loop closer to closing.

This is evident in other industries as well, the hyper-specialization across all industries has fragmented the ability for collaboration and transition to new forms of partnerships and cross-silo engagement. There needs for the recognition that businesses do not work in silos and the need to regroup together to understand the complexity of industries activities on a whole is evident. The only alternative option is to stop producing at all and allow the world time to regenerate.

7.3 Reflections

Interviews The researchers consider some of the possibilities for improvement for additional studies. Although the Green Building Conference was chosen as a good site for representation of companies that would engage sustainability, the wide variety of company employees that would be encountered was not considered. Some companies were represented by their owners and from these people we received a lot of good information. Other companies were represented by sales rep who's only job was to sell the product, occasionally these persons struggled to communicate the company business model. Scoping out the right representative from each company would have led to more congruent data for comparison. Additional to this it is always considered that using other languages than an interviewees native tongue can be cause if miss-communication or miss-interpretation. There was one company who refused to be interviewed in English but happily participated when the interview was conducted in Danish.

Interviews conducted later at the conference were less informative. This applied both to expert interviews and market interviews. In the less informative interviews, there was not enough follow-up questions on initiatives presented by the companies or lack thereof. Elaborating questions on business modeling in these interviews were also lacking which resulted in high level empirical data. In order to get more in-depth empirical, follow up should be applied more consistent throughout the conference and additional questions on initiatives that showed circularity should be included after game with business models.

Gamification The researches reflected on the use of gamification. Alternative to this method the researcher could show the companies the Ellen MacArthur Foundations butterfly structured illustration for CE and have the companies circle their initiatives. Using this method could prove effective as many are familiar with this model. The method could provide answers directly linked to CE and follow up questions could provide in depth information for the secondary assessment. The researcher, still, chose the gamification method as it would not lead the interviewees directly to CE.

After the utilization of the game, few reflections were made. In the game different terms had different colors, which raised a few questions from few of the companies. Therefore, an improvement to the could be that the game pieces should have been the same color to prevent misinterpretations of the game.

The game build on terms used in the game took inspiration in the 5 circular business models, which describes product life cycles. The terms were not loaded and gave room for interpretations.

Results There was a reflection of the information obtained on the business models in regard to how precise they were to the companies' actual business models. The reflection

was based on the observation that some company representatives seemed confused about the rules of game and how to play it. When a confusion occurred the researches guided the company representatives by explaining the game again and ask simple generic questions about their business model. This was assessed as enough to secure the validation of the empirical data.

However, the researcher observed that when building business models were presented in the game several companies mentioned sale as essential. In the presentation of the green initiatives the economic pillar of sustainability had a smaller focus than the other two pillars. However, as the game showed economic sustainability as essential it is, therefore, prioritized higher than presented here in the initiatives.

7.4 Recommendations

Impacting a meaningful reverse of the effects of climate change will require rapid, far reaching and unprecedented changes in all areas of industry and society [IPCC, 2018]. The change starts with reassessing the linear economic framework from which many have obtained an incredibly high standard of living and monetary wealth. Then the market needs to critically assess whether the short term benefits of resource intense development is worth the environmental consequences [De Wit et al., 2019]. The problem identified here is that businesses hold the greatest amount of influence in the transition to greener economies. Literature showed that in theory there are many possible applications of CE. This paper looked to investigate how businesses are picking up on trends like circular economic business models and if they are being utilized in practice. The discovery was that there is yet a lot to be done and that the framework and gateway to implementing these practices are blocked by a myriad of challenges.

Further investigations into CE could look into the economic benefits of CE further. Specifically the investigations could explore in depth the sense making in specific product and service providers within industries. The importance of management accounting, operations management and innovation management in pursing CE is necessary. As much as collaboration is important across government, business environmental and citizens.

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A Appendix

A.1 7 Elements of Circular Economy

A.2 Circular System Diagram

A.3 Circular Economic Concepts

A.4 Expert Interview Guide

A.5 Market Interview Guide

A.6 Empirical Analysis Tables

A.7 Sustainability Tables

Figure A.1: DISRUPT: 7 Key Elements, De Wit et al. [2019]

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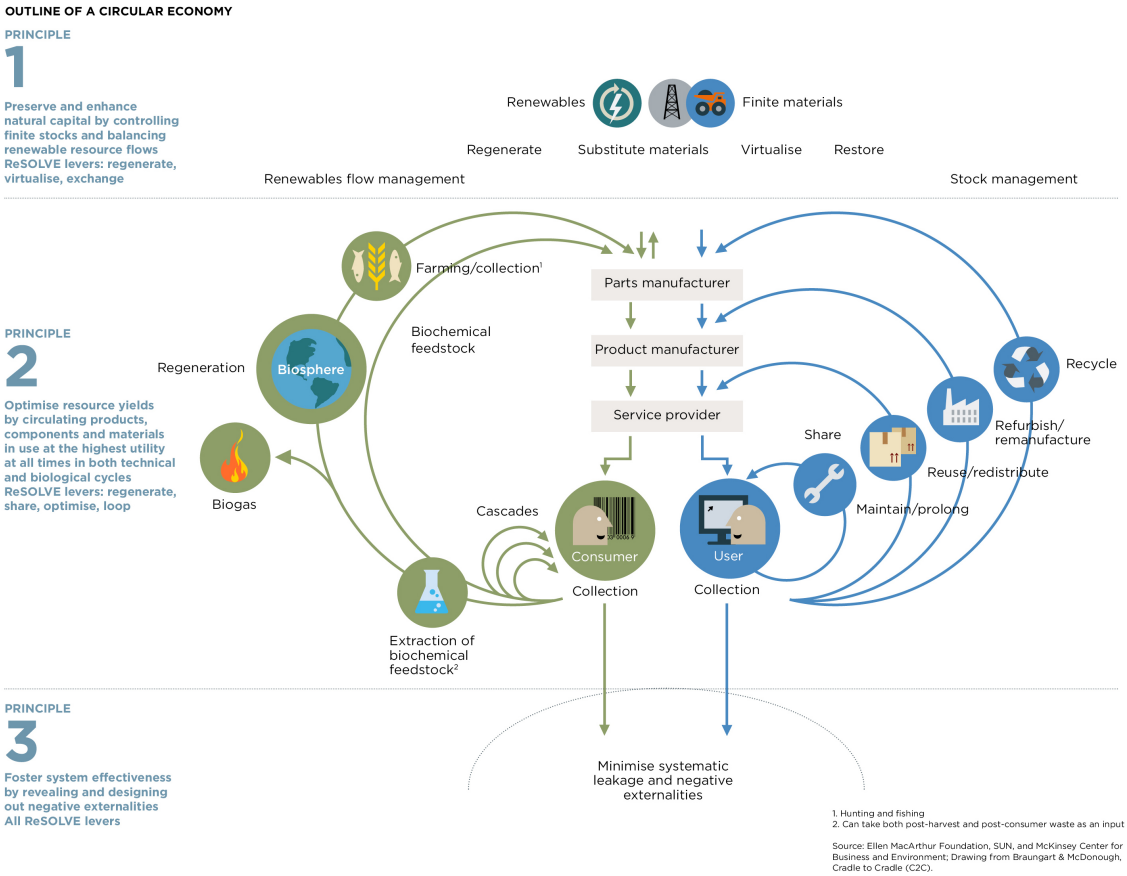

Figure A.2: Circular System Diagram, The Ellen MacArthur Foundation [2019]

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Categories	Characteristics	Concepts									
		Circular economy	Cradle to cradle	Closed supply chains	Regenerative design	Blue economy	Industrial ecology	Reverse logistics	Performance economy	Natural capitalism	Bio-mimicry
Motivation(s)	Focus on environment	●	●	●	●	●	●	●	●	●	●
	Focus on profitability			●				●			
	Including social aspects	●	●		●	●			●	●	
Proposition for waste management	Efficiency and waste reduction	●	●	●	●	●	●	●	●	●	●
	Zero waste	●	●		●						
	Technological/ biological substances	●	●								
Guidelines and tools	Business model perspective	●	●			●				●	
	Focus on operations		●	●	●		●	●			
	Measurability	●	●	●		●	●	●	●	●	
	Policy	●		●			●				
Economic sectors covered	Primary sector	●	●		●	●	●			●	
	Secondary sector	●	●	●	●	●	●	●	●	●	●
	Tertiary sector	●	●		●	●			●	●	
Economic scope	Macro-economic perspective	●				●			●	●	
	Meso-economic perspective		●	●			●				
	Micro: company level	●	●	●	●		●	●			
	Micro: product level	●	●		●			●			●
Activities during life cycle stages: Circular design of ...	Product development	●	●	●	●	●			●	●	●
	Raw material sourcing	●	●	●							●
	Production processes	●	●	●		●	●	●			●
	Use	●	●						●		●
	CRM							●	●		
	End of life/ disposal	●	●	●	●	●	●	●	●	●	●
	Transportation	●	●	●	●	●	●				

Figure A.3: Circular Economic Concepts, Geisendorf and Pietrulla [2018]

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Interview Guide

Expert interview

Knowledge we need	Questions asked
Presentation • Educational background • Work experience • How do they work with CE? • Who have which role?	Can we record this interview? Can you give a presentation of yourself? Can you tell us about the project that you are working on?
What is the current status in the Danish building sector? • Is the building sector doing business as usual? • What are the biggest challenges generally?	Can you tell us a bit about the current status in the Danish building sector?
How is CE in the Danish building sector today? • How is sustainability defined generally? o Is there a difference in the definition in the different trades? • How is CE defined? o Is there a difference in the definition in the different trades • Is the Danish building sector using CE business models? o Is there a preferred CE business model? • Who are the main providers of CE knowledge for the companies?	What has the development of green initiatives been in the Danish building sector?
Which Drivers and barriers are in CE?(DELPHI)(In the form of a questionnaire) • How can companies be motivated to integrate more CE? • What are the drivers and barriers for?	Can you list the drivers for the for CE in the building sector? Can you list the barriers for the for CE in the building sector? Can you provide a short description of the importance ofthe each of the above listed factors? Are the drivers and barriers different in the different trades?
Who can influence the building sector and how? • What is needed to promote more CE in the building sector? • Who have the biggest influence? • How can they use their influence?	In general, what will give the businesses in the building sector a bigger incentive to integrate CE?
Closing • Agreement and permission	Can we cite you in our report? Can we contact you again if we have further questions?

Figure A.4: Expert Interview Guide, primary source

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Interview Guide

Market interviews:

Knowledge we need	Questions asked
Presentation	Can we record this conversation? We are students, studying environmental management at AAU, interested in green building initiatives in the building sector?
Business presentation • What is the product/service? • How is it sustainable?	Can you tell us what green initiatives bring you to Building Green Aahrus?
Participants were presented with the game • No questions are presented during the game deliberately, however if a company presented a partial concept or idea, clarification was requested.	How is sustainability or CE represented in the business model?
Do the companies know CE? • What is the CE initiatives?	So to understand you correctly, your company does this and this, correct?
Closing Agreement and permission	Can we cite you in our report? Can we contact you again if we have further questions?

Figure A.5: Market Interview Guide, primary source

.

Categories	Characteristics	1. Cembrit	2. Climatic	3. Cramo	4.DBI	5. Danish Concrete Hardener	6. Fermacell	7. Fire Eater	8. Frøslev	9. Gamle Mursten	10. GHM Måleteknik
Motivations	Focus on the Environment	O			O	O	O		O O	O O	O
	Focus on profitability	O	O		O	O		O		O	O
	Include social aspects	O	O O	O O				O O	O		O O
Propositions in waste management	Efficiency and wast reduction	O O		O O	O	O	O	O	O O	O O	
	ZeroWaste									O	
	Technological/biological substances		(O)				O O	O	O		
Guidelines and Tools	Business model perspectiv			O			O	O		O O	
	Focus on operations	O	O O	O	O	O	O	O		O O	O O
	Measurability		O		O O	O	O O			O	O O
	Policy									O	
Economic Sectors Covered	Primary sector	O				O O	O O		O		
	Secondary sector	O				O O	O O	O	O	O O	
	Tertiary sector		O O	O	O O						O
Economic Scope	Macro-economic perspective									O	
	Meso-economic perspective				O O		O	O	O O	O O	
	Micro-economic perspective		O	O				O			
	Micro-product Level	O	O	O			O	O	O	O O	O
Activities during life cycle stages: Circular Design of...	Product development			O	O O	O		O	O O		O O
	Raw material sourcing	O O		O			O O	O	O O	O O	O
	Production processes	O		O			O		O	O O	
	Use		O O				O		O		O O
	CRM		O	O O	O	O		O O		O O	O O
	End of life/ disposal	(O)	(O)	O			O			(O) O	
	Transportation	O							O		

Figure A.6: Analysis Table 1 of 3

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Categories	Characteristics	11. Guldager	12. Innobyg	13. Miltonmegatherm	14. Natural Greenwalls	15. PanelByg	16. Phønix	17. Scanton	18. Skalflex	19. SolarLab	20. Sto design
Motivations	Focus on the Environment		O O	O	O	O	O O	O O	O	O O	O
	Focus on profitability	O	O O	O		O	O O	O O	O O	O	O O
	Include social aspects	O	O		O O			O O			O
Propositions in waste management	Efficiency and wast reduction	O O	O	O O		O O		O	O O	O O	O
	ZeroWaste										
	Technological/biological substances			O	O O	O	O	O (O)		O	
Guidelines and Tools	Business model perspectiv		O O								
	Focus on operations	O O		O O	O O	O O		O O	O O	O O	
	Measurability									O	
	Policy		O								
Economic Sectors Covered	Primary sector			O							
	Secondary sector	O	O	O		O O	O O	O O	O O	O	O O
	Tertiary sector	O O	O O		O O					O	
Economic Scope	Macro-economic perspective		O								
	Meso-economic perspective		O O								
	Micro-economic perspective					O		O	O		
	Micro-product Level	O		O	O O	O O	O O	O O	O O	O	O
Activities during life cycle stages: Circular Design of...	Product development	O O	O O	O O	O O	O O	O O	O	O O	O O	O O
	Raw material sourcing			O O	O O		O O	O O			(O) O
	Production processes	O			O O	O O				O	
	Use	O O		O O	O	O		O	O O	O	O
	CRM	O O		O	O		O				(O)
	End of life/ disposal	O		(O)	O	(O)	(O)	(O)		(O)	(O)
	Transportation										

Figure A.7: Analysis Table 2 of 3

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Categories	Characteristics	21. thermozell	22. Thors	23. Videncenter _ Teknologisk Intitut	26. KSK Group	27. Rexcon
Motivations	Focus on the Environment	O O	O	O O	O O	O O
	Focus on profitability	O			O O	O O
	Include social aspects		O		O	
Propositions in waste management	Efficiency and wast reduction	O	O	O O	O O	O O
	ZeroWaste	(O)				
	Technological/biological substances		O O		O	
Guidelines and Tools	Business model perspectiv			O		O
	Focus on operations	O O	O	O O	O O	O O
	Measurability	O	O	O O	O O	
	Policy			O		
Economic Sectors Covered	Primary sector					
	Secondary sector	O O	O O		O O	O
	Tertiary sector		O	O O		
Economic Scope	Macro-economic perspective			O		
	Meso-economic perspective	O		O		
	Micro-economic perspective		O	O O		O
	Micro-product Level	O O	O O	O O	O O	O
Activities during life cycle stages: Circular Design of...	Product development	O	O	O O	O O	O O
	Raw material sourcing	O O	O O		(O)	O
	Production processes	O O	O O		O	
	Use			O		O
	CRM			O		
	End of life/ disposal	(O)	O		(O)	(O)
	Transportation					

Figure A.8: Analysis Table 3 of 3

.

Kolonne1	Kolonne2	Kolonne3	Kolonne4
	Companies		
Green Initiatives	1. Cembrit	2. Climatic	3. Cramo
User friendly			
Security, safety and health for users		1	
Knowledge sharing			
Consultation and assistance			
Flexible product			1
Non-toxic materials	1		
Easy installment of product	1		
Easy separation of product			1
FSC certified products			
C2C certified products			
PFC certified products			
Reuse of product		1	1
Reuse of product components			1
Modular design			1
Security and safety for surroundings			
Clean materials in product		1	
Recycled material in product			
Products made of surplus material			
Water recycling in production	1		
Long life time in product	1		1
Resilient product			
Locally produced(in Denmark)			
Low energy in production			
Transport efficiency	1		
Energy efficient product			
Water efficient product			
Optimized product, size and weight			
Renting / leasing		1	
Digitalized(big data)			
Potentials			
Potential for reuse	1		
Potential for recyle	1	1	
Initiatives with CE focus	5	5	5

Kolonne5	Kolonne6	Kolonne7	Kolonne8	Kolonne9	Kolonne10
4. DBI	5. Danish Conc	6. Fermacell	7. Fire Eater	8. Frøslev	9. Gamle Murste
			1		
1					1
1					
			1		1
	1	1	1	1	
				1	
				1	
		1			1
			1		
	1	1			
		1			1
					1
	1				
					1
		1			
					1
				1	1
0	2	4	0	3	5

Figure A.10: Sustainability Analysis 2 of 5

.

Kolonne11	Kolonne12	Kolonne13	Kolonne14	Kolonne15	Kolonne16
10. GHM Målete	11. Guldager	12. Innobyg	13. Miltonmega	14. Natural Gree	15. PanelByg
1			1		
1	1			1	
		1			
		1			
	1				
			1		
	1				
1					
1					
			1		
				1	
			1		1
				1	
					1
	1				1
				1	
			1		1
	1			1	
1	1				
	1		1	1	
			1	1	1
2	4	0	5	5	3

Figure A.11: Sustainability Analysis 3 of 5

.

Kolonne17	Kolonne18	Kolonne19	Kolonne20	Kolonne21	Kolonne22
16. Phønix	17. Scanton	18. Skalflex	19. SolarLab	20. Sto design	21. thermozell
				1	
					1
1			1	1	
					1
			1		
	1				
				1	1
1					
1	1			1	
		1	1	1	
	1				
		1	1		
	1				
	1				
1	1		1	1	
3	5	0	2	3	3

Figure A.12: Sustainability Analysis 4 of 5

.

Kolonne23	Kolonne24	Kolonne25	Kolonne26	Kolonne27	Kolonne28
22. Thors	23. Videncenter	24. KSK Group	25. Rexcon	SUM	SUM % Initiatives
			1	4	3.85
				6	5.77
	1			4	3.85
	1			3	2.88
			1	8	7.69
1				7	6.73
			1	2	1.92
			1	4	3.85
				1	0.96
1				1	0.96
				1	0.96
1				5	4.81
				2	1.92
1		1	1	5	4.81
				2	1.92
1				6	5.77
1				6	5.77
				1	0.96
				1	0.96
			1	9	8.65
		1		5	4.81
				2	1.92
				2	1.92
			1	2	1.92
				4	3.85
				1	0.96
				4	3.85
1				4	3.85
				2	1.92
				104	100.00
				SUM	SUM %
		1	1	8	38.0952381
		1	1	13	61.9047619
6	0	3	6	21	100

Figure A.13: Sustainability Analysis 5 of 5

.

Figure A.14: Rexcon Commitment to SDG's

Figure A.15: Business Models 1-8

Figure A.16: Business Models 9-16

Figure A.17: Business Models 17-27

Hi Katarzyna and Louise

To answer your questions faster, ill do it in danish this time. Im sure Louise will translate them for you.

1. Jeg kan se flere værdiskabende følgevirkninger omkring min forretning. Både før og efter salget. Langt de fleste har jeg forsøgt at beskrive på min hjemmeside under 'What is it good for - in details.' I hvert af svarene ligger enten en værdi i sparet tid, økonomi, miljø-aflastning eller forbedret arbejdsmiljø, samt flere socialt værdiskabende egenskaber som et sundere indeklima, brugervenligheden samt den vedblivende værdi i produktet da det kan videresælges og folk kan få frigivet deres likvider igen, når der ikke længere er et behov for anvendelse. En heller ikke uvæsentlige gevinst ved anvendelse er at der skal støbes mindre fundamenter. Hvis der indgår beton fundamanter i bygge-projektet. ReBLOCK systemets lave egenvægt medfører at der kun er behov for smallere fundamenter og derfor et mindre behov for beton, og deraf en reduceret pris og miljøbelastning i projektet. Håber denne forklaring giver mening for jer ?
2. Ja, I har helt ret. Virksomhedens struktur er meget linier i øjeblikket. Som tidligere nævnt, er det en målsætning at kunne gøre den mere cirkulær ved bla. at kune tilbyde eks. tilbagekøbs-garanti efter endt brug af ReBLOCK som så kan recirkuleres ud i byggeriet til en reduceret pris og deraf minnimeret miljøbelastning vs. eks. fremstillingen af nye byggematerialer, eller kunne tilbyde kunderne en leasing aftale på system-komponent-niveau, særligt målrettet midlertidige projekter.
3. Jeg er ikke sikker på jeg forstår dette spørgsmål korrekt ? Men min umiddelbar besvarelse vil være 'Nej' - det er ikke noget vi har undersøgt nærmere. Medmindre man kan omtale den beregnede drifts-besparelser på 6% (Sammenlignet med Regl-konstruktioner) som en indvundet værdi i brugsfasen, eller det at ReBLOCK ved om-/udbygninger blot kan nedtages der hvor der bygges til på huset og genanvendes med ud i den tilbygning som opføres ? Eller går spørgsmålet mere på om der er andre markeder som produktet også kan finde sin anvendelse i, udover byggesektoren ?
4. Med hensyn til affald i produktionen. Så er der i anvendelsen af krydsfiner et spild på imellem 5,18% - 13,62% afhængig af hvad der produceres. Cement-spånpladerne har et produktionsspild på 9,53 % i fremstillingen. Og de Galvanizerede stålprofiler et spild på 3-4% afhængig af til hvilken type ReBLOCK der produceres til.
5. Mht. hvilke leverandører der levere råvarende til ReBLOCK, så er jeg af konkurrencehensyn ikke så begejstret for at dele det, når jeg ikke ved hvem der læser med i det senere offentligt tilgængelige materiale. Jeg håber i forstår. Det jeg kan sige om materialerne er at de alle er CE mærkede og PEFC eller FSC mærket. Råvarer producenterne ligger i EU, og at al forarbejdning af råvarene (Plade-materialer osv.) til færdige ReBLOCK's foregår i Danmark.

Jeg har vedhæftet et Data sheet for Regular udgave af ReBLOCK. Det eneste der adskiller den fra Basic er at Basic ikke har et 6-'Front Panel' af Cemnetplade, men istedet er lavet af det samme krydsfiner som 7-'Pack panel' - Pine-plywood. Og så indgår 8-'Drainage panels' heller ikke i Basic udgaven.

I skriver bare hvis jeg har misforstået noget, eller svaret helt i øst og vest på jeres spørgsmål.

God arbejdslyst.

Mvh Jesper Sørensen
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REXCON SYSTEM

Figure A.18: Mail from Jesper Sørensen