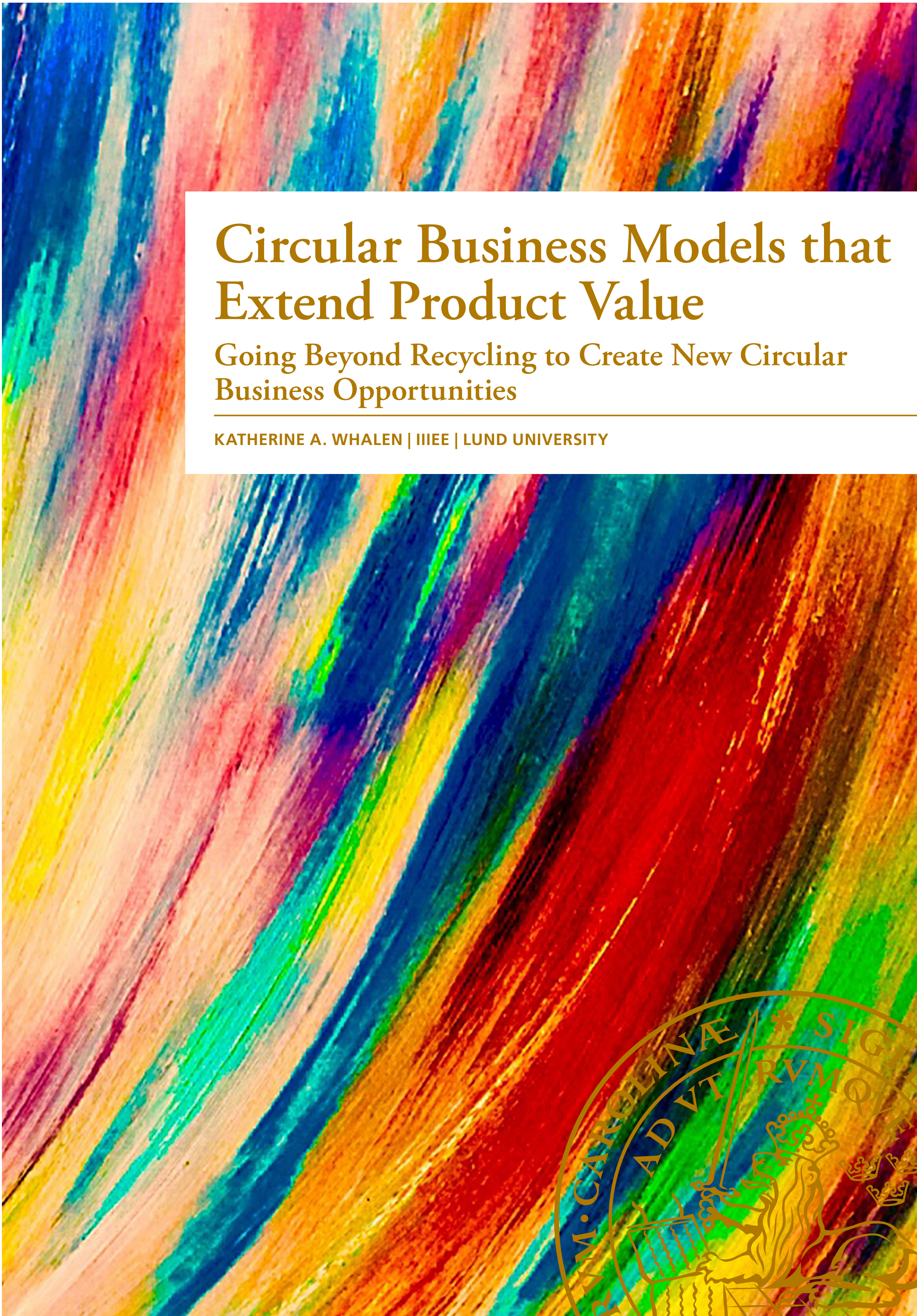
Circular Business Models that Extend Product Value

Going Beyond Recycling to Create New Circular Business Opportunities

Whalen, Katherine

2020

Document Version:
Publisher's PDF, also known as Version of record



Circular Business Models that Extend Product Value

Going Beyond Recycling to Create New Circular Business Opportunities

KATHERINE A. WHALEN | IIIEE | LUND UNIVERSITY

Circular Business Models that Extend Product Value

Going Beyond Recycling to Create New Circular Business Opportunities

Circular Business Models that Extend Product Value

Going Beyond Recycling to Create New Circular Business Opportunities

Katherine A. Whalen

LUND UNIVERSITY

DOCTORAL DISSERTATION

by due permission of the Faculty of Engineering, Lund University, Sweden.
To be defended at The International Institute for Industrial Environmental Economics, Lund University, 10 February 2020, 13:00.

Faculty opponent
Professor Tim C. McAloone

DTU, Lyngby, Denmark

Organization LUND UNIVERSITY	**Document name** DOCTORAL DISSERTATION
	Date of issue 10.02.2020
Author KATHERINE A. WHALEN	Sponsoring organization N/A

Title and subtitle
Circular Business Models that Extend Product Value: Going Beyond Recycling to Create New Circular Business Opportunities

Abstract
Over the past ten years, significant industry, policy, and scientific attention has been given to the 'circular economy', which aims to create a more sustainable society by decoupling economic growth from resource consumption. Firms are expected to play a significant role in the shift to a circular economy model by implementing circular business models that encourage prolonged use of products, components, and materials. Yet, despite interest in the circular economy, there is a lack of empirical research about the effects of these business models and how to support their adoption.

This thesis aims to advance understanding of business models for a circular economy, with a focus on firms that slow resource loops and reverse product obsolescence. Using an interdisciplinary research approach, the thesis draws on business model theory and product life extension. The thesis presents theoretical and empirical examinations of circular business models using a variety of qualitative research methods. This includes a case study approach with Nordic firms in the ICT and maritime sectors to identify specific constraining and enabling factors for firms to adopt circular business models. A document study of participants' reflections was also performed to evaluate one circular economy tool – the 'In the Loop' game.

It was found that firms contribute to a circular economy through two main overarching circular business model strategies: 'Extending Product Value' or 'Extending Resource Value'. While lack of market demand and high costs were identified as main constraints to adopting 'Extending Product Value' business models, the findings suggest that firms themselves can make adopting these models more competitive and cost-effective by refining their business offering. The findings confirm a number of factors could support the adoption of these business models, including policy interventions and game-based learning tools. Contextual differences between sectors and firms were also identified, including firm type (i.e., original equipment manufacturers or gap-exploiter), customer base (i.e., business-to-business or business-to-consumer), and geographic scope (i.e., national vs. international).

The thesis underlines several environmental implications of circular business models. It suggests firms focus on maximising efficiency and that the adoption of circular business models does not guarantee reduced resource consumption or primary production. Solutions beyond firm-level interventions are a key part to a circular economy that achieves its intended environmental goals.

Key words circular business model, product life extension, obsolescence, sustainability, business model, reuse, repair, refurbishment

Classification system and/or index terms (if any)		
Supplementary bibliographical information		**Language** ENGLISH
ISSN and key title 1402-3016 IIIEE Dissertations		**ISBN** 978-91-87357-55-8 (PDF) 978-91-87357-54-1 (Print)
	Number of pages 87	Price
	Security classification	

Signature Katherine A Whalen

Date 2019-12-13

Circular Business Models that Extend Product Value

Going Beyond Recycling to Create New Circular Business Opportunities

Katherine A. Whalen

LUND UNIVERSITY

The cover image entitled 'We are all change agents' was painted by Emanuele di Francesco. I interviewed Emanuele about his platform Circular Conversations (www.circularconversations.com) for an episode of the Getting in the Loop podcast. To me the painting illustrates the importance of collaboration in a circular economy. Each one of us has the power to be an agent for circular change; together we can achieve something greater than ourselves.

The International Institute for Industrial Environmental Economics

ISBN (PDF) 978-91-87357-55-8
ISSN (print) 978-91-87357-54-1

Printed in Sweden by Media-Tryck, Lund
University Lund 2020

NORDIC SWAN ECOLABEL
Printed matter
3041 0903

Media-Tryck is an environmentally
certified and ISO 14001:2015 certified
provider of printed material.
Read more about our environmental
work at www.mediatryck.lu.se

MADE IN SWEDEN

To Grandma Nancy, Wish you were here.

Table of contents

Acknowledgements

Over the past four years, I have had the honour to work alongside and learn from the best, and it is time to say thank you to everyone.

I would like to acknowledge my main supervisor Oksana Mont, for her sharp insight, continuous support, and practical approach throughout the entire PhD process. Thank you for your valuable input and feedback over the past four years. I am also grateful to have had a great team of co-supervisors along for the ride: Nancy Bocken, Yuliya Voytenko Palgan, Andrius Plepys, and Christian Kowalkowski, thank you for exposing me to a variety of additional perspectives. I have learned a lot about research and different disciplines from your comments and feedback.

I am grateful for the financial assistance of MISTRA, which made this research possible. I would also like to acknowledge my MISTRA REES colleagues: thank you for the stimulating discussions and great teamwork, it has been a pleasure collaborating with you in Linköping, Göteborg, and Lund. And, a special acknowledgement to Julia and Leon – I am so grateful we were able to share every step of this journey, and I look forward to continuing to work (and socialize) together.

Thank you to the researchers and staff at the IIIEE for the welcoming workplace, thought-provoking lectures, and, of course, great fika. I would especially like to thank Lena and Per for continuous encouragement and leadership. Special thanks also to Jenny Palm and all IIIEE article incubator attendees; the exchanges in these sessions helped me to significantly improve as a researcher. To all in the IIIEE PhD group: thank you for the camaraderie and kanelbullar, especially to Lars for guidance, Sofie for snack writing sessions and Swedish support, Jess for our in-depth circular economy conversations, and Heather for all the office chats.

I would like to thank all the co-authors, companies, and students with whom I have collaborated on this research and learned from in the process. I would also like to thank my final seminar discussion partner Marcus Linder for the invaluable feedback he provided on the first draft of this thesis. And, I recognise the financial contribution from the Foundation in memory of Lars Inge Grundberg that has supported this PhD thesis.

I've had the pleasure of working on various projects alongside my PhD studies. At the IIIEE this included teaching and supervising bachelor's and master's students, working behind (and in-front!) of the camera on the circular economy online course (MOOC), and coaching 21 circular entrepreneurs in the CBOOT programme. Thank you to all involved in these projects and for allowing me the opportunity to be a part of them.

I would like to thank those who have played an important role in shaping my thinking on circular economy outside and even before my PhD studies, especially my former colleagues at Circle Economy as well as David Peck and the rest of the circular economy team at TU Delft. I would also like to thank everyone who has contributed to the *Getting in the Loop* circular economy podcast. Listeners, thank you for tuning in and inspiring me each week. Guests, thank you for sharing your vast knowledge and teaching me there is always more to learn. I would run out of space if I mentioned all of you by name (there are over 30 of you by now!), but two guests deserve special mention: Ken Webster and Walter Stahel, it has been an honour to learn about the circular economy from you.

And finally, thank you to my wonderful family and friends. To Gerben, my parents, and grandparents, thank you for your continued support of all my endeavours. I am lucky to share this with you and I love you!

Katherine Whalen

Lund, December 2019

Abstract

Over the past ten years, significant industry, policy, and scientific attention has been given to the 'circular economy', which aims to create a more sustainable society by decoupling economic growth from resource consumption. Firms are expected to play a significant role in the shift to a circular economy model by implementing circular business models that encourage prolonged use of products, components, and materials. Yet, despite interest in the circular economy, there is a lack of empirical research about the effects of these business models and how to support their adoption.

This thesis aims to advance understanding of business models for a circular economy, with a focus on firms that slow resource loops and reverse product obsolescence. Using an interdisciplinary research approach, the thesis draws on business model theory and product life extension. The thesis presents theoretical and empirical examinations of circular business models using a variety of qualitative research methods. This includes a case study approach with Nordic firms in the ICT and maritime sectors to identify specific constraining and enabling factors for firms to adopt circular business models. A document study of participants' reflections was also performed to evaluate one circular economy tool – the 'In the Loop' game.

It was found that firms contribute to a circular economy through two main overarching circular business model strategies: 'Extending Product Value' or 'Extending Resource Value'. While lack of market demand and high costs were identified as main constraints to adopting 'Extending Product Value' business models, the findings suggest that firms themselves can make adopting these models more competitive and cost-effective by refining their business offering. The findings confirm a number of factors could support the adoption of these business models, including policy interventions and game-based learning tools. Contextual differences between sectors and firms were also identified, including firm type (i.e., original equipment manufacturers or gap-exploiter), customer base (i.e., business-to-business or business-to-consumer), and geographic scope (i.e., national vs. international).

The thesis underlines several environmental implications of circular business models. It suggests firms focus on maximising efficiency and that the adoption of circular business models does not guarantee reduced resource consumption or primary production. Solutions beyond firm-level interventions are a key part to a circular economy that achieves its intended environmental goals.

Popular science summary

Every year in the EU we throw away over 30 million tonnes of furniture, clothing, and electronic products. Because most of them are sent to landfill or burned for energy, you might think these products are waste. That is not true. Around 40% of these products still work or can be fixed. Companies could resell these products instead of producing new ones. Many believe this would be good for both business and the environment.

This thesis explores these benefits. It investigates why more companies do not use these existing products and how this approach could be encouraged in the future. The thesis concludes there are environmental and economic benefits to using existing products instead of producing new ones. Ultimately, it comes down to why and how companies adopt these approaches and implement them in practice. For example, individual actions by companies to take-back used clothing might actually increase new clothes production, especially if customers bring their old clothes back in return for in-store vouchers or discounts on future purchases.

Companies who wish to use existing products face a number of challenges. Company interviews in the Swedish/Danish maritime and ICT sectors identified high labour costs and (lack of) market demand as two significant barriers. Companies may find it difficult to compete with newly manufactured products. They may also face unfavourable legislation and consumer concerns over perceived product quality. Nevertheless, the research has identified numerous reasons why companies might want to use existing products. Benefits to business include making companies seem more environmentally friendly to their customers, earning additional revenue from new customers, and addressing future potential supply risks.

So, how can companies be supported in their efforts to use existing products instead of producing new ones? This thesis provides some guidance. The findings are useful for business developers in charge of 'circular economy' initiatives as well as entrepreneurs looking for their next 'circular business idea'. The study of 56 firms showed that companies use existing products in one of three ways. At one extreme, they can act as 'Facilitators' to help resell existing products without even physically touching the product. At the other, they can take on a 'Doers' role, physically repairing and updating the existing product, perhaps even bringing it back to an 'as new' state. Thirdly, between the two extremes, they can be 'Redistributors', where they physically handle products and only update them at a superficial level (if at all). This thesis suggests these roles are linked to business risks and opportunities as well as environmental benefits.

A plethora of tools and resources is available to companies to help support them in adopting these approaches. However, one major problem identified in the research is that many of these tools have not been tested and are not actually used by companies. One tool – the 'In the Loop' game – was tested in this research and was found to educate participants about drivers for circular business models.

Finally, the research stresses how the adoption of these approaches can be driven with support from policy. Policymakers working at the European Commission or national levels to implement 'circular economy packages' are encouraged to review the identified policy suggestions in this research. These include desired policy interventions identified from research on Swedish/Danish companies in the ICT and maritime sectors.

List of papers

Paper I Whalen, C.J., & Whalen, K.A. (2019). Circular Economy Business Models: A Critical Examination. *Journal of Economic Issues*. Forthcoming.

Paper II Whalen, K.A. (2019). Three circular business models that extend product value and their contribution to resource efficiency. *Journal of Cleaner Production, 226*, 1128-1137.

Paper III Whalen, K.A., Milios, L., & Nussholz, J. (2018). Bridging the gap: Barriers and potential for scaling reuse practices in the Swedish ICT sector. *Resources, Conservation and Recycling, 135*, 123-131.

Paper IV Milios, L., Beqiri, B., Whalen, K.A., & Jelonek, S.H. (2019). Sailing towards a circular economy: Conditions for increased reuse and remanufacturing in the Scandinavian maritime sector. *Journal of Cleaner Production, 225*, 227-235.

Paper V Whalen, K.A., 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. *Resources, Conservation and Recycling, 135*, 335-345.

Other publications

Journal Publications

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

Nußholz, J.L.K., Rasmussen, F.N., Whalen, K.A., & Plepys, A. (2019). Material reuse in buildings: Implications of a circular business model for sustainable value creation. *Journal of Cleaner Production*, In Press.

Whalen, K.A., & Whalen, C.J. (2018). The Circular Economy and Institutional Economics: Compatibility and Complementarity. *Journal of Economic Issues, 52*(3), 605-614.

Peer-Reviewed Book Chapters

Mont, O., Whalen, K.A., and Nussholz, J. (2019). Sustainable innovation in business models: celebrated but not interrogated. In F. Boons & A. McMeekin (Eds), *Handbook on Sustainable Innovation* (pp. 124-140). Cheltenham, UK: Edward Elgar Publishing.

Whalen, K.A., & Kijne, G. (2019). Game-Based Approaches to Sustainable Innovation. In N. Bocken, P. Ritala, L. Albareda, & R. Verburg (Eds.), *Innovation for Sustainability: Business Transformations Towards a Better World* (pp. 375-392). Cham: Springer International Publishing.

Conference Papers

Milios, L., & Whalen, K.A. (2018, June). *Sailing towards a circular economy? Potential for increased reuse and remanufacturing of ship components*. Paper presented at the International Conference on Resource Sustainability (icRS 2018), Beijing, China.

Nussholz, J., & Whalen, K.A. (2018, February). *Estimating reuse potential of secondary material streams: Decision-making factors to optimize environmental and commercial value from reuse in building products*. Paper presented at BAMB-CIRCPATH, Brussels, Belgium.

Whalen, K.A. (2017). Classifying circular business models: a practice-based review. In C. A. Bakker & R. Mugge (Eds.), *Product Lifetimes and the Environment* (Vol. 9, pp. 417-421). Delft, The Netherlands: IOS Press Ebooks.

Whalen, K.A. (2017). Risk & Race: Creation of a finance-focused circular economy serious game. In C. A. Bakker & R. Mugge (Eds.), *Product Lifetimes and the Environment* (Vol. 9, pp. 422-425). Delft, The Netherlands: IOS Press Ebooks.

Whalen, K.A., & Milios, L. (2019, September). *Circular Economy Policy at a Crossroads: Encouraging Durable Products or Enabling Faster Cycling of Short-lived Products?* Paper presented at the Product Lifetimes and the Environment Conference, Berlin, Germany.

Whalen, K.A., & Nussholz, J. (2016, September). *Building Extended Value Chains: Lessons from Swedish ICT Repair and Resale 'Gap Exploiters' for Original Equipment Manufacturers*. Paper presented at Electronics Goes Green 2016, Berlin, Germany.

Whalen, K.A., & Vakhitova, T.V. (2018, June). *Creating experiences, not lectures: experiential methods in context of sustainable development teaching*. Paper presented at the 9th International Conference on Engineering Education for Sustainable Development Conference (EESD), Rowan University, NJ.

Whalen, K.A., & Whalen, C.J. (2017, January). *The Circular Economy and Institutional Economics*. Paper presented at the Association for Evolutionary Economics Annual Meeting, Chicago, IL.

Reports

Mont, O., Plepys, A., Whalen, K.A., & Nußholz, J.L. (2017). Business model innovation for a circular economy: drivers and barriers for the Swedish industry – the voice of REES companies. Available at http://lup.lub.lu.se/record/833402ef-b4d4-4541-a10e-34d1e89d2146

Figures and tables

List of figures

List of tables

Abbreviations

B2B	Business-to-business
B2C	Business-to-consumer
BM	Business model
CBM	Circular business model
CE	Circular economy
EMF	Ellen MacArthur Foundation
EPV	Extending product value
ERV	Extending resource value
EU	European Union
ICT	Information and communications technology
OEM	Original equipment manufacturer
PSS	Product-service system

1. Introduction

Over two centuries ago, society experienced a significant technological boom with the beginnings of the industrial revolution. Since then, society's consumption has grown, and with it, so has our waste. Currently, over 2 billion tonnes of waste are generated globally each year, with this number expected to increase by 70% by 2050 (Kaza, Yao, Bhada-Tata, & Van Woerden, 2018). It is estimated that up to 60% of waste generated in the EU is not reused, recycled or composted (Eurostat, 2011). Similar numbers are identifiable for the US (EPA, 2017) and developing nations show even lower percentages (Kaza et al., 2018). At the same time, growing population and material demands are expected to double between 2010 and 2050 (Allwood, Ashby, Gutowski, & Worrell, 2011), leading to concerns about the over-consumption of finite resources.

This is the so-called *linear economy*, where materials are extracted, consumed, and discarded. Amid growing calls for climate action to drastically reduce greenhouse gas emissions (EEA, 2019), this linear economy is currently being challenged. There is urgent need for a new system that tackles this over-consumption and addresses the Earth's carrying capacity (Steffen et al., 2015). A *circular economy*, which decouples economic growth from resource use, has been presented as one vision for the future.

1.1 Background on the circular economy

Over the past few years, the idea of a circular economy (CE) has attracted significant attention. In the five years between 2011 and 2016, the number of academic articles published on the subject increased by a factor of 15 (Merli, Preziosi, & Acampora, 2018). A variety of actors, including governments, companies, and non-governmental organisations, are also interested and have created roadmaps and visions for moving towards a CE (European Commission, 2015; Dutch Ministry of Infrastructure and the Environment, 2016; SITRA, 2019). Perhaps the most influential non-state actor in CE – and one that may even be responsible for the global revival of interest in CE – is the Ellen MacArthur Foundation, a non-governmental organisation in the UK. The Ellen MacArthur Foundation has significantly influenced the conceptual thinking behind the topic, with their grey literature often cited in academic publications on CE (Kirchherr, Reike, & Hekkert, 2017).

One reason for this recent revival is the global trend regarding resource consumption, coupled with concerns over future access to raw materials. Modern technology requires a wider assortment of materials than in the past (Greenfield & Graedel, 2013) and overall material demand is predicted to increase in the future (Allwood et al., 2011; Elshkaki, Graedel, Ciacci, & Reck, 2018). Currently, some of these materials can only be sourced from limited geographical locations (European Commission, 2017). When the first Ellen MacArthur report was launched in 2012, there were growing concerns over future access to raw materials, as raw material prices had just reached an all-time high for a number of metals, including copper (BCC, 2010). Additionally, geopolitical tensions were high, due to export quotas on rare earth metals from China, which accounts for 97% of the world's production of rare earth elements (Reuters, 2010).

CE is often presented in two parts, drawing on two of the four different environmental perspectives identified by Clapp & Dauvergne (2011). In explaining why a CE is necessary, advocates take a Malthusian, *bioenvironmentalist perspective*, arguing that current global consumption is at or beyond the Earth's carrying capacity. One concept that is frequently mentioned is Kenneth Boulding's description of Earth as a spaceship "without unlimited reservoirs of anything, either for extraction or for pollution" (Boulding, 1966, p.4). After setting the stage, the way forward is presented. In line with the bioenvironmentalist perspective, a new global economy is advocated. However, this is where the similarities with bioenvironmentalists start to recede and the *market liberal perspective* comes into view. The new economic model – one modelled after a circular, closed-cycle system – appears more closely aligned with that of a market liberal perspective, as economic growth – rather than reduced consumption - is emphasised (Ellen MacArthur Foundation, 2013). Although achieving a CE could inherently reduce consumption of virgin materials, the concept itself does not always advocate a change in consumer consumption habits or reduced economic growth (Murray et al., 2015).

More often than not, CE comes down to the market liberal adage 'tech will fix it' (Kemper, 2012) by essentially redesigning processes and implementing smarter systems. In fact, critics of the CE concept (e.g., Murray, Skene, & Haynes, 2015; Zink and Geyer, 2017) have raised concern over its focus on resources rather than environmental impact with regard to environmental emissions, planetary boundaries, greenhouse gas emissions and consumption. At some point, costs of creating and sustaining a circular material flow will exceed benefits (Sauvé, Bernard, & Sloan, 2016). Andersen (2006) makes the case for recycling, arguing that the three benefits –market value of the recycled materials, reduced waste sent to incineration or landfill, and reductions in extraction of virgin materials – should outweigh the burdens (e.g., energy emissions).[1]

Although there is no single epistemological definition (Kirchherr et al., 2017), there has been some recent convergence in the conceptual framing of CE. Geissdoerfer, Savaget, Bocken, & Hultink (2017) clarify the concept of CE in relation to sustainability, concluding that CE prioritises economic/financial advantages and reduced resource consumption and pollution over societal aspects, unlike the concept of sustainability, which emphasises the triple bottom line of environment, economy, and society (Elkington, 1997).[2] Current literature emphasises *slowing resource loops* and *closing resource loops* (Bocken, de Pauw, Bakker, & van der Grinten, 2016).

A number of 'circular strategies' (repair, refurbishment, remanufacturing, recycling) are associated with these two approaches (Nußholz, 2017). Slowing resource loops includes product life extension strategies such as maintenance, repair, refurbishment, and remanufacturing, while closing resource loops is linked to recycling (Bocken et al. 2016). It should be noted that *narrowing resource loops*, such as by using less material or saving energy, is also part of the concept. However, some authors argue that this aspect should be used in combination with the other two strategies, as it would only result in marginal environmental improvements if implemented alone (Allwood et al., 2011; Bocken et al., 2016). Therefore, this thesis refers to a CE as an *economic system based on the decoupling of environmental resources from economic growth* that can be achieved by slowing and closing resource loops.

Firms are expected to play a significant role in the shift to a CE model by changing how they structure their business strategy and operations. Here, the term *circular business model* (CBM) has emerged in recent years, used by both practitioners and academics. The concept is also used in industry and governments to describe numerous types of firms and organisations (Kiørboe, Sramkova, & Krarup, 2015). In line with the definition of CE applied in this thesis, CBMs *offer the opportunity for firms to align how they capture, create, and deliver value by slowing and closing resource loops*. As will be discussed further in Section 2.2, emphasis has been placed on *slowing rather than closing resource loops*, as these strategies are thought to be more financially beneficial for firms and more environmentally sound.

---

1 He also argues that circular material flows should be created only when socially desirable. In making these decisions, society as a whole should be taken into account. A recycling project should be executed only if the benefits outweigh the disadvantages, for example, a new school being built.

2 The term 'triple bottom line' was coined by Elkington (1997) and is a three-prong sustainability framework that measures firms against profits (their economic responsibility), the planet (their environmental responsibility), and people (their social responsibility).

CBMs are anticipated to contribute to both the firm and society's triple bottom line (Antikainen & Valkokari, 2016). Economic advantages are promised to firms in the form of new customers, additional revenue streams, and strengthened customer relationships (Linder & Williander, 2017). Simultaneously, social benefits such as job creation are anticipated (European Commission, 2015) and environmental benefits, such as from product life extension, are also expected. For example, one study showed that extending the UK's average clothing lifespan by just three months could result in a 5-10% reduction in carbon, water, and waste-related footprints (WRAP, 2012b).

Although the concept of CBMs is relatively novel, aspects of CBMs have been addressed in other research streams because CE draws on a variety of established fields. Numerous authors (e.g., Prendeville and Bocken, 2017; Sabbaghi, Cade, Behdad, & Bisantz, 2017) have investigated product life extension through research on remanufacturing, refurbishment, and repair. These strategies align with existing Design for the Environment (DfE) practices (Jeswiet & Hauschild, 2005) and known material efficiency principles for products (Allwood et al., 2011). Closely related is the domain of Product-Service Systems (PSS),[3] where scholars have advocated that the marriage of services and products can promote environmental and economic benefits (Mont & Tukker, 2006).

1.2 Problem definition

CBMs, and particularly those that contribute to slowing resource loops, are increasingly recognised as key enablers to achieving a more CE (Bakker, Wang, Huisman, & den Hollander, 2014b; Lieder & Rashid, 2016). However, a number of theoretical and practical questions about CBMs still remain, and these have been consolidated into three main knowledge gaps.

A *first gap* is the lack of clarity about the term 'circular business model' (Lewandowski, 2016; Urbinati, Chiaroni, & Chiesa, 2017). In recent years, scholars and practitioners have identified a variety of CBMs to assist firms in adopting CE principles. At the start of the research for this thesis, this included the practitioner-developed ReSOLVE framework (Ellen MacArthur Foundation, 2015) and a peer-reviewed typology of CBM strategies (Bocken et al., 2016). However, no single definition existed at the start of this research. As there are many possible arrangements of CBMs, cohesive classification and terminology must be addressed before further

[3] Mont (2002) defines a product-service system as a "system of products, services, supporting networks and infrastructure that is designed to be competitive, to satisfy customer needs, and to have lower environmental impact than traditional business models."

research (such as assessing environmental benefits) can be undertaken (Nußholz, 2017).

The *second gap* concerns the uptake of these models. Aspects of CBMs have been addressed in other research streams, such as those related to repair, remanufacturing, and PSS. This existing literature has identified several drivers for implementing CBMs, including cost savings in manufacturing (King, Miemczyk, & Bufton, 2006; Stahel, 2010), environmental impact reduction (Mont, 2004), and increased brand protection and customer satisfaction (Firnkorn & Müller, 2012; Seitz, 2007). There also appears to be significant potential for reuse. It is estimated that over 40% of the approximate 30 million tonnes of furniture (Forrest et al., 2017), clothing (Environmental Audit Committee, 2019), and electronic products (European Commission, 2019a) discarded in the EU each year is still functional, or could be fixed with minor repairs (WRAP, 2012a). However, research suggests there is limited market penetration for firms that embed circular strategies in their business model. A recent study concluded that few firms focus on slowing resource loops, with the market penetration for end of life product refurbishment estimated between 2-3% (OECD, 2019). If CBMs supposedly lead to competitive and economic advantage, why do more firms not implement CBMs, and how can this gap be addressed?

This question is also of academic relevance, as a recent review found that most research on CBM strategies has focused on closing rather than slowing resource loops (Merli et al., 2018). Previous research on slowing resource loops has focused mainly on one firm type: original equipment manufacturers (OEMs) (Matsumoto, 2009). Another type of firm has now come into the vernacular: gap-exploiters. This term is used to describe third-party firms (not OEMs) that employ product life extension strategies and 'exploit' the residual value of existing products (Hollander & Bakker, 2016). Studies related to slowing resource loops often focus on the outcomes of such models by quantifying the potential economic and environmental savings (e.g., André, Ljunggren Söderman, & Nordelöf, 2019; Cooper and Gutowski, 2017; Farrant, Olsen, & Wangel, 2010; Mont, Dalhammar, & Jacobsson, 2006; Sandin and Peters, 2018), rather than by studying how or why the firm undertakes such models (e.g., Brown, Bocken, & Balkenende, 2019; Seitz, 2007). Research on how business model strategies to slow resource loops have been employed by firms and embedded in their business models remains underexplored, especially for gap-exploiter firms.

In the fields of eco-design and sustainable business model innovation, there are a number of tools and methods intended to support firms in the design and development of new sustainable business models and products (Baumann, Boons, & Bragd, 2002; Rossi, Germani, & Zamagni, 2016; Schaltegger, Hansen, & Lüdeke-Freund, 2016). It is assumed tools and methods can also help support the adoption of CBMs (Lewandowski, 2016; Nußholz, 2018), but knowledge is limited about their ability to serve as support for developing CBMs (Bocken, Strupeit, Whalen, & Nußholz, 2019).

The *third and final gap* centres on the uncertainty regarding the environmental impact of CBMs in terms of greenhouse gas emissions savings and waste generation/resource extraction avoided. CBMs, especially those that focus on slowing resource loops, may provide new ways of generating economic value, while decoupling and reducing overall resource consumption (Ghisellini, Cialani, & Ulgiati, 2016; Manninen et al., 2018). However, many questions remain about CBMs regarding their contribution to reducing resource consumption. Simply put, some scholars (e.g., Stål and Corvellec, 2018; Zink and Geyer, 2017) are unconvinced that adoption of CBMs leads to environmental improvements, because it is unclear why and how CBMs may be adopted in practice and how this affects intended environmental benefits such as greenhouse gas emissions and resource savings.

1.3 Objective and research questions

In view of these knowledge gaps, the objective of this research is to analyse the current state in literature and practice and advance understanding on the development of business models for a CE. This research will help fill a gap in knowledge about devising and evaluating CBMs and will provide recommendations to companies and policymakers about business models for CE. To address the objective, the following research questions and sub-questions have been developed:

RQ1: *Why do more firms not implement circular business models, especially those that contribute to slowing resource loops?*

- How are circular business models conceptualised, and how can they contribute to reducing resource consumption?
- What are the constraining factors for firms looking to adopt these models?

RQ2: *How can the adoption of CBMs, especially those that contribute to slowing resource loops, be supported?*

- What are the enabling factors for firms looking to adopt circular business models?
- What tools and methods play a role in the development of these models?

1.4 Research scope and delimitations

In this section, the scope and boundaries of this research are presented. First, this thesis focuses on CBMs, rather than CE in general. It is important to make clear that the scope does not include economic transition and reflections on the 'economy' and existing economic models are not brought into the discussion.

Business models can be studied from many levels or perspectives, including 1) product, 2) business, 3) company, and 4) industry (Wirtz, Pistoia, Ullrich, & Göttel, 2016). The research in this thesis aligns with current perspectives that converge between company and industry levels. As this type of business model perspective can be used as a framework for systems thinking (Suskewicz & Josh, 2009), it aligns well with the overarching topic of CE, which emphasises an overarching systems-level approach. Therefore, although the use of 'business model' in this research will centre on a firm, its boundaries are not limited to those of the firm. *Emphasis is placed on a systems-level approach*, in other words, not just how a firm does business but also how it interacts with the surrounding industry.

In terms of sustainable transformation, systems-level innovation, rather than a product or material level, has the greatest environmental savings potential (Brezet, 1997; Ceschin & Gaziulusoy, 2016). Although product design does affect the overall business case for CBMs, in this research, emphasis is placed on the *design of systems-level aspects of CBMs*, such as interaction with regulatory frameworks, partner networks, and collection channels, rather than firm-level specifics (e.g., top management support or relations between team managers) or product-level specifics (e.g., the firm's design of products or detailed material choices).

Finally, in terms of CE strategies (Bocken et al., 2016), emphasis is placed on *slowing resource loops*, rather than closing resource loops, due to considerations explained in Section 1.2 and Section 2.1. There is a focus on *products rather than materials*. Part of the research also focuses on two sectors: maritime and ICT. *Geographical constraints* may apply, as two papers also focus on firms in the Nordics. There is also a clear European focus in discussions relating to policy, as policy research was only conducted at a European Commission and EU Member State level. The research period for this thesis was between November 2015 and December 2019.

1.5 Research process and papers

This thesis is based on the research presented in five peer-reviewed research articles (Table 1). Other publications by the author of relevance to this thesis that are not included in this selection can be found at the start of the thesis on page xvii. Figure 1 illustrates how the research fits together.

Table 1. Research papers and contributions by the author.

Publication		**Contribution by the researcher (K.A. Whalen)**	**Contribution to Research Questions**
Paper I	Whalen, C.J. & *Whalen*, K.A. (2019). Circular Economy Business Models: A Critical Examination. Journal of Economic Issues.	The researcher (second author) collaborated with an economist and contributed to the design of the research framework, bringing in knowledge on the circular economy and circular business models. The researcher conducted the majority of data collection and analysis, and wrote parts of the article.	RQ1a: How are circular business models conceptualised, and how can they contribute to reducing resource consumption?
Paper II	*Whalen*, K.A. (2019). Three circular business models that extend product value and their contribution to resource efficiency. Journal of Cleaner Production.	As sole author, the researcher designed the research framework, methodology, conducted all research and analysis, and wrote the entire article.	RQ1a: How are circular business models conceptualised, and how can they contribute to reducing resource consumption?
Paper III	*Whalen*, K.A., Milios, L., & Nussholz, J. (2018). Bridging the gap: Barriers and potential for scaling reuse practices in the Swedish ICT sector. Resources, Conservation and Recycling.	As the first author, the researcher designed the literature review, contributed to the development of the methodology and research design, conducted data collection and most of the analysis, and wrote most of the article.	RQ1b: What are the constraining factors for firms looking to adopt these models? RQ2a: What are the enabling factors for firms looking to adopt circular business models?
Paper IV	Milios, L., Beqiri, B., *Whalen*, K.A., & Jelonek, S.H. (2019). Sailing towards a circular economy: conditions for increased reuse and remanufacturing in the Scandinavian maritime sector.	The researcher (third author) contributed to the literature review and development of the methodology, conducted part of the data collection and analysis, and wrote parts of the article. The researcher assisted in supervising the second and fourth authors in their data collection and analysis.	RQ1b: What are the constraining factors for firms looking to adopt these models? RQ2a: What are the enabling factors for firms looking to adopt circular business models?
Paper V	*Whalen*, K.A., 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. Resources, Conservation and Recycling.	As first author, the researcher contributed to the design of the research framework and was involved in data collection and facilitation of the tool for two of the three cohorts. The researcher was involved in data analysis and wrote much of the article. With support from the second author, the researcher took on the role of project manager to ensure all authors contributed to data analysis, article writing, and the review process.	RQ2b: What tools and methods play a role in the development of these models?

This research involved three main phases. The research process was iterative, with each focus area building on the others (Table 2). The *conceptual phase* focused on providing a theoretical foundation. In this phase, conceptualisations of CE and their relation to the business model concept were reviewed to gain an understanding of how CBMs can be defined (Paper I). This was based on academic knowledge and combined with lessons from practice (Mont et al., 2019; Whalen, 2017a). The contribution of these business models to reducing overall resource consumption and greenhouse gas emissions was also the subject of reflection (Paper I, Paper II). This included creating a framework to help characterise business models with greater potential for resource efficiency and reflecting on how CBMs could be optimised and improved to increase their potential for CE and resource efficiency (Paper II).

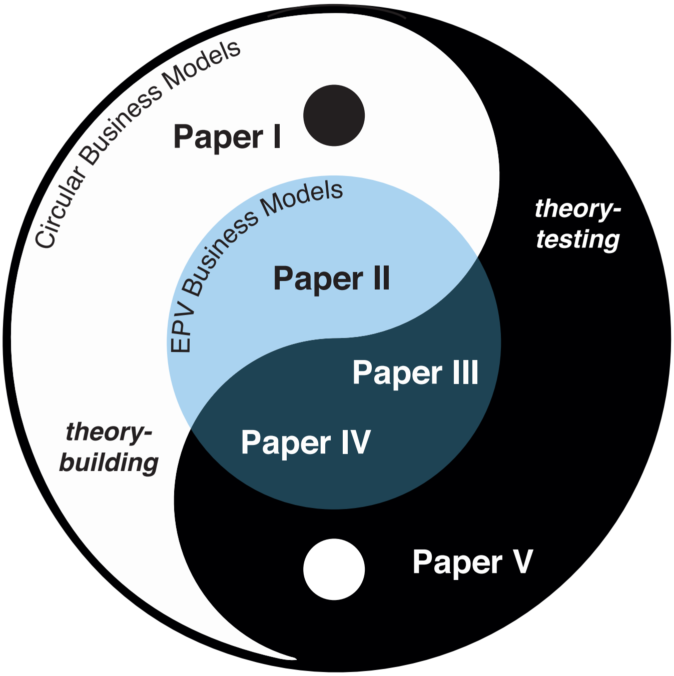


Figure 1. Graphical depiction of the research.
Mapping of the logical flow between the papers.

Table 2. Overview of the evolving nature of the research.

	Conceptual phase	Fieldwork phase	Testing phase	Synthesis phase
Goals	Explore the theoretical foundation of CBMs, how the concept is understood in literature and practice, and how CBMs could be optimised and improved to increase their potential for circular economy and resource decoupling	Identify constraining and enabling factors for CBMs, specifically those contributing to slowing resource loops	Explore how to develop circular business models	Answer research questions
Knowledge gaps addressed	Gap 1 and 3: Understanding the concept and their unknown environmental impacts	Gap 2: Advancing the development of CBMs	Gap 2: Advancing the development of CBMs	Gaps 1, 2, 3
Sources	Literature related to the circular economy, practical examples	Literature, companies, experts, authorities	Literature, experts, companies, university students	All prior work
Methods	Literature and practice review, content analysis	Interviews, expert surveys, company visits, literature analysis	Literature and practice review, document study	Analytical reflection
Outcomes	Review of CBMs and research gaps; Framework for EPV BM development and characterisation of resource efficiency potential	Constraining and enabling factors to circular business models at company level as well as macro-level; Recommendations to business and regarding adoption of CBMs	Evaluation of one specific tool	Chapeau; Recommendations to business developers, entrepreneurs, and policymakers regarding the development and implementation of CBMs
Dissertation Papers	• Paper I • Paper II	• Paper III • Paper IV	• Paper V	• Papers I-V
Related Publications	• *Whalen* & Milios (2019) • Mont, *Whalen* & Nußholz (2019) • *Whalen* & Whalen (2018) • *Whalen* (2017a)	• Nußholz, Nygaard Rasmussen, *Whalen*, & Plepys (2019) • Mont, Plepys, *Whalen*, & Nußholz (2017)	• Bocken, Strupeit, *Whalen*, & Nußholz (2019) • *Whalen* & Kijne (2019) • *Whalen &* Vakhitova, 2018 • *Whalen* (2017b)	• N/A

During the *fieldwork phase*, constraining and enabling factors relevant to CBMs were identified and assessed with case companies to improve understanding of business conditions that support these business models. A specific focus was on business models that contribute to slowing resource loops to improve understanding of how these models can be implemented in practice and the factors that contribute to the uptake of these practices (Papers III and IV).

During the *testing phase*, research focused on exploring tools and methods related to the design of CBMs. The diversity of existing business model design tools and methods was mapped and critically assessed as methodological support tools for businesses to design resource efficient business models (Bocken et al., 2019). This resulted in a list of tool criteria to help guide the design of new tools for CBM innovation. One type – game-based approaches – is further investigated, and one existing tool is assessed to examine how it could support users' understanding of CE concepts and help users ideate different business model strategies (Paper V).

Finally, during the *synthesis phase*, all previous work was reviewed and analysed in relation to the three identified research gaps. Additional research was also undertaken to keep abreast of knowledge advances in the field.

1.6 Target audience

The findings of this thesis are of value to a variety of actors. The work is relevant to the growing body of academic research on CE. Specifically, it is of interest to scholars investigating issues related to CBMs, especially their design, evaluation, and supporting policies. Due to the interdisciplinary nature of the research, other academic audiences may also find it relevant, including scholars with an interest in business model innovation, sustainable business, product reuse, repair, and remanufacturing, environmental management, and policy and sustainability studies.

The applied nature of the research also makes it interesting to practitioners. The research provides practical insight into potential barriers to CBMs and possible ways of overcoming these to implement such models in practice. The work is thereby relevant to business innovators, including business developers and entrepreneurs looking to adopt CE strategies in their own firms. This insight is also relevant to knowledge brokers or institutions that act as intermediaries between academia and practice. Two examples of these actors in the field of CE include the Ellen MacArthur Foundation and Circle Economy.

The research offers tools and frameworks that can be useful to these practitioners. For example, sustainability directors interested in increasing the resource efficiency of their existing business models may find it useful to consider the CBM environmental framework in Paper II, while professionals looking to create awareness about CBMs may find the evaluation of the tool in Paper V relevant.

Finally, the thesis highlights the role of policy in supporting the creation of CBMs, while also ensuring that the desired environmental benefits and effects are achieved. The findings are also relevant to policymakers focused on business development and environmental policy at national and international levels. In particular, policymakers looking to promote the adoption of CE may benefit from the applied research on circular businesses, including the identified environmental considerations and suggested policy interventions.

1.7 Thesis outline

This thesis comprises six chapters and five appended research articles. Chapter 1 explains the motivation for undertaking this research and formulates the research questions. Chapter 2 provides an overview of the main theoretical and conceptual research perspectives that the work draws on. The methodological positioning and approaches to data collection and analysis are highlighted in Chapter 3, before an overview of research findings is presented in Chapter 4. Chapter 5 synthesises the results into a discussion and reflection on the work. The thesis concludes by answering the research questions, presenting the main contributions made by the research, and reflecting on directions for future research in Chapter 6.

2. Theoretical and conceptual perspectives

2.1 Overview of business model theory

A *business model* is a representation (or model) of the two main purposes of business – value creation and value capture (Shafer, Smith, & Linder, 2005). Richardson (2008) expands this definition to include value proposition, value creation and delivery, and value capture (see Figure 2). Business model theory is closely related to and builds on multiple fields of research including business strategy, Porter's value chain theory (1985), resource-based theory, network theory, and organisational theory (Hedman & Kalling, 2003). However, the concept as a whole lacks a theoretical grounding in business studies or economics (Teece, 2010). Circular economy scholars often use the business model concept, as it focuses beyond the boundaries of a single firm (Zott, Amit, & Massa, 2011) and illustrates how firms interact with the value chain around them (Bocken, Short, Rana, & Evans, 2014). This positioning between company/industry-level perspectives (Wirtz et al., 2016) can be used to provide a systemic overview of how a firm contributes to CE through how it does business.

Value proposition	**Value creation and delivery**	**Value capture**
Who are the customers and what is the value to them? What types of product/service(s) are the focus of this business model?	How are activities, partners, channels, and resources arranged?	How does the firm make money? What costs are involved?

Figure 2. Core pillars of the business model.
Developed from Osterwalder, Pigneur, & Tucci. (2005); Richardson (2008).

Perhaps because of this potentially broad perspective, a business model can fulfil many functions. It governs the value chain's structure (Zott & Amit, 2010). As an expression of business strategy, it can be used as a tool for innovation (Kowalkowski, Windahl, Kindström, & Gebauer, 2015; Stähler, 2002) as well as communication of strategy (Magretta, 2002). Business models can "help a manager to capture, understand, communicate, design, analyse, and change the business logic of their firm" (Osterwalder et al., 2005, p. 11). Business models can be used to assist in entrepreneurship, not just for new firms but also in existing ones (Zott & Amit, 2010), and firms may use the business model as a tool to help commercialise new technological developments (Chesbrough & Rosenbloom, 2002).

Scholars have proposed various ways to describe and organise the 'elements' of business models. These different elements share three common aspects: they describe 1) the activities being performed, 2) how these activities are linked, and 3) who performs the activities (Zott & Amit, 2010). For example, Osterwalder et al. (2005) summarised business model elements into four overarching pillars: (1) product, or value proposition (2) customer interface (3) infrastructure management and (4) financial aspects. Each firm has a specific configuration of elements that describe and define how the organisation creates, captures, and delivers value. Firms are said to undertake *business model innovation* by changing this configuration (Taran, Boer, & Lindgren, 2015).

Linear, sustainable, and circular business models

The notion of value is central to the business model concept (Chesbrough & Rosenbloom, 2002). Value can be internal (from the shareholder perspective) or external (from the customer perspective) (Bititci, Martinez, Albores, & Parung, 2004). Value is often equated to economic terms, but other forms of value are possible (Zott et al., 2011), such as social and environmental value (Boons, Montalvo, Quist, & Wagner, 2013). Social and environmental goals are traditionally secondary to economic value for most businesses (Freeman & Gillbert Jr, 1992). However, in light of the social and ecological exploitation as mentioned in Chapter 1, there has been growing interest in moving away from only maximising shareholder profits to also extending stakeholders to include the environment and society (Stubbs & Cocklin, 2008). Sustainable businesses are expected "to increase shareholder value without increasing material throughput" (Fiksel, 2006, p. 16).

In the domain of sustainable innovation, academic research has expanded the scope of business models to the societal level around a firm (Boons & Lüdeke-Freund, 2013). This enables firms to create competitive advantage while contributing to sustainable development (Ludeke-Freund, 2009). Schaltegger et al. (2016) present an extended definition, including both a description of the purpose of a sustainable business model and three main elements:

> "A business model for sustainability helps describing, analysing, managing, and communicating (i) a company's sustainable value proposition to its customers, and all other stakeholders, (ii) how it creates and delivers this value, (iii) and how it captures economic value while maintaining or regenerating natural, social, and economic capital beyond its organizational boundaries." (Schaltegger et al., 2016, p. 6)

Circular economy business models (CBMs) are positioned as a subset of sustainable business models (Bocken et al., 2014), prioritising economic and environmental value over social value (Geissdoerfer et al., 2017). Some differences can be observed when distinguishing sustainable and CBMs from those of conventional business models, especially in how scholars define CBM elements (e.g., Lewandowski, 2016; Planing, 2015). Table 3 provides an overview of how a CBM of a manufacturing firm might differ from a traditional, 'linear' business model or sustainable business model.

Table 3. Comparison between linear, sustainable, and circular business models.
The perspective is through the lens of a hypothetical manufacturing firm. Source: Author.

	Linear business model	Sustainable business model	Circular business model
Value proposition	Business continuity; maximises shareholder profits	Business, society and environmental continuity; creates positive societal and environmental value while doing business	Business continuity by resource scarcity concerns; Maximising economic value by slowing or closing resource loops to reduce material throughput; proposition for retrieval of products from customers needed (reverse logistics)
Value creation	Focuses on direct supply chain for the production of new products	Focuses on resource efficiency improvements in the supply chain and product lifecycle	Focuses on systemic value creation throughout the entire product lifecycle and collaboration with other partners to ensure this when parts of the lifecycle are outside the firm's focus
Value delivery	Centres on products offered through one-way buyer-seller relationship	Centres on products that 'do less bad' to environment/society	Centres on products, services, or processes that reduce material throughput by the creation of new channels for distribution/collection and new market segments
Value capture	Based on consumption; usually shorter term financial pay-back	Based on reducing impacts to environment/society; usually unclear direct economic benefits	Based on decoupling resources from economic growth and recapturing value (multiple times from one product); usually longer term financial pay-back

Three main differentiating characteristics are: 1) Propositions for retrieval of products after use by customers is not an issue for linear business models nor sustainable business models, whereas it is crucial for CBMs; 2) CBMs take on a more systemic focus, going beyond the direct network needed for production of products to considerations of product cycling and disposal, potentially through collaboration with partners; and 3) Linear business models operate on a 'sell more, sell faster' philosophy; sustainable business models operate on a 'do with less' philosophy; and CBMs operate on a 'do the same or more by decoupling' philosophy. CBMs focus heavily on resources and less on societal benefits than sustainable business models, although social benefits such as labour creation may be cited as indirect benefits of circular business.

Some differences can also be observed between how traditional and CBM researchers define business model elements. CBM scholars often characterise and distinguish value propositions according to the firm's contribution to a CE, for example the firm may offer 'reusable or recyclable products', 'long-lasting products', 'reusable or recyclable production inputs' (Lüdeke-Freund, Gold, & Bocken, 2018) or 'create value from waste' (Bocken et al., 2014). This, however, does not necessarily reflect the value proposition that is communicated to the customer (e.g., lower price or time saving).

2.2 Review of the circular business model field

The CE advocates a change in how companies operate, calling for a move from traditional linear business models to circular ones. However, perhaps partly because of the various understandings of CE, it is difficult to assess a CBM, as there are multiple *definitions* (Lewandowski, 2016; Planing, 2015). Views differ on the type of firms that can play a role in contributing to a more CE. Some take a manufacturer-centred perspective, arguing that firms are circular only when products return to producers (Lieder & Rashid, 2016; Linder & Williander, 2017). Others do not make this distinction, taking a more open, systemic perspective (Bakker et al., 2014b; Bocken et al., 2016).

In an effort to clarify CBM understanding, *classification schemes* have been devised to assist conceptualisation. This echoes conventional business model literature where business model archetypes are often derived from theory and practice to help clarify concepts (Bakker, Hollander, Hinte, & Zijlstra, 2014a; Bocken et al., 2016; Lüdeke-Freund et al., 2018). However, most archetypes are not peer-reviewed and do not explicitly describe a business model according to traditional business model literature (e.g., Osterwalder and Pigneur, 2010). For example, Lewodowski (2015) draws on a framework originally developed to describe generic CE strategies, the ReSOLVE

Framework of the Ellen Macarthur Foundation (2015), and does not explicitly define how value is created, captured, or delivered.

One exception to the lack of theoretically derived classifications is the six CBM archetypes developed by Bocken et al. (2016), building on the work of Bakker et al. (2014a). This framework is the sole peer-reviewed CE business model typology (at time of research) that attempts to present a conceptual derivation for its development, and defines each type according to its main business model dimensions (see Table 4). The first three archetypes (CBM1-3) relate to product life extension strategies, while the final two (CBM5-6) address recovery of materials; CBM4 relates to reduced consumption. However, upon further inspection, the archetypes do not appear to be on the same level. 'Industrial Symbiosis' for example, can be argued as a sub-domain of 'Extending Resource Value', while the 'Access/Performance model' can be viewed as a way to distribute 'Classic Long Life' and 'Extend Product Value'.

Table 4. Theoretical archetype framework for CBMs.
Adapted from Bocken et al. (2016).

Archetype		Value proposition	Value creation & delivery	Value capture
CBM1	Access/ Performance Model	Delivery of functionality or use instead of ownership	Lower cost of ownership to consumer; offers firms economic incentives to slow resource loops (perform maintenance, undertake repair)	Pay per unit of service; pay for functionality; pay per use
CBM2	Extending Product Value	Use and/or recovery of used products or components	Collection or redistribution or used products; perform repair; refurbishment; remanufacturing	New forms of value; reduced material or overall costs
CBM3	Classic Long Life	Offer long-lasting products	Durable, high-quality product and long-term customer service	Usually premium price
CBM4	Encourage Sufficiency	Encourage reduced consumption	Quality products, high levels of customer service; firm takes stance against obsolescence	Premium pricing due to slower sales
CBM5	Extending Resource Value	Use and/or recovery of wasted resources	Take-back; collection, recycling; recovery; and/or use of waste; often takes place at product level	Reduced material of overall costs
CBM6	Industrial Symbiosis	Waste outputs used as inputs	Outputs used as feedstock for different use; often takes place at manufacturing and process level to benefit business	Reduced operating cost; new business lines

Although these archetypes are modelled off the main concepts of *slowing and closing resource loops*, the relevancy of each within CE literature, and their potential to contribute to a more CE, varies. Extending the product life rather than recycling the product to base materials is expected to retain the greatest value (Stahel, 1982). When products are reused or remanufactured instead of recycled, more of the product's added value stays with the product or components; this usually makes reuse and remanufacturing more economic than recycling (Nasr & Thurston, 2006). For example, one study showed that 3.5 times more money could be gained from reselling a car versus recycling it (Benton & Hazell, 2013).

This prioritisation of slowing over closing echoes those from waste management practice, such as the generic hierarchy of the 3R principle of 'reduce, reuse & recycle' (Laseter, Ovchinnikov, & Raz, 2010) and 'Lansink's ladder', a Dutch waste hierarchy that includes waste prevention, design for waste prevention, product re-use, material recycling, material recovery for use as a fuel, incineration, and landfill (Parto, Loorbach, Lansink, & Kemp, 2007). These strategies were later adopted in China as the foundation for their CE principles (Yuan, Bi, & Moriguichi, 2006). Business models that relate to product lifetime extension therefore have supposedly higher potential to contribute to a CE. The next section defines product life extension and its associated environmental benefits.

2.3 Overview on product life extension

Product life extension aims to postpone or reverse product obsolescence (Bakker et al., 2014b), with the latter possible through the undertaking of four product integrity strategies: recontextualising, repair, refurbishing, and remanufacturing (Hollander, Bakker, & Hultink, 2017).[4] As differing terminology regarding these four terms can be identified in literature, this thesis will use those according to definitions presented in Hollander et al. (2017) as shown in Table 5. It is also worth noting that use of the term 'reuse' varies in literature, with some research referring to reuse as an all-encompassing term for any of these strategies. For example, the Waste Framework Directive (2008/98/EC) refers to reuse as "any operation by which products or components that are not waste are used again for the same purpose for which they were conceived." This thesis uses the term 'obsolete' to refer to both broken and/or unwanted products and 'previously obsolete' to refer to products whose obsolescence has been reversed.

[4] Obsolescence occurs when a product is no longer useful or wanted by a consumer. Obsolescence may be 'relative' or 'absolute' (Cooper, 2004). The former means the product is still functional; the latter means the product has failed, functionally or technically.

Table 5. The four product integrity strategies.

Product Integrity Strategy	Definitions from Hollander et al. (2017)
Recontextualising	"Use of an obsolete product (or its constituent components), without any remedial action, in a different context than it was (they were) originally designed for."
Repair	"The correction of specific faults in an obsolete product, bringing the product back to working condition, whereby any warranty on the repaired product generally is less than those of newly manufactured equivalents and may not cover the whole product, but only the component that has been replaced."
Reconditioning	"The process of returning an obsolete product to a satisfactory working and/or cosmetic condition, that may be inferior to the original specification, by repairing, replacing or refinishing all major components that are markedly damaged, have failed, or that are on the point of failure, even where the customer has not reported or noticed faults in those components."
Remanufacturing	"A term for a series of industrial processes in a factory environment, whereby an OEM (original equipment manufacturer), an OEM contracted third party, or a third party licensed to carry the OEM brand name, disassembles obsolete products into components, to a level as far down as needed to bring as many of those components as considered eligible after testing back to at least OEM original performance specifications and recombines those components—generally originating from different used products—with as few as possible new parts, to manufacture new products of a similar type and specification, that result in a new product with a warranty that is identical to that of an equivalent product manufactured out of all new parts."

Much of the existing research on firms and their adoption of product life extension strategies has focused on remanufacturing (Cooper & Gutowski, 2017) and OEMs (Matsumoto, 2009). However, this area of research has recently expanded in new directions, such as identifying constraining and enabling factors for undertaking product repair and refurbishment (e.g., Kissling et al., 2013; Ongondo, Williams, Dietrich, & Carroll, 2013; Sabbaghi et al., 2017). Focus has also been growing on the factors that impact the environmental profile of product life extension (Bakker et al., 2014b; Richter, Tähkämö, & Dalhammar, 2019).

Postponing obsolescence (through maintenance or design for long life) or reversing obsolescence is advocated in sustainability studies because of the two main perceived environmental benefits. First, they reduce environmental impacts from product disposal (i.e., landfill and incineration) as they avoid obsolescence (Fortuna & Diyamandoglu, 2017). Second, they reduce environmental impacts from new products (resource depletion and energy consumption) as they avoid new product production (Sandin & Peters, 2018). However, research suggests this 'displacement rate', or the amount of new production that is avoided by use of obsolete products, is not actually one-to-one (Farrant et al., 2010). This means that new production is not always avoided when product life extension is undertaken. A number of other factors have been found that affect the environmental benefits of product life extension.

These have been translated in Table 6 according to their related business model pillar (from Section 2.1).

Table 6. Factors affecting the environmental benefits of product life extension.
Mapped according to business model elements. Table from Whalen (2019) (Paper II).

	Value proposition	*Value creation and delivery*	*Value capture*
Factors influencing the environmental benefits gained through product life extension	Product type (e.g., energy consumption in use) Customer behaviour (e.g., replacement rate, transport)	Transportation (e.g., distance travelled, method) Activities relating to reversing product obsolescence (e.g., washing, cleaning, repairing, refurbishment, remanufacturing) Firm operations (e.g., physical stores, warehouses)	Pricing strategy of firm (e.g., influence on new production)

Product type is linked to the firm's value proposition and appears to have an influence over environmental benefits. Research suggests there may be a certain point when products that consume resources in use (i.e., energy and water consuming products) are better off being replaced by more efficient, newer models rather than having their lives extended (van Nes & Cramer, 2006). Customer behaviour, such as only buying new or obsolete products, can also affect the potential environmental benefits by influencing the displacement rate of the offering (Guide Jr. & Li, 2010).

How a firm creates and delivers value also directly influences overall environmental benefits from reversing product obsolescence. Activities related to remedial action (e.g., washing and cleaning) as well as the distance and method used to transport obsolete products (e.g., reverse logistics) are linked to resource consumption and greenhouse gas emissions (Zamani, Sandin, & Peters, 2017). Once products have been transported, additional firm operations, such as storage in physical warehouses, can also contribute to additional carbon footprint and resource consumption through usage of electrical energy and heating (Fortuna & Diyamandoglu, 2017).

Finally, how a firm captures value from product life extension may affect primary production, and thereby impact the overall environmental benefits from undertaking product life extension. Most firms want to avoid cannibalisation of product sales, meaning that previously obsolete products are not usually intended to displace primary production (Zink & Geyer, 2017). This would mean that reversing product obsolescence does not affect new production, as the previously obsolete products are intended for a customer base that is different from those purchasing new products. Firms offering both new and previously obsolete products may stimulate production through specific price adjustments, such as by using profits gained from sales of previously obsolete products to lower the cost of new products; this pricing strategy is referred to as ‘global optimisation’ (Ovchinnikov, Blass, & Raz, 2014). Firms may also incentivise the return of obsolete products through sales discounts and store credits, further stimulating consumption (Stål & Corvellec, 2018; Whalen, 2017a).

3. Research design

This chapter expands on the research positioning in relation to the different research paradigms and explains the methodological choices made in this study.

3.1 Research positioning

The research design process is shaped by the researcher's worldviews, or "a basic set of beliefs that guide action" (Guba, 1990, p. 17). These worldviews are underpinned by philosophical assumptions with unique characteristics. The philosophical worldview posited by the author is *pragmatism*. Pragmatism is a "radical departure from age-old philosophical arguments about the nature of reality and the possibility of truth" (Morgan, 2014, p. 5). It rejects abstract discussions about ontology and epistemology in favour of reorienting the focus towards human experience (Dewey, 2008).

Experience is built around the source of beliefs and the meanings of our actions, and since experiences always occur in a specific context, pragmatists believe it is not always possible to use prior experience to predict the outcomes of future actions (Morgan, 2014). Human experiences can be separated into *habits*, which occur in a relatively unquestioned fashion, and *inquiry*, which is the process of self-conscious decision-making. In pragmatism, the term 'production of knowledge' is avoided; rather the outcome of inquiry is 'warranted assertions'. The pragmatic researcher always brings forward some set of prior beliefs and knowledge to the situation, as knowing cannot be separated from doing – the knower and the known are inseparable.

In positioning itself among other philosophical paradigms used in social research, pragmatism breaks down the dualism of realism (a defining characteristic of post-positivism) and idealism (a defining characteristic of constructivism) in favour of defining truth as "what works at the time" (Creswell, 2014, p. 11). Instead of committing to philosophy or reality, pragmatists are concerned with "applications – 'what works' – and solutions to problems" (Creswell, 2013, p. 28). Rather than focusing on methods, pragmatism favours the research problem and using multiple approaches to understand it (Rossman & Wilson, 1985). Pragmatists are "free to choose the methods, techniques, and procedures of research that best meet their needs and purposes" (Creswell, 2014, p. 11), shaping the pluralistic approaches used in this research. The research seeks not only seeks to understand the phenomenon of CBMs and how they contribute to reduced consumption; it also concerned with applications of these business models in practice and solutions to problems. There is a solutions-oriented nature to the work, which is in line with pragmatism's focus on practical implications of research (Creswell, 2014).

3.2 Overarching research approach

As the idea of CBMs is relatively novel, much of this work takes an exploratory approach to investigate the research questions. However, CE itself draws from multiple disciplines, such as PSS, reuse, and waste management literature. These can also provide a theoretically based point of view that can be useful to identify more meaningful research directions for CBMs. The interdisciplinary nature of the thesis lies in its integration of environmental science and management science in the research of CBMs.

While grounded in theoretical concepts from established disciplines, the thesis also draws on the analysis of existing case studies from industry. The work could therefore also be said to take a trans-disciplinary approach because it aims to create a comprehensive picture of the research topic by making use of existing knowledge from multiple disciplines as well as industry practice (Sakao & Brambila-Macias, 2018).

In line with its pragmatist positioning, the research draws on the use of multiple research methods. Using multiple approaches to data collection enables exploration of a phenomenon from different sides and leads to a richer understanding of it (Cutcliffe, 2000). The research is qualitative in nature, with case study research and document analysis comprising the two main approaches. Table 7 presents an overview of the methods employed in this research and described in more detail in the following section. A qualitative approach was selected because such an approach is considered to be relevant when the underlying questions guiding research aim to examine how or why a phenomenon occurs (Yin, 2014).

Table 7. Overview of research methods.
Note: Literature reviews were performed during all phases of the research based on the paper's specific focus.

Type	Description	#	Year	Used in
Case Study Approach				
*Surveys**	Surveys sent via email and completed by stakeholders of ICT and maritime sectors in Sweden and Denmark	13**	2016; 2018	Paper III; Paper IV
Interviews	Personal interviews conducted with stakeholders in the maritime sector and ICT sectors in Sweden and Denmark	12*	2016; 2018	Paper III; Paper IV
Observation	Site visits at ICT gap-exploiter firms in Sweden for participant observation and documentation (e.g., via note taking, audio/photo recording)	3	2015-2017	Paper III
Document Analysis				
Case examples	Database of circular business models examples collected from a review of 37 literature sources obtained using keywords 'circular business model', 'business models for circular economy', and their variants (e.g., 'business models for circularity'; 'circular economy business model')	152	2016	Paper I; Paper II
Reflection write-ups	Solicited, two-page reflections created by participants after using the 'In the Loop' game	71	2015-2016	Paper V

* Surveys are normally considered quantitative methods data, but in this research they were analysed qualitatively.

**- Number of participants or responses.

3.3 Methods of data collection

This section highlights the main collection methods for the studies included in this thesis. A variety of research methods were employed, and more specific details can be found in the appended papers.

Literature reviews

Literature was reviewed at various points throughout the research to obtain a conceptual understanding of CBMs and provide clearer understanding of the research gaps in relation to related literature. As noted in the appended papers where relevant, sources were identified through a variety of academic databases including Scopus, ScienceDirect, Google Scholar, and Web of Science as well as authorities such as the European Commission briefings and CE-focused non-governmental organisations (e.g., Ellen MacArthur Foundation, Circle Economy). In addition to peer-reviewed literature, 'grey' literature sources were examined since CBMs are widely discussed by practitioners outside of academia. Although exact sources varied from paper to paper, literature included analysis of books, academic journals, reports, newspapers, conference proceedings, company websites, and company reports.

A *CBM database* of empirical case examples was created from a review of academic and grey literature that took place between August and November 2016 and used to provide insight from practice for Papers I and II. The case examples were identified using the search terms 'circular business model', 'business models for circular economy', and their variants (e.g., 'business models for circularity'; 'circular economy business model'), first by searching peer-reviewed journal articles in academic search directories (i.e., Science Direct) and afterwards by snowballing grey literature from the reference lists of the peer-reviewed journal articles. Additional sources were identified from European Commission briefings, Google searches, and CE-related organisations' websites (e.g., Ellen MacArthur Foundation, Circle Economy). In total, 152 unique examples of 'circular business models' from practice were identified from a review of 37 different sources (Table 8).

Table 8. Sources reviewed in creation of the circular business model database.
Examples are listed by publication year.

Publication Year	Publications Reviewed
2010	Park et al.
2012	Damen; Ellen MacArthur Foundation; Lee et al.
2013	Ellen MacArthur Foundation; Schulte; Kok et al.; Joustra et al.
2014	Bakker et al.; Ellen MacArthur Foundation; Genovese et al.; Lacy et al.; Mentink
2015	Bocken et al.; De Jong et al.; Ellen MacArthur Foundation (a); Ellen MacArthur Foundation (b); Ellen MacArthur Foundation (c); Florin et al.; ING Economics Department; Kiørboe et al.; Linder & Williander; Murray et al.; Planing; Prendeville & Bocken; Roos & Agarwal; van Renswoude et al.; Whalen et al.
2016	Antikainen & Valkokari; Beulque & Aggeri; Bocken et al.; Ellen MacArthur Foundation; Guldmann; Lewandowski; Lieder & Rashid; Ovaska et al.; Scheepens et al.

Case study approach

Case study research design is useful for providing in-depth descriptions of social phenomena (Yin, 2014). While it is often used to develop theory, it can also be used to test theory "where a theory proposes that something is a necessary condition for something else to occur" (Perri 6 & Bellamy, 2012, p. 102). A case study approach was identified as a relevant method in this research, as the thesis aims to identify necessary conditions for the adoption of CBMs and explore 'why' and 'how' questions rather than uncover frequencies or patterns. This approach was used during the fieldwork phase (Papers III and IV) and carried out in different sectors to enable comparison across sectors.

Case study research design requires multiple forms of evidence in order to help converge along multiple lines of inquiry (Yin, 2013). First, *semi-structured interviews* were held with company representatives as part of the data collection process. The predetermined structure contributed to consistency in comparing the responses, but allowed the researcher to stray from the questions to deepen understanding as necessary. Secondly, *survey questionnaires* were used to further verify the information collected in the interviews. In this research, surveys, despite their more common application in variable oriented and quantitative research (Perri 6 & Bellamy, 2012), were used to collect qualitative data that helped guide discussion on barriers to implementing product life extension strategies and stakeholders' desired policy interventions. The survey questions were informed by the literature review findings.

Document studies

Documents contributed as data sources for three papers in this thesis (Papers I, II, and V). In Papers I and II, primary documents (e.g., company websites, company communication materials) and secondary material (e.g., case descriptions in academic literature) were used to collect information about the business models identified in the CBM database. These documents can be distinguished as records because they were set up for administrative or political purposes, rather than for personal purposes (Hodder, 1994). In Paper V, participants created two-page reflection documents after using the 'In the Loop' game. These documents are characterised as solicited documents (Flick, 2006), as the participants were explicitly asked to write a reflection after the intervention. Document analysis, especially of Internet documents, can be a time-effective way to study and show how specific issues are understood and represented. However, it may be difficult to interpret their content or meaning because the context in which they were developed is not always explicit; documents may also not be transparent and cover only one side of an issue, so triangulation of data sources and data methods is also important (Flick, 2006). Further limitations about the specific documents used in this research are explicitly discussed in Papers II and V.

3.4 Methods of data analysis

The main method of data analysis in this thesis was *qualitative content analysis* (Flick, 2006). Although there are multiple approaches to this type of analysis, three activities can be said to characterise this qualitative content analysis: data condensation, the use of data displays, and verifying conclusions (Miles, Huberman, & Saldana, 2013). The use of *existing analytical frameworks* has contributed to data condensation, while assisting with the systematic identification of themes (Bryman, 2012). For example, Paper II uses the six business model archetypes developed by Bocken et al. (2016) to initially classify case examples, which then enables further structuring and investigation of case examples in the 'Extending Product Value' category. The business model framework is another example of an existing analytical framework used in this research. Both Paper II and III draw on adaptions to the 'value creation, delivery and capture' framework of Osterwalder et al. (2010) as a way to describe a firm's business model.

Directed and conventional coding approaches (open coding) (Hsieh & Shannon, 2005) have also been used to compare the data to existing theoretical frameworks and capture emerging meaning from practice. For example, in Paper II, a coding scheme was developed only after an initial and iterative review of the case example database. Similarly, in Paper V, an a-priori coding process was developed that still allowed the identification of new themes from the document analysis (Miles & Huberman, 1994).

After data condensation, *data displays* such as matrixes and tables were created to help communicate findings. In some instances, these can be found directly in the published papers (Papers III, IV, V) or in appendixes (Paper II). The data was compared to existing literature findings to assess potential gaps or new aspects, which is a type of *deductive modes of reasoning*. Papers III and IV are two examples of where this method was used. Here, the constraining and enabling factors identified by the stakeholders were checked against those previously identified from literature, with the aim of these papers being to contribute to theory-testing. *Inductive modes of reasoning* were used to contribute to forming new hypotheses. Papers I and II illustrate two examples where inductive modes of reasoning were used in this thesis, with the aim of these papers being to contribute to theory-building rather than theory application.

To sum up, this research is qualitative in nature and iterative qualitative content analysis approaches were used in each paper. The research has allowed both deductive and inductive modes of reasoning, thereby generating new insights into CBMs and investigating existing theories in greater detail. The trans-disciplinary nature of the research has also expanded the boundaries of existing frameworks and assertions on CBMs.

3.5 Reliability and validity

Validity, reliability, and replicability have been touted as three important criteria for evaluating social research (Bryman, 2012). Validity relates to the soundness and quality of the findings, and validity can be divided into *external and internal validity* (Bryman, 2012).

External validity emphasises the generalisability of the research findings. In line with the pragmatist worldview of this research, generalisation of the research outcomes should be approached with caution. It is not possible to reflect on the work without acknowledging its context. Accordingly, the case study results of Papers II, III, and IV should not be generalised, as case study findings are specific to their context. However, case studies can be used for falsification processes of generalised theories. If one observation is found to not follow the prescribed understanding of the theory, the theory must be revised (Flyvbjerg, 2006). Therefore, specific research findings from the Scandinavian context in Papers II and III could play a role in challenging the current general understanding of circular businesses.

Internal validity focuses on measuring the validity of the researcher's causality in experimentation. In line with the pragmatist view of the research, this type of validity is concerned with assessing the researcher's inquiry. This assessment of 'what works' involves a social dimension of producing evidence, such as peer review (Morgan, 2014). In this thesis, a number of strategies were used to contribute to internal validation. These included peer review processes for all papers, presenting the work to other scholars and practitioners (e.g., at international and national conferences as well as internally at the IIIEE) at various points for feedback, conducting multiple literature reviews to follow developments in the field, and attending courses on research methods as well as those related to discipline-specific knowledge. Mixed research methods enable triangulation and reflection from multiple perspectives.

Finally, *reliability and replicability* relate to the quality of the research approach as well as its findings and conclusions (Bryman, 2012). Reliability is closely related to internal validity, while replicability relates to a future researcher's ability to repeat the same process and arrive at the same conclusion. Research transparency practices were adopted in this thesis to address concerns relating to reliability and replicability of the work conducted by the author. All material collected and produced relating to each journal article was included at submission and can be found in the journals' online accompanying supplementary material. This includes interview protocols, surveys, and databases. However, the philosophical positioning of this research in pragmatism would warn that using the existing findings to predict future outcomes is fallible, and that replicability of this research will depend on the context of future inquiries as all experience is situationally dependent. The study is also time dependent, given that changes in institutional factors such as regulatory measures and social attitudes towards product life extension are anticipated in the future.

4. Key findings

This chapter addresses the key findings of the research. In line with the research questions, the chapter begins with an overview of how CBMs can be conceptualised. Based on research conducted in Papers I and II, an updated classification scheme is presented and the issue of environmental impacts from CBMs is addressed. This contributes to theory-building about CE, especially regarding one identified type of business model (Extending Product Value).

The adoption of CBMs in practice is then discussed, drawing on stakeholder research from Papers III and IV. The chapter concludes by presenting an overview of tools and methods that can assist in the development of CBMs. The opportunity to use game-based learning is one approach that is further discussed. Game-based learning tools are reflected upon, including one game-based learning tool called 'In the Loop' that is evaluated in Paper V. These findings contribute to 'theory-testing', by making assertions about the uptake of CBMs and the use of game-based approaches in CE.

4.1 Circular business model conceptualisation

The findings discussed in this section correspond to exploring the first sub-research question (*How can circular business models be conceptualised, and how can they contribute to reducing resource consumption?*). Key findings regarding the classification and conceptualisations of CBMs are presented, and then the findings related to environmental impacts of CBMs are explained. While the findings are theoretical, empirical examples underpin the papers from which this section draws its findings (Papers I and II).

Classifications

From analysis of the CBM database, two main overarching circular business strategies for firms were identified: 'Extending Product Value' business models (EPV BMs) and 'Extending Resource Value' business models (ERV BMs) (Paper I). Apart from EPV BMs and ERV BMs, a third strategy – 'Pay-Per-Use' – is frequently mentioned in CBM literature; it is also called the 'Access/Performance' model (Bocken et al., 2016).

However, this was found to be a sub-category of CBMs, as it is a mechanism for capturing value that can both extend product or resource value. For example, Rype Office offers service-based contracts for their office furniture so they can retrieve them after use; they then refurbish and redistribute the products. BMA Ergonomics rents office furniture and performs refurbishment, while Carpet manufacturer Desso uses smart design (and recycler Aquafill) to recycle the fibres in old carpet tiles and make new textiles from them. The extent to which firms use 'Access/Performance' to postpone or reverse product and material obsolescence is also unclear from existing literature. From a review of the case examples in the CBM database, only a limited number of 'Access/Performance' examples clearly stated what happened to products after use (Whalen, 2017a).

EPV BMs and ERV BMs will now be described in further detail. Table 9 provides examples of each type based on cases from the CBM database. (Appendix A contains additional information regarding the upcoming analysis as well as references used to help compile the upcoming firm descriptions.)

Table 9. Examples from the circular business model database.

Classification archetype	Sample example
Extending Product Value	Agito Medical 'Refurbishment and resale of medical equipment (Kiørboe et al., 2015) Xerox 'Remanufacturing centre' (Florin et al., 2015) SAB Miller 'Bottle return and reuse' (Ellen MacArthur Foundation, 2014)
Extending Resource Value	Worn Again 'Textile recycling' (Ellen MacArthur Foundation, 2013) Freitag 'Re-use of truck canvas as textiles for bags' (Joustra et al., 2013) Grundfos 'Take-back and recycling of pumps' (Guldmann, 2016)

Extending Product Value Business Models

EPV BMs enable firms to postpone or reverse product obsolescence by creating long lasting products or recontextualising, repairing, refurbishing, and remanufacturing previously obsolete products. Firms identified in the CBMs database that contributed to postponing obsolescence emphasised selling high-quality, durable products. For example, Rolex, Patek Philippe, and Vitsoe offer products with a timeless and classic design; these factors were credited with enabling long product life and the avoidance of new consumption. As a result, the products were priced with high upfront costs, reflecting that they are long-term investment pieces. Some firms (e.g., Eastpack and Miele) also offered long-term product warranties and repair guarantees in return for premium pricing. Paper II furthered understanding of EPV BMs that reverse product obsolescence. It showed that *firms with these EPV BMs have varying degrees of* *interaction with products*.[5] A sliding scale of firm-product interaction was introduced that considers the level of interaction between the product and firm (see Figure 3).

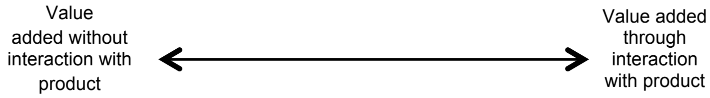


Figure 3. Sliding scale of firm-product interaction.
From Whalen (2019) (Paper II).

Using this scale, *three types of business models that extend product value by reversing product obsolescence were identified: 'Facilitators', 'Redistributors', and 'Doers'.* These types of EPV BMs will now be discussed in further detail. On the left side of the scale in Figure 3, 'Facilitators', reverse product obsolescence without physically interacting with products. By acting as platforms or product market places, 'Facilitators' offer a place where customers can exchange their unwanted products with new customers, either in person or online. Moving towards the right of the scale, 'Redistributors' physically interact with products but do not undertake remedial action. This saves the firm time and money; staff does not need to be capable of performing repair, refurbishment or remanufacturing. Finally, at the right side of the scale, 'Doers' have the most interaction with products, undertaking remedial action on products. These three types are further described in Table 10 according to the three business model elements defined in Section 2.1.

To execute such business models, firms often have multiple value propositions: one for acquiring obsolete products and one for redistributing these previously obsolete products to new customers. Approaches to acquiring obsolete products identified included trade-in credits, share of resale value, or even discounts on new products (Paper II). In the example of Corporate Mobile Recycling, customers were even willing to pay for collection services because of the data security offered by the firm. A few firms also used service contracts as a way to enable product return. In a similar fashion, firms may also have multiple channels: one for collecting obsolete products

[5] EPV BMs were selected for further inspection because investigation of the two main approaches indicated that ERV BMs have received considerable attention in related research areas (waste management, recycling, industrial symbiosis) and CE literature (Allwood, 2014). In contrast, knowledge on EPV BMs is underdeveloped, considering the limited research on repair and refurbishment as noted in Section 1. One exception is remanufacturing research, where a considerable body of knowledge has built up over recent decades (e.g., Ijomah et al., 2004; Sundin and Bras, 2005; Sundin et al., 2008).

from customers and one for redistributing them to new customers (Paper II; Paper III). In some cases, however, the customer is the same. Two examples of this are iRepair and Rype Office. These firms perform repair or refurbishment for product owners in return for a servicing fee.

Table 10. Three archetypes of EPV business models that reverse product obsolescence.
From Whalen (2019) (Paper II).

	Facilitator	Redistributor	Doer
Value proposition	Contributes to EPV by re-contextualising products without direct product interaction. Provides mutually beneficial mediation services to suppliers and customers of obsolete products.	Contributes to EPV by re-contextualising products with minimal product interaction. Provides benefits and services to suppliers and customers of obsolete products, such as collection and reduced costs, respectively.	Provides similar benefits and services to suppliers and customers as offered by Redistributors, but with products that have undergone remedial action. Performance of this action alone may be a main offer to customers.
Value creation & delivery	Activities are associated with product re-contextualisation, and channels are arranged to connect supplier and customer. Value is captured and delivered without firms directly interacting with products. An online platform, such as an online website or app, is often a key resource for these firms to enable brokerage between suppliers and customers.	Activities, channels, partners, and resources are associated with product re-contextualisation and reflect the firm's minimal interaction with products, such as collection, inspection, and repackaging of obsolete products.	Undertakes activities associated with remedial action on products. This involves a high level of product interaction and includes product repair, refurbishment, and remanufacturing.
Value capture	Revenue associated with sales of obsolete products, mainly from transaction fees. Costs are reduced by not directly interacting with products.	Revenue associated with product resale to customers, such as direct sales or commission. Additional revenue may be earned from suppliers, such as through service fees from take-back of obsolete products, or reduced production costs if products can be reused internally. Costs associated with take-back operations and benefits, such as trade-in credits.	Revenue associated with resale of remediated products or service fees from performing remedial action. Remedial action can be a significant operational cost, although this can bring about internal benefits such as lower production costs if components are re-incorporated in new production.
Example firms	Poshmark (Online platform where customers post their unwanted clothing and purchase from others)	Walmart (Repackages and resells video games acquired through a video game trade-in programme)	Caterpillar (Remanufactures cores collected through deposit-system on machinery)
	Clothing Exchange (Organises in-person events where people bring and swap clothes)	Steelcase Solutions (Donates or resells furniture collected through take-back programme)	Norsk Ombruk (Provides take-back services and performs remedial action on white goods)

Regardless of their approach to value creation and delivery, most firms with EPV BMs were identified to capture economic value from the resale of previously obsolete products (Paper II). For example, Blocket earns revenue by charging customers a fee to advertise their products on the platform. Firms such as Philips create new revenue streams by reselling their refurbished products to a new customer base. There were some exceptions to resale as a form of value capture. Firms were identified as being able to internally reuse products, often as a way to reduce costs and new production. For example, instead of being discarded after use, Braiform recollects hangers from their clients' stores; after cleaning and potentially some modification, the hangers are redistributed again for use. Other firms focused on capturing social benefits rather economic value. One, a non-profit called Matsentralen, collects unused food and redistributes it to charities; another, the Danish firm Vestas, used their marketing budget to refurbish wind turbines for use in socio-economic disadvantaged countries.

Extending Resource Value Business Models

These business models focus on using resource waste outputs as new inputs. Although this firm type was not investigated in detail in this research, analysis of the CBM database provides some insights into this archetype. A variety of value propositions were identified. Some firms focused on providing material waste or recycled material to an end client. Firms often created, delivered, and captured value by undertaking recycling and then selling the recycled material to producers or manufacturers to be used again in new production (e.g., Umicore). In a few examples, however, the end client was a waste processor, and the firm created value by providing a service that collected waste. For example, the firm Cirkle used existing logistics to collect different waste streams from households that were then sold to waste treatment firms.

Other firms' value propositions focused on processing material waste and then providing products made from these recovered resources. For example, Interface's Net-Works programme recovered discarded nylon fishing nets and created new flooring from the recycled nylon. Firms such as British Sugar and the Guitang Group focused on using production by-products to create new revenue streams. In the example of Pure Waste Textiles, the firm created and delivered value by selling their recycled material as well as products made from it.

Firms like Plus Pack and Arla Foods captured waste from their own production and used it again internally as input for new production. This often generated internal benefits for the firm, such as lower material input prices or reduction in cost by avoiding landfill fees. Firms can also create and deliver value by converting waste feedstock into energy. In return, value is captured in the form of cost savings and new revenue streams. For example, Kroger grocery store avoids landfill fees by converting its food waste into energy, while Xella Danmark powers its production using energy created from production waste streams – and also sells the excess energy to other firms. Finally, firms were identified that did not engage in the collection and recovery of waste. Instead, these firms contributed to extending resource value by offering products made from recycled or non-virgin material. Apart from appearing sustainable to customers, these business models had a variety of benefits, such as reduced production costs. For example, Philips reduced material costs by using recycled plastic in its Senseo coffee machines. Firms may also be able to charge a premium because of the uniqueness of the final product. Freitag uses discarded canvas from trucks to make new, fashionable bags; as a result, no bag is the same.

Like firms with EPV BMs, collection and take-back schemes may be necessary for ERV firms to acquire waste materials. Multiple firms sometimes formed partnerships to undertake resource collection and recycling activities. For example, in collaboration with I:CO, apparel firm H&M collects old clothing in store for recycling. Another example is soft-drink firm Coca-Cola and plastic producer APPE, which formed a plastic bottle recycling initiative called Infineo.

A morphological chart that summarises the two main approaches is shown in Figure 4. It is also important to point out that EPV BMs and ERV BMs were not found to be mutually exclusive – a variety of firms combine them (Paper II). This allows recovery of materials when obsolete products cannot be resold, as identified in Paper III.

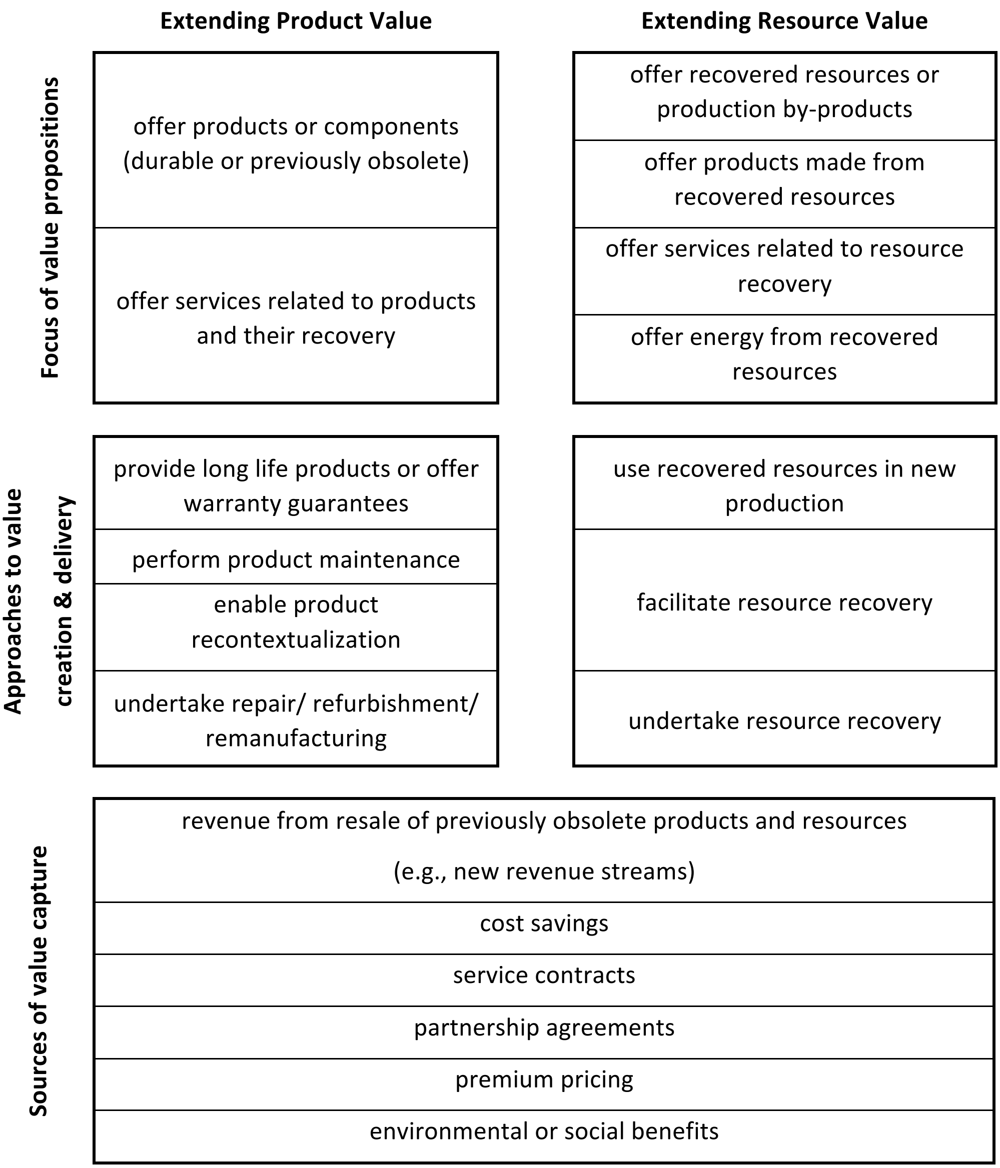


Figure 4. Proposed framework to illustrate circular business models elements.
Developed from an empirical review of circular business models. Note: value capture spans both columns, as similar approaches were identified in both categories.

Environmental impacts of circular business models

This section presents main findings relating to the environmental impacts of CBMs. Many of the environmental benefits of CBMs depend on which primary production processes are avoided when product and resource value is extended (Paper I, Paper II). Given this, Papers I and II identify scenarios where *CBMs may actually impede environmental impact reduction*. CBMs often offer customers discounts on new products or store credit in exchange for their current products (Paper II). While this is a way to acquire obsolete products for resale, it can also drive consumption and sales of new products, thereby increasing production. Paper I addresses ten points to illustrate that CBMs do not inherently decouple economic and resource consumption. In particular, one concern is that of rebound effects at systems level. It is argued that most firms want to avoid cannibalisation of product sales, so they do not actually intend to displace primary production by reversing product obsolescence.

Additionally, carbon savings will be limited if carbon intensive processes are still undertaken when extending product or resource value (Nußholz, Nygaard Rasmussen, & Milios, 2019a). Resource efficiency will also be limited if substantial primary resources such as water and energy are used (e.g., through product cleaning or material recycling). Significant primary material inputs may even be necessary to meet regulatory standards, as in the case of using construction waste in new building projects (Nußholz, Nygaard Rasmussen, Whalen, & Plepys, 2019b).

Paper II specifically investigates which environmental impacts firms with EPV BMs should consider and how they could increase resource efficiency. Table 11 presents the findings according to the three types of EPV BMs. The findings reveal that different environmental impacts are relevant for each firm type. They also suggest higher firm-product interaction has greater resource efficiency potential. For example, 'Doers' are in the position to increase product efficiencies, while 'Doers' and 'Redistributors' can take obsolete products out of circulation if they are past their optimal lifetime.

Table 11. Environmental considerations for EPV firms based on archetype.
From Whalen (2019) (Paper II).

	Facilitators	Redistributors	Doers
Value proposition	• Focus on products that have a relatively high-embedded energy compared to their use-phase environmental impacts. • Encourage 'smart' customer replacement rate. • Consider possible rebound effects from offers, such as monetary gain.	• Monitor energy-consuming products and upgrade/dispose after optimal life. • Encourage 'smart' customer replacement rate. • Consider possible rebound effects from offers, such as monetary gain. • Avoid the use of trade-in credits or other offers that may encourage consumption.	• Monitor energy-consuming products and upgrade/dispose after optimal life. • Encourage 'smart' customer replacement rate. • Increase product efficiencies through repair, refurbishment, and/or remanufacturing. • Consider possible rebound effects from offers, such as monetary gain. • Avoid the use of trade-in credits or other offers that may encourage consumption.
Value creation and delivery	• Consider impacts of firms' offices and related equipment. • Consider product transport distances generated by the business model, and encourage customers to use resource-efficient means.	• Consider product transport distances and design resource efficiency considerations into business model. • Consider impacts of firms' offices and related equipment. • Ensure energy efficiency of physical warehouses and stores.	• Consider product transport distances and design resource efficiency considerations into business model. • Consider impacts of firms' offices and related equipment. • Ensure energy efficiency of physical warehouses and stores.
Value capture	• Consider possible rebound effects from how value is captured, especially for firms that offer both newly manufactured and obsolete products.	• Consider possible rebound effects from how value is captured, especially for firms that offer both newly manufactured and obsolete products.	• Consider possible rebound effects from how value is captured, especially for firms that offer both newly manufactured and obsolete products.

4.2 Adoption of EPV BMs

This section addresses conditions for adoption of CBMs in practice, with an explicit focus on EPV BMs. First, constraints to the adoption of EPV BMs are presented, to address the second sub-research question of RQ1 (*What are the constraining factors for firms looking to adopt circular business models, especially those that contribute to slowing resource loops?)*. These findings draw on existing reuse and remanufacturing literature, supplemented by empirical data from companies. A logical follow-up to identifying constraining factors is to identify aspects that could help overcome these constraints and serve to facilitate EPV BMs. Therefore, to address the first sub-research question of RQ2 (*What are the enabling factors for firms looking to adopt circular business models, especially those that contribute to slowing resource loops?),* potential enabling factors are presented. These factors are identified through 1) analysis of firms' existing business models to point to existing factors that serve as enabling conditions, and 2) mapping of desired policy interventions that could assist in overcoming existing constraints.

This work investigates business models from a company-industry level, investigating the interaction between firms and their surrounding system. Part of this surrounding system is the regulatory framework within which firms conduct their business operations, as these frameworks influence their licence to operate. Both operational and regulatory factors were identified in the research.

Constraining factors

Factors perceived as barriers to EPV BM operations identified through the research on stakeholders in the Swedish/Danish maritime and ICT sectors are shown in Table 12. More information regarding the number and type of stakeholders who responded to these surveys can be found in Section 3 of both Paper III and Paper IV. Constraining factors to adoption of EPV BMs are summarised below, drawing on the findings of Papers III and IV, as well as related existing literature. The studied stakeholders did not perceive all factors previously identified in literature as constraints. One overall finding is that factors appear to be dependent on the geographical location of the operating firm as well as the type of firm and their sector. Factors may also be inter-connected, with one directly influencing another.

One of the main perceived constraints to EPV BMs was *cost*. Costs were mainly associated with additional service offerings and increased operational complexity. For example, *taxes on labour* ranked high on the list of perceived barriers in both Paper III and IV. This is because *additional resources* (skilled labour) are needed to perform remedial services (Kowalkowski & Kindström, 2014). A direct link between the choice to either perform remedial services or send the product to recycling was also identified, as costs associated with remedial action correlate with the time of remedial action due to labour costs (Paper III). Stakeholders in Paper IV also expressed concern about the *availability of skilled labour* that could undertake such remedial actions.

Table 12. Barriers to EPV business operations identified in the research.
Rated 1-5 on perceived size of barrier (5 being the highest perceived barrier). Compiled from Paper III (Whalen et al., 2018) and Paper IV (Milios et al., 2018).

	Maritime Sector			ICT Sector	
Type of barrier	*Shipyards*	*Shipping companies*	*OEMs*	*GIAB*	*INREGO*
Questions asked to both sectors					
The time it takes to repair or remanufacture components and return them to markets	4	3	3	1	4
The design of the components makes it difficult to repair or remanufacture	3	3	3	3.5	2.5
The high tax on labour in Sweden/Denmark, as repairs are labour intensive operations	5	3	5	4.5	4.3
The price of new components is cheaper than repaired or remanufactured	4	4	3	5	4
Waste rules and associated administration	3	2	1	4	1
Customers prefer new, instead of reused or remanufactured components	5	2	3	4	5
Questions asked only to maritime sector					
Lack of specialised skills (lack of labour force) for reuse	5	4	-		
Lack of specialised skills (lack of labour force) for remanufacturing	2	2	1		
One-off large ships (with many small components and work objects) makes it difficult to salvage and repair all types of components (few standard products in all ships)	3	3	2		
Waste infrastructure is not well developed to take-back ship components for reuse	4	4	3		
Finding a suitable customer for the reuse of components	2	2	1		
Questions asked only to ICT sector					
The design of the product				3.5	2.5
Difficult to cooperate/collaborate with other companies and/or stakeholders				3	2
Relationship issues based on your position in the value chain (i.e., tension between OEM and retailer)				5	1
Environmental labels and certification systems do not work for reconditioned products				-	3
Lack of visions and political leadership from the public sector				3	1
Not enough access to products				2	4
The quality of incoming products				2	1 to 4
Difficult to arrange take-back logistics				4	2.5
High costs associated with take-back of products				3	4
Reconditioned products cannot comply with requirements in procurement tenders of organizations				-	4
People do not realise that reconditioned products can be as good as new ones				5	4 to 5
Data security concerns from customers				4	2.5

The research identified *lack of market demand and perceived additional customer benefits* as sizeable barriers to the adoption of EPV BMs. Stakeholders in both Paper III and IV expressed concern about the ability to compete with low prices of new products. The shipyards and designers interviewed in Paper IV also believed that acceptance of previously obsolete products by ship-owners would be limited because they did not stipulate aspects in requirement briefs. In fact, many design briefs explicitly called for new products or components. A similar incentive for new products in (public) procurement bids was identified in Paper III. Customers' time demands also factor into whether components are repaired, reconditioned, remanufactured, or replaced with a new product. For example, engine remanufacturing experienced high demand when lead-time for new engines was two years compared to a few months for remanufactured engines (Paper IV).

The findings suggest that firms face a variety of challenges when acquiring obsolete products. Firms find it *difficult to predict and maintain a sufficient volume of supply* because they are reliant on existing products rather than new production (Paper III; Kissling et al., 2013; Ongondo et al., 2013). *Obtaining this supply incurs costs* relating to reverse logistics, collection, and incentivising the return of obsolete products (Paper III; Ylä-Mella, Keiski, & Pongrácz, 2015), and the *type and quality of the products* may vary (Ongondo et al., 2013). Firms that are not OEMs (gap-exploiters) may be constrained in their ability to perform remedial action because of *lack of access to repair manuals, spare parts, or even IP issues* (Paper III; Berchicci & Bodewes, 2005).

Current regulatory frameworks were perceived as not adequately supporting EPV BMs, with existing policies viewed as hindering the extension of product value by encouraging new production or not clearly prioritising EPV BMs over other approaches. Reuse and refurbishment organisations in the ICT sector may compete with recyclers or manufacturer collection schemes due to lack of legislative enforcement for reuse over recycling (Paper III; Kissling et al., 2013; Ongondo et al., 2013). Safety and environmental standards stipulated by regulatory bodies also appear to have tremendous influence over whether EPV BMs can even be considered. For example, in the case of the shipping industry, Paper IV identified that significant upgrades to obsolete engines would be required for them to meet new NOx emission limits. Regulatory bodies also specify new equipment in many cases (Paper IV).

Finally, customer awareness and perception of obsolete goods were demonstrated as a concern in both Papers III and IV. This lack of awareness affects both demand for and supply of such products. Consumers may be unaware of take-back schemes for obsolete products, which results in lower supply of such goods. Customers may also be unaware or have misconceptions about the extension of product value, which in turn hinders their willingness to consider such options (van Weelden, Mugge, & Bakker, 2016). One particular customer concern identified as relevant to ICT products concerned data privacy (Paper III). Firms may prefer that obsolete computers or mobile phones containing company data be sent to recycling out of data safety concerns. However, firms can take this issue seriously and use certified licensed software to successfully wipe data (Paper III).

Enabling factors

The research suggests a number of factors must be taken into consideration when a firm wishes to implement an EPV BM. EPV BMs often rely on *partnerships*. These partners may help to perform remedial activities (Paper II) by adding additional services where the firm currently lacks such capabilities. One example of this is GIAB (Paper III), which sends phone they cannot repair to mobile phone remanufacturers. Partners may also assist in helping the firm overcome a lack of access to products, as illustrated by GIAB and their reliance on insurance companies for broken phones (Paper III). Although firms with EPV BMs can spend significant time training their partners' sales personnel, this awareness has been found to lead to increased supply to EPV firms (Paper III).

Monetary value was found to be a key part of the value propositions for EPV businesses to help them obtain obsolete products. Paper II identified a number of monetary mechanisms used by firms to directly compensate customers for their used goods. These included various types of revenue sharing schemes, where customers share cost savings with the firm. In the study of ICT firms (Paper III), economic benefits were the main form of value for GIAB's insurance companies – helping them to save money by reducing insurance claims by 30%. Stakeholders in the maritime industry (Paper IV) also emphasised the perceived benefits to the customer in economic terms, such cost savings.

Other incentives for customers to supply obsolete products were identified, including *services* that aligned with customer needs and concerns. For instance, one of INREGO's selling points that enables them to acquire obsolete products is a promise to their business customers that they will handle their data in a secure way. This is observed in their services: from pick up in secure and traceable boxes, use of data wiping software, and verified certificates after the data has been wiped. To address potential issues related to poor quality of supply, INGREO also chose to focus on a specific customer segment where product quality is higher (i.e., business-to-business (B2B) rather business-to-consumer (B2C)) (Paper III).

Optimised reverse logistics and processes can help to streamline the return process and reduce costs. INREGO focuses on collecting large numbers of products from one location rather than arranging one-off collection. Existing logistics services (e.g., standard post) are also used where possible, as illustrated by GIAB; however, as found in Paper II, this is often dictated by product size. Once products are received, both companies had *clear sorting procedures* for how to make time-efficient decisions about which products to remediate or recycle; this is crucial in keeping costs low. Firms can also *redesign products* to enable easier remediation, thereby reducing remedial action time and costs. This would enable such activities to be more economically beneficial for firms (Paper IV), but mainly applies to firms that can influence design (i.e., OEMs). Access to spare parts and product repair manuals can also help firms undertake remedial action. Again, OEMs also have an advantage over gap-exploiter firms operating in this category, with readily available spare parts and access to product repair manuals (Sabbaghi et al., 2017).

Desired policy measures identified from the research conducted with stakeholders in the ICT and maritime sectors are shown in Table 13. (See Section 3 in Paper III and Paper IV for more information about number and type of stakeholders who responded to these surveys.) These include *reduced labour taxation* for those undertaking remedial action on products, which would make EPV BMs more competitive against new production (Paper III, Paper IV). However, it appears a VAT reduction on previously obsolete products would not affect the maritime sector, as internationally operating vessels are exempt from VAT (Paper IV). To address customer concerns about previously obsolete products, product warranties and quality guarantees backed by *reuse standards* could help inform customers and ensure qualities (Paper IV). This would help guarantee that previously obsolete products meet technical specifications and increase customers' trust and acceptance of EPV businesses.

Table 13. Policy interventions to support EPV business identified in the research.
Rated 1-5 on priority of desired intervention (5 being the highest priority). Compiled from Paper III (Whalen et al., 2018) and Paper IV (Milios et al., 2018).

	Maritime Sector			ICT Sector	
Type of barrier	*Shipyards*	*Shipping companies*	*OEMs*	*GIAB*	*INREGO*
Questions asked to both sectors					
Better waste infrastructure for collection for reuse	5	3	3	5	5
Changes in the original design of the products (e.g., for ICT: modularisation, increased durability, and improved quality; for maritime: favour design of ships for modularity, deconstruction and reuse at component level)	3	3	5	5	2
Reduce tax on labour for reuse and remanufacturing	5	4	5	4	5
Reduce VAT for repaired (second-hand) and remanufactured components	2	2	3	5	3
More information to customers that remanufactured components are as good as new (good for the economy and for the environment)	4	4	5	5	3
Questions asked to only maritime sector					
Make eco-design and durability criteria more demanding for new ships	4	4	4		
Encourage the use of Environmental Product Declarations (EPD) to facilitate the assessment of products and material sustainability	3	3	1		
Mandatory national targets for reuse/preparation of reuse in the marine sector, by government	3	3	3		
Questions asked to only ICT sector					
Make waste legislation less complex and reduce administration				4	1
Receive more information about the functionality from the previous user				2	1
Set up online platforms to coordinate supply of used ICT with demand for reconditioned ICT				4	-
Taking reconditioning into account in eco-labelling and certification systems				5	1
Quality certification system for reconditioned and remanufactured products				2	3 to 4
Increase prices on raw materials to raise the price of new ICT				5	4
More visions and leadership from politicians and the public sector				5	1
More ambitious targets and progressive use of public procurement in the public sector to promote reconditioned goods				5	4 to 5
More functional procurement in the public sector				5	3 to 5
Change rules and practices in municipal procurement (e.g., that new ICT equipment is bought every 3rd year)				3	-

4.3 Tools for designing circular business models

This section continues to address the second sub-research question of RQ2 (*What tools and methods play a role in the development of CBMs?)* by identifying tools and methods available for designing CBMs and reflecting on how these approaches can contribute to the development of CBMs. A game-based tool was selected for further testing to help assess its contribution as a tool to support the understanding of CE concepts and different business model strategies.

Existing circular business model methods and tools

In recent years, a number of tools and methods for CBM innovation have emerged (Pieroni, McAloone, & Pigosso, 2019). Due to its relatively recent emergence as a research field, researchers and practitioners have looked to disciplines related to CE for tools that can be used in CBM innovation. This includes eco-design tools such as those focused on recycling and reuse (Chiu & Chu, 2012) as well as business models tools focused on sustainability (Upward & Jones, 2016) and Product-Service Systems (Pigosso & McAloone, 2015; Tan et al., 2010). Even generic and traditional business model innovation tools, such as the business model canvas of Osterwalder and Pigneur (2010) and the Lean Startup approach described in Ries (2011), are used in practice (CBOOT, 2019). Tools and methods may be quantitative or qualitative (Bovea & Pérez-Belis, 2012) and take various forms, including serious games, cards, frameworks, and checklists.

These *tools support three main phases for CBM innovation*: 1) Ideate and Design 2) Implement and Test and 3) Evaluate and Improve (Bocken et al., 2019). Tools may take a broad perspective on the CBM development process. For example, the tool developed by Nußholz (2018) reflects on the entire product lifecycle and how value can be captured numerous times from a product throughout its lifecycle. Other tools focus solely on one specific use such as product ideation, creating customer value, or supply chain management (Baldassarre, Calabretta, Bocken, & Jaskiewicz, 2017; Haines-Gadd, Chapman, Lloyd, Mason, & Aliakseyeu, 2018). Game-based approaches have also received attention as organisations look to integrate sustainability in their operations and support the 'fuzzy front end' of sustainable product and business model innovation (Whalen & Kijne, 2019). This interest in game-based approaches has also carried over into CE-related literature (Kirchherr & Piscicelli, 2019; Whalen, 2017b).

Game-based approaches complement and bring a fresh, new perspective to CBM innovation, especially in the 'Ideate and Design' phase. The interaction and engagement levels achievable through games (Connolly, MacArthur, Stansfield, & McLellan, 2007), as well as their assistance with critical thinking (Ke, 2009), are attractive to those wanting to engage others in CE innovation and depict the complexity of CE. Characteristics of game-based approaches such as time-compression (Michael & Chen, 2006) are also well suited to CE. By simulating possible outcomes and allowing players to experience the consequences of certain actions, otherwise unperceivable long-term effects may become tangible. The serious game Risk & RACE (Whalen, 2017b), for example, is designed to introduce CBMs concepts such as cash flow, fixed cost, reverse logistics, and Product-Service Systems, to entrepreneurs and students. Another serious game tool called 'In the Loop' is intended to engage and assist with planning and modelling complex systems and introduce participants to circular business strategies (Paper V).

Evaluation of methods and tools

Despite the growing number of CBM tools and methods, recent studies suggest that research in this area is underdeveloped (Bocken et al., 2019). Tools that offer quantitative assessment of the environmental aspects of CBMs are lacking, as most examples only go so far as to provide thought-provoking qualitative question sets (Manninen et al., 2018). Many tools have not been empirically tested and others are not widely used in practice (Bocken et al., 2019). To address this lack of evaluation and assessment, the 'In the Loop' serious game was selected for further study (Paper V).

'In the Loop' is a tool that aims to create awareness of CE business strategies using game-based learning (Whalen & Peck, 2014). In terms of assessing 'In the Loop' as a tool for creating awareness of CBMs, the findings from Paper V suggest it is a suitable tool for use in the 'Ideate and Design' phase of CBM innovation and such serious games may be used to introduce participants to circular business strategies and concepts.

'In the Loop' provides players with an understanding of the motivations for CBMs from a resource perspective, by illustrating the driving forces behind material criticality (Paper V). Participants reflected on the importance of systems thinking and interconnections between business, environment, and supply chains. The tool also encouraged players to recognise feedback loops between different actors and take a systems-oriented approach, which is necessary when designing CBMs. However, there is room for improving the visibility of certain circular business strategies in the game. For example, the participants mentioned recycling more frequently than other circular business strategies, perhaps in part due to the focus on materials in the game (Paper V). Table 14 provides a sample of these descriptions.

Table 14. Quotes relating to circular strategies.
Select examples from student reflections after playing the 'In the Loop' game (Paper V).

Circular strategies

Some participants described multiple circular strategies along with their anticipated advantages.

> "Manufacturers of today could gain an advantage in the future by designing with recycling/reuse/remanufacturing in mind and/or adapting their production systems so that they can handle both newly produced and used materials or components." [RMPP16]

> "After this gamely experience I will be concentrating more on the 'R' words – recycle, refurbish, reduce, reuse etc., and look for alternatives because one day we will be left with no raw material to produce anything." [SP]

> "We need to produce products in such ways as to make them easy to recycle and remanufacture. I also understood the need to try and manufacture products using 'more accessible' materials such as steel and aluminium rather than cobalt and gallium." [SP]

> "Combined with an effort to control the gathering of the recycled material (for example switching to a more service oriented business model) a company could theoretically become virtually independent of suppliers." [RMPP16]

Recycling only

Not all participants mentioned circular strategies other than recycling.

> "[The game] actually reveals two ways of material handling at the end of PLM: either discarding or recycling. By discarding materials, companies don't pay money but lose the control of material in the long term. ... Recycling materials by company itself cost a lot. However, the company is able to gain this material at the time it wants at lower price. More importantly, the company now becomes a supplier and influences the material market." [RMPP16]

> "Hopefully the recycling trend will increase and [they] will develop substitutions for the most needed [materials]. I think it is important for people all over the world to understand the problem. It shall be obvious to recycle and a part of people's life style." [RMPP15]

> "It seems like companies that recycle are most likely able to deliver in time, because they can affect their own supply chain in a different way and are not that dependent on what happens in the market of raw materials." [SP]

> "Finally, here is an opportunity to use the resources of the earth wisely to fulfil present generation's needs as well as assure that there are enough resources for future generations to live upon. I strongly believe that this strategy would encourage companies to strive towards using more recyclable materials, as well as awakening them to manufacture products for easier disassembly which enhances scraps recovery." [RMPP15]

Different terminology was also used by each set of cohorts. This was attributed to different course-specific terminology and suggests games can be used to reinforce CE business model concepts that have been previously introduced to participants. Finally, the use of games in CBM innovation could provide a different dimension to design and innovation, by encouraging hands-on thinking and reflection, compared with quantitative tools such as life cycle assessment. As noted in Paper V, participants reflected on the game from both their private and professional viewpoints, and many were emotionally stimulated during the game as well as during reflection.

5. Discussion

This section discusses the main findings of the research and how they relate to existing research. First, conceptualisations of CBMs are reflected upon, then the constraining and enabling factors for EPV BMs are discussed. The section concludes with a reflection on how the implementation of CBMs can be supported.

5.1 Characterising circular business models

Classifications

Unlike many previous CBM categorisations (e.g., Bocken et al., 2016; Lacy, Keeble, & McNamara, 2014) the findings explicitly exclude the 'Access/Performance' model as a main CBM category. This is because the analysis demonstrates that the key characteristic of the 'Access/Performance' model is 'Pay-Per-Use', which is actually a mechanism for value capture that can contribute to both extending product or resource value. 'Access/Performance' models alone are not inherently circular – additional circular value creation and delivery activities are required to ensure extension of product and component life (Paper I; Urbinati et al., 2017). Recent work by Lüdeke-Freund et al. (2018) lends supports to characterising this feature as a method for capturing value and excluding it from main categorisations. Figure 4 also merges 'Classic Long Life' under 'Extending Product Value' and 'Industrial Symbiosis' under 'Extending Resource Value', as they can be argued to be tools for extending product and resource value, respectively. 'Encourage Sufficiency' is also excluded, as most identified business model dimensions for these cases overlapped with business model dimensions from other archetypes, and the methods identified as encouraging limited purchases related more to marketing (Paper I; Whalen, 2017a).

As illustrated by the follow-up research on EPV BMs in Paper II, the proposed classification of EPV BMs and ERV BMs can be further sub-divided in many ways. Because of this, the categorisation might be viewed as too general. However, it could also prove useful for firms to keep two simple guiding principles in mind when developing CBMs. Instead of attempting to match and remember a number of possible archetypes and their definitions (e.g., Circular Supplies; Resource Recover;

Product Life Extension; Product as Service; Sharing Platform (Lacy et al., 2014)), firms need only start by asking, 'How can we contribute to Extending Product or Resource Value?'.

One reoccurring theme across traditional and sustainable business model literature is that archetypes are often not mutually exclusive (Bocken et al., 2014; Boons & Lüdeke-Freund, 2013; Osterwalder et al., 2005). In such cases, morphological charts have been applied to findings in related research areas (e.g., the typology of service-minded businesses described in Lay et al. (2009)), because they are a useful way to organise different possible combinations of features. While this was the main reason behind depicting the findings as shown in Figure 4, the figure does not attempt to provide an exhaustive overview of possible CBM arrangements. However, studying these various configurations further could potentially assist CBM innovation by providing insight into ways for firms to create, deliver, and capture value. Since the framework was developed, Lüdeke-Freund et al. (2018) has presented a similar morphological chart for CBM design options. Future research could compare the usefulness of both approaches as tools to help assist the development of CBMs.

The analysis of EPV firms suggests three main archetypes of EPV BMs that reverse product obsolescence, based on increasing degree of firm-product interaction: 'Facilitators', 'Redistributors', and 'Doers'. As far as the author is aware, this is the first time that such models have been characterised by their level of firm-product interaction. The research indicates that the costs and capabilities of these EPV BM firms correlate with higher firm-production interaction. For example, Distributors do not need staff to be capable of performing repair, refurbishment or remanufacturing. However, these conclusions should be further studied as they depend on contextual factors including product-type, the firm's strategy, and the system in which it operates. Similar follow-up research could also be done for ERV BMs or EPV BMs that postpone product obsolescence as this type of research was only undertaken for EPV BMs that reverse product obsolescence. The initial review of ERV BMs suggest that, like EPV BMs, there are multiple ways firms can approach creating, delivering, and capturing value in ways that align with extending resource value.

Anticipated contributions to reduced resource consumption

Overall, the findings suggest CBMs focus on maximising efficiency, rather than decoupling resource consumption from economic benefits. In line with Zink and Geyer (2017), the research highlights concerns about the rebound effects of CBMs. For example, offering discount coupons to encourage obsolete product take-back could actually lead to increased consumption. As part of this, the research argues many firms do not want to avoid new production. For example, the customers of previously obsolete products are often different to those who purchase new products, because firms do not want to cannibalise new product sales. As such, it is likely new production will not be affected by sales of the previously obsolete product.[6]

Paper II also introduced the business pricing strategy of 'global optimisation' to the field of CBMs, based on the work of Ovchinnikov et al. (2014), who show that lowering the price of new products when firms undertake remanufacturing could actually lead to increased new production. This is attributed to overcoming one of the constraining factors to EPV BMs noted in this research. As firms are limited in their ability to undertake EPV BMs by the availability of obsolete products (Paper III), Ovchinnikov et al. (2014) conclude that firms may increase production to increase the supply of obsolete products and the number of obsolete products available for resale. However, global optimisation pricing is only one possible pricing strategy, and previous research suggests it may not be a common strategy in practice (Ovchinnikov, 2011). Such pricing may also be beneficial if it enables firms with products designed for circularity to increase their market share and compete against less sustainable products.[7] It appears that no single pricing strategy is inherently 'bad', although strategies should be considered and assessed on a case-by-case basis when considering the environmental impacts of EPV firms.

The research proposes that certain actions by OEM firms to implement CBMs could have little effect on reduced resource consumption. Considering these findings, the author would argue for a shift *from a focus on firm level to a focus on implementing change at a systems level*. However, the author recognises that previous work has potentially focused on CBMs at firm level implementation because of the difficulty and lack of tools to study these approaches at a systems level (Korhonen, Nuur, Feldmann, & Birkie, 2018). One initial step may be to reflect on the type of CE we would like to create.

Recently, two possible CE types have been characterised (Webster, 2019). One is 'Centralised Circularity', characterised by material control and in-house research and design where companies recover their own brand goods and enable this by using proprietary technology. The other is 'Distributive Circularity', which is more bottom-up and network based. Resources are distributed, and there are open standards, data, and knowledge. Findings from this research suggest a tendency towards the first CE type, given the identified license-to-operate barriers for gap-exploiters identified in Paper III related to IP and availability of spare parts. This idea is further substantiated by Haines-Gadd and Charnley (2019) who propose stability and control as one of the five intangible forms of value that is created through circular business. It is

[6] There may still be environmental benefits, especially if the consumer would have purchased a new product instead of the previously obsolete one.

[7] The author has attended circular economy workshops with Dutch firms, where this strategy was investigated as a way for firms to compete on the market with lower-price point firms.

recommended that firm motivations and the potential for each type of CE to decouple resource consumption from economic growth be further explored.

If firms wish to decouple resource consumption from economic growth, it is also recommended that they incorporate existing components or materials into production (such as through remanufacturing or recycling) while offering previously obsolete products to other customer segments. This could contribute to displacing resource consumption in primary production without cannibalising sales. Addressing consumption and incentivising people to consume less could also have a significant environmental impact, such as the research done on sufficiency business models by Bocken and Short (2016). Although it is not directly considered to be part of the CE concept (Ghisellini et al., 2016), sufficiency has a direct impact on reduced consumption. However, like the environmental considerations shown in Table 11, it is unlikely that most companies would be willing to undertake such activities if they interfere with profits. Paper I calls for the perusal of a 'higher efficiency' that sees public policy taking an active role to encourage extension of product and resource value that is coupled with environmental impact reduction. In Section 5.3, this idea is further explored and specific policy measures that could encourage the extension of product value are identified.

The research also theoretically linked increased firm-product to increased resource efficiency of EPV BMs. Additional empirical research should be undertaken to verify this further. However, in a study of one firm that could be classified as a Doer, André et al. (2019) confirmed that one significant environmental benefit of these firms is ensuring correct end-of-life disposal and directing products to state-of-the-art recycling. (In fact, they found the environmental impacts of activities related to product remediation were negligible, despite the studied firm conducting operations at a large geographical scale.)

Finally, as noted in Paper II, the research suggests that firms' potential to contribute to reduced resource consumption differ according to the type of firm. Gap-exploiters may actually have less potential than OEMs to significantly contribute to reduced resource consumption, as OEMs control production and are therefore more likely to displace new production by reusing obsolete components or products. They also have influence on the design of products and access to spare parts, which can help enable EPV BMs. As previous research has advocated the use of third parties in the creation of closed loop supply chains (e.g., Kumar & Putnam, 2008; Savaskan, Bhattacharya, & Van Wassenhove, 2004), one possible way to increase gap-exploiters' resource reduction would be through collaborative partnerships with OEMs.[8] This would allow gap-exploiters access to spare parts, design manuals and obsolete products. At

[8] The case of Norsk Ombruk is an example of one such partnership. The Norwegian gap-exploiter remanufactures white goods in partnership with OEMs (Townsend, 2018).

the same time, OEMs could reduce risk, such as by not needing to invest in infrastructure for collection or remedial action capabilities.

5.2 Constraining and enabling factors for circular business

The research provides considerable insight into the constraints facing implementation of EPV BMs. It was found that these factors are highly context-dependent, especially in terms of sector, geographical location, and firm type. No single factor can be attributed as the main reason, but some factors appear to be more important than others. Perhaps unsurprisingly, the research shows that one of the most important considerations for firms is cost. Considering the low price of newly manufactured products, it is a challenge for firms to take the costs of remedial action into account and still remain competitive against new products. For example, the time it takes to perform remedial action is directly linked to labour costs; firms in the geographical location where this research took place face some of the highest taxes in all of the EU. These institutional factors could help explain some of the differences between results of previous studies, where costs of labour were not found to be the most significant barriers to EPV BMs (Kissling et al., 2013).

Recent work by the author (Nußholz et al., 2019b) and others (Kaddoura, Kambanou, Tillman, & Sakao, 2019) corroborate this research's findings that costs are still a major concern for companies and a significant cost item is labour. These new studies suggest that the economic benefit of extending product value is not as great as the environmental benefits. While the production phase is usually the most 'costly' from an environmental perspective, it is often not the most 'costly' from an economic perspective as significant monetary costs (mainly linked to labour) are incurred when reversing product obsolescence. Companies could improve economic benefits by finding ways to reduce these costs, such as by designing products for easy repair. Automation and standardisation of these 'reverse' processes could also help bring costs down, but this might reduce the potential social benefits of a CE, such as job creation.

This thesis suggests firms are reluctant to implement EPV BMs if they do not perceive that it will provide a customer benefit. These findings are in line with new research on circular value propositions that emphasises the importance of shaping a value proposition that aligns with environmental goals without comprising customers needs (Hankammer, Brenk, Fabry, Nordemann, & Piller, 2019; Tunn, Bocken, van den Hende, & Schoorman, 2019). In the maritime sector, there appears to be limited initiative from ship-owners to ensure the extension of product value that goes beyond the upkeep and operation of their ships. However, in the ICT sector, firms such as GIAB and INREGO have identified a clear benefit to customers and constructed a value proposition that aligns with these customers needs. This is a 'win-win' solution for both parties.

There is evidence to suggest that firms can overcome constraining factors through careful construction of their business models. GIAB's business model directly addresses customer concerns previously identified in literature as barriers to repair operations: cost, time, and convenience of repair (Sabbaghi et al., 2017). GIAB avoids having to make accurate estimates of repair costs ahead of time because they invoice the insurance partners after the process has been completed. They make it convenient for customers and avoid significant time delays as, instead of undertaking repairs in-house, they often replace customer's phones with refurbished models of the same type. These phones are then sent to repair and refurbish partners, sometimes in a different country where labour costs are lower, which also addresses another issue of cost.

It might be argued that such recommendations are not relevant to incumbents and only applicable to start-ups that have the chance to start from 'scratch'. However, companies could use concepts such as 'intrapreneurship' and 'design thinking' to develop circular value propositions and business models within their organisations.[9] The review of EPV BMs conducted in the research and EPV BM framework in Paper II also shows that OEMs can and do contribute to slowing resource loops in multiple ways.

5.3 Supporting the adoption of circular business models

In implementing CBMs, the findings appear to align with recent research that stresses the importance of collaboration between firms (Bocken, Schuit, & Kraaijenhagen, 2018; Brown et al., 2019). Many of the firms studied in Paper II and both firms in Paper III had partnerships that enabled direct access to obsolete products. It is presumed that this would also translate to ERV firms as, instead of needing partnerships to acquire obsolete products, they would need them to acquire used resources.

The findings also confirm other work (e.g., Stahel, 2019), which highlights the role of governing bodies in helping to assist firms in the transition to a CE. These include making market conditions more suitable for EPV firms, by reducing VAT on repair services and addressing waste collection regulations to increase the competiveness of

[9] Intrapreneurship is a term introduced by Pinchot (1985) that encourages entrepreneur-like thinking in corporate environments. Design thinking is a process that encourages customer-driven experimentation (Liedtka, 2018).

using previously obsolete products. In fact, some countries have already begun adopting identified measures for certain product groups (Wilts, Bahn-Walkowiak, & Hoogeveen, 2018). At the same time, a gap between promises and action was also identified, with policymakers emphasising the importance of CE (e.g., European Commission, 2015), but not updating tendering calls and procurement criteria to reflect these desires.[10] As found in Paper IV, previously obsolete products might even be explicitly stated as undesirable. This can be because of a perceived quality and reliability concern between new and previously obsolete products.

Similar to the conclusions of Vermunt, Negro, Verweij, Kuppens, & Hekkert (2019), the findings indicate that polices aimed at stimulating CBMs should consider the contextual differences between firms, including sector and geographical location, as it was observed that not all policy interventions mentioned in the context of CE would have the desired outcomes. For example, VAT reductions, which are proposed as a way to increase uptake of CBMs, would have limited effect in the maritime industry as the sector is governed by different regulations due to its global scope. Paper IV goes as far as to suggest that only through *mandatory regulation*, does it appear that EPV BMs can be further enabled in the maritime industry, as voluntary actions by single stakeholders are not successful because of the highly competitive nature and global complexity of the sector. Here, the *creation of a standards body* to oversee and ensure quality of previously obsolete products could be a potential way to address increased uptake of CBMs in the maritime industry. Environmental standards or metrics that assess the environmental benefits of CBMs could also be created; this would be a way to check that outcomes match the intended goals.

Evaluation of the 'In the Loop' game suggests the use of game-based learning as one way to support education about CBMs. This research is particularly noteworthy, as few CBMs tools have been evaluated in practice (Bocken et al., 2019). Evaluation of the game proved to educate participants about drivers for CBMs, especially resource supply constraints and material price volatility. It was shown that the participants related the game to their private and professional viewpoints in an effort to contextualise the game, which could be helpful to keep in mind when developing new CBM tools.

Following the research on 'In the Loop', some suggestions for 'Ideate and Design' phase tools can be made. First, games can be used to help assist education and awareness about CE and CBMs, but be aware that participants look to *contextualise* their experience based on previous knowledge (Paper V). Because of this, knowledgeable facilitators should be present when tools are used, to assist participants

[10] However, this has the potential to change in the near future for computers and monitors. Revisions to EU Green Public Procurement criteria will emphasise a life-cycle approach (European Commission, 2019b).

in drawing correct conclusions and ensure the outcomes are aligned with intended objectives.

A second suggestion for future updates to 'In the Loop' can be made from linking reflection on the gameplay to the research findings that highlight the role of partnerships in building CBMs. Recent research suggests new skills and capabilities are needed to help facilitate the creation of these partnerships. This includes the ability to collaborate and undertake shared problem solving (Kirchherr & Piscicelli, 2019; Sumter, Bakker, & Balkenende, 2018) as well as the ability to share risks and rewards and foster a collaborative culture and mind-set (Brown et al., 2019). It is recommended that CE tools and methods incorporate such skills and capabilities into their learning objectives. In the case of the 'In the Loop' game, adjustments could be made to further encourage the development of such skills. Although it is not explicitly mentioned that participants cannot collaborate, it is the author's experience that participants have a natural tendency to compete against each other and there is limited incentive in the gameplay that reinforces or encourages collaboration. Future studies on how CBM partnerships are initiated and facilitated could also lead to easier arrangement of such collaborations and further support the development of CBMs.

6. Conclusions

This research explored the growing discourse in academia and industry surrounding CBMs and contributes to this discourse through theoretical and empirical research. CBMs were presented as a way for companies to capture economic value by decoupling resource consumption, thereby benefitting both business and the environment. The research confirms that CBMs can be environmentally and economically beneficial, if overall system effects are considered when these models are designed and implemented.

Firms can contribute to a CE in two ways: they can either '*Extend Product Value*' or they can '*Extend Resource Value*'. Three main archetypes for EPV BMs that reverse product obsolescence were also identified (in increasing degree of firm-product interaction): 'Facilitators', 'Redistributors', and 'Doers'. While these models are often viewed as more economically viable and environmentally beneficial than ERV BMs, there is limited uptake of EPV BMs in practice and surprisingly limited research on firms who undertake these models.

Why do not more firms implement circular business models?

Due to the limited geographical scope, number of firms studied, and focus on EPV BMs, the extent to which this work can be generalised to other contexts with different institutional factors or even other CBMs (e.g., ERV BMs) remains unclear. However, the research provides a closer look at CBMs in practice and suggests CBMs have more inherent risks than traditional linear models. From studying EPV BMs in the ICT and maritime sectors, one main risk identified is higher costs of operations (Paper III and IV). Many of the activities associated with EPV BMs (such as reverse logistics and repair) are attributed to labour costs, which in the area where this research was undertaken are quite high.

Another risk is lack of market demand. Unless EPV BMs are perceived to provide a customer benefit, firms are not willing to change from business as usual. This not only includes demand from consumers and business customers but also governments, as a gap was identified between policy intentions and action in terms of the support for EPV BMs in tendering processes. Partnerships and collaboration are also needed between firms, but as Paper III points out, developing such working relationships can be time intensive. Other factors such as unpredictable supply and limited control over quality of products also make it difficult for firms to make a business out of extending product value. However, there are a number of ways these factors can be supported.

How can the adoption of circular business models be supported?

From studying firms that have implemented EPV BMs, the research suggests the main driver for adoption is market demand. However, the research supports the idea that firms themselves can make adopting EPV BMs more competitive and cost-effective by refining their business offering and identifying market opportunities. There is evidence to suggest that successful EPV firms are able to find a 'win-win' solution and configure a business model in such a way that aligns extending product value with customer needs. For example, INREGO and GIAB found gaps in the existing market; their choice for customers and offerings also coincided with avoiding the typical 'constraining factors' of EPV firms, such as time of repair and poor quality of obsolete products.

As shown through the framework for categorising EPV BMs that reverse product obsolescence (Table 10), certain EPV BMs may also pose less inherent risks for firms. For example, 'Facilitators' do not perform remedial action, so they do not need to invest in skilled labour that can repair products; it is hypothesised that these models would be less costly to implement than 'Doer' models that would require such labour.

The research also highlights the importance of policy in the uptake of EPV BMs (Papers I, III, IV). Policymakers should consider the impacts that proposed legislative measures would have on firms, due to identified contextual differences including firm type (OEM, gap-exploiter), customer base (B2B or B2C), and their geographical scope of operations (national vs. international).

It is concluded that policy has two main roles. First, it can make market conditions more favourable for EPV BMs. One example is by increasing the competitiveness of previously obsolete products in relation to newly manufactured products by removing VAT on the former. Some countries have already adopted such a measure for certain product groups. Other examples include standards to alleviate concerns from customers and guarantee quality or public procurement requirements to increase market demand for previously obsolete products. Second, it is argued that public policy must play a role if we want to ensure that environmental benefits result from adoption of CBMs. Although CE advocates call for the adoption of CBMs to reduce resource consumption, it was found not all CBMs decouple resource consumption from production.

Finally, there appears to be no shortage of tools and methods to address CBM development. Examination of these tools highlighted three significant gaps. First, it is unclear how many of these tools are actually used in practice. Studies in related fields including eco-design conclude that the existence of tools does not guarantee adoption by users (Baumann et al., 2002; Rossi et al., 2016). However, to the best of the author's knowledge, a review of application of tool usage in practice has not been undertaken for CBMs. Second, many of the identified tools have not been evaluated in practice, so their contribution to supporting the adoption of CBMs is untested. Third, most identified tools were of a more generic nature rather than focused on a specific sector or aspect of CBMs.

In testing one tool, 'In the Loop' (Paper V), it was concluded that game-based learning approaches can be used to help support the development of CBMs. In particular, they appear well suited to the 'Ideate and Design' phase of designing CBMs, as they encourage active reflection and experiential learning. However, such games must be tested against their learning objectives, and participants' learning improves if an experienced facilitator guides the use of the tool and conducts a guided reflection afterwards.

6.1 Contributions of the research

The work contributes to the growing discourse on CBMs in academia and industry through theoretical and empirical research. This section presents a summary of main contributions to interdisciplinary sustainability research, and in particular, emerging work in CE. The study focused on an overlooked aspect of CE (product life extension) and how this is embodied in firms through EPV BMs.

The research has contributed to theory-building by increased understanding of how firms may arrange their business models to contribute to a CE. Building on previously limited research on EPV BMs, a *framework for how firms can contribute to extending product value* (compiled from secondary empirical data from a database of 152 CBM case examples in practice) has contributed to increased understanding of how firms' business models can create, deliver, and capture value in ways that contribute to slowing resource loops and reversing product obsolescence. It also shows that even within previously identified classifications, business operations can be heterogeneous (Paper II).

The research has linked CBMs to their environmental implications based on conceptual and existing empirical studies, proposing *ten ways CBMs lead to increased resource consumption, or rebound* (Paper I). As such, the work makes a theoretical contribution by critically reviewing previous assumptions about the environmental benefits of CBMs. By scrutinising the subject of CBMs from an environmental perspective and focusing on the systemic implications of adopting these models, the research also makes a contribution to business research, where recent work on CBMs has thus far mainly focused on managerial aspects and accepted their environmental benefits without significant questioning (e.g., Hopkinson, Zils, Hawkins, & Roper, 2018; Zaoual and Lecocq, 2018).

The work contributes to theory-testing by conducting applied research on CBMs. Empirical case studies in the ICT and maritime sectors provide insight into the adoption of EPV BMs in practice. By studying two Swedish EPV firms conducting repair and refurbishment of ICT, the research identified *constraining and enabling factors for ICT firms that undertake EPV BMs* (Paper III). Research conducted with ten stakeholders in the Danish/Swedish maritime sector provided insight into the *constraining as well as enabling factors relating to the adoption of EPV BMs in the maritime sector* (Paper IV). The immediate outcomes are case-specific, so generalisation should be used with caution, but the research does supplement the few existing studies focusing on reuse, repair, and refurbishment firms' operations, especially those of gap exploiter-type firms and the maritime sector.

Finally, the *validation of the 'In the Loop' tool* through analysis of 71 student reflections (Paper V) contributes to existing research on CBM tools by furthering knowledge on the assessment of such tools in practice. This helps to address a current and significant limitation of most such tools, which is that they are not assessed after development. Such work has relevance beyond CE research applications. For example, the research presents a documented methodology that could be used by researchers to assess similar tools. This could help generate further knowledge about the applications and usefulness of game-based learning.

6.2 Implications for practice

The research has identified recommendations for both industry practitioners and policymakers. These implications will be discussed further in this section, first for practitioners and then for policymakers.

The research shows that *CBMs are not automatically better for the environment than linear business models*, by identifying situations where CBMs models could actually lead to increased production and consumption. To increase the chance of displacing resource consumption in primary production and achieving the decoupling goals of CE, it is recommended that firms use a combination of strategies that extend product and resource value. For example, firms can work to postpone product obsolescence by designing durable products; they can also incorporate existing components or materials into production (such as through remanufacturing or recycling) alongside offering previously obsolete products to other customer segments to increase the chance of displacing resource consumption in primary production.

This thesis suggests *there are significant opportunities for maximising value in our current system*, starting by investigating how product or resource value could be extended in an existing situation. How can a 'win-win' solution be created that aligns customer needs with extending product or resource value? Firms investigated in this research were able to identify a shared problem or opportunity around which to build a business case by drawing on close collaborations with partners. This does not only apply to entrepreneurs or start-ups. The review of EPV BMs and resulting EPV BM framework (Table 10) show that incumbent firms can and do contribute to slowing resource loops in multiple ways. The author suggests one possible way for incumbents to approach this is by using intrapreneurship or design thinking to help develop circular value propositions within their organisations.

A number of findings can also assist with this CBM innovation. First, the EPV BM typology (from Paper II) and morphological chart (Section 4.1), could be used to *provide inspiration during the design of new CBMs*. Second, the environmental considerations listed in Table 11 could be used to help reflect on the environmental impacts of CBMs and trigger thinking about how firms could further reduce their impacts. Third, it is recommended that firms are aware of the constraining and enabling factors presented in Section 4.2, as the research suggests that successful circular firms find ways to directly address and overcome these constraints through their value propositions. Finally, the research suggests that game-based learning is relevant for understanding CE and inspiring action. The evaluation of the 'In the Loop' game (Paper V) could be useful for educators, facilitators, and instructors wishing to use game-based learning in workshops, by providing recommendations that could help them in tool selection, workshop facilitation, and participant assessment.

For policymakers, the research has implications for the on-going CE discussions between governments and industry. Desired policy interventions identified from stakeholders in the Swedish/Danish ICT and maritime sectors (see Table 13) give some *suggestions for future policy measures* that could help support the adoption of CBMs. These include:

- Reducing VAT on product repair to incentivise EPV BMs[11]
- Adjusting waste collection regulation to create separate targets for product reuse and encourage reversal of product obsolescence over recycling

[11] Some governments, including Sweden, Ireland, the Netherlands, Slovenia, and Belgium, have already introduced reduced VAT on repairs of various products to encourage consumers to repair and reuse them (Wilts et al., 2018).

- Using public procurement to create market pull for circular products
- Acquiring access to spare parts, repair manuals and increased warranty periods to encourage EPV BMs
- Creation of standards bodies for various product groups to gain customer trust of previously obsolete products

Policymakers should consider the impacts of proposed legislative measures before implementation, as this research identified different outcomes depending on firm type (OEM, gap-exploiter), customer base (B2B or B2C), and geographical scope of operations (national vs. international). The thesis also suggests that policy should have some way of measuring the environmental impact of CBMs, if the aim in stimulating their adoption is their contribution to environmental issues, such as reduced resource consumption. Here, the use of metrics and indicators that aim to assess system-level impacts could be used to provide insight into the effect of these business models on reducing resource consumption.

6.3 Further research

There is still work to be done on CBMs. Based on the conclusions and limitations of this research, this section first presents five suggestions for further research regarding CBMs in general before detailing further recommendations for the study of EPV BMs.

First, this research highlighted various mechanisms for how CBMs create, delivery and capture value. However, the identified mechanisms are not expected to be exhaustive, and further case studies are likely to identify even more. Specifically, the value firms receive from implementation of CBMs should be studied further. In particular, it is suggested firms may have motivations other than financial profit as their reason for adopting CBMs, but research investigating such motivations is still in its early stages (Haines-Gadd & Charnley, 2019; Nußholz et al., 2019b). Further work to identify these motivations could be useful in assisting with policy recommendations, as well as assessing the environmental impacts of CBMs. Such research could also help other firms make the business case surrounding CBMs.

Second, one limitation of this work is that it does not attempt to quantify the environmental and economic costs and benefit of CBMs. The findings suggest that these depend on how such business models are implemented in practice. As such, future research focused on case studies that assess the actual costs and benefits of these models are recommended. Conducting studies on the three types of EPV firms identified in this research, for example, could help to test the hypotheses put forward in this research about firm-product interaction.

Third, the research reflects on the role policy can play in the transition to a CE, noting stakeholder preferences for existing and proposed policy measures. To support continued adoption of CBMs, further work could focus on assessing what policymakers at a national and EU level are doing to implement the identified desired interventions. If we want CBMs to deliver on environmental benefits, follow-up research should focus on the creation and implementation of metrics or standards to quantify the environmental impacts of CBMs. Research has begun to investigate CE indicators (e.g., Saidani, Yannou, Leroy, Cluzel, & Kendall, 2019).

Fourth, the methodological limitations of this research could help guide future research. As this research has only studied existing business models that were already developed, it is 'static' in its perspective and can provide only limited insights into why and how firms go about the process of designing and implementing CBMs. In-depth case studies and longitudinal or participatory action research of firms trying to adopt circular business practices are recommended, as this could help to improve understanding of how firms go about designing and implementing CBMs. Recent studies (Ranta, Keränen, & Aarikka-Stenroos, 2019) corroborate this as an existing gap in the research. Moreover, this research emphasised external constraints to the adoption of CBMs, in line with recent research by Vermunt et al. (2019). However, studies by Guldmann and Huulgaard (2020) suggest internal factors play a more significant role than external ones. One possible explanation of this is that the survey in Papers III and IV did not ask questions related to internal factors, and the firms studied were not going through the process of adopting CBMs. Because of this limitation, future research could study firms going through the process of implementing CBMs and attempt to quantify the extent to which internal versus external factors hinder or enable the implementation of CBMs.

Fifth, given the limited evaluation of CBMs tools and methods, further research in this area is recommended. As far as the author is aware, the uptake of existing CBM tools in industry has not been studied, although work is taking place on identifying tools and indicators relevant to CBMs (Kravchenko, Pigosso, & McAloone, 2019; Pieroni et al., 2019) and developing new CBM tools (Blomsma et al., 2019). Further research on CBM tools in collaboration with firms could provide insight in terms of practitioners' requirements and help guide new tool design by identifying where they currently lack support. It is also proposed that enabling and constraining factors identified from research be used to guide the development of future tools to help firms overcome specific barriers for CBMs.

Further research could be done with additional participants to assess the suitability of the 'In The Loop' game for other target groups, including business practitioners and policymakers. The research presents a methodology that could be used by others to assess tools, including game-based learning approaches. As there is limited assessment of such tools in practice, this would address one of the shortcomings with game-based learning and help further knowledge about their value and application.

Turning to EPV BMs, further investigation into the constraining and enabling factors for EPV firms in other sectors is suggested. This would enable comparison between the sectors studied in this research (ICT and maritime) and other sectors, such as textiles, apparel and furniture, to identify which factors are sector-specific and which are cross sectorial. The applicability of the identified factors to other firm types could also be studied, as for example in Paper III, only factors for gap-exploiter type firms were identified. Such research could enable better recommendations to policymakers wishing to encourage EPV BMs and business developers looking to adopt such models. The transferability of the identified factors to ERV firms could also be further researched.

Finally, specific constraining and enabling factors to EPV BMs identified in the research could be studied in more detail. In the maritime sector, investigations could examine how a standards body could help EPV firms by creating an overview of existing bodies from other sectors and reflecting on their suitability to the maritime industry. In the ICT sector, discourse on repair and consumer rights is a growing area of focus that impacts EPV firms (Svensson et al., 2018). New regulations must be studied to see how they contribute to enabling EPV BMs or act as barriers for firms, especially in how they impact gap-exploiters' operations. The author is aware of research on consumer acceptance of previously obsolete products, aimed at increasing understanding of physiological effects and willingness of firms to adopt EPV BMs (Mugge, 2018). Much like regulatory factors, this acceptance most likely varies according to context and is shaped by social, economic, and geographical factors. Due to this research's limited geographical scope, investigations into EPV BMs in different locations should be a priority research area in the future.

7. References

Allwood, J.M. (2014). Chapter 30 - Squaring the Circular Economy: The Role of Recycling within a Hierarchy of Material Management Strategies. In E. Worrell & M. A. Reuter (Eds.), *Handbook of Recycling* (pp. 445-477). Boston: Elsevier.

Allwood, J.M., Ashby, M.F., Gutowski, T.G., & Worrell, E. (2011). Material efficiency: A white paper. *Resources, Conservation and Recycling, 55*(3), 362-381. doi:10.1016/j.resconrec.2010.11.002

Andersen, M.S. (2006). An introductory note on the environmental economics of the circular economy. *Sustainability Science, 2*(1), 133-140. doi:10.1007/s11625-006-0013-6

André, H., Ljunggren Söderman, M., & Nordelöf, A. (2019). Resource and environmental impacts of using second-hand laptop computers: A case study of commercial reuse. *Waste Management, 88*, 268-279. doi:10.1016/j.wasman.2019.03.050

Antikainen, M., & Valkokari, K. (2016). A Framework for Sustainable Circular Business Model Innovation. *Technology Innovation Management Review, 6*(7), 5-12. doi:10.22215/timreview/1000

Bakker, C., Hollander, M., Hinte, E., & Zijlstra, Y. (2014a). *Products that Last: Product Design for Circular Business Models.* Delft, The Netherlands: TU Delft.

Bakker, C., Wang, F., Huisman, J., & den Hollander, M. (2014b). Products that go round: exploring product life extension through design. *Journal of Cleaner Production, 69*, 10-16. doi:10.1016/j.jclepro.2014.01.028

Baldassarre, B., Calabretta, G., Bocken, N.M.P., & Jaskiewicz, T. (2017). Bridging sustainable business model innovation and user-driven innovation: A process for sustainable value proposition design. *Journal of Cleaner Production, 147*, 175-186. doi:10.1016/j.jclepro.2017.01.081

Baumann, H., Boons, F., & Bragd, A. (2002). Mapping the green product development field: engineering, policy and business perspectives. *Journal of Cleaner Production, 10*(5), 409-425. doi:10.1016/S0959-6526(02)00015-X

BCC. (2010, December 31). Copper enters 2011 at record high. *BBC News*. Retrieved from https://www.bbc.com/news/business-12098576

Benton, D., & Hazell, J. (2013). *Resource resilient UK: A report from the Circular Economy Task Force*: Green Alliance.

Berchicci, L., & Bodewes, W. (2005). Bridging environmental issues with new product development. *Business Strategy and the Environment*, 14(5), 272-285. doi:10.1002/bse.488

Beulque, R., & Aggeri, F. (2016). *Circular Business Model Innovation: Key Patterns and Challenges to unleash recycling value creation potential.* Paper presented at EGOS, Naples, Italy. Retrieved from https://halshs.archives-ouvertes.fr/halshs-01290810v1.

Bititci, U.S., Martinez, V., Albores, P., & Parung, J. (2004). Creating and managing value in collaborative networks. *International Journal of Physical Distribution & Logistics Management, 34*(3/4), 251-268. doi:10.1108/09600030410533574

Blomsma, F., Pieroni, M., Kravchenko, M., Pigosso, D.C.A., Hildenbrand, J., Kristinsdottir, A.R., Kristoffersen, E., Shahbazi, S., Nielsen, K.D., Jönbrink, A.-K., Li, J., Wiik, C., & McAloone, T.C. (2019). Developing a circular strategies framework for manufacturing companies to support circular economy-oriented innovation. *Journal of Cleaner Production, 241*, 118271. doi:10.1016/j.jclepro.2019.118271

Bocken, N., Strupeit, L., Whalen, K., & Nußholz, J. (2019). A Review and Evaluation of Circular Business Model Innovation Tools. *Sustainability, 11*(8), 2210. doi:10.3390/su11082210

Bocken, N.M.P., de Pauw, I., Bakker, C., & van der Grinten, B. (2016). Product design and business model strategies for a circular economy. *Journal of Industrial and Production Engineering, 33*(5), 308-320. doi:10.1080/21681015.2016.1172124

Bocken, N.M.P., Schuit, C.S.C., & Kraaijenhagen, C. (2018). Experimenting with a circular business model: Lessons from eight cases. *Environmental Innovation and Societal Transitions, 28*, 79-95. doi:10.1016/j.eist.2018.02.001

Bocken, N.M.P., & Short, S.W. (2016). Towards a sufficiency-driven business model: Experiences and opportunities. *Environmental Innovation and Societal Transitions*. doi:10.1016/j.eist.2015.07.010

Bocken, N., Bakker, C., & Pauw, I. de. (2015). *Product design and business model strategies for a circular economy: Proceedings of the Sustainable Design and Manufacturing Conference, Seville, 2015*. UK: Future Technology Press.

Bocken, N.M.P., Short, S. W., Rana, P., & Evans, S. (2014). A literature and practice review to develop sustainable business model archetypes. *Journal of Cleaner Production, 65*, 42-56. doi:10.1016/j.jclepro.2013.11.039

Bocken, N.M.P., Short, S.W.; Rana, P.; Evans, S. (2014). A literature and practice review to develop sustainable business model archetypes. *Journal of Cleaner Production, 65*, 42-56. doi:10.1016/j.jclepro.2013.11.039

Boons, F., & Lüdeke-Freund, F. (2013). Business models for sustainable innovation: State-of-the-art and steps towards a research agenda. *Journal of Cleaner Production, 45*, 9-19. doi:10.1016/j.jclepro.2012.07.007

Boons, F., Montalvo, C., Quist, J., & Wagner, M. (2013). Sustainable innovation, business models and economic performance: An overview. *Journal of Cleaner Production, 45*, 1-8. doi:10.1016/j.jclepro.2012.08.013

Boulding, K.E. (1966). The economics of the coming spaceship earth environmental quality in a growing economy. *Resources for the Future*, 3-14.

Bovea, M.D., & Pérez-Belis, V. (2012). A taxonomy of ecodesign tools for integrating environmental requirements into the product design process. *Journal of Cleaner Production, 20*(1), 61-71. doi:10.1016/j.jclepro.2011.07.012

Brezet, H. (1997). Dynamics in ecodesign practice. *Industry and Environment, 20*, 21-24.

Brown, P., Bocken, N., & Balkenende, R. (2019). Why Do Companies Pursue Collaborative Circular Oriented Innovation? *Sustainability, 11*(3), 635. doi:10.3390/su11030635

Bryman, A. (2012). *Social research methods*. Oxford; New York: Oxford University Press.

CBOOT. (2019). *Bootcamp for Starting Entrepreneurs in a Circular Economy*. Retrieved from https://cboot.vito.be/en

Ceschin, F., & Gaziulusoy, I. (2016). Evolution of design for sustainability: From product design to design for system innovations and transitions. *Design Studies, 47*, 118-163. doi:10.1016/j.destud.2016.09.002

Chesbrough, H., & Rosenbloom, R. S. (2002). The role of the business model in capturing value from innovation: evidence from Xerox Corporation's technology spin-off companies. *Industrial and Corporate Change, 11*(3), 529-555. doi:10.1093/icc/11.3.529

Chiu, M.-C., & Chu, C.-H. (2012). Review of sustainable product design from life cycle perspectives. *International Journal of Precision Engineering and Manufacturing, 13*(7), 1259-1272. doi:10.1007/s12541-012-0169-1

Clapp, J., & Dauvergne, P. (2011). Chapter 1: Peril or Prosperity? Mapping Worldviews of Global Environmental Change. In J. Clapp & P. Dauvergne (Eds.), *Paths to a green world: the political economy of the global environment* (2nd ed., pp. 1-18). Cambridge, MA: MIT Press.

Connolly, T.M., MacArthur, E., Stansfield, M., & McLellan, E. (2007). A quasi-experimental study of three online learning courses in computing. *Computers & Education, 49*(2), 345-359. doi:10.1016/j.compedu.2005.09.001

Cooper, D.R., & Gutowski, T.G. (2017). The Environmental Impacts of Reuse: A Review. *Journal of Industrial Ecology, 21*(1), 38-56. doi:10.1111/jiec.12388

Cooper, T. (2004). Inadequate Life? Evidence of Consumer Attitudes to Product Obsolescence. *J Consum Policy,* 27, 421–449. doi:10.1007/s10603-004-2284-6

Creswell, J. (2013). *Qualitative Inquiry & Research Design: Choosing Among Five Approaches*. Thousand Oaks, CA: SAGE Publications.

Creswell, J. W. (2014). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*. Thousand Oaks, CA: SAGE Publications.

Cutcliffe, J. R. (2000). Methodological issues in grounded theory. *Journal of Advanced Nursing, 31*(6), 1476-1484. doi:10.1046/j.1365-2648.2000.01430.x

Damen, M.A. (2012). *A resource passport for a circular economy: An assessment of the possible content and format of a resources passport in order to successfully contribute to the achievement of the circular economy* (Unpublished master's thesis). University of Utrecht, Utrecht, Netherlands.

De Jong, E., Engelaer, F., & Mendoza, M. (2015). *Realizing Opportunities of a Circular Business Model.* De Lage Landen. Retrieved from http://circulatenews.org/2015/04/de-lage-landen-realising-the-opportunities-of-a-circular-business-model

Dewey, J. (2008). Reconstruction in philosophy. In J. Boydston & R. Ross (Eds.), *The middle works of John Dewey, 1899-1924* (Vol. 12, pp. 77-202). Carbondale: Southern Illinois University Press.

Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives, OJ 2008 L 212/3.

Dutch Ministry of Infrastructure and the Environment (2016). *A Circular Economy in the Netherlands by 2050. Government-wide Programme for a Circular Economy 2016.* Retrieved from https://www.government.nl/documents/letters/2016/09/14/government-wide-programme-for-a-circular-economy

EEA. (2019). *Trends and projections in Europe 2019 - Tracking progress towards Europes climate and energy targets* (Report No. 15/2019). Retrieved from https://www.eea.europa.eu/publications/trends-and-projections-in-europe-1

Elkington, J. (1997). *Cannibals with forks: the triple bottom line of twenty-first century business*. Capstone: Oxford.

Ellen MacArthur Foundation. (2016). *Circular Economy Case Studies*. Retrieved from www.ellenmacarthurfoundation.org/case-studies

Ellen MacArthur Foundation. (2015a). *Delivering the Circular Economy: a toolkit for policymakers*. Isle of Wight, UK: Ellen MacArthur Foundation.

Ellen MacArthur Foundation. (2015b). *Towards a circular economy: business rationale for an accelerated transition*. Isle of Wight, UK: Ellen MacArthur Foundation.

Ellen MacArthur Foundation. (2015c). *Growth Within: a circular economy vision for a competitive Europe*. Isle of Wight, UK: Ellen MacArthur Foundation.

Ellen MacArthur Foundation. (2014). *Towards the Circular Economy Vol. 3: accelerating the scale-up across global supply chains*. Isle of Wight, UK: Ellen MacArthur Foundation.

Ellen MacArthur Foundation (2013). *Towards the Circular Economy Vol. 2: opportunities for the consumer goods sector*. Isle of Wight, UK: Ellen MacArthur Foundation.

Ellen MacArthur Foundation (2012). *Towards the Circular Economy Vol. 1: an economic and business rationale for an accelerated transition*. Isle of Wight, UK: Ellen MacArthur Foundation.

Elshkaki, A., Graedel, T.E., Ciacci, L., & Reck, B.K. (2018). Resource Demand Scenarios for the Major Metals. *Environmental Science & Technology, 52*(5), 2491-2497. doi:10.1021/acs.est.7b05154

EPA. (2017, October 2). *National Overview: Facts and Figures on Materials, Wastes and Recycling*. Retrieved from https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/national-overview-facts-and-figures-materials

Environmental Audit Committee. (2019). *Fixing fashion: clothing consumption and sustainability*: *Sixteenth Report of Session 2017–19.* Retrieved from https://publications.parliament.uk/pa/cm201719/cmselect/cmenvaud/1952/full-report.html

European Commission. (2019a). *Waste Electrical & Electronic Equipment (WEEE)*. Retrieved from https://ec.europa.eu/environment/waste/weee/index_en.htm

European Commission. (2019b). *Green Public Procurement for Computers and Monitors*. Retrieved from https://susproc.jrc.ec.europa.eu/computers/

European Commission. (2017). *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: On the 2017 List of Critical Raw Materials for the EU, COM(2017) 490 final*. Retrieved from https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52017DC0490

European Commission. (2015). *Communication of 2 December 2015 on Closing the loop - An EU action plan for the Circular Economy*. Retrieved from http://europa.eu/rapid/press-release_IP-15-6203_en.htm

Eurostat. (2011). *In 2011, 40% of treated municipal waste was recycled or composted, up from 27% in 2001* [Press release]. Retrieved from https://ec.europa.eu/eurostat/documents/2995521/5160410/8-04032013-BP-EN.PDF/c8bcd2cd-a8d0-4bf1-b862-62209408c532

Farrant, L., Olsen, S.I., & Wangel, A. (2010). Environmental benefits from reusing clothes. *The International Journal of Life Cycle Assessment, 15*(7), 726-736. doi:10.1007/s11367-010-0197-y

Fiksel, J. (2006). Sustainability and resilience: toward a systems approach. *Sustainability: Science, Practice and Policy, 2*(2), 14-21.

Firnkorn, J., & Müller, M. (2012). Selling Mobility instead of Cars: New Business Strategies of Automakers and the Impact on Private Vehicle Holding. *Business Strategy and the Environment, 21*(4), 264-280. doi:10.1002/bse.738

Flick, U. (2006). *An introduction to qualitative research*. London: Sage Publications.

Florin, N., Madden, B., Sharpe, S., Benn, S., Agarwal, R., Perey, R., & Giurco, D. (2015). *Shifting Business Models for a Circular Economy: Metals Management for Multi-Product-Use Cycles.* Sydney: UTS. Retrieved from http://wealthfromwaste.net

Flyvbjerg, B. (2006). Five Misunderstandings About Case-Study Research. *Qualitative Inquiry, 12*(2), 219-245. doi:10.1177/1077800405284363

Forrest, A., Hilton, M., Ballinger, A., & Whittaker, D. (2017). *Circular economy opportunities in the furniture sector.* Brussels: EEB.

Fortuna, L.M., & Diyamandoglu, V. (2017). Optimization of greenhouse gas emissions in second-hand consumer product recovery through reuse platforms. *Waste Management, 66*, 178-189. doi:10.1016/j.wasman.2017.04.032

Freeman, R.E., & Gillbert Jr, D.R. (1992). Business, ethics and society: a critical agenda. *Business & Society, 31*(1), 9-17.

Geissdoerfer, M., Savaget, P., Bocken, N.M.P., & Hultink, E.J. (2017). The Circular Economy – A new sustainability paradigm? *Journal of Cleaner Production, 143*, 757-768. doi:10.1016/j.jclepro.2016.12.048

Genovese, A., Acquaye, A., Figueroa, A., & Koh, S. (2014). Sustainable supply chain management and the transition towards a circular economy: Evidence and some applications. *Omega*, *66*(B), 344-357.

Ghisellini, P., Cialani, C., & Ulgiati, S. (2016). A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems. *Journal of Cleaner Production*. doi:10.1016/j.jclepro.2015.09.007

Greenfield, A., & Graedel, T.E. (2013). The omnivorous diet of modern technology. *Resources, Conservation and Recycling, 74*, 1-7. doi:10.1016/j.resconrec.2013.02.010

Guba, E.G. (1990). *The paradigm dialog.* Paper presented at the Alternative Paradigms Conference, Mar, 1989, Indiana U, School of Education, San Francisco, CA, US.

Guide Jr., V., & Li, J. (2010). The Potential for Cannibalization of New Products Sales by Remanufactured Products. *Decision Sciences, 41*(3), 547-572. doi:10.1111/j.1540-5915.2010.00280.x

Guldmann, E. (2016). *Best Practice Examples of Circular Business Models.* Retrieved from http://www2.mst.dk/Udgiv/publications/2016/06/978-87-93435-86-5.pdf

Guldmann, E., & Huulgaard, R.D. (2020). Barriers to circular business model innovation: A multiple-case study. *Journal of Cleaner Production, 243*, 118160. doi:10.1016/j.jclepro.2019.118160

Haines-Gadd, M., Chapman, J., Lloyd, P., Mason, J., & Aliakseyeu, D. (2018). Emotional Durability Design Nine—A Tool for Product Longevity. *Sustainability, 10*(6), 1948. doi:10.3390/su10061948

Haines-Gadd, M., & Charnley, F. (2019). Creating a Taxonomy of Value for a Circular Economy. In P. Ball, L. Huatuco Huaccho, R. Howlett, R. Setchi (Eds.), *KES-SDM 2019: Sustainable Design and Manufacturing 2019. Smart Innovation, Systems and Technologies: Vol. 155* (pp. 241-26). Singapore: Springer.

Hankammer, S., Brenk, S., Fabry, H., Nordemann, A., & Piller, F.T. (2019). Towards circular business models: Identifying consumer needs based on the jobs-to-be-done theory. *Journal of Cleaner Production, 231*, 341-358. doi:10.1016/j.jclepro.2019.05.165

Hedman, J., & Kalling, T. (2003). The business model concept: theoretical underpinnings and empirical illustrations. *Eur. J. Inf. Syst., 12*(1), 49-59. doi:10.1057/palgrave.ejis.3000446

Hodder, I. (1994). The interpretation of documents and material culture *Handbook of qualitative research.* (pp. 393-402). Thousand Oaks, CA, US: Sage Publications, Inc.

Hollander, M., & Bakker, C. (2016). Mind the Gap Exploiter: Circular Business Models for Product Lifetime Extension. In *Proceedings of Electronic Goes Green 2016+ : Inventing shades of green* (pp. 1-8). Fraunhofer IZM Berlin.

Hollander, M.C., Bakker, C.A., & Hultink, E.J. (2017). Product Design in a Circular Economy: Development of a Typology of Key Concepts and Terms. *Journal of Industrial Ecology, 21*(3), 517-525. doi:10.1111/jiec.12610

Hopkinson, P., Zils, M., Hawkins, P., & Roper, S. (2018). Managing a Complex Global Circular Economy Business Model: Opportunities and Challenges. *California Management Review, 60*(3), 71-94. doi:10.1177/0008125618764692

Hsieh, H.-F., & Shannon, S. E. (2005). Three Approaches to Qualitative Content Analysis. *Qualitative Health Research, 15*(9), 1277-1288. doi:10.1177/1049732305276687

Ijomah, W., Childe, S., & McMahon, C. (2004). Remanufacturing: A Key Strategy for Sustainable Development. *Design and Manufacture for Sustainable Development 2004*.

ING Economics Department. (2015). *Rethinking finance in a circular economy: Financial implications of circular business models.* Retrieved from https://www.ing.nl/media/ING_EZB_Financing-the-Circular-Economy_tcm162-84762.pdf

Jeswiet, J., & Hauschild, M. (2005). EcoDesign and future environmental impacts. *Materials & Design, 26*(7), 629-634. doi:10.1016/j.matdes.2004.08.016

Joustra, D.J., de Jong, J., & Engelaer, F. (2013). *Guided Choices Towards a Circular Business Model.* Retrieved from http://www.opai.eu/uploads/Guided_Choices_towards_a_Circular_Business_Model_pdf11.pdf

Kaddoura, M., Kambanou, M.L., Tillman, A.-M., & Sakao, T. (2019). Is Prolonging the Lifetime of Passive Durable Products a Low-Hanging Fruit of a Circular Economy? A Multiple Case Study. *Sustainability, 11*(18), 4819. doi:10.3390/su11184819

Kaza, S., Yao, L., Bhada-Tata, P., & Van Woerden, F. (2018). *What a Waste 2.0 : A Global Snapshot of Solid Waste Management to 2050*. Retrieved from https://openknowledge.worldbank.org/handle/10986/30317

Ke, F. (2009). A qualitative meta-analysis of computer games as learning tools. In R.E. Ferdig (Ed.), *Handbook of research on effective electronic gaming in education* (pp. 1-31). Kent State University, USA: IGI Global.

Kemper, A. (2012). Saving the planet: a tale of two strategies (ensuring environmentally-friendly business strategies). *Strategic Direction, 28*(9). doi:10.1108/sd.2012.05628iaa.009

King, A., Miemczyk, J., & Bufton, D. (2006). Photocopier remanufacturing at Xerox UK: A description of the process and consideration of future policy issues. In D. Brissaud, S. Tichkiewitch, P. Zwolinski (Eds.), *Innovation in Life Cycle Engineering and Sustainable Development* (pp. 173-186). Dordrecht: Springer.

Kiørboe, N., Sramkova, H., & Krarup, M. (2015). *Moving towards a circular economy – successful Nordic business models* [Policy Brief]. Copenhagen: Nordic Council of Ministers. Retrieved from http://norden.diva-portal.org/smash/record.jsf?pid=diva2%3A852029&dswid=5707

Kirchherr, J., & Piscicelli, L. (2019). Towards an Education for the Circular Economy (ECE): Five Teaching Principles and a Case Study. *Resources, Conservation and Recycling, 150*, 104406. doi:10.1016/j.resconrec.2019.104406

Kirchherr, J., Reike, D., & Hekkert, M. (2017). Conceptualizing the circular economy: An analysis of 114 definitions. *Resources, Conservation and Recycling, 127*, 221-232. doi:10.1016/j.resconrec.2017.09.005

Kissling, R., Coughlan, D., Fitzpatrick, C., Boeni, H., Luepschen, C., Andrew, S., & Dickenson, J. (2013). Success factors and barriers in re-use of electrical and electronic equipment. *Resources, Conservation and Recycling, 80*, 21-31. doi:10.1016/j.resconrec.2013.07.009

Kok, L., Wurpel, G., & Ten Wolde, A. (2013). *Unleashing the Power of the Circular Economy. Report by IMSA Amsterdam for Circle Economy*. Retrieved from https://mvonederland.nl/system/files/media/unleashing_the_power_of_the_circular_economy-circle_economy.pdf

Korhonen, J., Nuur, C., Feldmann, A., & Birkie, S.E. (2018). Circular economy as an essentially contested concept. *Journal of Cleaner Production, 175*, 544-552. doi:10.1016/j.jclepro.2017.12.111

Kowalkowski, C., & Kindström, D. (2014). Service innovation in product-centric firms: A multidimensional business model perspective. *Journal of Business & Industrial Marketing, 29*, 96-111. doi:10.1108/JBIM-08-2013-0165

Kowalkowski, C., Windahl, C., Kindström, D., & Gebauer, H. (2015). What service transition? Rethinking established assumptions about manufacturers' service-led growth strategies. *Industrial Marketing Management, 45*, 59-69. doi:10.1016/j.indmarman.2015.02.016

Kravchenko, M., Pigosso, D.C.A., & McAloone, T.C. (2019). Towards the ex-ante sustainability screening of circular economy initiatives in manufacturing companies: Consolidation of leading sustainability-related performance indicators. *Journal of Cleaner Production, 241*, 118318. doi:10.1016/j.jclepro.2019.118318

Kumar, S., & Putnam, V. (2008). Cradle to cradle: Reverse logistics strategies and opportunities across three industry sectors. *International Journal of Production Economics, 115*(2), 305-315. doi:10.1016/j.ijpe.2007.11.015

Lacy, P., Keeble, J., & McNamara, R. (2014). *Circular Advantage: Innovative Business Models and Technologies to Create Value in a World without Limits to Growth*. Accenture. Retrieved from https://www.accenture.com/t20150523T053139__w__/us-en/_acnmedia/Accenture/Conversion-Assets/DotCom/Documents/Global/PDF/Strategy_6/Accenture-Circular-Advantage-Innovative-Business-Models-Technologies-Value-Growth.pdf

Laseter, T., Ovchinnikov, A., & Raz, G. (2010). Reduce, reuse, recycle or rethink. *Strategy+ Business, 61*, 1-5.

Lay, G., Schroeter, M., & Biege, S. (2009). Service-based business concepts: A typology for business-to-business markets. *European Management Journal, 27*(6), 442-455. doi:10.1016/j.emj.2009.04.002

Lee, B., Preston, F., Kooroshy, J., Bailey, R., & Lahn, G. (2012). *Resources Futures*. London: Chatham House.

Lewandowski, M. (2016). Designing the Business Models for Circular Economy—Towards the Conceptual Framework. *Sustainability, 8*(1), 43.

Lieder, M., & Rashid, A. (2016). Towards circular economy implementation: a comprehensive review in context of manufacturing industry. *Journal of Cleaner Production, 115*, 36-51. doi:10.1016/j.jclepro.2015.12.042

Liedtka, J. (2018). *Why Design Thinking Works*. Retrieved from https://hbr.org/2018/09/why-design-thinking-works

Linder, M., & Williander, M. (2017). Circular Business Model Innovation: Inherent Uncertainties. *Business Strategy and the Environment*, 26(2), 182-196. doi:10.1002/bse.1906

Lüdeke-Freund, F. (2009). *Business Model Concepts in Corporate Sustainability Contexts: From Rhetoric to A Generic Template for "Business Models for Sustainability"*. Retrieved from https://ssrn.com/abstract=1544847

Lüdeke-Freund, F., Gold, S., & Bocken, N.M.P. (2018). A Review and Typology of Circular Economy Business Model Patterns. *Journal of Industrial Ecology, 23*, 36-61. doi:10.1111/jiec.12763

Magretta, J. (2002). *Why business models matter*. Retrieved from https://hbr.org/2002/05/why-business-models-matter

Manninen, K., Koskela, S., Antikainen, R., Bocken, N., Dahlbo, H., & Aminoff, A. (2018). Do circular economy business models capture intended environmental value propositions? *Journal of Cleaner Production, 171*, 413-422. doi:10.1016/j.jclepro.2017.10.003

Matsumoto, M. (2009). Business frameworks for sustainable society: a case study on reuse industries in Japan. *Journal of Cleaner Production, 17*(17), 1547-1555. doi:10.1016/j.jclepro.2009.07.011

McMurtry, J. (2016, September 6). How to Engage When Customers Don't Give a Damn (or Dime) About What You Say. *Target Marketing*. Retrieved from http://www.targetmarketingmag.com/post/engage-customers-dont-give-damn-dime-say/all/

Mentink, B. (2014). *Circular Business Model Innovation* (Unpublished master's thesis). TU Delft, Delft, Netherlands.

Merli, R., Preziosi, M., & Acampora, A. (2018). How do scholars approach the circular economy? A systematic literature review. *Journal of Cleaner Production, 178*, 703-722. doi:10.1016/j.jclepro.2017.12.112

Michael, D. R., & Chen, S. (2006). *Serious Games: Games that Educate, Train and Inform*. Canada: Thomson Course Technology.

Miles, M., Huberman, A., & Saldana, J. (2013). Qualitative data analysis: A methods sourcebook: Thousand Oaks, CA: SAGE Publications.

Miles, M.B., & Huberman, M.A. (1994). *Qualitative Data Analysis: An Expanded Sourcebook*. Thousand Oaks, CA: SAGE Publications.

Milios, L., Beqiri, B., Whalen, K.A., & Jelonek, S.H. (2019). Sailing towards a circular economy: Conditions for increased reuse and remanufacturing in the Scandinavian maritime sector. *Journal of Cleaner Production, 225*, 227-235.

Mont, O. (2004). *Product-service systems: panacea or myth?* Lund: Lund University.

Mont, O., Dalhammar, C., & Jacobsson, N. (2006). A new business model for baby prams based on leasing and product remanufacturing. *Journal of Cleaner Production, 14*(17), 1509-1518. doi:10.1016/j.jclepro.2006.01.024

Mont, O., Plepys, A., Whalen, K., & Nußholz, J.L. (2017). Business model innovation for a circular economy: drivers and barriers for the Swedish industry – the voice of REES companies. Retrieved from http://lup.lub.lu.se/record/833402ef-b4d4-4541-a10e-34d1e89d2146

Mont, O., & Tukker, A. (2006). Product-Service Systems: reviewing achievements and refining the research agenda. *Journal of Cleaner Production, 14*(17), 1451-1454. doi:10.1016/j.jclepro.2006.01.017

Mont, O., Whalen, K.A., & Nussholz, J. (2019). Sustainable innovation in business models: celebrated but not interrogated. In F. Boons & A. McMeekin (Eds), *Handbook on Sustainable Innovation* (pp. 124-140). Cheltenham, UK: Edward Elgar Publishing.

Mont, O.K. (2002). Clarifying the concept of product–service system. *Journal of Cleaner Production, 10*(3), 237-245. doi:10.1016/S0959-6526(01)00039-7

Morgan, D.L. (2014). Pragmatism as a Paradigm for Social Research. *Qualitative Inquiry, 20*(8), 1045-1053. doi:10.1177/1077800413513733

Mugge, R. (2018). Product Design and Consumer Behaviour in a Circular Economy. *Sustainability, 10*(10), 3704. doi:10.3390/su10103704

Murray, A., Skene, K., & Haynes, K. (2015). The Circular Economy: An Interdisciplinary Exploration of the Concept and Application in a Global Context. *Journal of Business Ethics*, 1-12. doi:10.1007/s10551-015-2693-2

Nasr, N., & Thurston, M. (2006). *Remanufacturing: A key enabler to sustainable product systems*. Retrieved from https://www.mech.kuleuven.be/lce2006/key4.pdf

Nußholz, J. (2017). Circular Business Models: Defining a Concept and Framing an Emerging Research Field. *Sustainability, 9*(10), 1810.

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, 197*, 185-194. doi:10.1016/j.jclepro.2018.06.112

Nußholz, J.L.K., Nygaard Rasmussen, F., & Milios, L. (2019a). Circular building materials: Carbon saving potential and the role of business model innovation and public policy. *Resources, Conservation and Recycling, 141*, 308-316. doi:10.1016/j.resconrec.2018.10.036

Nußholz, J.L.K., Rasmussen, F.N., Whalen, K., & Plepys, A. (2019b). Material reuse in buildings: Implications of a circular business model for sustainable value creation. *Journal of Cleaner Production*, 118546. doi:10.1016/j.jclepro.2019.118546

OECD. (2019). *Business Models for the Circular Economy*. Retrieved from https://www.oecd.org/environment/waste/policy-highlights-business-models-for-the-circular-economy.pdf

Ongondo, F.O., Williams, I.D., Dietrich, J., & Carroll, C. (2013). ICT reuse in socio-economic enterprises. *Waste Management, 33*(12), 2600-2606. doi:10.1016/j.wasman.2013.08.020

Osterwalder, A., & Pigneur, Y. (2010). *Business model generation: a handbook for visionaries, game changers, and challengers*. Hoboken, NJ: John Wiley & Sons, Inc.

Osterwalder, A., Pigneur, Y., & Tucci, C.L. (2005). Clarifying business models: Origins, present, and future of the concept. *Communications of the Association for Information Systems, 15*(1), 1-25.

Ovaska, J., Poutiainen, P., Sorasahi, H., Aho, M., Levänen, J., & Annala, M. (2016). *Business Models for a Circular Economy: Seven Companies Paving the Way*. Retrieved from http://jpovaska.com/business-models-for-a-circular-economy-e-book/

Ovchinnikov, A. (2011). Revenue and Cost Management for Remanufactured Products. *Production and Operations Management, 20*(6), 824-840. doi:10.1111/j.1937-5956.2010.01214.x

Ovchinnikov, A., Blass, V., & Raz, G. (2014). Economic and Environmental Assessment of Remanufacturing Strategies for Product + Service Firms. *Production and Operations Management, 23*(5), 744-761. doi:10.1111/poms.12070

Park, J., Sarkis, J., & Wu, Z. (2010). Creating integrated business and environmental value within the context of China's circular economy and ecological modernization. Journal of Cleaner Production, 18(15), 1494-1501. doi:10.1016/j.jclepro.2010.06.001

Parto, S., Loorbach, D., Lansink, A., & Kemp, R. (2007). Transitions and Institutional Change: The Case of the Dutch Waste Subsystem. In S. Parto & B. Herbert-Copley (Eds.), *Industrial innovation and environmental regulation: developing workable solutions* (pp. 233-257). Tokyo: United Nations Univ. Pr.

Perri 6, & Bellamy, C. (2012). *Principles of methodology: research design in social science*. London: SAGE.

Pieroni, M.P.P., McAloone, T.C., & Pigosso, D.C.A. (2019). Business model innovation for circular economy and sustainability: A review of approaches. *Journal of Cleaner Production, 215*, 198-216. doi:10.1016/j.jclepro.2019.01.036

Pigosso, D.C.A., & McAloone, T.C. (2015). Supporting the Development of Environmentally Sustainable PSS by Means of the Ecodesign Maturity Model. *Procedia CIRP, 30*, 173-178. doi:10.1016/j.procir.2015.02.091

Pinchot, G., III. (1985). *Intrapreneuring: Why You Don't Have to Leave the Corporation to Become an Entrepreneur*. Retrieved from https://papers.ssrn.com/abstract=1496196

Planing, P. (2015). Business Model Innovation in a Circular Economy Reasons for Non-Acceptance of Circular Business Models. *Open Journal of Business Model Innovation*, 1–11.

Porter, M.E. (1985). *The Competitive Advantage: Creating and Sustaining Superior Performance*. NY: Free Press.

Prendeville, S., & Bocken, N. (2017). Design for Remanufacturing and Circular Business Models. In M. Matsumoto, K. Masui, S. Fukushige, & S. Kondoh (Eds.), *Sustainability Through Innovation in Product Life Cycle Design* (pp. 269-283). Singapore: Springer Singapore.

Prendeville, S., & Bocken, N. (2015, Dec.). *Design for remanufacturing and circular business models.* Paper presented at the Ecodesign Conference, Tokyo, Japan.

Ranta, V., Keränen, J., & Aarikka-Stenroos, L. (2019). How B2B suppliers articulate customer value propositions in the circular economy: Four innovation-driven value creation logics. *Industrial Marketing Management*. doi:10.1016/j.indmarman.2019.10.007

Renswoude, K. van, ten Wolde, A., & Joustra, D.J. (2015). *Circular Business Models – Part 1: An introduction to IMSA's circular business model scan*. Retrieved from https://groenomstilling.erhvervsstyrelsen.dk/sites/default/files/media/imsa_circular_business_models_-_april_2015_-_part_1.pdf

Reuters. (2010, December 28). China cuts rare earth export quotas, U.S. concerned. *Reuters*. Retrieved from https://www.reuters.com/article/us-china-rareearth-idUSTRE6BR0KX20101228

Richardson, J. (2008). The business model: an integrative framework for strategy execution. *Strategic Change, 17*(5-6), 133-144. doi:10.1002/jsc.821

Richter, J.L., Tähkämö, L., & Dalhammar, C. (2019). Trade-offs with longer lifetimes? The case of LED lamps considering product development and energy contexts. *Journal of Cleaner Production, 226*, 195-209. doi:10.1016/j.jclepro.2019.03.331

Ries, E. (2011). *The Lean Startup: How Today's Entrepreneurs Use Continuous Innovation to Create Radically Successful Businesses*. United States: Crown Business.

Roos, G., & Agarwal, R. (2015). Services innovation in a circular economy. In R. Agarwal, W. Selen, G. Roos, & R. Green (Eds.), *The Handbook of Service Innovation* (501-520). London: Springer.

Rossi, M., Germani, M., & Zamagni, A. (2016). Review of ecodesign methods and tools. Barriers and strategies for an effective implementation in industrial companies. *Journal of Cleaner Production, 129*, 361-373. doi:10.1016/j.jclepro.2016.04.051

Rossman, G.B., & Wilson, B.L. (1985). Numbers and Words: Combining Quantitative and Qualitative Methods in a Single Large-Scale Evaluation Study. *Evaluation Review, 9*(5), 627-643. doi:10.1177/0193841x8500900505

Sabbaghi, M., Cade, W., Behdad, S., & Bisantz, A.M. (2017). The current status of the consumer electronics repair industry in the U.S.: A survey-based study. *Resources, Conservation and Recycling, 116*, 137-151. doi:10.1016/j.resconrec.2016.09.013

Saidani, M., Yannou, B., Leroy, Y., Cluzel, F., & Kendall, A. (2019). A taxonomy of circular economy indicators. *Journal of Cleaner Production, 207*, 542-559. doi:10.1016/j.jclepro.2018.10.014

Sakao, T., & Brambila-Macias, S.A. (2018). Do we share an understanding of transdisciplinarity in environmental sustainability research? *Journal of Cleaner Production, 170*, 1399-1403. doi:10.1016/j.jclepro.2017.09.226

Sandin, G., & Peters, G.M. (2018). Environmental impact of textile reuse and recycling – A review. *Journal of Cleaner Production, 184*, 353-365. doi:10.1016/j.jclepro.2018.02.266

Sauvé, S., Bernard, S., & Sloan, P. (2016). Environmental sciences, sustainable development and circular economy: Alternative concepts for trans-disciplinary research. *Environmental Development*. doi:10.1016/j.envdev.2015.09.002

Savaskan, R.C., Bhattacharya, S., & Van Wassenhove, L.N. (2004). Closed-Loop Supply Chain Models with Product Remanufacturing. *Management Science, 50*(2), 239-252. doi:10.1287/mnsc.1030.0186

Schaltegger, S., Hansen, E.G., & Lüdeke-Freund, F. (2016). Business Models for Sustainability: Origins, Present Research, and Future Avenues. *Organization & Environment, 29*(1), 3-10. doi:10.1177/1086026615599806

Schreier, M. (2012). *Qualitative content analysis in practice*. Los Angeles, [Calif.], London: SAGE.

Schulte, U.G. (2013). New business models for a radical change in resource efficiency. *Environmental Innovation and Societal Transitions, 9*, 43-47.

Seitz, M.A. (2007). A critical assessment of motives for product recovery: the case of engine remanufacturing. *Journal of Cleaner Production, 15*(11), 1147-1157. doi:10.1016/j.jclepro.2006.05.029

Shafer, S.M., Smith, H.J., & Linder, J.C. (2005). The power of business models. *Business Horizons, 48*(3), 199-207. doi:10.1016/j.bushor.2004.10.014

SITRA. (2019). *Finnish road map to a circular economy 2016-2025*. Retrieved from https://www.sitra.fi/en/projects/leading-the-cycle-finnish-road-map-to-a-circular-economy-2016-2025/

Stahel, W. (2010). *The performance economy*. New York: Palgrave Macmillan.

Stahel, W. (2019). *The Circular Economy - a user's guide*. New York: Routledge

Stahel, W.R. (1982). The product life factor. *An Inquiry into the Nature of Sustainable Societies: The Role of the Private Sector (Series: 1982 Mitchell Prize Papers), NARC*.

Stähler, P. (2002, October). *Business models as an unit of analysis for strategizing.* Paper presented at the International workshop on business models, Lausanne, Switzerland. Retrieved from http://www.hec.unil.ch/aosterwa/Documents/workshop/Draft_Staehler.pdf

Stål, H.I., & Corvellec, H. (2018). A decoupling perspective on circular business model implementation: Illustrations from Swedish apparel. *Journal of Cleaner Production, 171*, 630-643. doi:10.1016/j.jclepro.2017.09.249

Steffen, W., Richardson, K., Rockström, J., Cornell, S.E., Fetzer, I., Bennett, E.M., Biggs, R., Carpenter, S.R., de Vries, W., de Wit, C.A., Folke, C., Gerten, D., Heinke, J., Mace, G.M., Persson, L.M., Ramanathan, V., Reyers, B., & Sörlin, S. (2015). Planetary boundaries: Guiding human development on a changing planet. *Science, 347*(6223), 1259855. doi:10.1126/science.1259855

Stubbs, W., & Cocklin, C. (2008). Conceptualizing a "sustainability business model". *Organization and Environment, 21*(2), 103-127. doi:10.1177/1086026608318042

Sumter, D., Bakker, C., & Balkenende, R. (2018). The Role of Product Design in Creating Circular Business Models: A Case Study on the Lease and Refurbishment of Baby Strollers. *Sustainability, 10*(7), 2415. doi:10.3390/su10072415

Sundin, E., & Bras, B. (2005). Making functional sales environmentally and economically beneficial through product remanufacturing. *Journal of Cleaner Production, 13*(9), 913-925. doi:10.1016/j.jclepro.2004.04.006

Sundin, E., Östlin, J., Rönnbäck, A.Ö., Lindahl, M., & Sandström, G.Ö. (2008). Remanufacturing of Products used in Product Service System Offerings. In M.

Mitsuishi, K. Ueda, & F. Kimura (Eds.), *Manufacturing Systems and Technologies for the New Frontier* (pp. 537-542). London: Springer.

Suskewicz, M.W.J., & Josh. (2009). How to Jump-Start the Clean-Tech Economy. *Harvard Business Review, 87*(11), 52-60.

Svensson, S., Richter, J.L., Maitre-Ekern, E., Pihlajarinne, T., Maigret, A., & Dalhammar, C. (2018). *The Emerging 'Right to Repair' legislation in the EU and the U.S.* Paper presented at the Going Green - Care Innovation 2018, Vienna, Austria. Retrieved from http://lup.lub.lu.se/record/34ca32eb-5148-4b33-b82a-d7cfca46c672

Tan, A.R., Matzen, D., McAloone, T.C., & Evans, S. (2010). Strategies for designing and developing services for manufacturing firms. *CIRP Journal of Manufacturing Science and Technology, 3*(2), 90-97. doi:10.1016/j.cirpj.2010.01.001

Taran, Y., Boer, H., & Lindgren, P. (2015). A Business Model Innovation Typology. *Decision Sciences, 46*(2), 301-331. doi:10.1111/deci.12128

Teece, D.J. (2010). Business Models, Business Strategy and Innovation. *Long Range Planning, 43*(2–3), 172-194. doi:10.1016/j.lrp.2009.07.003

Townsend, M. (2018). *Norsk Ombruk: The Benefits Case for Remanufacturing in a Circular Economy*. Retrieved from https://www.slideshare.net/mike_earthshine/norsk-ombruk-the-benefits-case-for-remanufacturing-in-a-circular-economy

Tukker, A. (2015). Product services for a resource-efficient and circular economy - A review. *Journal of Cleaner Production, 97*, 76-91. doi:10.1016/j.jclepro.2013.11.049

Tunn, V.S.C., Bocken, N.M.P., van den Hende, E.A., & Schoormans, J.P.L. (2019). Business models for sustainable consumption in the circular economy: An expert study. *Journal of Cleaner Production, 212*, 324-333. doi:10.1016/j.jclepro.2018.11.290

Upward, A., & Jones, P. (2016). An Ontology for Strongly Sustainable Business Models:Defining an Enterprise Framework Compatible With Natural and Social Science. *Organization & Environment, 29*(1), 97-123. doi:10.1177/1086026615592933

Urbinati, A., Chiaroni, D., & Chiesa, V. (2017). Towards a new taxonomy of circular economy business models. *Journal of Cleaner Production, 168*, 487-498. doi:10.1016/j.jclepro.2017.09.047

van Nes, N., & Cramer, J. (2006). Product lifetime optimization: a challenging strategy towards more sustainable consumption patterns. *Journal of Cleaner Production, 14*(15), 1307-1318. doi:10.1016/j.jclepro.2005.04.006

van Weelden, E., Mugge, R., & Bakker, C. (2016). Paving the way towards circular consumption: exploring consumer acceptance of refurbished mobile phones in the Dutch market. *Journal of Cleaner Production, 113*, 743-754. doi:10.1016/j.jclepro.2015.11.065

Vermunt, D.A., Negro, S.O., Verweij, P.A., Kuppens, D.V., & Hekkert, M.P. (2019). Exploring barriers to implementing different circular business models. *Journal of Cleaner Production, 222*, 891-902. doi:10.1016/j.jclepro.2019.03.052

Webster, K. (2019, June). *The circular economy in lifelong learning.* Presentation at the World Economic Forum 2019, Helsinki, Finland.

Whalen, C.J. & Whalen, K.A. (2019). Circular Economy Business Models: A Critical Examination. *Journal of Economic Issues*. Forthcoming.

Whalen, K.A. (2017a). Classifying circular business models: a practice-based review. In C. A. Bakker & R. Mugge (Eds.), *Product Lifetimes and the Environment* (Vol. 9, pp. 417-421). Delft, The Netherlands: IOS Press Ebooks.

Whalen, K.A. (2017b). Risk & Race: Creation of a finance-focused circular economy serious game. In C. A. Bakker & R. Mugge (Eds.), *Product Lifetimes and the Environment* (Vol. 9, pp. 422-425). Delft, The Netherlands: IOS Press Ebooks.

Whalen, K.A. (2019). Three circular business models that extend product value and their contribution to resource efficiency. *Journal of Cleaner Production, 226*, 1128-1137. doi:10.1016/j.jclepro.2019.03.128

Whalen, K.A., 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. *Resources, Conservation and Recycling, 135*, 335-345.

Whalen, K.A., & Kijne, G. (2019). Game-Based Approaches to Sustainable Innovation. In N. Bocken, P. Ritala, L. Albareda, & R. Verburg (Eds.), *Innovation for Sustainability: Business Transformations Towards a Better World* (pp. 375-392). Cham: Springer International Publishing.

Whalen, K.A. & Milios, L. (2019, September). *Circular Economy Policy at a Crossroads: Encouraging Durable Products or Enabling Faster Cycling of Short-lived Products?* Paper presented at the Product Lifetimes and the Environment Conference, Berlin, Germany.

Whalen, K.A., Milios, L., & Nussholz, J. (2018). Bridging the gap: Barriers and potential for scaling reuse practices in the Swedish ICT sector. *Resources, Conservation and Recycling, 135*, 123-131.

Whalen, K.A., & Peck, D. (2014). In the Loop - Sustainable, Circular Product Design and Critical Materials. *IJAT, 8*, 664-676. doi:10.20965/ijat.2014.p0664

Whalen, K.A., & Whalen, C.J. (2018). The Circular Economy and Institutional Economics: Compatibility and Complementarity. *Journal of Economic Issues, 52*(3), 605-614.

Whalen, K.A. & Vakhitova, T.V. (2018, June). *Creating experiences, not lectures: experiential methods in context of sustainable development teaching*. Paper presented at the 9th International Conference on Engineering Education for Sustainable Development Conference (EESD), Rowan University, NJ.

Whalen, K., van der Plas, A., & Mertens, C. (2015). *Creating New Business Through Circular Design Thinking*. Circle Economy. Retrieved from http://www.circle-economy.com/library/books-reports/

Wilts, C.H., Bahn-Walkowiak, B., & Hoogeveen, Y. (2018). *Waste prevention in Europe : policies, status and trends in reuse in 2017* (EEA Report No 4/2018). Retrieved from the Publications Office of the European Union website: http://dx.doi.org/10.2800/15583

Wirtz, B.W., Pistoia, A., Ullrich, S., & Göttel, V. (2016). Business Models: Origin, Development and Future Research Perspectives. *Long Range Planning, 49*(1), 36-54. doi:10.1016/j.lrp.2015.04.001

WRAP. (2012a). *Composition and re-use potential of household bulky waste in the UK*. Retrieved from https://www.wrap.org.uk/sites/files/wrap/UK bulky waste summary.pdf

WRAP. (2012b). *Valuing Our Clothes: The True Cost of How We Design, Use and Dispose of Clothing in the UK*. Retrieved from http://www.wrap.org.uk/sites/files/wrap/valuing-our-clothes-the-cost-of-ukfashion_WRAP.pdf

Yin, R.K. (2013). Validity and generalization in future case study evaluations. *Evaluation, 19*(3), 321-332. doi:10.1177/1356389013497081

Yin, R.K. (2014). *Case study research : design and methods*. Thousand Oaks, CA: SAGE.

Ylä-Mella, J., Keiski, R.L., & Pongrácz, E. (2015). Electronic waste recovery in Finland: Consumers' perceptions towards recycling and re-use of mobile phones. *Waste Management, 45*, 374-384. doi:10.1016/j.wasman.2015.02.031

Yuan, Z.W., Bi, J., & Moriguichi, Y. (2006). The circular economy - A new development strategy in China. *Journal of Industrial Ecology, 10*(1-2), 4-8. doi: 10.1162/108819806775545321

Zamani, B., Sandin, G., & Peters, G.M. (2017). Life cycle assessment of clothing libraries: can collaborative consumption reduce the environmental impact of fast fashion? *Journal of Cleaner Production, 162*, 1368-1375. doi:10.1016/j.jclepro.2017.06.128

Zaoual, A.R., & Lecocq, X. (2018). Orchestrating Circularity within Industrial Ecosystems: Lessons from Iconic Cases in Three Different Countries. *California Management Review, 60*(3), 133-156. doi:10.1177/0008125617752693

Zink, T., & Geyer, R. (2017). Circular Economy Rebound. *Journal of Industrial Ecology*, 21: 593-602. doi:10.1111/jiec.12545

Zott, C., & Amit, R. (2010). Business Model Design: An Activity System Perspective. *Long Range Planning, 43*(2-3), 216-226. doi:10.1016/j.lrp.2009.07.004

Zott, C., Amit, R., & Massa, L. (2011). The business model: Recent developments and future research. *Journal of Management, 37*(4), 1019-1042. doi:10.1177/0149206311406265

Appendix

This Appendix explains the approach to data collection and analysis for the circular business model database. Whalen (2017a) presents a early (and simplified) version of this methodology. This approach was eventually expanded on as described in Paper II.

A.1 Approach to data collection

CBM examples were collected from a review of academic and grey literature between August and November 2016. As the aim was to converge current understanding of CBMs, only sources explicitly using the terms 'circular business model', 'business models for circular economy', and their variants (e.g., 'business models for circularity'; 'circular economy business model') were reviewed. CBM examples were first identified from peer-reviewed journal articles in academic search directories (Scopus and Science Direct). As CBMs are widely discussed by practitioners outside of academia, the search was also expanded to grey literature to provide an overview of CBM examples mentioned in practice. This grey literature was initially obtained from the reference lists of the peer-reviewed journal articles. Additional business model examples were identified from snowballing the grey literature, reviewing European Commission briefings, using the search engine Google, and reviewing the websites of CE NGOs (Ellen MacArthur Foundation, Circle Economy). In total, 246 examples of 'circular business models' from practice were identified from a review of 37 different sources (available in Table 8).

After a first read-through of the collected examples, two filters were applied prior to further analysis. First, each example was reviewed to ensure the example being described was, in fact, a business model. This requirement was fulfilled if the case description described all three pillars of a business model. Here, 44 examples were excluded (see Table A.1 for a complete overview). The majority of these excluded examples [n=21] that described specific products or material/supply chain innovations rather than the business model of a firm, for example, a design that reduced the need for specific virgin materials. An additional six examples were found that described conceptual design projects, while two other examples described specific technologies that enabled separation of waste materials.

Table A.1. Examples excluded as non-business model descriptions.

Products	Material /supply chain innovations	Conceptual/pilot projects	Technology	Industrial ecosystem projects	Business model unclear
LED light (Philips) [Joustra et al., 2013] 747 Airplane (Boeing) [Bakker et al., 2014] Car (Rolls Royce) [Bakker et al., 2014] Car (Porsche) [Bakker et al., 2014] Model train (Märklin) [Bakker et al., 2014] Turntables (Thorens) [Bakker et al., 2014] Blocks (LEGO) [Bakker et al., 2014] Aeron chair (Herman Miller) [Bakker et al., 2014] Handbag (Chanel) [Bakker et al., 2014]	Flyknit TM Technology (Nike) [Lacy et al., 2014] Lifecycle fabric (Climatex) [EMF, 2013] Biotechnology (Novozymes) [Lacy et al., 2014] Mushroom packaging (Ecovative) [EMF, 2013; Guldmann, 2016] Cradle-to-Cradle apparel (PUMA) (EMF, 2013) Reuse of materials (BMW i3) [ING Economics Department, 2015] Reuse of textiles from uniforms (KLM) [ING Economics Department, 2015] PEF polymer products (Avantium) [ING Economics Department, 2015] Supply chain innovation (Delhaize) [EMF, 2013] Track and trace textiles (Herning municipality) [Guldmann, 2016] Workwear innovation (Freitag) [Guldmann, 2016]	Customizable mobile phone (Project Ara) [Lacy et al., 2014] 'Carlsberg Circular Community' (Carlsberg) [Lacy et al., 2014] Recycling of capsules (Nespresso) [Beulque and Aggeri, 2016] Toasters for a CE (Agency of Design) [EMF, 2016] Reusable ambulance (DLL) [EMF, 2016] Customizable mobile phone (Phoneblocks) [Joustra et al., 2013]	Grease separator (Fogbusters) [Florin et al., 2015] Recycling technology (Zen Robotics) [Kiørboe et al., 2015]	Industrial symbiosis project (The Plant) [EMF, 2016] Industrial symbiosis project (Kalundborg Symbiosis) [Bocken et al. 2016, Bocken et al. 2015; EMF, 2016] Industrial symbiosis (Clean Cowra) [Florin et al., 2015]	Upcycling (Droog Design) [Bakker et al., 2014] Upcycling (2012 Architects) [Bakker et al., 2014] Product repair (Repair Café) [ING Economics Department, 2015] Reprintable paper (REEP Technologies) [EMF, 2016] Product life extension (BMW) [Lacy et al., 2014] Platform for creating online marketplaces (Sharetribe) [Ovaska et al., 2016] Extended life of equipment (Technogym) [Joustra et al., 2013] Battery leasing (Better Place) [Mentink, 2014] Durable clothing (Uniqlo) [EMF, 2013] Lunch services (Dabbawalla) [Bakker et al., 2014]

Five reports of projects initiating industrial ecosystems were also excluded, as the descriptions provided no further details about the business models apart from explaining that waste was shared among the companies. Finally, ten examples were excluded because their business models were not clearly identifiable. The dataset was then reviewed to ensure there were no repeat examples. In total, 50 duplicate examples were removed from the dataset, leaving 152 unique examples. Table A.2 identifies the examples mentioned in more than one source and notes the number of occurrences. The Philips 'Pay Per Lux' example was the most commonly cited CBM example, with mentions in seven of the reviewed sources.[12]

Table A.2 Repeated examples and number of occurrences.

# of occurrences in dataset	2	3	4	6	7
Example Represented by Company	AirBNB, Apple, Car2Go, Coca-Cola, Freitag Bags, I:CO, Gazelle, Girl Meets Dress, Lyft, Miele, Patagonia, Philips Medical, Rent the Runway, RePack, Ricoh, Rolls Royce Lease, SABMiller, ThredUP, Vitsoe, Xerox	British Sugar, Caterpillar, BMA ergonomics, Mud Jeans, Patagonia, Zipcar	H&M, Interface, Renault	Desso	Philips 'Pay Per Lux'

[12] As sources sometimes identified multiple business models for one firm (such as Philips' 'Pay Per Lux' and Philips 'Medical Equipment Reuse'), such instances were counted as different examples.

A.2 Approach to data analysis and categorisation

A database of the final 152 examples was created and a qualitative content analysis (Schreier, 2012) was performed. This included using both directed and conventional approaches (open coding) to compare the examples to existing theoretical CBM frameworks and capture emerging meaning from practice (Hsieh & Shannon, 2005). Examples were first categorised, if possible, into one or more of the six CBM archetypes of Bocken et al. (2016). The archetype descriptions in Table 4 were used to assist this categorisation. When it was challenging to definitively categorise an example, company websites or other informational sources were reviewed to provide more knowledge about the specific example.

To enable easier comparison within and across archetypes, each example's business model dimensions were then coded based on the information provided in the case descriptions. Some forms of value capture were challenging, as they were not always explicitly stated in case descriptions. In these instances, no code was assigned to value capture and the case was described using its other dimensions. After the first coding, similar codes were grouped and consolidated as illustrated in Table A.3. These codes were then mapped according to the business model dimension and archetypes to which they corresponded (see Figure on next page for an overview). As a result, patterns among the examples and archetypes were more easily recognised and overarching themes could also be identified.

Table A.3. Example of consolidating the codes.

Value creation and delivery options relating to the Extending Resource Value archetype	
Open coding	*CBM descriptors*
recovery of precious metals	undertake resource recovery
perform recycling activities	
process waste material	
undertake recycling	
recover material at end of life	
provide collection/take-back services to extract material value	facilitate resource recovery
redistribution for recycling	
waste collection activities using existing logistics	
ensure environmental disposal of materials	
use recycled inputs in new product	use non-virgin/recycled in production
use non-virgin materials in new product	
repurpose waste materials for new product	

	Access/Performance Model	Extending Product Value	Classic Long Life	Encourage Sufficiency	Extending Resource Value	Industrial Symbiosis
Value propositions	use of a specific product	used products/ components	durable or classic products	encourage reduced consumption	products (made from recycled/non-virgin materials)	products (from production by-products)
	function or output	services (for products)	services (to accompany sale of product)		non-virgin materials	energy
					services (to collect waste material)	
Value creation & delivery	one assest is repeatedly distributed (or shared)	enable reuse of used products	producing and selling durable products	education/awareness campaign	undertake resource recovery	internal recovery and use of waste materials for new processes
	service is offered from something not being used	undertake repair	providing long warranty guarantees		facilitate resource recovery	use of waste between business entities
	enabling maintenance and/or product retrieval	undertake reconditioning	producing and selling timeless, classic, product for life		use non-virgin/recycled in production	use of waste materials in new production processes
		undertake refurbishment				
		undertake remanufacturing				
Value capture	pay per use/service	resale of (used, repaired, reconditioned, refurbished, remanufactured) products	premium pricing	premium pricing	sale of (waste, recycled material, finished goods)	new revenue streams
	subscription/membership fee	new revenue streams			new revenue streams	cost savings
	reduced material cost	cost savings			cost savings	
		social benefits			social benefits	
					premium pricing	
		partnership agreements			partnership agreements	

Printed by Media-Tryck, Lund 2020 NORDIC SWAN ECOLABEL 3041 0903

Every year in the EU we throw away over 30 million tonnes of furniture, clothing, and electronic products. Because most of them are sent to landfill or burned for energy, you might think these products are waste. That is not true. Around 40% of these products still work or can be fixed. Companies could resell these products instead of producing new ones. Many believe this would be good for both business and the environment.

This thesis explores these benefits. It investigates why more companies do not use these products and how this approach could be encouraged in the future.

LUND UNIVERSITY

iiiee
THE INTERNATIONAL INSTITUTE FOR INDUSTRIAL ENVIRONMENTAL ECONOMICS

IIIEE Dissertations 2020:1
ISBN 978-91-87357-54-1
ISSN 1402-3016