Applying circular economy principles to building materials

Front-running companies' business model innovation in the value chain for buildings

Nussholz, Julia; Milios, Leonidas

2017

Applying circular economy principles to building materials: Front-running companies' business model innovation in the value chain for buildings

Julia Nussholz[(a)(b)], Leonidas Milios[(a)]
a) Affiliation: Lund University, International Institute for Industrial Environmental Economics (IIIEE), Lund, Sweden
b) Corresponding author: Julia Nussholz, julia.nussholz@iiiee.lu.se

Keywords: Circular economy; circular business model; business model innovation; construction sector; sustainable building design; resource efficiency

1. Introduction

To meet the United Nations Sustainable Development Goals (SDG) on sustainable production and consumption (goal 12), the construction sector should be considered a key area to improve efficient use of natural resources (goal 12.2) and reduce waste generation (goal 12.5). From all industrial processes in the European Union (EU), cement and iron and steel production – the main pillars of the construction industry - are responsible for about 40% of greenhouse gas (GHG) emissions in all industrial processes (EuropeanEnvironmentAgency 2014). Moreover, construction and demolition projects generate about a third of the total waste in the EU, with a significant share being landfilled (BioIntelligenceService 2011). With buildings being more energy efficient during their use phase, the relative importance of embodied energy and natural resources is becoming more significant to enhance resource efficiency of buildings (Crowther 1999; Thormark 2002). To save embodied energy and resources, scholars in the resource efficiency field have studied and developed a range of strategies that cycle resources at product, component or material level (from here onwards referred to as circular strategies) (Stahel 1994, 1997; Cooper and Gutowski 2017; Allwood et al. 2011). These circular strategies aim to first prolong the useful life of products and components (e.g. trough repair, refurbishment, or remanufacturing), and then close material flows (through recycling) once the end-of-life is irreversibly reached (Bocken et al. 2016; Stahel 1994). This has the potential to maintain the quality of resources over time (Braungart et al. 2007) beyond a single life and reduce resource extraction and waste generation (Zink and Geyer 2017).

Recently, circular strategies have gained renewed attention under the concept of a circular economy (EllenMacArthurFoundation 2017; EuropeanCommission 2015; Ghisellini et al. 2016). The attention is not only credited to the circular economy's potential to improve resource efficiency of the economic system, but also to its economic appeal as circular strategies are envisioned to conserve the residual economic value of resources (Cooper and Gutowski 2017). Companies in a circular economy can capitalize on resources' residual value and devise value-adding activities around prolonged useful life of resources (Bakker et al. 2014). To seize these economic and environmental benefits, the construction sector has been identified as one of the three high-potential sectors (EllenMacArthurFoundation 2017).

However, for the construction sector to transition towards a circular economy requires systemic innovation throughout the value chain (Ness and Xing 2017). Resources recovered at the end-of-life (components or materials) need to be reintegrated into the value chain. To realize this, companies need to collect and recover building components and materials in sufficient quantity and quality in an economic manner. In addition, also companies at the beginning of the value chain need to adapt the design of buildings to enable recovery of construction material at the end-of-life and its reintegration into new construction projects. To

aid such innovations, the recently advanced concept of a circular business model (Bocken et al. 2016; Bakker et al. 2014; MacArthur 2013) might be useful. Although the concept still lacks a commonly accepted definition, its builds on the idea that companies can develop an offer with a circular strategy in mind and capitalize on it by adjusting elements of their traditional business model. Thereby, business model innovation presents a way to embed a circular strategy into a company's logic of doing business in a more holistic way. In the construction value chain for buildings, a number of front-running companies have successfully devised business models that aid the implementation of circular strategies (Vandkunsten et al. 2016). However, not much is known about what business model innovations are emerging along the value chain that can contribute to cycling of resources. Understanding is still limited about what changes in business model elements can aid companies to successfully implement circular strategies. Therefore, this research aims to provide an overview of business model innovations that facilitate adoption of circular strategies for building materials. To guide this study following research question is formulated:

Which innovations of companies' business model elements can aid the application of circular strategies for building materials?

To answer this research question, a comparative case study design with six cases of companies operating circular strategies in the Dutch, Danish and Swedish construction sector is employed. All three countries have strong government support through front-running circular economy policy programmes (SOU 2017; MinIenM 2014; Naturvårdsverket 2012; Miljøministeriet 2014), with policy initiatives targeting specifically the construction sector (Rijksoverheid 2016; StateOfGreen 2017). Moreover, the three countries have a longstanding tradition of innovative business models. Fitting the explorative character of this research, companies were selected to represent different positions in the value chain for buildings and different strategies for cycling of resources. Data collection included multiple semi-structured interviews with company representatives and analysis of publically available documents and company reports. Data was collected in May-August 2017.

The paper proceeds with a review of literature on the building lifecycle (section 2.1), on circular strategies that can be employed at the various lifecycle phases (section 2.2), and an overview of the concept of business model innovation to aid implementation of circular strategies (section 2.3). Section 3 presents the analysis of the case studies and the findings. The paper concludes with a discussion and final remarks offered in section 4.

2. Literature background

2.1 Building lifecycle and circular strategies

To study the adoption of strategies for cycling resources, three lifecycle stages can be considered of particular importance: (1) Material and component manufacture, (2) Design and planning, and (3) End-of-life (Figure 1). This is because building components and materials at the end-of-life need to be reintegrated into the value chain requiring business in all three phases to innovate their practices[1]. Circular strategies that can be adopted in the

[1] However, it should be noted that also the lifecycle stage of *operation* and *refurbishment* are relevant for advancing circular strategies. A core of circular strategies is the extension of the useful life of products (Stahel 1994) (in the case of buildings e.g. through renovation and retrofitting (Adams et al. 2017). However, given the

building lifecycle have been widely studied in the literature on resource efficient building construction (Thormark 2001, 2002; Crowther 1999; Kibert 2004; da Rocha and Sattler 2009;

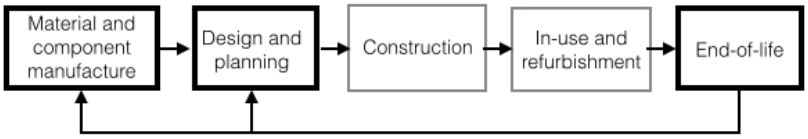

Figure 1 Illustration of the construction value chain for buildings based on Adams et al. (2017) and Kibert (2004) highlighting the three phases that will be of focus in this research.

Durmisevic and Brouwer 2002; Durmisevic 2006; Durmisevic and Yeang 2009).

Table 1 offers an overview of the circular strategies developed and discussed in literature for the three selected lifecycle phases.

Table 1 Overview of circular strategies for increasing resource efficiency in the construction of buildings.

Lifecycle phases	***(1) Material and component production***	***2) Design***	***(3) End-of-life***
Circular strategies	- Use fewer hazardous materials - Design for recycling - Prolonged lifespan - Design for product disassembly - Design for product standardisation - Use of secondary materials - Take-back schemes	- Design for disassembly - Design for adaptability and flexibility - Design for standardisation - Design out waste - Design for modularity - Specify recyclable materials - Design to reintegrate secondary production	- Disassembly - Selective demolition - Enable reuse of products and components - Closed-loop recycling - Open-loop recycling

The majority of the developed circular strategies (see Table 1) cannot be realized within a company's own processes or product development. To effectively implement them, it requires coordination of material exchange and logistic systems between distinct companies along the value chain (Wells and Seitz 2005). Several companies will be involved in the value creation processes, requiring coordination and alignment of business practices between companies (Wells and Seitz 2005). To realise these changes and capitalise on circular strategies, the concept of circular business models has been suggested as useful (Bakker et al. 2014; Bocken et al. 2016; MacArthur 2013). Therefore, the next section clarifies the understanding of the concept and how it can aid implementation of circular strategies in the building sector.

2.3. Business model innovation for circular strategies

Business models are understood as a management tool to study the organisational structure and value creation processes of businesses. Teece (2010) defines a business model as the organisational and financial architecture, describing how an organisation converts resources and capabilities into economic value. A definition commonly used is the one of Osterwalder and Pigneur (2010), stating that a business model is the *core logic how a company creates, delivers, and captures value* (Table 2)

limited scope of this research, the authors choose to focus on practices that close resource loops at component and material level.

Table 2 Core activities in a business model.

Value dimension	***Corresponding question***	***Business model elements***
Value proposition	*What value is provided and to whom?*	Product/service offer and value proposition Customer segment
Value creation and delivery	*How is value provided?*	Resources and capabilities Partner network Value chain activities
Value capture	*How does the company make profit and capture other forms of value?*	Financial structure (costs and revenue flows

Source: Based on Osterwalder and Pigneur (2010)and Demil & Lecoq (2010).

By rethinking the three value dimensions, i.e. what value is proposed, how value is created, delivered and captured (Table 2), business model innovation provides a more holistic approach for aligning the value creation logic of the company with circular principles (Bocken et al. 2016). Business model innovation can aid to devise an offer and a *value proposition* that proactively embeds a circular strategy. The other business model elements can be configured in such a way that they help to successfully operate it, e.g. by acquiring resources and capabilities for implementation, aligning the business model to those of value chain partners to coordinate closing resource loops (*value creation dimension*), and capitalising on the associated value (*value capture*) (Table 2).

The following section will analyse the case companies in regard to the three value creation dimensions (Table 2) in order to identify the business model elements that have been innovated to aid the implementation of circular strategies.

3. Case study analysis and findings

Table 3 offers a general overview of the six case companies. Thereinafter, sections 3.1- 3.3 present their business models, focusing on the innovative elements in the respective lifecycle phase that were found critical to aid adoption of a circular strategy.

Table 3 Overview of case companies.

	Lifecycle phases					
	(1) Material and component production		*(2) Design*		*(3) End-of-life*	
Case company	**A**	**B**	**C**	**D**	**E**	**F**
Description	Company producing a material composite and plank from by-products from the wood and plastic industry. **Number of employees**: 20	Company manufacturing plank products (e.g. interior design application, facades) from bio-waste materials (founded in 2005). Company also franchises use of technology for various applications. **Number of employees**: 60	Architecture company founded in 1970 with a design vision that embraces social and sustainability goals (e.g. putting people and communities in the centre). **Number of employees**: 70	Architecture company founded with the goal of becoming a sustainability and circular economy leader. **Number of employees**: 38	Company sorting, cleaning, and testing secondary bricks for reuse.	Recycling company specialized on sorting construction and demolition waste (founded in 2015). It is a subsidiary of a construction company and providing services to the holding construction company.

Offer	Construction products from planks (e.g. fences, terrace floors) from recyclable, long-life composite material made from by-products.	Franchising of technology for transforming various bio-waste materials into a strong construction material for planks. Sales of customized planks (e.g. shapes and colours) from own manufacturing plant.	Design and planning of buildings with high sustainability standards and social vision.	Design and planning of buildings based on circular thinking with high sustainability standards in a "cost-neutral" way.	Sorted and cleaned used bricks or facade panels made of used bricks.	Waste handling services on construction and demolition sides; Sales of sorted waste material streams (e.g. wood and other combustible waste, iron and metals, concrete, etc.).
Circular strategies operated	No hazardous materials, use of secondary materials, prolonged lifespan, design for disassembly, design for recycling.	No hazardous materials, use of secondary materials, design for durability, design for recycling.	Design for disassembly, design for modularity, design for reintegration of secondary production.	Design for disassembly, design for modularity, design for reintegration of secondary production, disassembly, Closed-loop recycling, enabling reuse of products and components.	Enabling reuse of products and components.	Sorting for open-loop recycling.

3.1 Business models for circular strategies in production of construction material

To contribute to closing resource loops during the production of construction material, it is critical that materials and components are designed for long-life and recycling and/or secondary material input is used (Allwood et al. 2011). Both case companies have developed long-lasting, recyclable materials used for the construction of planks and have devised a business model to capitalize on their innovative materials. To bring the plank products to the market, both companies target customers that value, amongst others, the lower environmental impact of the product (see Table 4). A main difference in the companies' business model innovation can be found in the way the offer and financial structure are devised. While Company A is only selling the products produced from the material composite, Company B also franchises the technology to produce the material and a plank product of their choice. For Company B, this results in a rising number of manufacturing plants and applications of the material. In addition, it secures revenue streams not only from the sale of the product, but also from the ongoing franchise royalty fees and commissions on sales by franchisees.

Table 4 Overview of innovative elements in case company A and B's business models.

		Lifecycle phases		
Case company	*Business model elements*	*(1) Material and component production*	*(2) Design*	*(3) End-of-life*
A	**Value proposition**	- Design for long-life, low maintenance, and recycling - Low total costs of ownership - Targeting public housing associations that value lower total costs of ownership and reduced environmental impact		
	Value chain activities			
	Resources and capabilities	- Technology for transforming bio-waste into material composite for planks		

	Partner network			
	Financial structure			
B	**Value proposition**	- Design for durability and recycling - Targeting customer segments that value circular solutions and reduced environmental impact		
	Value chain activities			
	Resources and capabilities	- Technology for transforming bio-waste into material composite for plank products		
	Partner network	- Developing partner networks that franchise technology and run own production unit and sales - Help partner and franchisee networks to develop further applications		
	Financial structure	- Franchising fee - Commission on sales of franchisees		

3.2 Business models for circular strategies in designing buildings

To contribute to closing resource loops, the designing of buildings is critical (Thormark 2001). Decisions made in the design phase determine the extent to which circular strategies can be realized at the end-of-life of buildings. Moreover, only through proactively adjusting the building design, reuse of secondary components and materials can be realized. Both case companies have adjusted their business model elements to enable these design changes and contribute to implementation of circular strategies. However, they have done so to a different degree. Company C has established partner networks to develop and test construction products from secondary materials, targets customers that value offers that incorporate circular economy principles, and actively advocates circular design to its clients. Company D's activities are similar (see Table 5). However, the company has gone a step further as it has specialised on circular economy solutions and aligned much of its core business with circular principles. Therefore, all of its business model elements have been devised in innovative ways (see Table 5). Most strikingly, the company has developed capabilities and key resources that enable it to disassemble buildings itself and recover materials and components. Thereby, it expands beyond its traditional value chain position and operates also activities in the (3) end-of-life of buildings and in the (1) production of materials and components (see Table 5).

Table 5 Overview of innovative elements in case company C and D's business models.

		Lifecycle phases		
Case company	*Business model elements*	*(1) Material and component production*	*(2) Design*	*(3) End-of-life*
C	**Value proposition**		- Improved social and environmental sustainability performance - Targeting organizations that are open to reuse and advocating design choices for reuse - Enabling small-scale projects	

	Value chain activities			
	Resources and capabilities	-Development of components from reused materials for testing	- LCA expertise - Being flexible when designing to adapt to available materials	
	Partner network		- Partner network to develop and test reuse solutions	
	Financial structure		- Offering higher than market price to acquire waste materials	
D	**Value proposition**		- Making circular economy an integral part of every offer - Guaranteeing same standard in regard to price, quality, aesthetic value, functionality, safety compared to conventional offer - Risk adverse material choices - Targeting organizations that are open to reuse and advocating design choices for reuse - Operating demolition services to facilitate reuse	
	Value chain activities		- Developed supply base and sometimes get contacted with offers	- Demolition and sorting on construction side
	Resources and capabilities	- Development and application of components from reused materials	- Department for R&D of reuse solutions - Embracing flexibility as a design tool to design with available materials	- Developing disassembly techniques and guidelines
	Partner network		- Partner network to develop reuse solutions and certification standards	
	Financial structure		- Offering to take disposed materials for a lower price than waste handlers or higher than market	

3.3 Business models for circular strategies at the end-of-life of buildings

The end-of-life management of buildings is critical to enable recovery of materials and prepare for reintegration into the value chain (Nordby 2009). This requires that components and materials are disassembled and sorted to prepare for reuse at highest value possible. Company E has developed a technology to enable recovery at component level (used bricks), and devised a business model for bringing the reused bricks to the market. Customers are targeted that value, amongst others, the reduced environmental impact of the product and the unique look of the reused bricks (see Table 6). Other supportive innovations in the business model are the development of a supplier network to ensure sufficient access to used bricks. This was a time-intensive process as currently demolishing companies dispose bricks in order to save labour, time and costs. Another critical innovation was the development of certification standards to assure the quality of bricks to customers. Therefore, partner networks consisting of research institutes, governmental organisations, and consumer protection organisations were established. Company F contributes to closing loops at material level. It had been established by its holding construction company to operate the sorting of construction and demolition waste on construction sites. Although material streams are still handled in a conventional manner and the business model has not been adjusted to undertake reuse activities at higher value than open-loop recycling or

waste-to-energy conversion (see Table 6), the establishment of the new business by the holding company can be considered as an important innovation in itself. With increasing maturity of the company (established only in 2015), more opportunities for reuse of materials and components in the holding company's constructions may be capitalised on. This can increase value capture for the holding company through keeping the revenues from sales of sorted material streams and the costs saving for waste management in their own company. To contribute to this, Company F is testing various options to enable reuse at higher level.

Table 6 Overview of innovative elements in case company E and F's business models.

		Lifecycle phases		
Case company	*Business model elements*	*(1) Material and component production*	*(2) Design*	*(3) End-of-life*
E	**Value proposition**			- Competitive price, certified quality standards - Targeting customers with an interest in reducing environmental impacts
	Value chain activities			- Developing supplier network of used bricks from demolishers
	Resources and capabilities			- Technology development for sorting, piling up and cleaning of bricks
	Partner network			- Partner network to develop certification
	Financial structure			- Paying for acquiring disposed bricks (negotiated case-by-case basis)
F	**Value proposition**			- Provides services to holding company (construction company) - Developing customer base for sorted waste material streams
	Value chain activities			- Sorting of construction and demolition waste
	Resources and capabilities			- Waste sorting technology
	Partner network			
	Financial structure			

4. Discussion and conclusion

To aid the adoption of circular strategies in the construction value chain for buildings, different innovative business models have been devised. This research aimed at providing an overview of business model innovations that facilitate adoption of circular strategies in the construction sector. While some of the investigated business models have been established with the purpose to aid cycling of resources, others have been existing since a longer time, but their business model elements have recently been reconfigured to facilitate cycling of resources. An overall finding is that the degree to the case companies have adjusted their business model elements compared to a traditional business model varies. Thereby, it strikes that the degree of innovation in business model elements reflects the extent to which implementation of a circular strategy and cycling of resources at higher value is accomplished. Companies that have aligned the core of their business or adjusted several

business model elements tend to realize a larger number of circular strategies or achieve cycling of resources at higher value.

A number of adjustments in business model elements appear to be supportive of the implementation of circular strategies. For instance, to devise a *value proposition*, all case companies create offers that ensure competitive price and quality compared to a traditional offer, yet with a reduced environmental impact and target customer segments to which this is of value (e.g. to meet LEED or BREEAM certification requirements). In order to *create and deliver value* from a circular strategy, case companies needed to develop a range of new capabilities, resources, as well as partner networks. Examples are the development of certification standards to assure quality of products from reused materials, research and development on recycling and reuse solutions, and the development of a customer base and a supplier network to access disposed materials and components. Interestingly, one of the studied architecture companies expanded its resources and capabilities beyond its traditional value chain position to also operate disassembly and sorting at demolishing sites. Through this innovation, the company was able to realize a larger range of solutions for reuse. Innovation in regard to *value capture* was less prominent in the studied cases. However, finding the right pricing to acquire disposed materials was of relevance for the companies engaged in the recovery of materials. One case company stood out as they devised their offer into a franchise model and captured value from franchise fee and commissions.

Looking at the construction value chain for buildings, the acquisition of disposed materials as well as the creation of market demand for reuse solutions seem to be major challenges to implementing circular economy principles. Currently, for demolishing companies at the end of the value chain, limited incentives exist to change practices to provide disposed materials and components for reuse. Companies that want to reintegrate resources into the value chain (e.g. secondary component producers and architects) experience difficulties to receive sufficient access. Moreover, even if reuse solutions are developed, in some cases, sufficient market demand is still lacking, for instance, due to users' concerns about functionality and quality of secondary construction material. Regardless of the value chain position, the fluctuations in quantity and quality of used resources requires all companies to adapt their business model to be able to operate more flexibly.

Future research should investigate if the findings of this study are applicable to a larger number of cases. In addition, as case companies were not able to remove all experienced barriers by means of business model innovation, future research should consider the policy interventions that can aid to remove barriers and capitalize on applying circular strategies in the construction sector.

References

Adams, K. T., M. Osmani, T. Thorpe, and J. Thornback. 2017. Circular economy in construction: current awareness, challenges and enablers. Paper presented at Proceedings of the Institution of Civil Engineers-Waste and Resource Management.

Allwood, J. M., M. F. Ashby, T. G. Gutowski, and E. Worrell. 2011. Material efficiency: A white paper. *Resources, Conservation and Recycling* 55(3): 362-381.

Bakker, C., M. Den Hollander, E. Van Hinte, and Y. Zljlstra. 2014. *Products that last: Product design for circular business models*: TU Delft Library.

BioIntelligenceService. 2011. *Service contract on management of construction and demolition waste - SR1: Final Report Task 2*. Brussels, Belgium: European Commission DG ENV.

Bocken, N., I. de Pauw, C. Bakker, and B. van der Grinten. 2016. Product design and business model strategies for a circular economy. *Journal of Industrial and Production Engineering* 33(5): 308-320.

Braungart, M., W. McDonough, and A. Bollinger. 2007. Cradle-to-cradle design: creating healthy emissions–a strategy for eco-effective product and system design. *Journal of cleaner production* 15(13): 1337-1348.

Cooper, D. R. and T. G. Gutowski. 2017. The Environmental Impacts of Reuse: A Review. *Journal of Industrial Ecology* 21(1): 38-56.

Crowther, P. 1999. Design for disassembly to recover embodied energy.

da Rocha, C. G. and M. A. Sattler. 2009. A discussion on the reuse of building components in Brazil: An analysis of major social, economical and legal factors. *Resources, Conservation and Recycling* 54(2): 104-112.

Durmisevic, E. 2006. Transformable building structures: Design for dissassembly as a way to introduce sustainable engineering to building design & construction.

Durmisevic, E. and J. Brouwer. 2002. Design aspects of decomposable building structures. *Delft University of Technology. Department of Building Technology. Proceedings of the CIB Task Group*.

Durmisevic, E. and K. Yeang. 2009. Designing for disassembly (DfD). *Architectural Design* 79(6): 134-137.

EllenMacArthurFoundation. 2017. *Achieving ‚Growth Within': A €320-Billion Circular Economy Investment Opportunity Available to Europe to 2025*.

EuropeanCommission. 2015. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: Closing the loop - An EU action plan for the Circular Economy. Brussels: European Commission.

EuropeanEnvironmentAgency. 2014. Annual European Union greenhouse gas inventory 1990–2012 and inventory report 2014: Submission to the UNFCCC Secretariat. Brussels, Berlgium.

Ghisellini, P., C. Cialani, and S. Ulgiati. 2016. A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems. *Journal of Cleaner Production* 114: 11-32.

Kibert, C. J. 2004. Green buildings: an overview of progress. *Journal of Land Use & Environmental Law* 19(2): 491-502.

MacArthur, E. 2013. Towards the circular economy. *Journal of Industrial Ecology*.

Miljøministeriet. 2014. Danmark uden affald: Ressourceplan for affaldshåndtering 2013-2018, edited by Miljøstyrelsen. København, Denmark.

MinIenM. 2014. Van Afval Naar Grondstof: Uitwerking van acht operationele doelstellingen. Den Haag, The Netherlands.: Ministerie Van Infrastructuur En Milieu.
Naturvårdsverket. 2012. From waste management to resource efficiency: Sweden's Waste Plan 2011, edited by S. E. P. Agency. Stockholm, Sweden.
Ness, D. A. and K. Xing. 2017. Toward a Resource-Efficient Built Environment: A Literature Review and Conceptual Model. *Journal of Industrial Ecology*.
Nordby, A. S. 2009. *Salvageability of building materials: Reasons, criteria and consequences regarding architectural design that facilitate reuse and recycling*: Norges teknisk-naturvitenskapelige universitet, Fakultet for arkitektur og billedkunst, Institutt for byggekunst, historie og teknologi.
Osterwalder, A. and Y. Pigneur. 2010. *Business Model Generation: a handbook for visionaries, game changers, and challengers*: John Wiley & Sons.
Rijksoverheid. 2016. Green Deal Circulaire Gebouwen. Den Haag, the Netherlands.
SOU. 2017. Från Värdekedja till värdecykel: så får Sverige en mer cirkulär ekonomi. Stockholm, Sweden: Statens Offentliga Utredningar.
Stahel, W. 1994. The utilization-focused service economy: Resource efficiency and product-life extension. *The greening of industrial ecosystems*: 178-190.
Stahel, W. 1997. The Service Economy:' wealth without resource consumption'? *Philosophical Transactions of the Royal Society of London A: Mathematical, Physical and Engineering Sciences* 355(1728): 1309-1319.
StateOfGreen. 2017. Circular Economy: Denmark as a circular economy solution hub. København, Denmark: State of Green.
Teece, D. J. 2010. Business models, business strategy and innovation. *Long range planning* 43(2): 172-194.
Thormark, C. 2001. Recycling potential and design for disassembly in buildings.
Thormark, C. 2002. A low energy building in a life cycle—its embodied energy, energy need for operation and recycling potential. *Building and environment* 37(4): 429-435.
Vandkunsten, G. AS, A. V. AS, H. C. AS, and M. T. Högskola. 2016. *Rebeauty: Nordin built component reuse*. Copenhagen:
Wells, P. and M. Seitz. 2005. Business models and closed-loop supply chains: a typology. *Supply Chain Management: An International Journal* 10(4): 249-251.
Zink, T. and R. Geyer. 2017. Circular economy rebound. *Journal of Industrial Ecology* Volume 00, Number 0(Research and Analysis): 1-10.