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Circular Business Model Design

Business Opportunities from Retaining Value of Products and Materials

Nußholz, Julia L.K.

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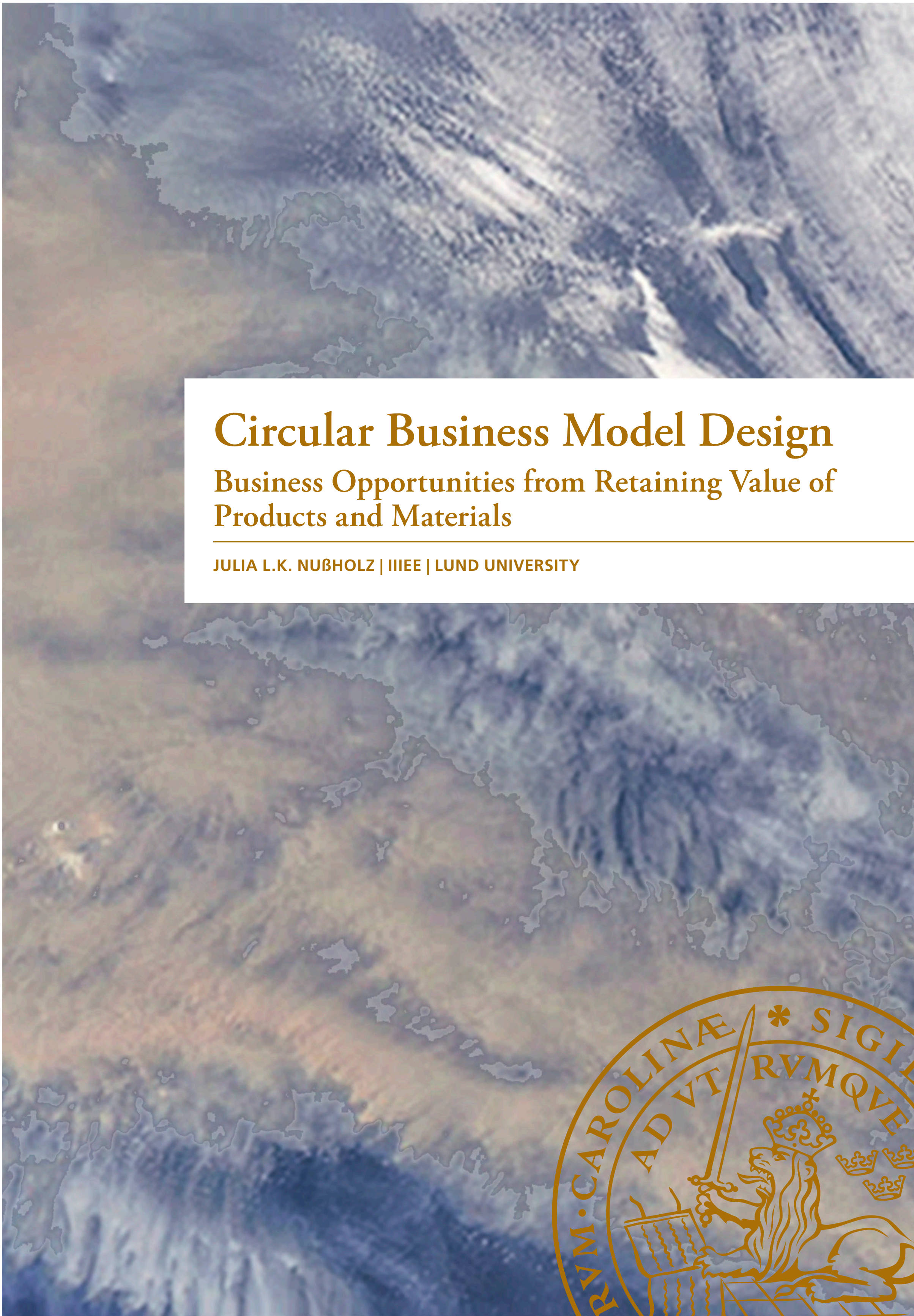

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JULIA L.K. NUßHOLZ | IIIEE | LUND UNIVERSITY

Today our economy is largely based on linear material flows, and many products, such as electronics, furniture, building materials and textiles, are discarded even when they could still be used. Without urgent action, global waste is expected to increase by 70% by 2060 and global materials use is expected to more than double. We are starting to realise that such linear material flows are not only inconsistent with 'planetary boundaries' for our life on this planet, but are also a loss of valuable products and materials.

One proposed solution is a shift towards a circular economy, in which products are not discarded but retained for as long as possible in a closed-loop system (e.g. through reuse, repair and remanufacturing of products, or recycling). Many suggest that circular economy strategies also offer new business opportunities for companies.

This thesis examines how companies can capitalise on the opportunities and devise circular business models that retain value embedded in products and materials. Based on cases of pioneering companies, the thesis explores what value the models create for the businesses, environment and society and how value is created. It explores the tools that can help practitioners integrate circularity in their business model, and proposes a new business model canvas for circular business models.

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Business Opportunities from Retaining Value of Products and Materials

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Abstract

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One proposed solution is a shift towards a circular economy, in which products are not discarded; instead, their embedded economic and environmental value is retained for as long as possible in a closed-loop system. This is achieved through, for example, reuse, repair and remanufacturing of products, or recycling. Many suggest that a circular economy also offers new business opportunities for companies.

This thesis focuses on how companies can devise 'circular' business models (CBM) to capitalise on such opportunities, focusing on CBMs that retain value embedded in products and materials. Based on pioneering companies that have devised CBMs for value retention, the thesis examines what value their business model creates for the environment, business, society, and customers, and how value is created. The thesis also explores how tools to help practitioners integrate circularity in their business model can be developed and improved.

A key finding is that CBMs for value retention have significant potential to reduce environmental impact, may have a promising business case, could generate employment, and could produce additional customer value. However, value is not created by default. Recommendations to secure value creation along the various value dimensions are provided. To help practitioners integrate circularity in their business models, a structured overview of CBM innovation tools is presented and a CBM canvas for value retention proposed. A guideline shows how CBM tools can be developed to more effectively support practitioners.

Future research is needed to improve methodology for comparing financial and societal value creation by circular versus linear business models. Implications for value creation if CBM were upscaled need further investigation. Whether the financial value alone will be sufficient to incentivise businesses to shift towards CBMs within the short time window we have to address climate collapse remains doubtful, so research is needed on policy interventions that can help accelerate the transition.

Key words circular economy, business model innovation, circular business model, resource efficiency, reuse, life cycle management, buildings, value creation, sustainability assessment

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Julia L.K. Nußholz

LUND UNIVERSITY

Cover photo is a cut-out of 'Thick Smoke Blankets Southeastern Australia' from NASA (Visible Earth) satellite imagery, published 2 January 2020. It shows smoke over the Pacific Ocean from bushfires on the east coast of Australia. Smoke blankets made their cycle around the globe back to Australia within several days, affecting atmospheric conditions globally.

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MADE IN SWEDEN

To my grandparents and all those who inspire me to live more sustainably and responsibly

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Acknowledgments

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Julia

Copenhagen, January 2020

Abstract

Today our economy is largely based on linear material flows, and many products, such as electronics, furniture, building materials and textiles, are discarded even when they could still be used. Without urgent action, global waste is expected to increase by 70% by 2060 and global materials use is expected to more than double. We are starting to realise that linear material flows are not only a loss of valuable products and materials, but are also inconsistent with 'planetary boundaries' and are a main cause of sustainability challenges. More than 50% of all greenhouse gas emissions are estimated to derive from materials management in our economy.

One proposed solution is a shift towards a circular economy, in which products are not discarded; instead, their embedded economic and environmental value is retained for as long as possible in a closed-loop system. This is achieved through, for example, reuse, repair and remanufacturing of products, or recycling. Many suggest that a circular economy also offers new business opportunities for companies.

This thesis focuses on how companies can devise 'circular' business models (CBM) to capitalise on such opportunities, focusing on CBMs that retain value embedded in products and materials. Based on pioneering companies that have devised CBMs for value retention, the thesis examines what value their business model creates for the environment, business, society, and customers, and how value is created. The thesis also explores how tools to help practitioners integrate circularity in their business model can be developed and improved.

A key finding is that CBMs for value retention have significant potential to reduce environmental impact, may have a promising business case, could generate employment, and could produce additional customer value. However, value is not created by default. Recommendations to secure value creation along the various value dimensions are provided. To help practitioners integrate circularity in their business models, a structured overview of CBM innovation tools is presented and a CBM canvas for value retention proposed. A guideline shows how CBM tools can be developed to more effectively support practitioners.

Future research is needed to improve methodology for comparing financial and societal value creation by circular versus linear business models. Implications for value creation if CBM were upscaled need further investigation. Whether the financial value alone will be sufficient to incentivise businesses to shift towards CBMs within the short time window we have to address climate collapse remains doubtful, so research is needed on policy interventions that can help accelerate the transition.

Popular science summary

Background and relevance

The industrial revolution two centuries ago set in motion new mechanised production processes that led to unprecedented levels of production and consumption. Paired with globalisation and rapid technological development, industrialised production drove welfare and economic prosperity in industrialised countries, but also led to unsustainable volumes and speed of resource flows through the economy. These resource flows are largely characterised by a linear approach (i.e. a 'take-make-dispose' approach). Virgin materials are extracted and manufactured into products. Products are disposed after a relatively short time, even though many of them could still be used.

Linear resource flows cause problems at both ends in terms of waste generation and resource use. The World Bank estimates that, globally, 2.01 billion tonnes of municipal solid waste are generated annually, with more than 33 percent not managed in an environmentally safe manner. Global material resource use is estimated at 90 billion tonnes annually. The International Resource Panel warns that the proportion of non-renewable materials compared with biomass and renewable materials continues to grow, resulting in even larger waste flows and higher emissions and pollution per unit of resources.

Meanwhile, the global economy is estimated to quadruple by 2060 according to a recent OECD study. Without urgent action, global waste is expected to increase by 70% compared with current levels by 2050. Global materials use is projected to more than double from 79 Gt in 2011 to 167 Gt in 2060. As a consequence, the availability of critical materials for our economy is also at risk. So far, achievements in decoupling material use from economic activities have been insufficient to reduce absolute volumes of material use.

We are starting to realise that such practices entail not only a loss of valuable products and materials but are also inconsistent with 'planetary boundaries' to our life on this planet. Amidst of efforts to mitigate climate crisis, the greenhouse gas (GHG) emissions embedded in products and materials are increasingly in focus of governments and companies that want to address their climate impacts. The OECD estimates that more than 50% of all GHG emissions are related to materials management (OECD, 2018). A major transformation of the economic system and the way we manage resources is required, in which the current linear model is transformed towards one that generates welfare and economic prosperity alongside reductions of resource use and waste.

One such alternative model is the circular economy, developed and researched since the 1960s. In the last decade, the idea has revived as a solution for decoupling environmental impacts from economic activities. It suggests a redesign of the current linear economic system, where the value of products, parts and materials, such as energy, materials, labour, and capital costs, is retained in a closed system at the highest level possible for as long as possible. Strategies in circular economy systems include reuse, repair, remanufacturing, or recycling. Advocates of a circular economy argue that this not only makes sense from an environmental perspective, but also from a business and societal perspective. By retaining the value that is embedded in products and materials during their production, new business opportunities arise, material costs for consumers and companies can be reduced, and additional jobs created.

A circular economy cannot be implemented without a shift in companies' practices. To enable this shift, business model innovation has been argued to be a key enabler. Business model innovation for circularity can be the development of new businesses (e.g. businesses repairing products or recycle materials that would otherwise be lost) or updates in existing business models (e.g. a change in product design to enable durability or repairability, or a new business partnership to enable collection of products after first use). Businesses incorporating circular economy strategies are then said to operate a circular business model (CBM). Since 2013, the concept of CBMs has become popular in the business community and among governments and scholars.

CBMs generate added value by retaining products, components and materials at their highest value for as long as possible (referred to as CBMs for value retention). Examples of CBMs for value retention are businesses that enable reuse of products (Humana for textiles or Gamle Mursten for building bricks), repair products (Inrego for consumer electronics), design products for long life and recycling (Fairphone for mobile phones), or remanufacture their products (Caterpillar for constructions machinery). A key aim is to maximise resource value throughout a product's life cycle, also after a first use phase. This is in contrast to linear business models where value of products is added upstream during manufacturing (and to some extent retail), but value is lost downstream after a single-use phase. Companies are promised numerous opportunities for value creation when shifting towards a CBM. These include not only the environmental value, but also business value, such as financial benefits from reduced material costs or multiple sales, and more attractive customer offers (e.g. product durability and lower life cycle costs). Despite the proposed value, implementation is currently limited, and practitioners experience many barriers.

Knowledge gaps and research questions

A key challenge to the implementation of CBMs for value retention is the uncertainty as to whether and how they create the intended benefits. In a predominantly linear economic system, in which negative environmental externalities of resource extraction and production practices are insufficiently incorporated in prices, there are many barriers to CBMs creating value. These include high upfront costs for product and technology development (e.g. sorting and remanufacturing technology), the need for redesign of linear value chains, development of new capabilities, and customer acceptance of circular-based offers. Also, the financial returns in CBMs are often uncertain. To date, empirical evidence of value creation in CBMs is scarce, especially from integrated assessments that consider multiple types of value (e.g. customer, environmental, and financial value). Consequently, understanding of how value is created in CBMs is also underdeveloped.

If CBMs are found to create sufficient value, then to implement them at scale, the *idea of value retention* needs to be incorporated in conventional business models. Several tools to aid practitioners have emerged in recent years, but one identified gap is identifying tools that have been tested and validated with practitioners, and creating an overview of the contribution of tools in the innovation process. Another gap is that some tools that are widely used in traditional management practice are not fully suited to support design of value retention models. For instance, business model canvases that offer standardised templates for mapping and analysing business models have not been designed to illustrate the multiple business cycles often needed for value retention (i.e. multiple cycles of sale and collection of products). Investigation is needed into how conventional business model canvases can be improved to better illustrate CBMs for value retention and their multiple business cycles.

To address these knowledge gaps, three research questions were asked.

Research question 1: *How can CBMs for value retention be defined?*

Research question 2: *What value do CBMs for value retention create and how?*

Research question 3: *How can tools for design of CBMs for value retention be advanced?*

Research approach

To answer the three research questions, this research employed an interdisciplinary, sometimes transdisciplinary, approach, characterised by close collaboration with practitioners in some of the research stages. Comprehensive empirical data was gathered through 13 case studies, analysed through both quantitative and qualitative methods. A participatory research approach with a case company spearheading circular economy implementation in the building sector created an approach for value assessment that integrates several types of value – financial, customer, environmental and network value. This was used to assess the impacts of their business model for three reuse products. This analysis was expanded by environmental assessment of three other building products. Tool development was based on comparative case studies of companies that have devised different types of CBMs for value retention, and on multiple rounds of testing and refinement with practitioners. Systematic literature reviews were conducted to create a theoretical and conceptual foundation for the research and develop a relevant research scope.

Key findings and contributions

Findings show that reuse of building products can save 77% of CO2-eq emissions if window glass is reused compared to linear-based windows, and 99% if bricks are reused compared to linear-based bricks. However, carbon saving potential of the investigated products differed substantially, and trade-offs between environmental impact categories were common. Overall, assessment of implications of the reuse business models for value creation revealed that reuse of building products can be a financially viable business model that delivers significant environmental impact reductions, can satisfy customer needs (i.e. building developers and investors), and create significant employment in the value chain. Therefore, it is suggested that CBMs for value retention are key for managing materials more sustainably and reducing a companies' environmental footprint.

A key finding is that CBMs that retain value in products and materials need to be carefully designed to deliver intended value. Based on the assessment, this research contributed recommendations for how to create value along the various dimensions. Life cycle management of product design and manufacturing processes is critical in creating environmental value. Processes such as transport or the addition of new materials should be kept as small as possible. Management of trade-offs between environmental impact categories is also important. Examples of recommendations for financial value creation are careful design of products and value chains, as processes to recover products can be more labour intensive or can require input of, often costly, new materials. In creating customer value, products need to meet the same functional requirements as conventional, linear products. Price-competitiveness with linear products is crucial and remains a key challenge for practitioners.

Another key contribution of this research is an adapted canvas for mapping CBMs for value retention that enable multiple cycles of value creation. It offers a standardised framework for the elements of a CBM for value retention, and its possible cycles to retain value of products, parts and materials. Inclusion of multiple cycles in the tool has the potential to promote a more holistic adoption of value retention through the life cycle, where ideally several CE strategies are applied simultaneously. Main benefits relate to its potential to clarify the concept to practitioners and guide them towards higher levels of value retention, or aid more in-depth academic analysis.

To sum up, the research offers three key contributions. First, it clarifies the concept of CBMs for value retention, consolidating state-of-the-art knowledge from the fields of CBMs, business models, and resource efficiency. Secondly, it presents comprehensive empirical data on value creation from a pioneering company that enables product reuse in the building sector. It formulates recommendations how value can be created in regard to customer, environmental, financial, and network value. Thirdly, it reviews existing tools that can support CBM innovation processes. Tools validated with practitioners are identified and their contribution in the innovation process is classified. It also advances and tests a business model canvas to map and analyse CBMs designed for creating and retaining value in multiple cycles (e.g. multiple cycles of product sale and collection). The tool is found to have potential to support practitioners in developing CBM ideas that can retain value of products, parts and materials at higher level.

Limitations and future research

This research assessed implications for value creation at the level of a business model along multiple value dimensions. Such integrated assessment is a relatively novel approach in the field. Methodology needs improvement to enable comparison with impacts of a linear business model, especially in terms of job creation and financial viability.

To improve understanding of value creation at macro-economic level, other methods such as consequential LCA, cost-benefit analyses or input-output analyses are required. It should also be noted that the timing of the evaluations in this research has implications for the results. The main case study of this research was a first production line of reused products. Value creation may differ once economies of scale come into effect or efficiency improved. Future assessment could investigate the business case over a longer period of time to assess financial value with improved efficiency of production practices or scale.

Even though the case company was able to recover investment costs, and outcomes were clearly desirable from a societal perspective (with regard to job creation and environmental impact reductions), it remains doubtful whether the current financial value is sufficient to incentivise implementation of CBMs at the required speed and scale (to address, for instance, climate collapse). Therefore, more research is needed on how the systemic conditions for companies enabling value retention can be improved and what policy interventions could accelerate the transition towards a CE.

List of figures

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List of papers

Paper I

Nußholz, J.L.K. (2017). Circular Business Models: Defining a Concept and Framing an Emerging Research Field. Sustainability, 9, 10.

Paper II

Nußholz, J.L.K. (2018). A circular business model mapping tool for creating value from prolonged product lifetime and closed material loops. Journal of Cleaner Production. Special Issue Product Lifetimes and the Environment. 197, p. 185-194, 10p.

Paper III

Nußholz, J.L.K., Nygaard-Rasmussen, F. & Milios, L. (2019). Circular building materials: Carbon saving potential and the role of business model innovation and public policy. Resources, Conservation & Recycling. Special Issue: Waste for Building Materials. 141, p- 308-316, 9p.

J.N. initiated the paper, developed the research design, collaborated with the case companies, collected and analysed all data apart from environmental assessment, and compiled the draft to which all authors contributed. F.N-R. reviewed life cycle analyses and calculated carbon saving potentials. L.M. developed the survey and contributed to data collection on desired policies.

Paper IV

Nußholz, J.L.K., Nygaard-Rasmussen, F. & Whalen, K., Plepys, A. (2020). Material reuse in buildings: Implications of a circular business model for sustainable value creation. Journal of Cleaner Production. Special Issue on Urban Mining. 245, 18p., 118546.

J.N. initiated the paper, developed the research design, collaborated with the case company, collected and analysed all data (besides only minor contribution in the life cycle assessment), and compiled the full draft. F.N-R. conducted the life cycle assessment, collected required data, and provided feedback in the review process. K.W. assisted with the conceptual development of the financial analysis, contributed to the background literature and provided feedback in the review process. A.P. contributed to the background literature and provided feedback during the review process.

Paper V

Bocken, N. Strupeit, L., Whalen, K., **Nußholz, J.** (2019). A Review and Evaluation of Circular Business Model Innovation Tools. Sustainability (Switzerland). 11,8, 2210.

N.B. initiated the paper and compiled the full draft; L.S. conducted and wrote up the database search for CBMI tools; K.W. wrote and compiled the methodology, J.N. focused on the background and overall editing of the paper. This being a collective effort, N.B., L.S., K.W. and J.N., jointly developed the methodology and spent equal time on categorising and coding the tools, and rounds of editing and writing.

Other publications

Journal article

Whalen, K. A., Milios, L., & **Nussholz, J.** (2017). Bridging the gap: Barriers and potential for scaling reuse practices in the Swedish ICT sector. Resources, Conservation & Recycling.

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Mont, O., Whalen, K. & **Nußholz, J**. (2019). Sustainable Innovation in Business Models: Celebrated but not interrogated. In: Handbook of Sustainable Innovation. Ed.: Boons, F. & McMeekin, A. Edward Elgar Publishing.

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Nußholz, J.L.K., Gustafson, F., Bocken, N. (Forthcoming). Circular business model innovation for a building developer: An experimentation approach to identify customer acceptance of circular façade elements. For presentation at Circular Materials Conference 2020. Gothenburg, Sweden.

Nussholz, J., Strupeit, L., Whalen, K., Bocken, N. (2019). Circular Business Model Innovation Tools and Approaches: a literature and practice review. New Business Models Conference. 3-5 July 2019. Berlin.

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Abbreviations

CE	Circular economy
CBM	Circular business model
CSP	Carbon saving potential
EEA	European Environmental Agency
EC	European Commission
FTE	Full time equivalent
GWP	Global warming potential
LCA	Life cycle assessment
OECD	Organization for Economic Cooperation and Development
R&D	Research and development

1. Introduction

The industrial revolution two centuries ago set in motion new mechanised production processes that led to unprecedented levels of production and consumption. Paired with globalisation and rapid technological development, industrialisation drove economic prosperity and welfare in industrialised countries, but also led to unsustainable volumes and accelerated resource flows through the economy. These resource flows are characterised by a linear approach (i.e. 'take-make-dispose'). Raw materials are extracted, manufactured into products that are disposed after a relatively short amount of time, although many of them can still be used (Frosch and Gallopoulos 1989; Stahel 2007).

Linear resource flows cause problems at both ends in terms of waste generation and resource use. It is estimated that, globally, 2.01 billion tonnes of municipal solid waste are generated annually, with more than 33 percent not managed in an environmentally safe manner (Worldbank 2018). Global material resource use is estimated at 90 billion tonnes annually. The proportion of non-renewable materials compared with biomass and renewable materials continues to grow, resulting in even larger waste flows and higher emissions and pollution per unit of resources (UNEP 2018).

Meanwhile, the global economy is forecast to quadruple by 2060 (OECD 2018). Without urgent action, global waste is expected to increase by 70% compared with current levels by 2050 (Worldbank 2018). Global materials use is projected to more than double by 2060, from 79 Gt in 2011 to 167 Gt (OECD 2018). Availability of critical materials for our economy is also at risk. For instance, 95% of all rare earth elements that have critical importance for economic activities in the EU are supplied by China (EuropeanCommision 2019). So far, achievements in decoupling material use from economic activities have been insufficient to reduce absolute volumes of material use (OECD 2018; UNEP 2018). The importance of these impacts has been shown by the recent report of the European Environmental Agency (EEA) on the State of the Environment, which finds that progress towards many of the environmental targets around a resource-efficient and circular economy is lagging (EEA 2019).

> "Europe's environment is at a tipping point. We have a narrow window of opportunity in the next decade to scale up measures to protect nature, lessen the impacts of climate change and radically reduce our consumption of natural resources."

Hans Bruyninckx, EEA Executive Director

December 2019

We have started to realise that linear material flows are inconsistent with 'planetary boundaries' (Rockström et al. 2009; Steffen et al. 2015) to our life on this planet. The CO_2 emission embedded in materials and products are increasingly the focus of governments and companies that need to lower their CO_2 emission to mitigate global warming (EEA 2014; EuropeanCommission 2019). A study by the Ellen MacArthur Foundation suggests that 45% of global greenhouse gas emissions result from manufacturing and consumption of products (EllenMacArthurFoundation 2019). An OECD study estimates that more than 50% of all greenhouse gas (GHG) emissions are related to material management (OECD 2018).

The economic system and the way we manage resources requires a major transformation, in which the current linear model is replaced by a model that generates welfare and economic prosperity while reducing primary resource use and waste generation (Stahel 2007). One such alternative model is the circular economy (CE).

1.1 From a linear towards a circular economy

In the quest for alternatives to the unsustainable linear system, the idea of a CE has been developed (Frosch and Gallopoulos 1989; Giarini and Stahel 1993; Boulding 1966)[1]. The CE suggests a redesign of the current, linear economic system towards closed-loop resource flows that preserve the embedded value in products for as long as possible at maximum utility. This is achieved by either lengthening the life of products or circulating them back into the system at different levels of product

[1] Since the 1960s, several research fields, such as Industrial Ecology (Jackson and Clift 1998; Lifset and Graedel 2002), The Performance Economy (Stahel 2010; Stahel 1997a) and Product Service Systems (Mont 2002; Morelli 2006; Tukker 2015), Biomimicry (Benyus 1997), EcoDesign (Knight and Jenkins 2009; Jeswiet and Hauschild 2005; Lofthouse 2006; Rossi et al. 2016; Bovea and Pérez-Belis 2012; Vallet et al. 2013), Cradle to Cradle (McDonough and Braungart 2010; Braungart 2000; Braungart et al. 2007) have developed strategies for generating changes in physical resource flows that have contributed to the foundations for the idea of a CE (Boulding 1966; Stahel 1994; Frosch and Gallopoulos 1989).

integrity (i.e. the extent to which a product remains identical to its original state, over time). (Hollander et al. 2017).

Strategies for this have been summarised in three categories: those that *narrow* resource loops (e.g. reducing production waste), *slow* resource loops (e.g. reuse, repair, remanufacturing), and those that *close* resource loops (e.g. recycling) (Bocken et al. 2016; Stahel 1994)[2]. Strategies for *narrowing* resource loops have been the focus of policy and business initiatives for longest (e.g. Cleaner Production and Eco-Design) (Allwood et al. 2011; Worrell et al. 2016; Boyle 1999; Fresner 1998; Remmen 1998). Although they remain an important prerequisite for achieving more resource efficient solutions[3] (Tillman et al. 2020), *slowing* and *closing* resource loops are considered to promote a more systemic change, where resource value is retained for as long as possible, and if applied correctly, 'waste' by intention is a resource for a new system (Braungart et al. 2007; Hollander et al. 2017). This is also acknowledged by the United Nations Environmental Programme (UNEP), which highlights resource extraction as a main cause of climate change and biodiversity loss and stresses that a systemic transformation of resource use beyond resource efficiency approaches is needed (UNEP 2018).

In recent years, the transition towards a CE has received increasing attention from a variety of actors, including academic scholars (Merli et al. 2018), businesses (OECD 2019), and policy-makers (EuropeanCommission 2015). The work of the Ellen MacArthur Foundation (EMF), a UK-based non-governmental organisation has particularly contributed to the recent popularity by, for example, communicating the concept through the widely used butterfly diagram (EllenMacArthurFoundation 2015b) and establishment of a cross-sectoral partner network. Merli et al. (2018) show that CE is a rapidly growing research field, with 56% of all publications published since the launch of the first EMF report. Governments have shown interest and devised policy programmes for transitioning towards a CE that specify targets, action areas, or roadmaps (Rijksoverheid 2016; EuropeanCommission 2015; Miljøministeriet 2014; InfrastructuurEnMilieu 2014). Industrial organisations such as the OECD or the World Business Council for Sustainable Development (WBCSD) have also promoted the idea in the private sector (OECD 2019; WBCSD 2017).

One reason for the recent revival of the CE idea is its emphasis on the economic rationale for such a shift. CE is largely presented as a way to decouple environmental impacts from economic growth (EllenMacArthurFoundation 2017, 2015a; EuropeanCommission 2015). Genovese and Pansera (2019) suggest that the

[2] *Narrowing* resource loops refers to using fewer materials, *slowing* resource loops to extending the useful life of products and parts, and *closing* resource loops to material recycling at the end of life) (Bocken, 2016; Stahel, 1996)

[3] Depending on types of products, strategies for narrowing resource loops can sometimes have the highest environmental savings potential (Tillman et al. 2019).

CE best fits within a technocratic, eco-modernist paradigm that emphasises the role of technology and economic growth in meeting the worlds social, economic and ecological challenges (Caradonna et al. 2015). However, changes in consumption habits or economic growth are rarely advocated (Murray et al. 2017). Some scholars have questioned the unpolitical stance of the CE discourse towards growth (Genovese and Pansera 2019), its ability to generate the promised 'radical' changes in resource management (Hofmann 2019) , or its ability to reduce primary material consumption (Zink and Geyer 2017).

Within the envisioned transition towards a CE, this thesis is concerned with CE application at company level. A key enabler for shifting industry practices towards circularity is adjustment of companies' business models to CE principles (OECD 2019; EuropeanCommission 2015). On the one hand, business model innovation is a means to helping companies transform various areas of their business activity towards a circular model (e.g. offers, products, value chains). On the other, it is a way to harness innovation opportunities and increase preparedness for changes in future legislation. This is relevant, as traditional linear business models will not be viable when policies are in place that internalise the costs of natural resources and emissions in prices (e.g. an effective carbon tax) (von Weizsacker et al. 1992; Bosquet 2000; Bovenberg 1999).

1.2 Circular business model innovation

The concept of a circular business model (CBM) was developed in 2013 (MacArthur 2013) and rapidly became popular (Merli et al. 2018), offering an alternative to the linear value creation model. By implementing CE strategies, value embedded in products, parts, and materials during their production is retained at highest value for as long as possible – ideally beyond a single-use phase. This is in contrast to linear business models, where value of products is added upstream during manufacturing and retail, but loses value downstream after a single-use phase (Achterberg et al. 2016).

A business model emphasises a system-level, comprehensive approach to describing how firms conduct their business activities. It does so by outlining the elements a business model is thought to consist of (i.e. the 'value creation architecture') and explaining how value is created, delivered, and captured (Osterwalder and Pigneur 2010; Zott et al. 2011). The business model lens has been applied by scholars outside the traditional management field, in exploring how companies can provide solutions to sustainability challenges (Massa and Tucci 2014). An example is the domain of sustainable business models, where the concept of value is expanded beyond the firm and its customers to other stakeholders such as the environment and society (Massa and Tucci 2014; Boons and Lüdeke-Freund 2013).

Although, CBMs are most commonly applied with a focus on the environmental dimension of adopting CE practices (Geissdoerfer et al. 2017), many other forms of value have been promised to businesses (Accenture 2014a; EllenMacArthurFoundation 2017). Advocates of a CE argue that CBMs not only make sense from an environmental perspective, but also from a business and societal perspective. Retaining the value that is embedded in products and materials during their production can generate new business opportunities (Bakker et al. 2014b), reduce material costs for companies (Moreno et al. 2016), or create new jobs (IISD 2018; Wijkman and Skånberg 2015).

To create and capture this value, different types of CBMs are suggested that can help create and capture value from CE strategies. A widely used typology is the ReSOLVE framework developed by the EllenMacArthur Foundation. It distinguishes six archetypes of business model innovations – Regenerate, Share, Optimise, Loop, Virtualise, and Exchange (EllenMacArthurFoundation 2015a) – covering a wide share of CE strategies (e.g. remanufacturing and repair) but also innovation strategies such as digitalisation or product service systems. With this diversity in understanding, there is not yet a common definition of how CBMs can be understood (Geissdoerfer et al. 2018).

In light of the urgent need for *slowing* and *closing* resource loops (Section 1.1), this thesis focuses on those CBMs that help retain value embedded in products, parts, and materials (referred to as CBMs for value retention). Value retention is understood as maintaining the quality and productivity of products, parts, and materials over time at highest level possible (Stahel 1997a; Stahel 2010). This is regarded as offering greatest potential for value creation and contributing towards the more systemic change in resource management (den Hollander & Bakker, 2018; Stahel, 2010).

Despite the claimed potential to address some of the systemic failures of the linear system, and the apparent consistency with companies' efforts to create value (Genovese and Pansera 2019), implementation of CBMs for value retention is not widespread in practice (Ritala et al. 2018). Companies that aim to shift to value retention models experience many barriers (Ritzén and Sandström 2017; Rizos et al. 2016; Kirchherr et al. 2018; De Jesus and Mendonça 2018; Guldmann and Huulgaard 2020) deriving from dominant cultural practices, markets, regulations, and technology (Kirchherr et al. 2018). Three key problems and knowledge gaps regarding value creation and design of CBMs for value retention were identified in this research; these are outlined in the next section.

1.3 Problem definition and knowledge gaps

Currently, implementation of CBMs for value retention in practice is limited in scale and speed (Ritala et al. 2018). This is partly driven by the uncertainty regarding the value CBMs create, and how, and the challenges of incorporating value creation in business model innovation processes. Three main problems and associated knowledge gaps are identified.

First, greater understanding of how the design of CBMs for value retention can be supported, what value they create and how, requires clarification of how CBMs for value retention can be defined. The CBM concept is used to describe a variety of strategies (e.g. repurposing, remanufacturing, repair, recycling) developed in fields fundamental to the CE concept (e.g. Industrial Ecology, Eco Design, or Product Service Systems). Before further research, strategies for value retention require further exploration. Existing CBM definitions also lack an environmental dimension to account for the fact that CE strategies do not result in environmental impact reductions by default (Allwood et al. 2011; Tillman et al. 2020; Zink and Geyer 2017). This calls for exploration of how such criteria can be considered in a definition, so that environmental impact reductions become an explicit aim in CBMs for value retention. Therefore, to develop an effective scope for this research, improved understanding is needed of *how CBMs for value retention can be defined*.

Secondly, uncertainty about the value created by CBMs for value retention, and how, is identified as another key challenge to their implementation. Practitioners face a challenge to identify when a circular strategy is worth pursuing, with regard to both environmental and business value (OECD 2019). CBMs for value retention are associated with numerous opportunities for value creation, including environmental value (Diener and Tillman 2015; Diener et al. 2015; Schenkel et al. 2015), business value, such as financial benefits (Moreno et al. 2016; De los Rios and Charnley 2016), and customer value (van Weelden et al. 2016; Schenkel et al. 2015; Gullstrand Edbring et al. 2016).

In a predominantly linear economic system, dominant cultural practices, markets, regulations, and technology pose many barriers to value retention (Kirchherr et al. 2018). These include the high upfront costs for technology development (Hart et al. 2019), the need for redesign of linear value chains (Lüdeke-Freund et al. 2019b), development of new capabilities (Pieroni et al. 2019), and customer acceptance of circular-based offers (Gullstrand Edbring et al. 2016). The financial returns are uncertain and empirical evidence of value creation is scarce (Hart et al. 2019).

To date, there is little empirical evidence of value creation at business model level, especially from integrated assessments that consider multiple types of value (e.g. customer, environmental, and financial value) (Lüdeke-Freund et al. 2017; Haines-Gadd and Charnley 2019). Consequently, understanding of how value is created is underdeveloped. Environmental assessments of circular product innovations are rather common (André et al. 2016; Böckin and Tillman 2019; Willskytt et al. 2019; Tillman et al. 2020), but integrated assessments feature less in literature. To the best knowledge of the author, the only studies are those of Mont et al. (2006) investigating financial, customer, and environmental value from a business model operating the leasing and remanufacturing of baby prams and Scheepens et al. (2016) investigating environmental and market value of a water recreation system in the Netherlands. Therefore, more research is needed on integrated assessments to advance understanding of *what value* CBM*s for value retention create and how*?

Thirdly, if CBMs for value retention are found to create sufficient value to form a viable industrial model, implementing them at scale means that the idea of value retention must be incorporated in conventional business model innovation processes. For this purpose, several tools to support practitioners have emerged in recent years (Pieroni et al. 2019). Adoption of such tools requires identification of tools that have been developed and tested with users, and an overview of tools' respective contributions in the innovation process. This is important, as research shows that many tools are being developed but not used in practice (Baumann et al. 2002), which may be due to limited testing of the tool by potential users (Tyl et al. 2015; Baumann et al. 2002)).

Another gap is that some tools that are widely used in traditional management practice are not fully suited to support design of value retention models. An example is business model canvases that offer standardised templates for mapping and analysing business models and that are widely used to help understand and communicate the business model and generate new business model ideas (Eppler and Hoffmann 2011; Doz and Kosonen 2010; Eppler et al. 2011; Osterwalder 2004). Canvases from traditional management literature have not been designed to illustrate the multiple business cycles that are often needed for value retention (i.e. multiple cycles of sale and collection of products) (Velte and Steinhilper 2016; Spring and Araujo 2016). This is also the case for canvases developed specifically for CBMs (Antikainen and Valkokari 2016; Rashid et al. 2013; Lenssen et al. 2013; Circulab 2018). An investigation is therefore needed into *how tools for design of CBMs for value retention can be advanced*.

1.4 Research objectives and questions

In line with the identified knowledge gaps, the overarching objective of this research is to improve understanding of *CBMs for value retention*, their *value creation*, and *design*. This research aims to achieve the overall objective by three means.

Firstly, a systematic literature review is conducted to clarify the concept of CBMs for value retention and to develop an effective scope for this research. This is guided by the following research question:

Research question 1: *How can CBMs for value retention be defined?*

Secondly, a participatory research approach involving a case company spearheading CE implementation in the building sector enables value assessment that examines several types of value – financial, customer, environmental and network value. The assessment was carried out on three of the company's reuse products. Implications of the company's business model for value creation are assessed. This analysis is elaborated by assessing the carbon saving potential of three other reuse-based building products. Based on the assessment, consideration for how to create value along the various dimensions are summarised. The analysis is guided by following research question.

Research question 2: *What value do CBMs for value retention create and how?*

Thirdly, a systematic literature and practice review identifies existing tools to support circular business model design and classify their contributions. Based on comparative case studies and multiple rounds of testing and refinement with practitioners, a tool to map circular business models for value retention and their multiple cycles of value creation is developed. The following research question is formulated to guide this part of the research.

Research question 3: *How can tools for design of CBMs for value retention be advanced?*

How each of the papers contributes to the research objectives and answers the research questions is outlined in the following section.

1.5 Overview of papers

In this thesis, CBMs for value retention are studied in five research papers (**Table 1**) to answer the three research questions (**Figure 1**). The research questions are addressed through multiple methods and data sources and increase understanding of the phenomena in a cumulative manner.

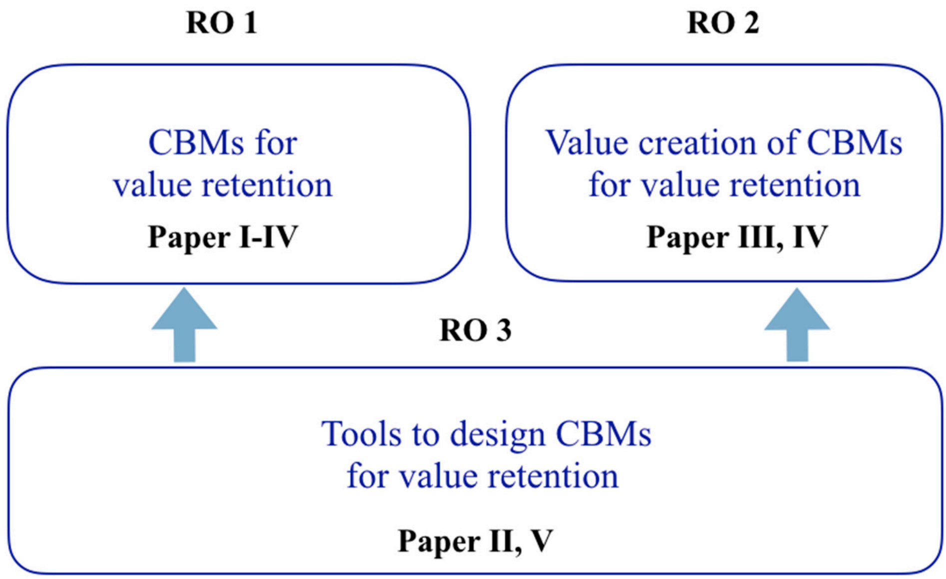

Figure 1 Mapping of research outputs, research objectives, and papers.

Paper I: Defining Circular Business Models

Circular Business Models: Defining a Concept and Framing an Emerging Research Field, develops the theoretical foundation and definition for this thesis and addresses the *first research question*. It addresses the lack of a common understanding of the concept of a CBM. Despite an increasing number of academic contributions on the concept, understanding what makes a business model circular varies considerably, hampering the theoretical development of CBMs. A systematic literature review helps to clarify the fundamentals of the concept from the perspectives of resource efficiency and business model innovation, and investigates differences in understanding of the resource efficiency strategies that classify a business model as 'circular'.

Paper II: A Tool for Mapping Circular Business Models

A Circular Business Model Mapping Tool for Creating Value from Prolonged Lifetime and Closed Material Loops addresses the *third research question* by exploring how multiple cycles of value creation can be incorporated in a business model canvas to enable mapping of business models that retain value throughout the life cycle. Business model canvases (i.e. standardised, visual representations of the elements a business model is thought to consist of) are a common approach in traditional business model innovation to help analyse and devise new business model ideas. Building on the widely used business model canvas by Osterwalder & Pigneur (2010), this paper identifies the potential cycles to slow and close resource loops (e.g. through resource recovery, long life, multiple use cycles) and how these cycles could be integrated with Osterwalder & Pigneur's representation. The final tool offers a standardised representation of the elements and possible cycles of CBMs to retain value of products, parts, and materials. The tool is developed and revised through multiple rounds of case studies, workshops and feedback from practitioners. It helps to answer the *third research question*. Main benefits relate to its potential to clarify the concept to practitioners and provide structure and guidance for business model design for multiple cycles of value creation and retention.

Paper III: Circular Business Model Design and Carbon Saving Potential

Circular Building Materials: Carbon saving potential and the role of business model innovation and public policy, addresses the *second research objective* through a comparative case study of three pioneering Scandinavian companies that develop and commercialise reuse of building products and materials. The paper examines business model innovations to implement reuse and the resulting carbon savings. The results show clearly that all three cases offer potential for carbon savings. As the carbon savings in the cases vary significantly, findings suggest that careful consideration of affected production processes and markets is key to attaining environmental value. As such, the paper contributes to answering the *second research question* of this thesis.

Paper IV: Implications of a Circular Business Model for Sustainable Value Creation

Material Reuse in Buildings: Implications of a circular business model for sustainable value creation, takes *Paper III* as a starting point and explores value creation of a CBM for material reuse in buildings beyond carbon saving potential. To provide a broader perspective on potential sustainability benefits of reuse business models, a single case study of a Scandinavian company is employed. Using a participatory research approach, indicators are co-created with company stakeholders to examine how reuse affects (1) environmental impacts, (2) customer value, (3) financial viability, and (4) network value. An overall finding is that the business model not only has potential to be competitive with linear production practices but, if designed carefully, it can also provide superior customer value, significant environmental impact reductions, and value for network partners. Considerations to safeguard environmental and financial value of reuse solutions are also identified. The paper helps to answer the *second research question* of this thesis.

Paper V: Methods and Tools for Circular Business Model Design

A Review and Evaluation of Circular Business Model Innovation Tools, helps answer the *third research question* by reviewing and structuring the landscape of emerging tools and methods developed to support the CBM innovation process. The paper seeks to create a comprehensive overview of tools through a systematic literature and practice review. Tools are classified with regard to their purpose, target audience, and entry point in the innovation process (e.g. idea generation, implementation, evaluation). In addition, tools are evaluated with regard to rigour and transparency of their development process (i.e. developed with users and tested in practice), to identify tools with high potential to support CBM innovation process in practice. Based on this, a guideline for future tool development as well as gaps and opportunities to inform future research are suggested.

Table 1 Overview of research papers.

Paper #	Title	Research approach	RQ	Year
I	Circular Business Models: Defining a Concept and Framing an Emerging Research Field	Qualitative	RQ1	2017
II	A Circular Business Model Mapping Tool for Creating Value from Prolonged Lifetime and Closed Material Loops	Qualitative	RQ3	2018
III	Circular Building Materials: Carbon saving potential and the role of business model innovation and public policy	Qualitative and quantitative	RQ2	2018
IV	Material reuse in buildings: Implications of a circular business model for sustainable value creation.	Qualitative and quantitative	RQ2	2020
V	A Review and Evaluation of Circular Business Model Innovation Tools	Qualitative	RQ3	2019

1.6 Scope and limitations

This thesis focuses on *business model innovation* to help retain value of products, parts, and materials. Other aspects of CE implementation, such as policy, or product design, are largely beyond the scope here. Various dimensions of the scope are explained below and summarised in **Table 2**.

This thesis uses the business model as *unit of analysis.* Business model innovation is regarded as useful because of its ability to help companies plan, analyse, and structure the often comprehensive changes for shifting towards a circular model, e.g. the design of new value chain networks (upstream or downstream) (Lüdeke-Freund et al. 2019b; Wells and Seitz 2005), or products (Moreno et al. 2016; De los Rios and Charnley 2016). The unit of analysis of a business model is the level between the firm and the industry (Wirtz et al. 2016; Massa and Tucci 2014). This makes it useful for analysing interactions or economic exchanges within larger actor networks around the focal firm, which is essential for most types of circular value chains (Wells and Seitz 2005).

This thesis uses the business model *conceptualisation* developed by Osterwalder and Pigneur (2011) (Section 2.1) that distinguishes nine business model elements. The conceptualisation chosen has a technology orientation (i.e. operative planning for technological development) and an organisational theory orientation (i.e. integrated presentation of the company organisation) (Teece 2010; Wirtz et al. 2016). This orientation on internal company processes is deemed more useful for studying implementation of CBMs for value retention, compared to conceptualisation that involves a focus on strategy or tactics.

CE implementation and associated business model design differs from *sector* to sector. This thesis focuses on the manufacturing sector with its various industries. The manufacturing sector is well positioned to address CE-based innovations, for example through product design, value chain management, and offers of green products, and has a long-standing history in driving environmental impact reductions. The majority of business model innovations investigated in this thesis are business models developing products for the building sector (Paper III and IV).

The CE is associated with various *CE strategies*, such as restoration, anaerobic digestion, repair, remanufacturing, and recycling (EllenMacArthurFoundation 2015a) (Section 1.2). With the focus here on the manufacturing sector, business models investigated in this thesis can best be considered part of the technical cycle of the CE framework (i.e. butterfly diagram by the Ellen MacArthur Foundation). Bio-based solutions are therefore not considered this research. Also, the strategy of sharing to optimise resource utilisation during the use phase of products and reduced idling times (Zvolska et al. 2019; Curtis and Lehner 2019) has not received specific attention in this research.

The *geographical scope* of case studies compiled in this thesis was predominantly southern Scandinavia. The Scandinavian context was selected due to its long-standing tradition in business model innovation, and a policy context encouraging resource efficiency and CE practices (SOU 2017; Miljøministeriet 2014). Maintaining the geographical context was a deliberate choice in case study design, to increase similarity of the context, and thereby comparability of the cases.

The research was conducted between November 2015 and June 2019, with case study material for the business model evaluations (*Paper III* and *IV*) collected between May 2017 and January 2019. In this period, implementation of CBMs advanced, and CBMs received greater attention from the academic, policy and business community (Rosa et al. 2019). To respond to the rapid developments, this thesis also considers recent academic contributions published before finalisation of writing (November 2019) in Sections 2 and 4.

Table 2 Overview of the research scope in different domains.

Domain	Within scope	Outside scope
Unit of analysis	BM (positioned between the level of the firm and industry)	Product design, policy
BM conceptualisation	Technology, organisation focused	Strategy, tactics focused
Sector	Manufacturing sector	Food, Agriculture, Water, Urban
CE Strategies	Slowing and closing resource loops	Narrowing resource loops
Geography	Southern Scandinavia (partly other industrialised countries)	Developing countries
Time	November 2015-2019	After November 2019

1.7 Thesis outline

This thesis proceeds with presenting the theoretical and conceptual foundations (Section 2), the methodology (Section 3) and the findings and discussion in regard to the three research questions (Section 4). Section 4 also presents a reflection on the methodological approach and conceptual framework used in this thesis (**Figure 1**). Section 5 presents the conclusions in regard to the key contributions and suggestions for future research.

2. Theoretical and Conceptual Foundations

This chapter considers how to conceptually and theoretically frame the study of *CBMs for value retention*, their *value creation, and design*. It is divided into four topics: (1) Business model innovation, (2) CBMs for value retention, (3) value creation of CBMs for value retention and (4) and tools to support their design.

2.1 Business model innovation

Business models are a simplified and aggregated representation of the company organisation, enabling analysis of how a company conducts business activities with a wider set of stakeholders (Casadesus-Masanell and Ricart 2007; Chesbrough and Rosenbloom 2002; Demil and Lecocq 2010). Business models describe a set of interrelated and interdependent elements, and the activities within these elements, that depict the company's value creation architecture (i.e. the organisational structure and value creation processes) (Zott et al. 2011). These elements revolve around three questions: '*How does a company create value?*' (e.g. the value proposition and how customer needs are addressed); '*How does it deliver value?*' (e.g. through which channels value to targeted customers is delivered); and '*How does it capture value?*' (e.g. the financial architecture) (Osterwalder and Pigneur 2010). A widely used representation of the business model concept is the business model canvas of Osterwalder and Pigneur (2010), which distinguished nine business model elements that form the value creation architecture of a business (see **Table 3**).

Table 3 The business model framework adapted from Osterwalder & Pigneur (2010), and Richardson (2008)

Business model dimension	Corresponding questions	Business model elements
Value proposition	How does the company create value?	Offer and value proposition Customer segments Customer relationships
Value creation and delivery	How does the company deliver value?	Key partners Channels Key resources Key activities
Value capture	How does the company capture value?	Costs Revenues

Because of the arguably broad perspective, a business model relates to many choices that managers make about how the organisation should operate (e.g. supply chain, integration, pricing, marketing) (Casadesus-Masanell and Ricart 2010). As a management tool, it fulfils many functions, such as a building plan to guide business model design (Osterwalder et al. 2005), to check consistency and logic of innovations (Shafer et al. 2005; Wirtz et al. 2016), or analysis of strategic innovation decisions (Hamel 2001).

Innovating the business model can involve either designing an entirely new business model, or reconfiguring the elements of an existing business model (Amit and Zott 2010; Trapp 2014). It can be a 'vehicle to innovation', allowing managers to bring innovative technologies and products to the market, or it can be a source of innovation itself, updating 'the old way of doing things' (Amit and Zott 2010). Business model innovation can result in change in several or all of the business model elements, i.e. incremental or radical innovation (Amit and Zott 2010; Wirtz et al. 2016). Several authors have highlighted the need for a dynamic understanding of business models, consisting of different multiple iterative steps (e.g. ideation, implementation and evaluation) (Frankenberger et al. 2013; Osterwalder and Pigneur 2010). Business model innovation also involves different levels of detail, from changes at a conceptual level to changes at managerial level and in operational practices (Casadesus-Masanell and Ricart 2010; Teece 2010).

Application of the business model concept is heterogeneous in terms of definitions, elements, perspectives, and abstraction levels (Wirtz et al. 2016). However, a unified understanding is gradually emerging, and four consolidating themes are identified: 1) a comprehensive and systematic perspective of how firms do business; 2) the role between operational process management and strategy, 3) a new unit of analysis between business and the industry (referred to as the value network in this thesis (Massa and Tucci 2014; Boons and Lüdeke-Freund 2013); and 4) the focus on value and capture (Wirtz et al. 2016).

Together with examining environmental and social impacts from business practices (Section 1), the business model lens has also been applied to explore business models contributing to sustainability objectives. Here, the scope of business models has expanded to the societal level around the firm (e.g. society and environment) (Massa et al. 2017; Lüdeke-Freund et al. 2016; Lüdeke-Freund 2010; Bocken et al. 2014). One type of sustainable business model is considered, CBMs (Bocken et al. 2014; Geissdoerfer et al. 2018), which are explained in the next section.

2.2 CBMs for value retention

In recent years, the concept of CBMs has become popular and entered policy and business discourses (OECD 2019; EuropeanCommission 2015). CBMs are envisioned to reconcile creation of commercial and environmental value through adoption of CE strategies. In contrast to linear business models, in which a product is commonly lost after a single-use phase and its embedded value is lost, CBMs support the development of product systems that retain the embedded environmental and economic value at the highest utility possible (Stahel 1994; EllenMacArthurFoundation 2013).

While providing new opportunities for companies to create and capture value (Bocken et al. 2016; Bakker et al. 2014b; Moreno et al. 2016), adopting CE strategies also requires holistic and radical changes in companies' offers and value chains (Urbinati et al. 2017; Lüdeke-Freund et al. 2019a; Rosa et al. 2019; Wells and Seitz 2005). This can be changes downstream in a companies' value chain processes (e.g. collection of a product after sale to their user) and/or upstream (e.g. acquiring supply of secondary materials as input for their own production) (Urbinati et al. 2017; Freudenreich et al. 2019; Rosa et al. 2019). Depending on whether circularity is realised only between companies or includes consumers, this may involve a variety of actors and development of entirely new value networks (Wells and Seitz 2005; Singh and Ordonez 2016).

In light of such increased complexity, the business model lens is deemed helpful because of the concept's usefulness in analysing, structuring, planning, and communicating how value from incorporating CE strategies can be created (Mont et al. 2019; Geissdoerfer et al. 2016).

With the variety of possible CE strategies relevant in the context of the CBMs (as outlined above), the use of the concept in academic literature is divers, and proposed definitions and typologies differ substantially (Geissdoerfer et al. 2018; Roos 2014; Linder and Williander 2015; Den Hollander and Bakker 2016; Accenture 2014a; EllenMacArthurFoundation 2015a; Rosa et al. 2019; Bocken et al. 2016; Lüdeke-Freund et al. 2019b). The main differences are whether a single firm or a network of firms are considered, but also which types of CE strategies are considered relevant. For instance, Geissdoerfer et al. (2018: p.4), consider CBMs as business models, in which

> "[b]y closing, narrowing, slowing, intensifying, and dematerialising loops, the resource inputs into and the waste and emission leakage out of the organisational system are minimised, and consequently, the sustainability performance improved".

Similar to this definition, some of the typologies that define archetypes of CBMs (i.e. patterns how CE strategies can be integrated in business models and commercialised), suggest archetypes for *narrowing*, *slowing*, *closing*, *dematerialising* (i.e. substitution of product utility by services and software solutions), and *intensifying* resource flows (i.e. a more intense use phase)[4]. The RESOLVE framework presented in Section 1.2 presents archetypes of all these changes in material flows (EllenMacArthurFoundation 2015a). Other typologies focus only on slowing and closing resource loops (Bocken et al. 2016; Bakker et al. 2014b; Whalen 2019). As a result, opinions vary on whether CBMs include strategies for sufficiency (Bocken et al. 2016), industrial symbiosis (Bocken et al. 2016; Moreno et al. 2016), optimisation of production processes (EllenMacArthurFoundation 2013) (Bocken et al. 2016), optimisation of use patterns (EllenMacArthurFoundation 2013), and sharing (EllenMacArthurFoundation 2013; OECD 2019; Accenture 2014b).

Building on scholars' contributions that are fundamental to the origins of the CBM concept (Stahel 1994; Braungart et al. 2007), this thesis focuses on CBMs that enable retention of the value embedded in products, parts, and materials through *slowing* and *closing* resource loops. Value retention is understood as maintaining the quality and productivity of products, parts, and materials over time at the highest level possible (Stahel 1997b, 1994) and can be achieved at various levels of integrity and utility as established in the waste hierarchy (EuropeanCommission 2009). Product integrity is the extent to which a product remains identical to its original state (i.e. as manufactured) over time (Den Hollander 2018) (Stahel 2010). Value retention is thought to go beyond resource efficiency approaches for narrowing resource loops, as it can reduce the speed of resource flows through the economy and thereby contribute to a more systemic and radical change in the way resources are managed (Stahel 1994; Braungart et al. 2007).

It is important to note that much research demonstrates that implementing CBMs for value retention will not by default result in environmental impact reductions. Environmental gains from value retention at product level can come with trade-offs in other environmental impact categories or can be outweighed by rebound effects at system level. An example is when the processes to get products and materials into a condition suitable for reuse offset the environmental savings from retaining embedded value (Worrell and Reuter 2014; Gaines 2012; Björklund and Finnveden

[4] Geissdoerfer et al. (2018) highlight these additional categories of intensifying resource flows (i.e. a more intense use phase) and dematerialising (i.e. the substitution of product utility by services and software solutions). Usually these are considered as part of slowing resource loops.

2005; Agrawal et al. 2012; Choi et al. 2006). In the case of energy-intensive products, use-phase impacts can outweigh environmental gains from extending product value (Cooper and Gutowski 2017; Bakker et al. 2014a; Richter et al. 2019a).

In current conceptualisations of CBMs, environmental considerations are insufficiently considered, even though environmental impact reductions are identified as one of the main drivers of companies to shift towards circular practices (OECD 2019; Mont et al. 2017). Therefore, in order to find a starting point and define a scope on value retention for this research, but also to account for the environmental value dimension, clarification is needed on *how CBMs that enable value retention can be defined*.

2.3 Value creation of CBMs for value retention

Many studies explore how CE implementation is approached from a business model perspective (Section 2.2). Contributions on what value is available for companies transitioning towards a circular model and how value is created feature less in literature, especially those supported by empirical data (Haines-Gadd et al. 2018). In traditional management literature, value is typically considered as value captured for the firm (Chesbrough and Rosenbloom 2002), its customers (Magretta 2002), and shareholders (Zott et al. 2011). Value creation is derived from customers' willingness to pay more than the costs of delivering the benefits associated with an offer (e.g. economic, technological, or user benefits) (Anderson et al. 2009). The difference between the costs required to realise the offering and the price paid is the value captured (Anderson et al. 2009).

The concept of value in the business model definition is adaptable with regard to the type of value created (Massa and Tucci 2014). In the domain of sustainable business models, for instance, value is understood more broadly, and also includes stakeholders such as society and the environment (Massa and Tucci 2014; Lüdeke-Freund et al. 2018; Bocken et al. 2014). This creates possibilities to realign an organisation's search for profits with innovations that also benefit the environment or society (Seelos and Mair 2005; Lüdeke-Freund et al. 2016; Freudenreich et al. 2019). Value derived from sustainable innovations is typically distinguished as 1) environmental, 2) social, and 3) economic value (Bocken et al. 2014).

In the case of CBMs, the overall value is derived from maximising the embedded environmental and economic value in resources, such as energy, materials, labour, and capital costs (Roper et al. 2017) for as long as possible (Haines-Gadd and Charnley 2019; Ghisellini et al. 2018; Den Hollander et al. 2017; Webster 2017) (Section 2.2). This is best exemplified by the idea of the 'power of the inner-circles' of the EMF butterfly diagram (EllenMacArthurFoundation 2015a), where products are ideally “kept as close as possible to the original product” (den Hollander et al. 2017; p.519). In theory, the smaller the loop, the more profitable or environmentally beneficial it is, as environmental or economic costs to retain or restore a product’s value are minimised. The higher the degree of product integrity (i.e. the extent to which a product remains identical to its original state over time and does not need activities to be restored) (also introduced as Inertia Principle, (Stahel 2010), the smaller the loop and the greater the effectiveness of the loop. In contrast to linear business models, this requires a life cycle perspective in managing value (Spring and Araujo 2016).

In an effort to clarify what value CBMs create and how, Haines-Gadd & Charnley (2019) devise a framework that classifies ‘circular value’. Circular Value is defined as

> “[…] the environmental, societal, economic and consumer benefits that are available within closed loops systems which are generated through partnerships and maximize the utility of resources across the entire value chain of systems”

Next to stakeholders for whom value is created (i.e. consumers, society, environment, economy), the framework distinguishes tangible and intangible types of value (**Figure 2**). Tangible value includes value from resources, consumer value, value from data and knowledge, and relationship value. Intangible value can stem from Sustainability Image, Symbiosis, Altruism, Behaviour Change, Stability and Control.

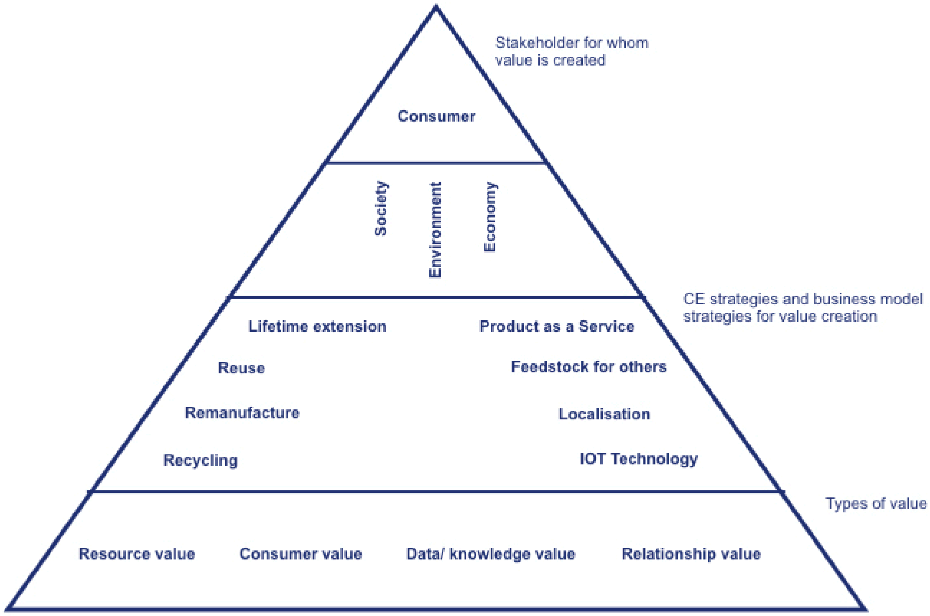

Figure 2 Circular Value Conceptualisation, adapted from Haines-Gadd & Charnley, 2019.

Building on Haines-Gadd & Charnley's conceptualisation, this research investigates value for the environment, economy, society and customers. In the context of the manufacturing sector (Section 1.6), the term 'customers' is regarded as more accurate than 'consumers'.

In the case of value retention models, *what* value is created for these different stakeholders varies according to, for example, sector or CE strategy. Indicators must be selected on a case basis, as suggested in sustainability assessment (Lüdeke-Freund et al. 2017; Turcu 2013) (see Method, Section 3.2.3). Literature contributions on several types of value specific to value retention models are presented in the following section, providing some background for the case-based indicator development in this thesis (Section 3.2.3).

For the economy, CE implementation can provide business advantages to companies. This includes new business opportunities, such as recovering products or materials that were previously discarded (Bakker et al. 2014b), but also new revenue sources (e.g. resale of products on the aftermarket) or costs savings (e.g. secondary material input, avoided waste handling fees) (Moreno et al. 2016).

For customers, benefits are anticipated from reduced overall lifecycle costs (Schenkel et al. 2015), reduced downtime of products by offering repair services (Türkeli et al. 2019), lower purchasing prices of secondary-based products (Kerr and Ryan 2001; Rajala et al. 2018; Hopkinson et al. 2018), or lower environmental footprints (Antikainen and Lammi 2016; Mugge et al. 2017; van Weelden et al. 2016). For society, benefits are most commonly expected from job creation effects. New value adding activities may be arranged for the recovery and reuse process (Wells and Seitz 2005; Singh and Ordonez 2016). Hestin et al. (2015) show that these activities are generally more labour-intensive than heat recovery, so they may have potential to increase net job creation. Several recent studies identify potential for net job creation from increased CE activities in different sectors and regions, and from using various types of economic input-output models (IISD 2018; Wijkman and Skånberg 2015; Trinomics et al. 2018; Hestin et al. 2015; Milios et al. 2018).

For the environment, if primary material extraction and waste generation are reduced, CE strategies can reduce environmental impacts per unit of function delivered (Stahel, 1994). However, this is not always the case, and much research has shown trade-offs at product level (Bakker et al. 2014a; Allwood et al. 2011) or rebound effects at system level (Zink and Geyer 2017) that can outweigh the environmental benefits from CE implementation (see Section 2.2).

How value is created in value retention models builds in principle on the value rationale explained earlier in this section. However, how value is created at operational level in empirical cases is still underexplored. Perhaps partly because contributions on value creation stem from different research fields, or focus on different types of value or CE strategies, it is still difficult to arrive at a coherent picture of value creation of value retention models. Another reason could be that what value and how value is created differs with business models, sector, or product applications. To date, research on how CBMs for value retention create value is scarce. For value creation of businesses, Schenkel et al. (2015) review types of value that are created from closed-loop supply chains. For the environment, Tillman et al. (2020) summarise and classify which CE strategies for which types of products can result in environmental improvements. Tillman et al. (2020) also summarise common trade-offs to guide practitioners in how value is created. However, especially, for the customer and the societal dimension, empiric examples of value creation are lacking. Therefore, there is a need for further investigation of *what value CBMs for value retention create and how?*

2.4 Tools for designing CBMs for value retention

Traditional management literature and practice have acknowledged the need for tools to assist business model innovation processes. Business model innovation processes are often characterised as being discovery-driven (McGrath 2010) and dependent on trial-and-error-learning (Sosna et al. 2010), and consisting of multiple, iterative steps (e.g. ideation, integration, implementation, evaluation) (Frankenberger et al. 2013). Tools can provide structure and guidance in these processes. Specific purposes have been the support of analysis, planning, idea generation or evaluation (Remane et al. 2017; Garfield et al. 2001; De Reuver et al. 2013; Eppler and Hoffmann 2011). Common types of tools are business model patterns to harness creativity during idea generation (Gassmann et al. 2014; Abdelkafi et al. 2013; Amshoff et al. 2015; Timmers 1998), canvases (i.e. visual representations) to facilitate group interaction and communication (Osterwalder 2004; Eppler and Hoffmann 2011), and road maps to identify transition paths to proposed business models (De Reuver et al. 2013). In this thesis, a tool is defined as a "set of prescriptive steps that is replicable and can be independently undertaken to achieve a specific, intended outcome" (Bocken et al. 2019b) (Appendix A). Various forms of tools are considered, such as checklists, frameworks, typologies, methodologies, guidelines, or games to help operationalise or implement a specific objective (Rossi et al. 2016; Bovea and Pérez-Belis 2012).

As the CBM concept has emerged relatively recently, tools for CBM innovation are also a new phenomenon. However, in fields related to the CE, such as EcoDesign, Product Service Systems, Cradle2Cradle, Biomimicry, Remanufacturing, a large number of tools have been developed (Rossi et al. 2016; Baumann et al. 2002; Pieroni et al. 2019). Tool development was primarily focused on eco-innovation of products (Baumann et al. 2002; Jones et al. 2001; Rossi et al. 2016; Bocken et al. 2011). This included CE strategies such as product durability, design for product life extension, and recycling approaches (Chiu and Chu 2012; McAloone and Andreasen 2004; Veerakamolmal and Gupta 2000). Some tools have been adopted at industrial scale, including guidelines (ISO Standards) and analysis methods (e.g. life cycle assessment or material flow analysis). Scholars in the field of PSS moved beyond product design and developed a range of tools to support design of integrated product and service systems, in which utility is provided in a more resource efficient manner (Mendes et al. 2015; Lim et al. 2012; Morelli 2006; Lelah et al. 2014; Zine et al. 2014; Mourtzis et al. 2018). Another domain comprises sustainability tools for business model design to help companies meet their sustainability ambitions (Breuer et al. 2018; Schoormann and Knackstedt 2018).

With popularisation of the CE concept in recent years, tools specifically for CBM innovation processes have emerged in academic and grey literature. Echoing approaches in traditional management literature, tools include canvases (Antikainen and Valkokari 2016), archetypes (Bakker et al. 2014b), databases (VITO, 2019), or common innovations approaches (e.g. experimentation) (Weissbrod and Bocken 2017). Despite these recent contributions, tools development for CBM innovation processes is in a nascent stage, and two main knowledge gaps are identified.

First, an overview of tools specifically for CBM innovation, including their contributions in the innovation process, is lacking. One recent review focuses on sustainable innovation tools, including those for CBM innovation (Pieroni et al. 2019), but contributions of CBM innovation tools have not yet been analysed in depth. Many contributions have not been tested and their development has not been transparent, or do not include guidelines for application by practitioners. This brings risks that their fit with practitioners' needs may be limited (Baumann et al. 2002) or that sustainability objectives may be 'diluted' during the process, and environmental and societal benefits jeopardised (Geissdoerfer et al. 2016; Baldassarre et al. 2017). Therefore, tools that have been developed and tested with users, and that offer guidelines for application, need to be identified.

Secondly, traditional management practice has employed business model canvases as an effective tool for, e.g., business model analysis, idea generation or communication of business models (Osterwalder 2004; Eppler and Hoffmann 2011). Canvases are meant to reduce complexity and illustrate the tacit structures of business models (Doz and Kosonen 2010; Eppler and Hoffmann 2011). However, these canvases insufficiently represent CBMs that retain value embedded in products, parts or materials.

Canvases designed with linear business models in mind do not illustrate that value retention often requires several business cycles, in which products are collected, reconditioned, and returned to the market (i.e. slowing resource loops). When value of products or parts cannot be retained longer, materials are to be recycled where possible (i.e. closing resource loops). Enabling such cycles often requires distinct value creation architectures for each cycle (Selvefors et al. 2019). Different partner networks, customer segments, distribution channels to retain and capture value in multiple cycles may be needed (Spring and Araujo 2016). Value creation architectures need to be devised with the respective cycles and CE strategies in mind (Spring and Araujo 2016)[5].

To effectively support practitioners, canvases for value retention models should visually incorporate the multiple cycles. The newly emerging CBM canvases include a broader understanding of value (economic, social, and environmental) and consideration of external to the business model factors (e.g. trends & drivers, stakeholder involvement), but not the idea of retaining value and slowing and closing resource loops (Antikainen and Valkokari 2016; Circulab 2018; Sustainn 2017). There is therefore a need to explore *how canvases for value retention models can be advanced to account for multiple cycles of value retention.*

The following chapter outlines the methodology for the research.

[5] For instance, if multiple use cycles of a product are enabled, the value proposition, from the very start, needs to be thought of as more fluid and may be redefined throughout the product lifecycle (Araujo and Spring, 2016). Each use cycle may require different value networks, such as partnerships for securing sufficient supply of secondary products (Kissling et al. 2013) or for enabling recycling of products at the end-of-life (Fairphone 2018). Cycles will result in different costs and revenues (e.g. collection costs or new revenue streams from aftermarkets) (Krystofik et al. 2017).

3. Methodology

This chapter explains the scientific position of the research within the scientific research paradigms and outlines the methodology used to achieve the research objectives (Section 1.4). The chapter is divided into five major topics: scientific positioning of the research (Section 3.1), research methods (Section 3.2), data collection (Section 3.3), data analysis (Section 3.4), and a discussion of reliability and validity (Section 3.5).

3.1 Scientific positioning of the research

Research is conducted within specific research paradigms that encompass the basic belief system or world view regarding the nature of the world, the individual's role in it, and the relationship to this world and its parts (Guba and Lincoln 1994). Paradigms have different standpoints with regard to ontology, epistemology, and methodology (Guba and Lincoln 1994), so have important consequences for the practical conduct of research (e.g. research aim, nature of knowledge, knowledge accumulation, quality criteria, values and ethics), and for the interpretation of research results (Guba and Lincoln 1994). Four alternative paradigms are discussed in the philosophy of science: positivism, critical realism, critical theory, and social constructivism (Guba and Lincoln 1994). Reflection on the underlying research paradigms is a prerequisite of the research process (Bryman 2016), especially when conducting interdisciplinary research that integrates disciplines and theory (Jerneck et al. 2011).

This research builds on a pluralistic approach to the scientific paradigms that acknowledge several valuable ways of 'knowing'. It recognises and integrates two scientific paradigms: (1) social constructivism and (2) critical realism. A pluralistic approach to scientific paradigms is especially suitable for interdisciplinary and transdisciplinary research that investigates complex, societal issues (Miller et al. 2008). *Interdisciplinary* research, in this thesis, is understood as the combination and (partial) integration of elements from two or more academic disciplines that enrich each other to study a phenomenon that does not fit in a single discipline (Sakao and Brambila-Macias 2018). *Transdisciplinary* research is understood as the inclusion of non-academic stakeholders, where academic and non-academic partners temporarily collaborate for addressing a sustainability 'problem' or knowledge gap (Sakao and Brambila-Macias 2018).

CBMs comprise an emerging research field with its origin in research from resource efficiency but also innovation management. Studying CBMs for value retention requires an *interdisciplinary* lens to account for its different theoretical and disciplinary aspects. The *transdisciplinary* and *participatory* approach (*Paper IV*) is deemed useful for contributing to solving 'real-world' sustainability problems that require new ways of knowledge production in research and decision-making in practice (Sakao and Brambila-Macias 2018; Blackstock et al. 2007). This enables a better understanding of a 'real-world' problem and generates knowledge that is more suitable for addressing this problem (Mobjörk 2010; Kurka et al. 2013).

In the following, the scientific positioning (within social constructivism and critical realism) of this research is described in regard to the three paradigm-defining components: ontology, epistemology, and methodology.

3.1.1 Ontology

The ontological position refers to belief about the form and nature of reality, so what there is and what can be known about it. The author of this thesis acknowledges a 'real' reality, but believes that this reality can be only imperfectly and probabilistically understood. Claims about reality (e.g. *'what value do CBMs for value retention create?'*) must be subject to the best possible critical examination. As this thesis advances conceptualisations of the CBM phenomenon (e.g. *'how can CBMs for value retention be defined?'*), the researcher also acknowledges the constructivist element of the research. In the constructivist paradigm, realities are understood as multiple, intangible mental constructions that are based on experiences (Guba and Lincoln 1994). Form and content are dependent on the individual researcher's constructions, and they are local and specific in nature, although some of their elements can be shared among many researchers and across cultures holding the same constructions. Guba and Lincoln (1994 p.111) state that "constructions are not more or less 'true', in any absolute sense, but simply more or less informed and/or sophisticated".

The author distances her research from the positivistic paradigm that assumes a comprehendable reality characterised by natural laws and mechanisms, where the researcher arrives at a 'true' description of the phenomenon. The paradigm of critical theory is not applicable to this research either, as it does not explicitly engage with the interrogation of the existing economic system and institutions that give rise to linear business practices, or the social political and economic values that have shaped current neo-liberal economic frameworks[6].

3.1.2 Epistemology

Epistemology refers to the relationship between the researcher and what can be known. In line with the critical realist paradigm, the author acknowledges that the researcher and investigated phenomenon are not independent and that researcher and research phenomenon influence each other. For instance, to answer *'what value do CBMs for value retention create?'*, selection of indicators is not a value-neutral process (Turcu 2013) and is influenced by the researcher's views, as well as practitioners engaged in CBM design. Therefore, the author recognises the responsibility to maintain objectivity as a "regulatory ideal" (Guba and Lincoln 1994: p.110). Critical examination and interaction with critical examiners (e.g. supervisors, editors peer-reviewers) have been regarded vital to ensure that reality is apprehended as closely as possible. In line with the constructivist paradigm, the author recognises a transactional and subjectivist view in the research process based on an interactive link with the research phenomenon. Findings, such as a definition to clarify *'how can CBMs for value retention be defined?'*, are constructed throughout the research process (Guba and Lincoln 1994).

3.1.3 Methodology

Methodology refers to how the researcher can go about finding out whatever she or he believes needs to be known (Guba and Lincoln 1994). In critical realism, the emphasis is placed on the triangulation as a way to falsify hypotheses, and methodological techniques are applied to increase the objectivity of the inquiry. This thesis employs triangulation of methods (e.g. literature review and case studies to gather multiple evidence), and data sources (e.g. involving various participants to evaluate the value created by a CBM for value retention) to increase validity of the conclusions on design of value retention models. In line with the social constructivist paradigm, this research also acknowledges a dynamic and individual nature of social constructions (Guba and Lincoln 1994).

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[6] Critical Theory rejects 'instrumental modes' of scientific knowledge that renders the existing institutional arrangements more efficient and effective to maintain current forms of power (Brenner 2009). Although CBMs can potentially play a role in radically different economic systems (e.g. those that incorporate negative externalities in prices and enable consumption and production based on sufficiency) (Genovese and Pansera 2019), studying CBMs without questioning the very existence of neo-liberal economic frameworks can be considered instrumental, so is not in line with the premises of Critical Theory (Brenner 2009; Jerneck et al. 2011; Springett 2003).

Constructions (e.g. the canvas for mapping CBM for value retention developed throughout the research) are developed and refined through the interactions between and among researcher and research object (e.g. cases of CBMs, against which the tool has been tested). In line with this paradigm, the author engaged in a process where various constructions are interpreted, compared, and contrasted to arrive at constructions that are more informed and sophisticated than the predecessor (e.g. arriving at a visualisation tool that is generic enough to visualise a wide variety of CBM types). The author acknowledges that her values are intrinsic to the constructivist paradigm. They can, for instance, influence the development process of constructions (e.g. environmental values that shape viewpoints on the degree of circularity that companies should engage with) or the selection of participants (e.g. own understanding of CBMs that informs case selection).

3.2 Research methods

This thesis combines multiple quantitative and qualitative methods to arrive at a more comprehensive understanding of CBMs for value retention and add to completeness of the inquiry (Bryman 2016; Creswell and Creswell 2017). Main methods employed in this thesis are case study methods (single and multiple case study designs), a systematic literature review, and life cycle assessment. These methods are chosen to suit the research objective and research questions (Section 1.4) (Verschuren et al. 2010) and the ontological and epistemological positions (Bryman 2016). Considerations and design decisions for each method are outlined in the following section and summarised in **Table 6**.

3.2.1 Case studies

Objectives of this thesis included clarification of *'how can CBMs for value retention be defined?'* and *'what value do CBMs for value retention create and how?'*. Case studies were a key method for obtaining empirical knowledge about value retention models (*Paper II, III*, and *IV*). Case studies are a common methodological approach for empirical inquiry of a particular phenomenon "[…] within its real-life context" (Saunders et al., 2007: 139). They are particularly suited to obtaining a rich understanding of a research phenomenon and its context (Saunders et al., 2007; Gerring, 2006: 352), and therefore for exploratory and explanatory research (Saunders et al. 2007). The choices for the different case study designs employed in this thesis are explained in the following.

A multiple case study approach (Gerring 2006) was used to develop a canvas tool for CBMs for value retention (*Paper II*). To enhance applicability of the tool for diverse types of value retention models (i.e. to increase external validity), the first phase of the tool development examined six companies from different sectors that operate different types of value retention models (jeans leasing, ICT reuse, mobile phone manufacturer, furniture rental, building products with secondary materials, reuse of office furniture). In the second phase of the tool development, a single case study from the IT sector (Fairphone) was used to demonstrate and evaluate the final tool.

A comparative case study design (Verschuren et al. 2010) with three Scandinavian companies from the building sector was used to investigate value retention models concerning reuse of building products and materials and to investigate their carbon saving potential (*Paper III*). Appropriate to the explorative character of the study and the objective to investigate a variety of innovative business model configurations, case companies were selected that operate different CE strategies at different steps in the building value chain. Case companies were selected from the same institutional context (southern Scandinavia) to improve comparability of cases.

A single case study design (Flyvbjerg 2006) of a Scandinavian company that commercialised three building products based on reuse (

Table 5) was used to examine implications on value creation (*Paper IV*) (see Section 3.2.4 for definition of reuse). The single case study design was chosen to gain a more comprehensive and in-depth understanding of the value creation. This was deemed suitable, as empirical evidence of implications on CBMs' value creation is largely absent (Hart et al. 2019). To triangulate data sources and strengthen data analysis, this case study research used a participatory approach (Baum et al. 2006), in which the author was placed at the case company for six months. This enabled a better understanding of the company's business model (e.g. product design, production processes, operations), but also regarding key stakeholders and suitable indicators. It also facilitated access to data and interview participants.

3.2.2 Systematic literature review

Systematic literature reviews were conducted to help answer the research questions *'How can CBMs for value creation be defined?'* (*Paper I*) and *'What tools exist to support design of CBMs for value creation?'* (*Paper V*). The systematic approaches to literature review are based on explicit procedures (e.g. specific search terms used, databases considered, timeframe applied) in order to increase transparency, replicability, and thoroughness of the research, and to minimise bias of the researcher (Bryman 2016; Jesson et al. 2011). This increases the likelihood of generating unbiased and comprehensive accounts of the literature (Bryman 2016). More details on the search strategies can be found in the appended papers.

3.2.3 Sustainability evaluation

The evaluation approach in this study involved a *transdisciplinary and participatory research approach* (Mobjörk 2010), in which the researcher was placed at the case company for a period of six month. Participatory research differed from conventional research in that it involved practitioners at multiple stages of the research process, including 1) in idea generation and choice of method and techniques, and 2) in the review, verification, and refining of ideas and results (Blackstock et al. 2007).

The *evaluation approach* followed the two steps suggested by Lüdeke-Freund et al. (2017) to perform integrated sustainability evaluations at a business model level (see *Paper IV* for more details).

First, value aspects of materiality were identified. This was done by reviewing literature and consulting key stakeholders of the case company, including three business developers and one senior architect from the case company, as well as a sustainability manager of a leading Scandinavian building developer. Suitable indicators to operationalise the value aspects were identified through review of sustainability assessment approaches and their indicators (e.g. Key Performance Indicators in the building sector, Global Reporting Initiative).

Secondly, three business developers and a senior architect of the case company were consulted to discuss the list of pre-selected indicators. This resulted in a final set of indicators that was considered suitable to reveal the most relevant implications on value creation of the reuse business model for different stakeholders.

The evaluation design was primarily informed by practitioners' perspectives on key value implications related to their business model and relevance of indicators to industry stakeholders. Indicator selection was determined by feasibility considerations in relation to data accessibility, data sensibility, resources, and time (Turcu 2013).

Final selection included four indicators that are defined in **Table 4**.

Table 4 Explanation of indicators for business model assessment, as presented in (Nußholz et al. 2020).

Value dimensions	Explanation
Financial value	Implications on the case company's financial structure and viability are investigated by identifying costs and revenues
Network value	Implications for other firms in the value network are investigated by calculating overall employment creation and identifying business opportunities for other actors in the value network that would not occur in linear production practices
Customer value	Benefits from material reuse for building developers and investors are investigated.
Environmental value	Environmental impact reductions compared with linear reference products are examined along multiple impact categories, focusing on Global Warming Potential (GWP)

3.2.3 Life cycle assessment

Life cycle assessment (LCA) (Baumann and Tillman 2004) was used to learn more about the environmental value of CBMs for value retention and changes in different environmental impact categories compared with linear reference products (*Paper III* and *Paper IV*).

Paper III investigated three solutions for reusing building products and materials (i.e. bricks, concrete, and wood-composite facades) with regard to their carbon saving potential. Products were developed and commercialised by companies operating in southern Scandinavia. A desk review of existing LCA studies identified the main contributing processes in the life cycle and their reduction potential if primary materials were replaced with secondary products or materials (see Appendix C for an illustration). Based on this, carbon saving potential of the investigated reuse products were calculated.

Paper IV conducted a more in-depth assessment of the environmental performance of three reuse-based products (wood cladding, concrete, and windows) compared with primary-based alternatives. Products were developed and commercialised by a Scandinavian case company. LCAs were conducted at product level following the *European Product Standard EN15804*, using a cradle to gate approach (A1-A3). LCAs were modelled in Simapro using the Ecoinvent 3.4 database. The focus was on the impact category of global warming potential (GWP) as an indication of carbon saving potential and environmental impacts (Kalbar et al. 2017). The impacts in other categories were discussed when trade-offs or significant savings were identified. More details on data and modelling choices for the reuse products and their reference products can be found in *Paper IV*.

In *Papers III* and *IV*, **reuse** refers to the use of secondary products or materials (e.g. by-products and waste materials) for producing building materials. The term **reuse** is used as an umbrella term common in academic publications about reuse and recovery of building materials (see e.g. (Thormark 2000; Demir 2009; Guy and McLendon 2000; Guy et al. 2006; Addis 2012), where it refers to both products and materials[7].

To clarify what is meant by **reuse** for each product, **Table 5** explains reuse strategy and processes of each product.

Table 5 Description of reuse strategy of the six investigated products (Nußholz et al. 2019; Nußholz et al. 2020).

Material	Reuse characterisation	Process description	Paper #
Wood and plastics	By-product use and recycling	Production of material composite for facades, floors and fences from secondary plastics (HDPE) and by-products from wood industry	*III*
Concrete	Material recycling	Crushed concrete from demolished buildings is used to substitute primary aggregate in new concrete	*III*
Bricks	Product reuse	Bricks from demolished buildings are sorted, cleaned, and sold for application in new buildings.	*III*
Glass	Product reuse	Post-consumer windows are collected from demolition sides and dismantled to obtain glass. Glass is assembled into new windows by adding customised frames and a second layer to comply with energy efficiency standards.	*IV*
Wood	By-product use	Wood is obtained from by-products and lower-grade production of a plank producer in proximity of the case company. Through cutting, surface treatment and mounting, the wood is developed into floor and façade cladding (indoor and outdoor).	*IV*
Concrete	Material recycling	Post-consumer concrete from demolition side is crushed into aggregates and through mixing with primary cement and other concrete components developed into new concrete.	*IV*

[7] Compared with the waste hierarchy (EuropeanCommission 2009), this definition encompasses the steps of reuse and recovery of the waste hierarchy. In the waste hierarchy reuse is defined as “any operation by which products or components that are not waste are used again for the same purpose for which they were conceived”. Recovery is defined as “any operation the principal result of which is waste serving a useful purpose by replacing other materials which would otherwise have been used to fulfil a particular function, or waste being prepared to fulfil that function, in the plant or in the wider economy”.

3.3 Data collection

The main methods for data collection used in this thesis are in-depth semi-structured interviews and surveys. Details on the use of each method are outlined in the following and summarised in **Table 6**.

3.3.1 Interviews

The main source of information included practitioners and stakeholders of the investigated case companies. To obtain their input, in-depth semi-structured interviews (Leech 2002) were held.

To develop the canvas for mapping CBM for value retention (*Paper II*), multiple rounds of semi-structured interviews with case company representatives were used to validate and improve the tool. For *Paper III* on Circular Business Model Design and Carbon Saving Potential and *Paper IV* on the Implications of a Circular Business Model on Sustainable Value Creation, semi-structured interviews with company representatives were held to gain understanding of the investigated business models, their elements, and underlying product systems. For *Paper IV* on the Sustainability Evaluation of a Circular Business Model, four semi-structured interviews were held with customers of the case company (i.e. building developers and investors) to identify potential benefits from material reuse and develop a survey to assess customer value.

3.3.2 Surveys

Two stages of the research process relied on surveys (Saunders et al. 2007) to collect data.

Paper III on Circular Business Model Design and Carbon Saving Potential aimed to identify barriers experienced by case companies related to reuse for building materials and products, as well as policy interventions that could help lift these barriers. The survey consisted of statements on barriers and policy interventions that respondents were asked to score on a Likert-type scale of 1-5 (5 being the most relevant).

In *Paper IV* on Value Creation of a Circular Business Model, a survey was used to assess customer value, and was completed by building developers of the case project. The survey consisted of main drivers for value creation developed from literature review and interviews (Section 3.2.1). To develop the survey, a literature review was first conducted to identify key value drivers on sustainability assessment of buildings (Klotz et al. 2007; Celik and Attaran 2011), conventional value metrics in building developers related to selection of building products (van Bueren and

Broekhans 2013; Zaeri et al. 2016), and value creation from circular practices (Schenkel et al. 2015; Witjes and Lozano 2016; Park et al. 2010). Based on the identified value drivers, indicators were formulated. In a next step, three interviews were held with personnel from Scandinavian building developers to verify and improve the list of indicators. The survey was then shared with customer companies of the project. For each customer company, two employees (holding positions of *Sustainability Director*, *Project Development*, *Business Development Director*, *Public Relations Manager*) ranked the extent to which different types of value were realised from the project on a scale of 0-3, with 0 representing “not realised” and 3 “fully realised”.

3.4 Data analysis

The thesis used three specific methods for data analysis: cost structure analysis (Kajüter 2002), customer value analysis (Maas and Graf 2008), and network analysis (Ward et al. 2013). The process of each analysis is explained in the following sub-sections and summarised in **Table 6**.

3.4.1 Cost structure analysis

In *Paper IV* on Implications of a Circular Business Model for Sustainable Value Creation, a cost structure analysis was performed to identify key cost drivers in the value chains of the three investigated reuse products. Based on the company’s internal accounting data and through semi-structured interviews with company employees, the three value chains were modelled, including the associated activities and material inputs. Costs documented in the invoices from the three projects (accessed through company’s internal accounting data) were then allocated to the various value chain activities and inputs. To identify profitability, costs were subtracted from the revenues (also accessed through company’s accounting data) of the three products. Company employees were consulted to verify accurate understanding of financial data and value chains.

3.4.2 Customer value analysis

To improve understanding of the customer value created by the business model for material reuse in the building sector *(Paper IV)*, a survey on potential benefits from material reuse for building developers and investors was developed based on literature and expert interviews with leadership personnel of Scandinavian building developers (Section 3.3.2). The final list of indicators was categorised into three overarching groups, (1) *Business value*, (2) *Stakeholder value and product* *performance*, and (3) *Green leadership*, and was operationalised through survey questions. Respondents' answers were analysed regarding realisation of different types of value from the project on a scale of 0-3, with 0 representing "not realised" and 3 "fully realised" (Section 3.3.2). Based on the survey results. average values were calculated for each survey question and presented in bar charts.

3.4.3 Network value analysis

To improve understanding of the jobs created in the reuse project investigated in *Paper IV*, the *equivalent of full-time employment* for half a year for one person (*FTE*) (Ward et al. 2013) was calculated. Estimates of hours spent on the project by the case company and project partners (i.e. material suppliers, manufacturers, installers) were collected from accounting data of the case company and surveys with project partners. The resulting sum of total work hours was divided by an average of working hours per week in Scandinavia (37) and the number of months of work per half-year to arrive at the *FTE*. The focus of this analysis was on impacts at business model level and assessing outcomes of the project rather impacts whether the project for material reuse was upscaled. Net employment in other sectors and potential substitution effects were outside the scope of the study, and can be considered in future research (Section 5.3).

To add to the insights on employment creation, qualitative analysis of the value chain processes was performed, to identify whether *(1) new value-adding activities* were created compared with conventional, linear material recovery, or whether *(2)* some of the value chain processes were *more labour intensive* (see Appendix C for an illustration of value chain processes). This improved understanding of new or improved business opportunities for value chain partners involved in wood, glass, and concrete reuse.

3.5 Reliability and validity

Research results and their interpretation are judged against criteria of reliability and internal and external validity (Yin and Campbell 2003; Saunders et al. 2007) to support knowledge claims (Altheide and Johnson 1994). To ensure reliability, internal validity and external validity of the research, several approaches were applied that are explained in the following.

3.5.1 Reliability

Several strategies were used to ensure *reliability* of research methods and data analysis, i.e. the extent to which findings are replicable (Merriam 1995) and consistent with the data collected. Data collection and data analysis were documented. Interviews were recorded and transcribed and resulting case study descriptions documented. Search strategies and results of literature reviews were described in the published papers of this thesis. Survey development was documented, and final surveys and results are appended in the respective papers. LCA models and reasoning of modelling choices were appended in the published paper. Documents of data analysis (e.g. cost structure and customer value analysis) were recorded and made available to peer-reviewers.

The use of appropriate methods and their application, as well as the analysis and interpretation of data, were strengthened through peer-review processes of scientific journals in which the research was published. Peer-reviewer feedback on methods and analysis was addressed to improve the soundness of methodological approaches. Many opportunities for peer-feedback were organised, such as courses and presentations to other researchers, thereby strengthening clarification and documentation of methods.

A *limitation to reliability* is the constructivist approach in which several of the research elements in the thesis are embedded. Analysing and conceptualising CBMs is a constructivist undertaking. An interpretative element and subjectivity are inherent to this constructivist research, influencing for instance the understanding of how a CBM for value retention is defined or which types of value are considered. The researcher can be considered as a facilitator and participant in the reconstruction and integration of different voices on the topic (Guba and Lincoln 1994). Preconceptions, as well as social, political, cultural, and demographic factors of the researcher (i.e. interpreter), shape and structure interpretation.

3.5.2 Internal validity

Internal validity of case study research, i.e. consistency of the findings with reality (or interpretations of reality) (Merriam 1995; Guba and Lincoln 1981) was strengthened through several approaches. First, findings were triangulated, using several quantitative and qualitative data sources (e.g. interviews with company employees and accounting data) and involving several participants (e.g. multiple employees per case companies). Secondly, interpretation of data and results were discussed with co-authors until consensus of understanding was reached (e.g. on policy barriers). In case of uncertainty, findings were presented to interviewees to verify the accuracy of data interpretation of data. Thirdly, throughout the research process, findings and research approaches were presented and discussed at international conferences, in research seminars, courses, summer schools, and with practitioners at CBM-related events. This involved research communities of different fields, such as the environmental assessment, business management, sustainable business models, product development, and cleaner production.

Limitations to internal validity derive from the subjective and normative elements that are inherent to research positioned in the constructivist paradigm (see above). Constructivist research is guided by developing more sophisticated and informed conceptualisations and experience with the research phenomenon to arrive at constructions that have relative consensus (Guba and Lincoln 1994). Peer-review processes and presentation to the research community (e.g. scientific conferences and workshops) aided development of consensus and verified recognition of the author's conceptualisations. Limitations to internal validity play a role in the analysis of case studies. Internal validity may be compromised by the subjective element inherent to interpretation of case study data. Again, discussions with co-authors help to improve accuracy interpretation of data, as well as feedback by practitioners involved in the case companies.

3.5.3 External validity

External validity of case studies, i.e. the generalisability of findings to other cases with similar characteristics (Merriam 1995), can be increased by strategic selection of cases (Seawright and Gerring 2008; Gerring 2006; Flyvbjerg 2006). In this thesis, case study samples and their variables were carefully selected (Seawright and Gerring 2008). To increase generalisability, case study selection aimed to keep important context variables between cases constant to increase their comparability (e.g. institutional framework), but to have a certain degree of variation in other important variables (e.g. circular strategy operated and value chain position).

Despite careful sampling of case studies, high context specificity of cases can create *limitations to external validity*. CE practices comprise diverse strategies and their implementation and associated business model design differs between sectors. In this study, the investigated value retention models were primarily business models for reuse of building products (**Table 5**) in the Scandinavian building sector (*Paper III* and *IV*). As such, generalisability to other sectors, CE strategies, or geographical region should be approached with caution. However, as other elements of the research (e.g. conference papers, courses, presentations, peer-review, reports, book chapters, master thesis supervision) address other types of business models, CE strategies, sectors and geographic regions, findings presented in this summary integrate knowledge that is relevant beyond the discussed case studies. Findings add to the overall knowledge of design of CBM for value retention and their value creation.

Table 6 Overview of research and data methodology of the five paper.

Paper #	I	II	III	IV	V
Contributions	Conceptualising circular business models	Development of canvas to map CBMs for value retention	Carbon saving potential of CBMs for value retention	Sustainable value creation of CBMs for value retention	Review of CBM tools
Research Questions	RQ1	RQ3	RQ2	RQ2	RQ3
Main methods	Systematic literature review	- Comparative case study - Single case study	Comparative case study	Single case study with three sub-units	Systematic literature review
Main data sources	Academic literature	- Publically available data on case companies - Interviews - Workshops	- Interviews - Surveys - LCA data	- Interviews - Surveys - Ecoinvent database - Accounting data	Academic and grey literature
Methods for data analysis	Qualitative analysis	Qualitative analysis	- LCA - Qualitative analysis	- Cost structure analysis - LCA in Simapro - Qualitative analysis - Calculation of equivalent for employment creation	Qualitative analysis
Strategies for reliability	Documentation of search strategy and results	Detailed documentation of research process	- Documentation of data sources and calculations - Documentation of survey replies	- Documentation of data sources and calculations - Documentation of survey replies - Presentation of LCA models and modelling decisions	Documentation of search strategy and results
Strategies for internal validity	Discussion with supervisors and academic peers	Collection of feedback during tool development	Discussions with co-authors on interpretation of results	Discussions with co-authors on interpretation of results Triangulation of data	Multiple rounds of review by each co-author
Year	2017	2018	2017-2018	2018-2019	2019

4. Findings and Discussion

This chapter summarises and discusses the key findings of this thesis, incorporating recent literature findings where available. The chapter is structured around three topics: How can CBMs for value retention be defined (Section 4.1), what value do they create and how (Section 4.2), and how can tools for their development be advanced (Section 4.3). Reflections on the methodological approach (Section 4.4) and conceptual framework (Section 4.5) are then presented. More detailed results, and discussion of contributions and limitations, can be found in the papers that form the thesis.

4.1 How can CBMs for value retention be defined?

The first research question asked *how can CBMs for value retention be defined?* Understanding of what characteristics define a business model as circular varies in academic and grey literature, and coherent conceptualisations are in a nascent stage (as demonstrated in Section 2.2). Specifically, for CBMs that focus on value retention of products, parts and materials, several clarifications are needed. Clarification is required as to which CE strategies are relevant and what is meant by value retention. Finally, to help consideration of environmental impact reduction, definition of the concept needs to include an environmental criterion.

Papers I and II contributed to answering the first research question. A key argument made in both papers is that the elements of a CBM do not necessarily differ compared with a linear business model, but they differ in their goal to implement a CE strategy to retain value and reduce environmental impacts. In the following, these two defining characteristics are explained.

4.1.1 CE strategies for value retention

Value retention in this thesis was defined based on the idea of product integrity for retaining economic and environmental value embedded in products, parts and materials in the economic system (Section 2.4). According to den Hollander & Bakker (2018: p. 519), product integrity aims to

> “keep the product in [their] state, or in a state as close as possible to the original product, for as long as possible, thus minimizing and ideally eliminating environmental costs when performing interventions to preserve or restore the product’s […] economic value over time”

Product integrity is the extent to which a product remains identical to its original state (‘as manufactured’) over time. From a business model perspective, several CE strategies could potentially attain this goal. Based on reviewing the CBM field in *Paper I*, three types of CE strategies are identified as most relevant for value retention:

- *substitute primary material input with secondary production,*
- *extend the average lifetime of products through long-life design and measures, such as repair or remanufacturing, and*
- *recycle materials.*

With these types of strategies, both the input and output side of the business model is considered. In the upstream value chain, primary material input can be substituted with secondary products, parts, and materials (e.g. use of recycled materials in product manufacturing). In the downstream value chain, additional use of products and parts can be enabled to retain value (e.g. remanufacturing for sale on the after-market). Meanwhile, companies should strive to take responsibility for closing material loops when the end of life is irreversibly reached.

Paper II built on these three types of CE strategies and argues that to implement them, CBMs should be thought to consist of *multiple cycles of value creation.* For instance, in the case of an original equipment manufacturer that offers repair services, cycles could consist of a first sale, collection, repair, and resale on the aftermarket. A key argument put forward is that it often requires value creation in multiple cycles and design of separate value creation architectures to effectively operationalise and capitalise on each cycle (e.g. different customer segments or partner networks in a first sale vs. aftermarket sale) (Araujo and Spring 2006; Velte and Steinhilper 2016). This argument is further developed in Section 4.3.1 and is the basis of a canvas for CBMs for value retention.

4.1.2 Environmental impact reductions

With their origin in environmental management strategies such as Cradle2Cradle (McDonough and Braungart 2010; Braungart et al. 2007), Industrial Symbiosis (Albino and Fraccascia 2015), or the performance economy (Mont 2002; Mont et al. 2006; Stahel 2010), a key objective of CBMs, next to economic goals, is environmental impact reduction (Geissdoerfer et al. 2017). *Paper I* highlighted that implementation of CE strategies does not realise environmental impact reductions by default. Environmental benefits may vary with the circular strategy applied, product characteristics, environmental hotspots, or business model design (Tillman et al. 2020; Richter et al. 2019b; Bakker et al. 2014a; Willskytt et al. 2016). Both at product and system level, there are trade-offs and rebound effects that can undermine environmental benefits from retaining resource value. Key considerations for securing environmental benefits were summarised in *Paper I*.

The aim of environmental benefits must be specifically set, when designing CBMs, optimising the relationship between economic and environmental value creation.

Environmental benefits can be measured in various ways, e.g. in terms of resource efficiency (i.e. the ratio of net input required for performing a certain function) or reductions in environmental impacts (e.g. by means of life cycle analysis). As improvements in resource efficient do not guarantee reductions in environmental impact (for instance, if there was no reduction in the most harmful processes or materials[8]). Based on the CE strategies for value retention above and the criteria of environmental impact reduction, this thesis defines CBMs for value retention as

> …how a company creates, captures, and delivers value and reduces environmental impacts through extending useful life of products and parts (e.g., through long-life design, repair and remanufacturing) and closing material loops (i.e. material recycling)[9] .
>
> *Based on Paper I (Nußholz 2017).*

The definition is regarded as useful, as it clarifies which CE strategies can be deemed most relevant in the context of CBMs for value retention. It adds an environmental criterion that stresses that companies should strive to take responsibility for closing material loops when the end of life is irreversibly reached and ensuring that environmental impacts are reduced. It provides a starting point for research on value creation (Section 4.2) and tools for design of value retention models (Section 4.3) and guides case study selection in this thesis.

[8] Other instances include situations when not all environmental impact categories are reduced, or if waste and pollutants have not been reduced. Reduction in volume of some materials may trigger substitution by other materials with higher environmental impact or system level effects can outweigh benefits at product level (e.g. may not be a suitable substitute and may prevent new production).

[9] Extending the useful life and closing material loops pertain to the upstream value chain (e.g. substituting primary material input with secondary products, parts, and materials) and to the downstream value chain (e.g. products and parts for additional use to retain value). Ideally, both of these interventions should be considered.

4.2 What value do CBMs for value retention create and how?

After clarifying how CBMs for value retention can be defined, the second research question asked *what value do CBMs for value retention create and how? Papers III* and *IV* contributed to answering this question by evaluating case studies of CBMs for reuse of building products and materials (see Section 3.2.1). Implications for sustainable value creation for different stakeholders were analysed, including (1) implications for environmental value, (2) financial value for the case company, (3) customer value, and (4) value for network partners (see Section 3.2.3 and **Table 4** for explanation of the indicators). This addressed the gap in empirical evidence of value creation from value retention models (Section 1.3). How value creation is affected along the four indicators is summarised and discussed below.

4.2.1 Environmental value

This thesis investigated the potential for environmental impact reductions from reuse of building products and materials through life cycle assessments of six circular building products (with two different methodological approaches (*Papers III* and *IV*) (Section 3.2.4). Findings clearly show that all products have significant potential for environmental impact reduction at product level (**Table 7** and **Table 8**). Investigated products were (1) window glass, (2) bricks, (3, 4) concrete with secondary aggregates, (5) façade material with secondary plastic, (6) floors and cladding from wood off-cuts. The products were commercialised by companies operating at different steps of the building value chain (building design, product manufacturing, demolition).

Table 7 Carbon saving potential (CSP) of three reuse products investigated in Paper III (based on Nußholz et al. 2019a).

	Reused bricks	**Recycled concrete aggregates**	**Facades from wood-plastic composite[10]**
Final results of primary-based product in CO_2-eq/kg primary product	0.256	0.012	1.73-2.18
Final results in kg CO_2-eq/kg secondary-based product	0.0027	0.004	0.76-0.78
CSP in kg CO_2-eq/kg	0.25	0.008	0.95-1.42
CSP (%)	99%	67%	56%-64%

[10] The range in emissions of the wood-plastic composite (WPC) case results from accounting for varying ratios of wood/plastic in WPC production. Reported CO_2 values do not contain stored, biogenic carbon.

Table 8 LCA Results of Global Warming Potential Impact Category for three reuse products investigated in Paper IV (based on Nußholz et al. 2020).

	Concrete with recycled aggregates	Windows with reused glass	Cladding and flooring from reused wood
Final results of primary-based product (t CO_2-eq)	2761	72.5	73.3
Final results of secondary-based product (t CO_2-eq)	260	16.5	73.3
CSP(t CO_2-eq)	11	56	n.a.[11]
CSP (%)	4%	77%	n.a.

Despite the overall positive results, environmental impact reductions differed strongly between the investigated products. Products with particular potential for carbon savings were reused bricks (99% CSP compared with the linear reference products) and reused glass in windows (CSP of 77%).

Reuse of products and materials is not always effective in generating environmental impact reductions across all impact categories (i.e. trade-offs), nor does it address the environmental hotspot of a product by default. In the case of concrete (*Paper IV*), 91% of Global Warming Potential (GWP) impacts derive from cement, which cannot be reduced by using secondary aggregates. Nevertheless, using secondary aggregates reduced other impacts, such as land use impacts by 37%, and mineral fossil and renewable resource depletion, water depletion, and human toxicity by 30%.

4.2.1.1 How is environmental value created?

Findings show that reuse of building products and materials has significant potential to reduce environmental impact, but environmental benefits are not generated by default. In some cases, processing and input of primary materials for manufacturing of new products or getting products into a suitable condition or location for reuse can outweigh environmental savings from avoided primary materials. This particularly applies to building products that are governed by strict regulations on, for example, energy-efficiency and construction safety. Reuse at higher levels of product integrity for the same purpose (e.g. glass and bricks) had higher potential for environmental impact reductions. This is in line with understanding of the inner circles of the CE framework, where less processing is needed to retain products in

[11] Carbon saving potential for the wood product is not available. This is because the product category rule for wood and wood-based products for use in construction (EN16485) prescribes a physical mass allocation approach. Employing physical mass allocation renders the benefit of the stored carbon of co-products equal to the main product (planks), even if the next cascading step of the co-product provides carbon storage rather than incineration with heat recovery. This is highlighted as a limitation of LCA standards to application of CE practices (i.e. product systems with secondary material use), which is discussed in more detail in *Paper IV*.

the economic system. Kaddoura et al. (2019) find that on average product life extension is a “low-hanging fruit” to generate environmental impact reductions.

Generation of environmental benefits requires careful operationalisation of reuse, as unavoidable processes (e.g. transport for collection and cement input for new products) may be dominant contributions to the total environmental impacts. A prerequisite is selection of a CE strategy that is effective in addressing the hotspot of products, as well as managing the trade-offs commonly associated with the strategy. A recent overview of Tillman et al. (2020) provides comprehensive guidance for selecting a suitable CE strategy depending on product characteristics. If business models are upscaled, effects at system level should be investigated, including substitution effects in other markets (e.g. Consequential LCAs). It should also be noted that for other types of value retention models (e.g those operating a PSS system), considerations how environmental value is created differs (Yang et al. 2017).

4.2.2 Financial value

This thesis investigated the implications of three material reuse solutions for financial viability and the financial structure of the case companies’ business model (*Paper IV*). Because of data confidentiality, only implications for financial viability are discussed. Findings show that producing with reused materials has potential as a price-competitive production strategy compared to linear based production. All three reuse solutions were able to recover investment and production costs after the first production line, but generated only modest profits for the case company.

Findings should be seen in the context of an emerging value chain and product design. They present a snapshot of a first production line at one point in time when it was still characterised by experimentation and limited optimisation of production processes. Therefore, especially for the case of windows and wood floors and cladding, there is a significant potential for improving the financial value. Production of products can be optimised through leaner production processes. Fixed costs (e.g. initial R&D costs) will be reduced in future production lines and economies of scale can be utilised.

4.2.2.1 How is financial value created?

Although the case company was able to recover investment costs, *Paper IV* indicates that financial viability for reuse solutions can be challenging. Reuse solutions can require substantive manufacturing processes and input of primary materials. At the same time, secondary materials can still generate substantial costs (**Figure 3**, **Figure 4** and **Figure 5**). The widespread assumption that reuse strategies generate savings from reduced costs for materials (Moreno et al. 2016; ING 2017; EllenMacArthurFoundation 2017) may not always be realised. Safeguarding economic viability requires careful product and value chain design and control of cost factors to ensure that total costs do not exceed those of primary-based products.

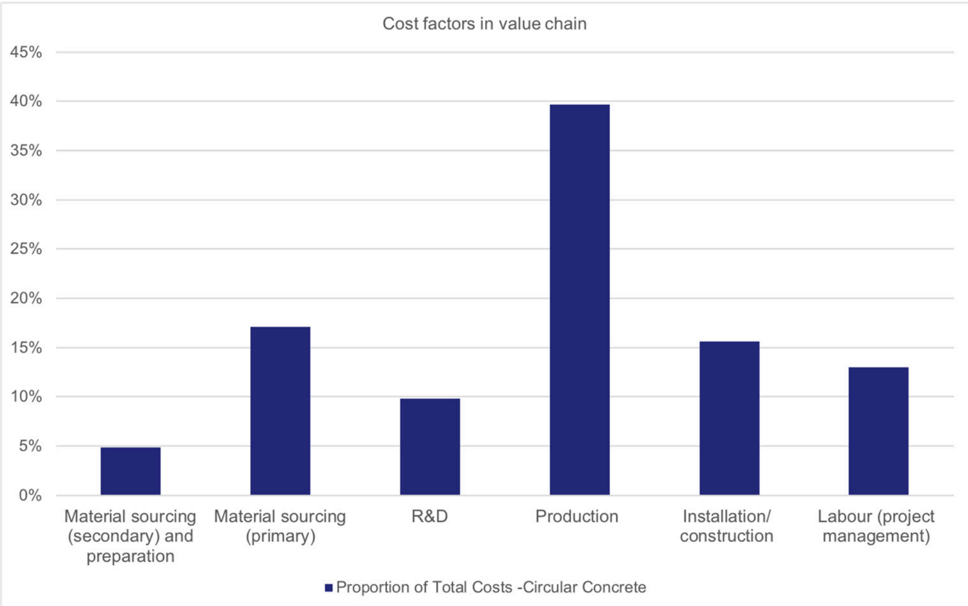

Figure 3 Cost structure of secondary-based concrete, from Nußholz et al. (2020).

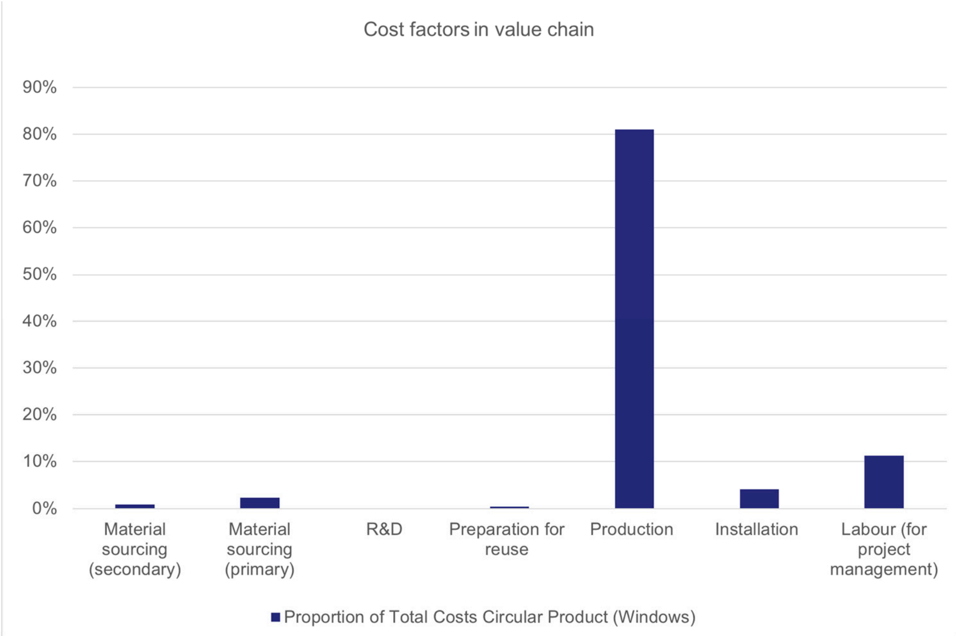

Figure 4 Cost structure of secondary-based windows, from Nußholz et al. (2020).

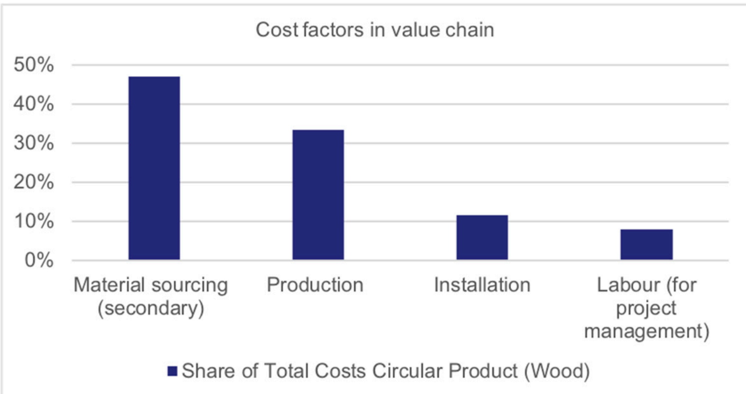

Figure 5 Cost structure of secondary-based wood flooring and cladding, from Nußholz et al. (2020).

Financial value could be derived from integration of value chains, lean management, and economies of scale. With modest profits, this is regarded as important for securing price competitiveness with linear products.

Even though the case company was able to recover investment costs, it remains doubtful whether the observed financial value is sufficient to incentivise implementation of CBMs at the required speed and scale (to address, for instance, climate collapse).

Once business models for product and material reuse are upscaled, effects at system level should be investigated, including net value-added impacts across the entire economy that consider market and substitution effects (e.g. through econometric analyses).

4.2.3 Customer value

CBMs for value retention are often regarded as creating offers that deliver superior customer value compared with traditional linear offers (Sinclair et al. 2018; Moreno et al. 2016; Schenkel et al. 2015). *Paper IV* examined customer value from material reuse for the two building developers and investors in the building project.

Customers were generally positive to the reuse products (**Figure 6**). Customer value was demonstrated across all the investigated indicator categories (*Business Value*, *Stakeholder Value*, *Green Leadership*) (see Section 3.3.2 for indicator development). In particular, the opportunity to innovate and create knowledge that may better prepare their organisations for future industry trends or changes in legislation was valued highly. Development of products that can deliver significant environmental improvements was also ranked highly.

Customers gave no indication of superior financial benefits. This may partly stem from the additional costs of R&D required for the first production line, but also from the timing of the evaluation, because exit and long-term financial performance of the building, along with the effects of economies of scale, were unknown. Customers did indicate potential for future cost savings, through reduced costs from production efficiency and economies of scale. To advance understanding on financial benefits from reuse products, research is needed with a longitudinal approach that can capture benefits of the building to customers that only become apparent later (e.g. exit performance, future market value, life cycle costs).

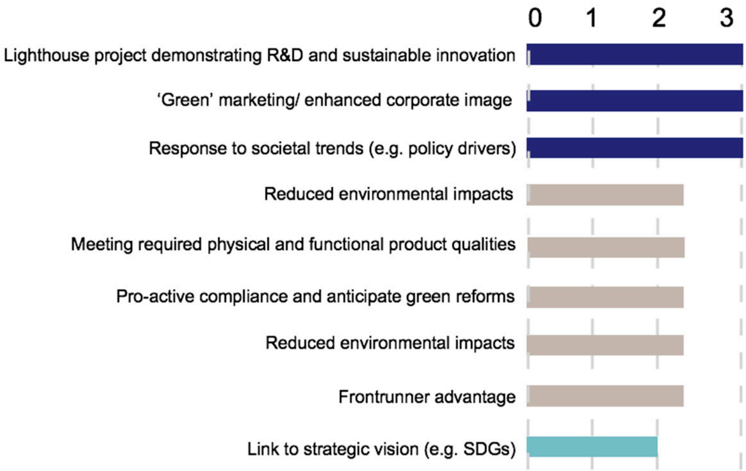

Figure 6 Value realised for building developers based on average scores of self-ranking, from Nußholz et al. (2020).

4.2.3.1 How is customer value created?

A prerequisite for customer value creation is that functional properties and price are competitive with those of linear alternative products (*Paper IV*). The importance of financial competitiveness with linear products is a key consideration when building developers choose offers that enable product or material reuse (Gustafson 2019). Added customer value can be derived from offering products with a lower environmental impact and preparing organisations for future changes in legislation (Schenkel et al. 2015; Antikainen and Lammi 2016).

As this thesis explored customer value of building products to building developers, transferability of findings to other customer groups (e.g. end-users, private customers) or product may be limited. Recent literature explores customer benefits in various product groups (e.g. mobile phones, (Mugge et al. 2017) and fast-moving consumer goods (Mishra et al. 2018), but assessment of actual value creation is lacking.

4.2.4 Network value

Paper IV also investigated implications for benefits of value chain partners, including collectors, manufactures, and installers, and the case company that developed reuse products. Focus was on employment created directly during the project (see Appendix C for an illustration of value chain processes). Several studies highlight employment creation as a benefit from implementation of CE strategies such as reuse (Wijkman and Skånberg 2015; Trinomics et al. 2018; IISD 2018).

Findings resonate with the common assumption that value retention models generate wider economic benefits for partners in the value network. Calculating total hours created throughout the project from collection, manufacturing, installation, and product development for the involved companies, significant employment creation was observed. Results show that reused-based windows, concrete and wood created and financed a total of 18.4 jobs (eq. to 6 months of full-time employment) during the project, including development, material sourcing, manufacturing, and installation (see Section 3.4.3 for methodology). More than two-thirds of the jobs were created in other companies than the case company. The value chain step that was most labour-intensive varies according to product (**Figure 7**, **Figure 8**, and **Figure 9**).

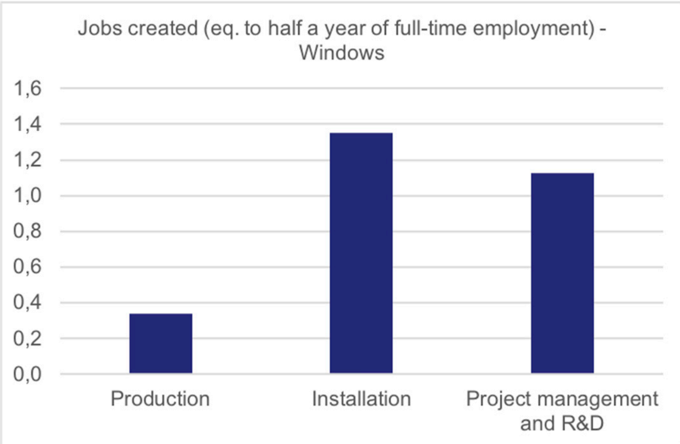

Figure 7 Jobs created for windows were made from reused glass, from Nußholz et al. (2020).

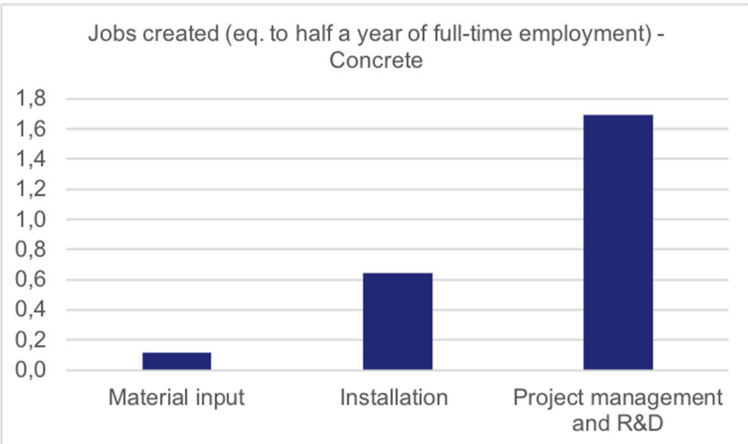

Figure 8 Jobs created for concrete with recycled aggregates, from Nußholz et al. (2020).

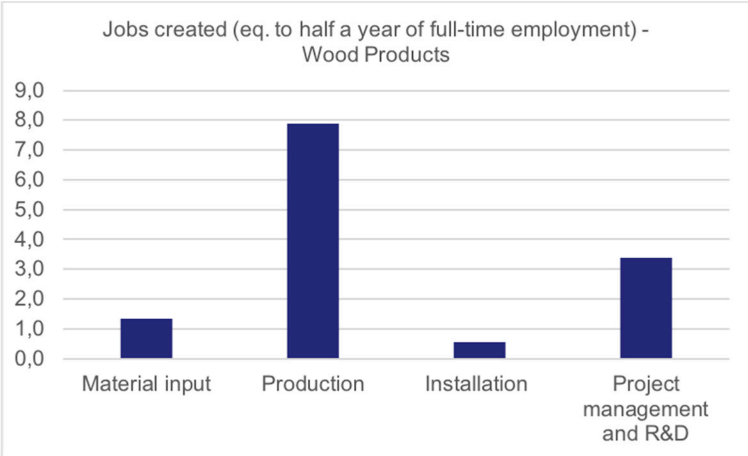

Figure 9 Jobs created for use of wood off-cuts for flooring and cladding, from Nußholz et al. (2020).

It should be noted that job creation impacts calculated in this study represent a snapshot of the impacts from production at a specific moment in time. With improved product design or more integrated, lean value chains, job creation may be lower. About a third of all labour was involved in research and development and project management, which would not occur to the same extent in future production.

The study does not investigate implications for value for partners in the network if the business model were to be upscaled, including potential substitution effects on employment in other industries (i.e. new value-adding production activities minus value-adding activities for primary products that are substituted) This could also include investigation of the types of jobs created or their geographic location. One remaining question is whether more jobs were created from the project compared with manufacturing of linear products. Because of data limitation (Section 4.4), no quantitative comparison was possible. However, a qualitative comparison of the value chain processes (i.e. new or more labour-intensive activities in production based on reuse compared with linear production) is presented in the next section, to give an indication as to whether higher or lower job creation can be expected compared with linear manufacturing.

4.2.4.1 How is network value created?

Value for partners in the value chain network and additional jobs is derived from new ‘business opportunities’ from reuse that would not occur in linear production. These can be:

1) *new business opportunities* (e.g. activities for recovery of products and materials that were previously discarded with lower forms of value recovery), or

2) *more labour-intensive activities* compared with linear production.

Hestin et al. (2015) show that these activities for recovery at higher level of value are on average more labour intensive than heat recovery. Retaining value at higher levels (i.e. capitalising on the inner circles of the CE butterfly diagram (EllenMacArthurFoundation 2017) is expected to create higher employment overall than linear practices (IISD 2018).

Qualitative analysis of the value chain processes indicates 1) new or improved business opportunities for partners in the value chain network, and that 2) several processes can be considered more labour intensive compared to linear production practices. This mainly concerned material collection, manufacturing and installation of reuse products.

Examples of *(1) new business opportunities* that would not occur in linear production are dismantling of end-of-life windows and collection of wood, both providing new revenue opportunities for the companies involved.

Examples of *(2) more labour-intensive value chain processes* are the wood floor and façade cladding, as planks from by-products are shorter.

As shown in **Figure 7**, **Figure 8** and **Figure 9**, employment is also created in research and development of products and product management, but these increases may be lower in the future production line and as production practices become more efficient.

When aiming to upscale upcycling as production strategy in the industry, it is important to consider changes at macro-economic level and shifts in economic activities (Trinomics et al. 2018). Future research is also needed to investigate net job creation impacts compared to linear production that would occur when upcycling solutions are upscaled.

4.3 How can tools for designing CBMs for value retention be advanced?

The third research question was '*How can tools to support design of CBMs for value retention be advanced?'* and this was addressed in *Paper V* and *Paper II*. An overview and classification of emerging tools, and a guideline for CBM tool development and a canvas for mapping value retention models, is presented.

Paper II reviewed and analysed existing tools designed to support the CBM innovation process. Tools come in a variety of forms, such as serious games, frameworks, canvas tools or web-based tools. Tools have a variety of purposes, including support of circular product design or education on specific aspects of CE (e.g. material criticality or financial implications). The majority of tools target business practitioners but three tools are identified that also target educators and students. While nine of the 13 tools are of generic nature (i.e., suitable for different sectors), some are designed for specific product sectors (e.g. textiles, building products). Identified tools target different stages in the CBM innovation process (e.g. ideate, design, implement, evaluate). There are tools for all stages of the innovation process, but those addressing the ideate and design stage (Section 2.3) are most prominent. There are no integrated tools that address all stages in a holistic manner.

The review identified 13 tools that had been developed with users, tested in practice[12], and with published guidelines to facilitate application by others than the authors (see selection criteria in Appendix A and Section 2.4). These tools were classified according to purpose, target audience, and stage in the innovation process (e.g. idea generation, implementation, evaluation). The list of tools is presented in Appendix B and their characteristics in *Paper V* (Bocken et al. 2019b).

Based on the review, several gaps and opportunities to advance tool development to support design of CBMs for value retention are identified.

- There are currently many tools available for CBM innovation, but few have been developed and tested with users. Tools could be advanced by a transparent development process and validation and improvement with users (Lofthouse 2006), which is currently lacking for most of the emerging tools.
- Tools could benefit from an interdisciplinary approach, but this has been applied recently by some authors (Geissdoerfer et al. 2016; Konietzko et al. 2020). While design science is one promising field to inspire tool development, fields such as business studies and engineering (Baumann et al. 2002), but also other disciplines, such as biology, could provide inspiration for tool development (Bocken et al. 2019a).
- Tool development could also benefit from better consideration of the business model innovation process. The various phases (Frankenberger et al. 2013) could be considered more specifically, as they are potentially of quite different nature: on the one hand ideating, developing and testing new propositions, and on the other, requiring internal 'change management' and novel collaborations to establish CBMs and value chains. Both integrated tools that support entire process throughout the stages change (Guldmann et al. 2019), or tools that address details of the specific stages, may be of value.

[12] Involvement of users in tool development is identified as a critical factor to increase the match with users' needs and uptake of the tools in practice (Baumann et al. 2002; Tyl et al. 2015) (Section 2.4). Tools developed through the involvement of users are considered to have higher potential to support circular business model innovation process in practice.

Based on the selection criteria developed and applied in *Paper V*, as well as insights from the literature reviewed, a guideline for CBM tool development was developed (**Table 9**). The ten criteria are aimed to help guide future research and practice contributions of CBM innovation tools. More details on the development of the guideline can be found in *Paper V*.

Table 9 Checklist for circular business model tool development (Bocken et al. 2019b)

Checklist for Circular Business Model Tool Development
1. The tool is purpose-made for circular business model innovation
2. The tool is rigorously developed—from both literature and practice insights.
3. The tool is iteratively developed and tested with potential users.
4. The tool integrates relevant knowledge from different disciplines.
5. The final tool version has then been used by practitioners, preferably multiple times, and this process is evaluated to assess use and usefulness.
6. The tool provides a transparent procedure and guidance on how others can use the tool.
7. Circular Economy or broader sustainability objectives and impact are firmly integrated into the tool and safeguarded when tool application is facilitated by others than the tool developer.
8. The tool is simple and not too time-consuming.
9. The tool inspires or triggers (business) change.
10. The tool is adaptable to different (business) contexts.

4.3.1 Canvas for CBMs for value retention

One specific area identified for advancing tools for design of CBMs for value retention was business model canvases[13] (Section 2.4). Existing canvasses for CBM innovation do not yet illustrate the multiple business cycles that are required for devising businesses for value retention (Bakker et al. 2014b), so the guiding function of canvasses for value retention models is limited.

Paper II investigated how canvas tools can be advanced to support the design of value retention models. To develop a canvas tool, a stepwise approach was applied, based on multiple rounds of testing and improvement with users (**Table 10**). Starting

[13] Visual, standardised representations of the elements of a business model. Because of their ability to clarify the concept and provide a guiding template of the elements a business model is thought to consist of, business model canvases are widely used in traditional management literature and practice (Section 2.4).

from an initial conceptual framework developed from literature,[14] rigorous testing with users and practitioners was conducted to identify gaps and improvements until a final framework was reached. Improvements centred around generalisability to allow representation of various types of value retention models. Terminology was tested and improved multiple times to ensure accurate descriptions of the cycles and to increase the guiding function for users. Visuals were improved, including writing space, clarity, and guiding quality; for instance, sizes of columns were adapted to more clearly differentiate the cycles and visualise the underlying waste-hierarchy prioritisation. In the final step, a single in-depth case study was employed to exemplify the tool's effectiveness. The activities and methods employed in each step of the process are described in **Table 10**.

Table 10 Overview of research approach and methodological techniques, from Paper II (Nußholz 2018)

Aim	**Activities**	**Date collection method**	**Participants**	**Input**	**Output**
Phase 1: Identification of gaps and improvements					
Development of the initial conceptual outline (developed from literature) into the final tool.	1. Comparative case studies 2. Four case study applications 3. Two case study applications based on interview data 4. Workshops 5. Expert interview 6. Rounds of literature review	- Publically available data on companies' websites - Semi-structured interview with company representatives on their business models - Workshops with graduate students and academic experts	- Graduate students - Group of academic experts - Company employees	First conceptual outline of framework based on initial literature review	Final framework with revised descriptions and graphics
Phase 2: Exemplification of effectiveness and value					
Testing of the final tool on the mobile phone company Fairphone, which implements CE strategies via a prolonged use phase, repair, and recovery	1. Case study application	- In-depth case study design and feedback	- Academic experts - Industry expert	Final version of the developed tool	Needs for improvement and future research

[14] The initial framework illustrated the generic cycles at input and output side of the business model that can be utilised for slowing and closing resource loops.

The final framework is presented in **Figure 10**. It offers a standardised representation of the generic cycles of value retention models. These cycles are integrated with the business model elements of the business model canvas (Section 2.1).

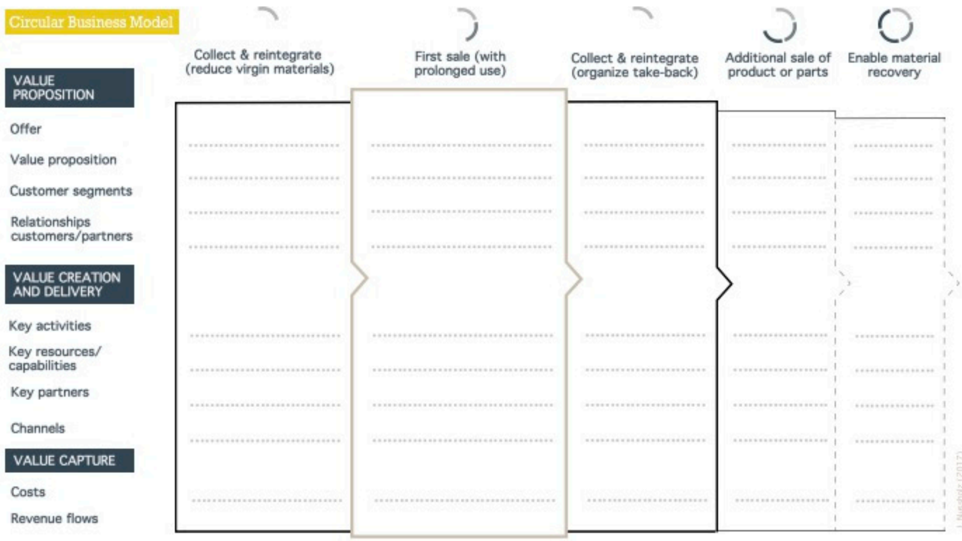

Figure 10 Circular Business Model Canvas for retaining value in products and materials, from Paper II (Nußholz 2018).

The main benefits of the canvas relate to its potential to guide practitioners in innovating their business model towards higher levels of value retention. The generic visualisation can reduce complexity and order potential cycles for embedding value retention in the business model. Inclusion of multiple cycles in the tool has the potential to promote a more holistic adoption value retention throughout the life cycle, ideally several cycles simultaneously, or CBMs can be devised around products that are designed for multiple use cycles (Selvefors et al. 2019).

This is important, as Whalen (2017) shows that many existing business models labelled as 'circular' fail to implement the concept in a holistic way. For example, even though a product take-back system is in operation, value retainment of products (e.g. through repair or recycling) is not realised (Whalen 2017), jeopardising environmental value creation of CBMs. Conceptualising CBMs as multiple cycles is considered key for guidance in CBM design and for harnessing potential environmental savings, even though this might be challenging to implement in practice.

In addition to the improved guiding function, if a company operates multiple cycles, the canvas can unravel a larger variety of phenomena than existing canvases[15]. It can indicate innovation opportunities from 'uncaptured' cycles, help align business model elements in the various cycles, and enhance understanding and communication of the business model among internal and external stakeholders.

A guideline for application of the tool was published to disseminate the tool and guide practitioners in its application (see list of publications).

4.4 Reflections on the methodological approach

A multiple methods approach with comprehensive triangulation of data (e.g. time, sources, types) was used to address value creation and design of CBMs for value retention. The combination of multiple methods was deemed suitable to address the gap in empiric evidence of value creation at the unit of analysis of a business model (Section 1.3).

Methods for value assessment were selected to explore the implications of reuse for value creation retrospectively. To improve understanding of potential impacts resulting from upscaling of business models, more comprehensive modelling and forecasting is required, including assessment of macro-economic effects and environmental impacts at system level (e.g. consequential LCA, cost-benefit analyses or input-output analyses) (Section 4.2).

C*omparison with a linear business model* was only considered for environmental impacts (i.e. LCA of reuse products and their linear reference products). For other value indicators, such as job creation and financial implications, comparison with a linear product was not an objective scope (see *Paper IV* for more details). This is mainly due to the focus on the business model of a single case study and a retrospective assessment, so questions on a macro-economic level, e.g. job creation compared with linear models, is outside the scope. Also, limitations in data availability (e.g. on revenue and cost structure of a linear reference product) and a lack of established methods hindered comparison of financial value and job creation.

Value creation with regard to financial, customer, and network value was assessed in a *single case study*. Such an approach is deemed useful because of its ability to provide an in-depth, data-rich description of the phenomenon (Yin 2013) and provides a source of tangible and context-dependent knowledge (Flyvbjerg 2006). It allows for more detailed understanding of underlying value creation processes

[15] For instance, the business model canvas (Osterwalder and Pigneur 2010) or canvases for circular business model innovation (Antikainen and Valkokari 2016) (Section 2.4).

and considerations for how value is created. To further the understanding of financial value creation or employment creation, future research could adopt case study designs with a larger number of cases. Especially when looking at financial implications, a longitudinal timeframe could be useful to unravel variances and long-term development of financial structures of companies operating value retention models.

Integration of multiple methods was used to examine value creation along several indicators (*Paper IV*). This approach allowed more breadth in the analysis, but compromised its depth. Although the various methods have different depths (e.g. LCA compared with a cost structure analysis), each method is considered suitable for contributing relevant insights to the discussion and overall findings. The integrated and transdisciplinary approach helps improve understanding of a complex, multi-facetted real-world phenomenon (i.e. value creation of CBMs for value retention).

Integrated assessment of value creation of reuse business models, including network effects (*Paper IV*), is to the best of the author's knowledge a unique approach. Results are affected by the timing of the evaluation, which captures effects at a specific point in time. As such, the evaluation approach in this thesis represents a snapshot of an emerging value chain and product design, impacting especially the understanding of financial value for the case company, as well as its customers (Section 4.2). Indicators used in the evaluation were derived from stakeholders' input to identify relevant indicators. For other types of CBMs, sectors, or customers, indicators may be different.

Literature review and analysis of typologies for development of a *definition of value retention models* seemed useful at the start of this research. However, methods of morphological analysis could also be useful to capture the variety of characteristics associated with the concept. A similar contribution was found by Lüdeke-Freund (2019a) and Curtis and Lehner (2019). At the beginning of this research in 2015, contributions on CBMs were in a nascent stage and not sufficiently comprehensive to benefit from morphological analysis.

The *canvas for CBMs* for value retention (*Paper II*) appears to be better suited for product-based offers. Although a variety of CBM cases was used for developing the tool (Section 4.3.1), future research should test the tool on a larger set of cases, including companies with service-based offers. Applying the tool to the case of Fairphone (*Paper II*) also suggests that the more cycles a company operates, the higher the added value of the tool compared to the traditional business model canvas. With only one intervention addressed, the traditional business model canvas (Osterwalder and Pigneur 2010) might be sufficient.

The criteria for *reviewing existing tools* for CBM design (*Paper V*) could be furthered by additional study of practitioners' needs and requirements in the CBM innovation process. However, testing and validation during tool development were required for shortlisting, so the review incorporated considerations of practitioners' needs to some extent. Another limitation of *Paper V* is that the authors' own experience of developing CBM tools may affect objectivity to some degree. This potential weakness was addressed through the four review phases of the tools, involving a different co-author each time.

4.5 Reflections on the conceptual framework

This thesis employed a framing of CBMs focusing on value retention (Section 2.2).

By enabling a focus on value creation of value retention models, the conceptual framework developed for this thesis (**Figure 1**) helped to advance understanding of their potential as a viable business model and to deliver more sustainable outcomes. A novel contribution is the approach for integrated assessment of various types of value and the empiric evidence. This allows critical reflection of '*what value CBMs for value retention create*' and discussion of '*how*' value is realised when applied in practice. By proposing '*how tools for design of CBMs for value retention can be advanced*', implementation of the concept in practice can be supported.

The conceptual framework (**Figure 1**) is deemed useful to allow for higher level synthesis of the research findings from the appended papers. It developed a consistent theme from the publications that has significant breadth and depth and that integrated theoretical contributions with empirical and design-oriented contributions.

The conceptual framework omitted several aspects from the papers. For instance, policy interventions that could help lift barriers experienced by companies that operate value retention models (*Paper III*), and business models from other sectors than the building sector featured less in this thesis (*Paper II*). Configurations of the value creation architectures of the investigated case studies were not presented and compared in detail (*Paper I, II, III, IV*). Findings with regard to '*how value is created*' in terms of environmental value could be elaborated, as this was considered in *Papers I, III*, and *IV*. To discuss '*how value is created*' for the four indicators in an equal manner, these findings were published in a separate publication geared to practitioners (see *Checklist for Environmentally Sound CBM Design* in the list of publications).

The framework effectively summarised the key findings of the appended publications, linking theory, empirics, and a design-oriented part. The focus on CBMs for value retention was useful to define an adequate scope, but omitted other types of CBMs. Research elements could be expanded though policy interventions and more details on case studies' business model configurations.

5. Conclusions

This chapter summarises the key contributions of the thesis. Overall, the thesis contributed to theory development and offered an empirical account on CBMs for value retention, and suggestions to advance tools for their design. These research elements are summarised as contributions to practice (Section 5.1) and as contributions to theory (Section 5.2).

5.1 Key contributions to practice

This thesis contributes to practical implementation of CBMs for value retention in the following ways.

First, the thesis provided a *definition* of the concept of CBMs for value retention. The definition is regarded useful, as it clarifies which CE strategies can be deemed most relevant in the context of value retention that can contribute to a more systematic shift towards sustainable resource management (Section 1). It adopts a critical stance, as it emphasises that companies should strive to take responsibility for closing material loops when the end of life is irreversibly reached and ensure that a reduction in environmental impacts is achieved.

Secondly, through multiple empirical case studies, this thesis helped advance *understanding of sustainable value creation* of CBMs for value retention. It offered a detailed analysis of a CBM for reuse of building products of a pioneering Scandinavian company promoting a CE transition in the sector. A comprehensive account of implications for value creation in relation to multiple indicators, i.e. 1) environmental, 2) financial, 3) customer and 3) network value, was provided. This advances the understanding of whether CBMs for value retention can deliver the envisioned sustainability value.

Thirdly, a key finding is that CBMs that retain value in products and materials need to be carefully designed to deliver the intended sustainability value. Based on the assessment conducted in this thesis, *recommendations for how to create value along* the various value dimensions were summarised that can provide guidance for designing CBMs.

Fourthly, an *overview of existing tools* that have been developed and tested with users was conducted. The tools are classified based on their purpose, form, target user and entry point in the innovation process, allowing practitioners to identify validated tools fitting their specific needs and purpose. Also, a *checklist* with recommendations to increase uptake of tool was proposed that can support, e.g., consultants in future tool development.

Fifthly, a *canvas to map CBMs for value retention* that enable multiple cycles of value creation was presented. It offers a standardised framework of the elements of a CBM for value retention and its possible cycles to retain value of products, parts and materials. Inclusion of multiple cycles in the tool has the potential to promote a more holistic adoption of value retention through the life cycle, where ideally several CE strategies are applied simultaneously. Main benefits relate to its potential to clarify the concept to practitioners and guide them towards higher levels of value retention.

Sixthly, based on systematic literature review of existing tools and literature on tools development in related fields (e.g. sustainability tools, eco-design tools), a *guideline to support tool development* was developed. The guideline aims to help practitioners such as consultants in the CE field develop tools and increase their uptake in practice.

5.2 Key contributions to conceptual and methodological development

This thesis contributes to theoretical and conceptual development of CBMs for value retention in the following ways.

First, the thesis contributed a *theoretical framing of CBMs for value retention* and summarised the *state-of-the-art* of knowledge on the topic. Building on a systematic review of CE strategies and contributions on CBMs, it developed a *definition* that offers a starting point for research in this thesis.

Secondly, this thesis developed a *conceptual lens* for CBMs for value retention by *conceptualising the idea of value creation in multiple cycles* and integrating it with traditional business model conceptualisations. This change in conceptualisation was deemed important, as multiple cycles require rethinking of value creation processes and have implications for business model design. Consideration of multiple cycles can unravel a larger variety of phenomena when analysing CBMs for value retention. To aid analysis of multiple cycles, a *framework illustrating the multiple cycles of value retention models* was proposed (**Figure 10**).

Thirdly, *empirical insights on sustainable value creation* of CBMs for value retention are provided. Findings include a comprehensive overview of implications for the case company's financial structure, environmental impacts, customer value, and for value for network partners. This helps evaluate whether material reuse is a viable business model that can deliver improved sustainability outcomes. It also increased understanding of whether the assumed value rationale of CBMs (i.e. maximising retention of resource value – ideally through the 'power of the inner loops' of the EMF's CE diagram) (Section 2.3) is realised in practice. At least with regard to the environmental value, higher levels of product integrity (Section 2.3) corresponded with higher reduction potential of environmental impacts (compare example of bricks and glass reuse).

Fourthly, based on analysis of empirical cases, how CBMs for value retention create value is discussed. *Considerations to secure sustainable value creation* in terms of environmental, financial, customer, and network value are put forward that advance academic knowledge on effective design of CBMs.

Fifthly, an *overview of existing tools for CBM design* is provided and tools that have been developed and validated with users are identified. The landscape of existing tools is structured, and gaps identified. Suggestions on how tool development can be advanced are made, including avenues for future research and a *guideline for tool development* to increase uptake of academic tools in practice.

Sixthly, an interdisciplinary and *integrated assessment approach* is developed for examining the sustainable value creation of a business model for reuse of building products. The assessment approach was co-developed with key stakeholders of the case company in a participatory, and transdisciplinary research approach. It combined multiple methods to enable integrated analysis of sustainability effects at business model level (i.e. between the company and the industry level (Massa and Tucci 2014), which to date is largely absent in literature (Lüdeke-Freund et al. 2017).

5.3 Future research

Due to the urgency to deviate from resource intensive, linear consumption and production practices (EEA 2019), and the broad scope of the research questions this thesis addressed, many topics for future research can be suggested. With the developments in conceptual contributions in the field (Merli et al. 2018), future research should adopt more applied and practice-based approaches to respond to the short remaining time-frame to address sustainability challenges, such as climate collapse. Future research identified is consolidated and presented in three themes: *implementation*, *operationalisation*, *scaling up* of CBMs for value retention.

Implementation of CBMs for value retention requires more research on innovation approaches and processes that can support organisational development, as found in *Paper V*. This includes organisational change involving internal stakeholders (e.g. leveraging capabilities and aligning goals across departments) (De los Rios and Charnley 2016) and changes involving external stakeholders (e.g. establishing value chain networks that can retain value of resources and close loops) (Jørgensen and Remmen 2018).

Operationalisation of CBMs for value retention requires research on specific business model elements, such as value chain management (e.g. take-back schemes) or generating customer value (e.g. which offers are likely to receive customer acceptance). It requires improved synthesis of the conditions for value creation and guidelines for practitioners of key considerations when integrating value retention in business models. Recent contributions have provided a good starting point for analysis of environmental benefits and product design. For instance, Kaddoura et al. (2019) explore how durable products can reduce environmental impacts, and Tillman et al. (2020) summarises what CE strategies fit which kind of products. As found in *Paper V*, sector-specific tools for reducing environmental impact reductions from CBM design could increase consideration of such findings in business model design. As found in *Paper IV*, understanding of the impacts from value retention models on social value creation is still limited, as well as how these can be considered in CBM design (Kristensen and Remmen 2019; Geissdoerfer et al. 2017).

Customer value remains underexplored, including how offers and customer relationships can be revised to address barriers to value retention. This was also identified as a gap in the current landscape of tools (*Paper V*), as there are currently no tools for matching customer needs with value of CE-based offers. Due to sensitivity of data, *Paper IV* only discussed implications of reuse of building products on financial value creation. Future research could provide more detailed analysis of a case companies' business case, over a longer period of time.

Scaling up of CBMs for value retention requires more research identifying material streams and business model types with high potential to deliver strong sustainability outcomes (*Paper IV*). This includes investigation of impacts (e.g. from material reuse) if business models were to be scaled up. Also, there is a need to improve methodology for comparing the effects of a CBM compared with a linear one if scaled up (Bocken et al. 2019a). *Paper IV* suggests that macro-level assessments (e.g. consequential LCAs and econometric analyses) could account for net value added and net job creation benefits or environmental savings at industry level (i.e. so that market and substitution effects beyond product level are considered). This also includes substitution effects at system level in regard to material flows and job creation (Trinomics et al. 2018). More research is needed on the metrics for assessing value creation from an integrated sustainability perspective.

Similar to the assessment approach in this thesis (*Paper IV*), future research should identify indicators relevant for decision-makers in policy and business. Because business value alone might not be enough to incentivise businesses to implement CE strategies at the required speed and scale to achieve CO_2 emission reduction targets, research on policy interventions is also needed. This includes which policy interventions can help remove barriers to CE strategies and how the institutional framework of business models can be altered to improve competitiveness with linear offers (Milios 2017).

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Appendices

Appendix A: Selection criteria for tool review

Table 11 Overview of tool selection criteria used while reviewing publications, from Paper IV (Bocken et al. 2019)

No.	Criteria	Explanation/Description	1st initial screening	2nd detailed screening
1	The publication must be relevant to CE / CE business models	The initial screening focused on a broad relevance to CE/ CE business models, and the second screening filtered out those not specifically developed for this purpose. Recent literature reviews have included various sustainable business (model) tools – however, as our focus is on CBM, we focus here on CE specific ones.	X	X
2	The publication is about a tool, process or method (in a broad sense)	We define a 'tool' to mean a set of prescriptive steps that is replicable and can be independently undertaken by practitioners to achieve a specific, intended outcome. In other words, a procedure or process on how to use the tool exists and this enables others to use it. Within this understanding, different forms of tool are possible, including processes, frameworks, typologies, and board games.	X	X
3	The tool must be rigorously developed	The tool must be developed rigorously, building on insights from literature and practice.		X
4	The tool has been validated in practice, and this has been documented	To be considered 'validated in practice', the tool must be empirically tested and then documented in the publication. 'Thought experiments', or where the authors apply a tool conceptually to a case study themselves to illustrate how the tool could be used in practice are not considered validated in practice.		X
5	A procedure is ready on how others can use it	A procedure is available for use by others, so the tool can be used independently.		X

Appendix B: CBM tool database

Table 12 Overview of shortlisted tools for detailed categorisation, from Paper V (Bocken et al. 2019)

No.	Authors	Year	Title
1	Antikainen M., Aminoff A., Kettunen O., Sundqvist-Andberg H., Paloheimo H	2017	Circular economy business model innovation process – Case study
2	Bocken N., Miller K., Evans, S.	2016	Assessing the environmental impact of new Circular business models
3	Evans S. & Bocken N.	2014	A tool for manufacturers to find opportunity in the circular economy
4	Haines-Gadd M., Chapman J., Lloyd P., Mason, J., Aliakseyeu, D.	2018	Emotional Durability Design Nine—A Tool for Product Longevity
5	Heyes G., Sharmina M., Mendoza J.M.F., Gallego-Schmid A., Azapagic A.	2018	Developing and implementing circular economy business models in service-oriented technology companies
6	Leising E., Quist J., Bocken N.	2018	Circular Economy in the building sector: Three cases and a collaboration tool
7	Manninen K., Koskela S., Antikainen R., Bocken N., Dahlbo H., Aminoff A.	2018	Do circular economy business models capture intended environmental value propositions?
8	Mendoza J.M.F., Sharmina M., Gallego-Schmid A., Heyes G., Azapagic A.	2017	Integrating Backcasting and Eco-Design for the Circular Economy: The BECE Framework
9	Nußholz J.L.K.	2018	A circular business model mapping tool for creating value from prolonged product lifetime and closed material loops
10	Pigosso D.C. A., Schmiegelow, A., Andersen M.M.	2018	Measuring the Readiness of SMEs for Eco-Innovation and Industrial Symbiosis: Development of a Screening Tool
11	Sinclair M., Sheldrick L.; Moreno M., Dewberry E.	2018	Consumer Intervention Mapping: A Tool for Designing Future Product Strategies within Circular Product Service Systems
12	Whalen K., Berlin C., Ekberg J., Barletta I., Hammersberg P.	2018	'All they do is win': Lessons learned from use of a serious game for Circular Economy education
13	Whalen, K.	2017	Risk & Race: creation of a finance-focused circular economy serious game

Appendix C: Overview of production processes of reuse products

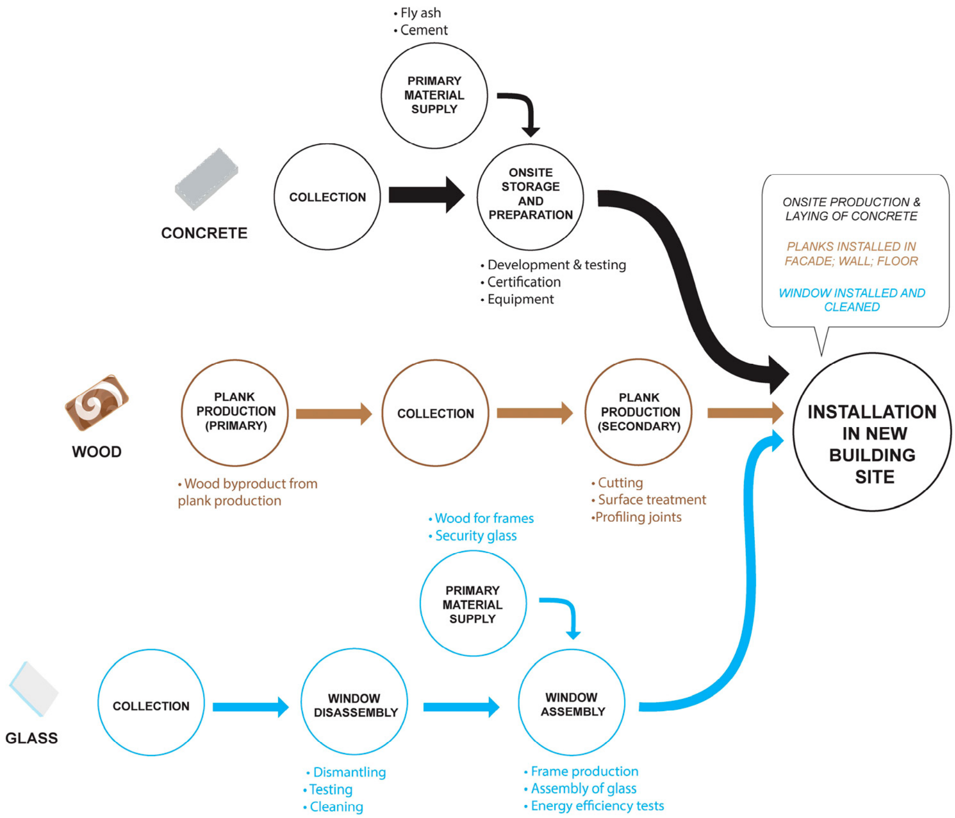

Figure 11 Overview of production processes of reuse products, from Paper IV (Nußholz et al. 2020)