Proceedings of the IS4CE2020 Conference of the International Society for the Circular Economy
6 – 7 July 2020, University of Exeter, Exeter
https://www.is4ce.org

Assessing and evaluating circular business models through challenging life cycle costing approaches

***M. Miguel[1,2], S. Choudhary[1], G. Heron[1] and N. Coleman[2]**

[1] Management School, University of Sheffield, Conduit Road, Sheffield, S10 1FL
[2]Tata Steel Europe, Group Sustainability HSE&Q, Carbrook Hall Road, Sheffield, S9 2EQ

*mecia.miguel@tatasteeleurope.com; migmiguel1@sheffield.ac.uk

Abstract

The transition to Circular Economy involves rethinking of products, services, changes throughout the value chain, and implementation of circular business models. Potential economic gains and cost savings from circular business models have been mentioned as drivers to implement circular thinking within organisations. However, companies still struggle in understanding the economic benefits and implications associated with such a transition. To overcome this, metrics that provide economic information associated with circular products and business models are needed. Life cycle costing (LCC) has been identified as a potential economic quantitative assessment method. Through a systematic literature review, this paper presents the strengths and limitations associated to LCC in assessing the economic implications of circular business models.

The review recognised that LCC can provide a life cycle and multiple stakeholder perspectives, which are relevant to overcome some challenges associated with the implementation and design of circular business models. Furthermore, environmental and social LCC can include externality costs, which is an important factor for Circular Economy. Nonetheless, there is a lack of empirical studies implementing multiple stakeholder perspective and accounting for externalities. Several challenges were also identified: lack of understanding of the cost implications of products/materials with multiple life cycles; difficulties in allocating costs among multiple stakeholders; lack of data availability and low quality. These are relevant issues for costing associated to circular business models and should be addressed in future research.

Keywords: C*ircular Business Model; Life cycle costing; Circular Economy*

Introduction

In recent years, the concept of Circular Economy (CE) has gained more relevance, capturing the attention of practitioners, politicians and academics (Govindan & Hasanagic, 2018). Achieving CE in businesses is linked to multiple practices: eco-design, cleaner production, eco-efficiency, reverse logistics, and business model innovation (Bocken et al., 2016; Geissdoerfer et al., 2018; Ghisellini, Cialani, & Ulgiati, 2016).

Discussions in the literature have highlighted business model innovation as a source of competitive advantage for companies – as they offer new ways of creating, delivering, and capturing value, while producing positive environmental and social effects – more than product or service innovation (De Angelis, 2018; Pieroni, McAloone, & Pigosso, 2019).

The Ellen McArthur Foundation (2015) proposed the ReSOLVE framework that outlines six strategies for businesses to become circular: regenerate, share, optimise, loop, virtualise and exchange. These principles can be applied to several business model components (Lewandowski, 2016), leading academics to discuss the relevance of the topic (Linder & Williander, 2017), to frame the circular business model concept (Bocken et al., 2016; Lewandowski, 2016; Nußholz, 2017) and to develop multiple typologies and taxonomies (Lewandowski, 2016; Lüdeke-Freund, Gold, & Bocken, 2018; Urbinati, Chiaroni, & Chiesa, 2017).

Circular business models (CBMs) are new types of business models, where the value creation is built on keeping the economic value embedded into products after their use and exploit it for new offerings (Linder & Williander, 2017; Rosa, Sassanelli, & Terzi, 2019). Thus, requiring a return flow to the producer from users, involving closed-loop supply chains and reverse operations (e.g. remanufacturing or reuse) (Linder & Williander, 2017). These are also aspects of wider sustainability agendas, as efficient closed loops and reverse logistics systems allow leveraged synergies to occur. Resultantly, business models can provide the rationale for value proposition (i.e. value proposition, customer relationships and customer segments); value creation and delivery (i.e. channels, key partners, activities and resources); and value capture (i.e. cost structure and revenue streams) (Osterwalder & Pigneur, 2010). Transitioning to a CE requires rethinking these three value dimensions by implementing circular strategies (Nußholz, 2017).

Potential cost savings and economic gains associated with CBMs, such as an increase in long-term revenues through remanufacturing activities, are often mentioned as a driving force of CE transition (Govindan & Hasanagic, 2018; Gusmerotti et al., 2019). However, unknown cash flows, insufficient internalisation of externalities, and the shift of financial and operational risks from consumer to producers act as barriers (Govindan & Hasanagic, 2018; Werning & Spinler, 2020). To overcome identified barriers and accelerate CE transition, companies should adopt a systematic approach to understand where value is created (Urbinati, Chiaroni, & Chiesa, 2017). Thus, methods for assessing the economic benefits and impacts of circular products and business models are needed (Bocken et al., 2016; Lieder & Rashid, 2016; Pieroni, McAloone, & Pigosso, 2019).

Life cycle costing (LCC) has been identified as a potential method for assessing economic benefits (Kambanou & Sakao, 2020). LCC is a method for calculating costs and revenues of an offering over its life cycle, supporting decision-making at product or service level (Hunkeler et al., 2008). Initially, conceptualised to determine financial costs associated with assets and products, LCC has evolved to accommodate the full life cycle of an offering and external costs (i.e. environmental and social LCC) (Hunkeler et al., 2008). Most of the literature reviews addressing life cycle costing focused on: evaluating different methodological approaches (Korpi & Ala-Risku, 2008), assessing its application to different sectors (De Menna et al., 2018; Ilg, Hoehne, & Guenther, 2016; Naves et al., 2019), integrating LCC with life cycle assessment (Miah, Koh, & Stone, 2017) and analysing LCC as a tool to manage costs in new product development (Wouters & Morales, 2014). Only Settanni et al. (2014) analysed the literature of life cycle costing within the context of product service systems and proposed a new methodology to be implemented in the defence and aerospace industries. This shows that there is still a gap in the body of knowledge in understanding the potentials and challenges of LCC in evaluating the circular shift.

Therefore, this research aims to identify strengths and limitations of LCC in assessing the economic benefits and impacts of CBMs. An outline of future research is also provided. The rest of the paper is organised as follows. In Section "Research method", the systematic literature review process is detailed. This is followed by Section "Findings" where the final sample is characterised, the main strengths and limitations are provided. Finally, the section "Final remarks and future research" concludes the article and outlines a future research agenda.

Research method

This research performed a systematic literature review following the protocol outlined by Denyer and Tranfield (2009), who suggest that evidence informed by a systematic literature analysis is more accessible and relevant to a wider audience (beyond academia). This review focused on locating articles dealing with developing or applying life cycle costing at company level. Life cycle costing has been included and developed as part of framework(s) for sustainability assessments (Swarr et al., 2011). Therefore, to ensure that no relevant studies were excluded from the analysis, two Boolean search strings were developed:

("life cycle cost*" AND ("product*" OR "servic*" OR "supply chain"))

(("life cycle sustainability assess*" OR "life cycle sustainability analy*") AND ("product*" OR "servic*" OR "supply chain"))

The suffix * was used to include all derivational and inflectional suffixes of the words "cost", "product", "service", "assessment" and "analysis". The keyword search was conducted on Scopus and Web of Science databases, considering the disciplines of environmental sciences; social sciences; economics, finance and econometrics; business and management. The search was restricted to peer-reviewed journals in English published between 2008 and 2019.

Table 1 gives an overview of the search results. The search yielded 1,180 articles, from this sample 463 duplicates were removed. The abstract of the 717 unique articles was carefully analysed and papers performing cost analysis other than LCC, applying LCC at regional or national level, and where LCC played a minor role were excluded. This led to the exclusion of 615 articles from the analysis, resulting in 102 articles to be further assessed. Through cross-referencing 11 articles were identified and added to the sample, thus resulting in a final sample of 113 articles. A content analysis (i.e. text in-depth qualitative analysis) was performed to identify strengths and limitations of LCC methods (Krippendorff, 2013).

Table 1: Search protocol and results

	Field	Results	Unique results	Final sample*
Scopus	Title, Abstract, Keywords	719	717	113
Web of Science	Topic	461		

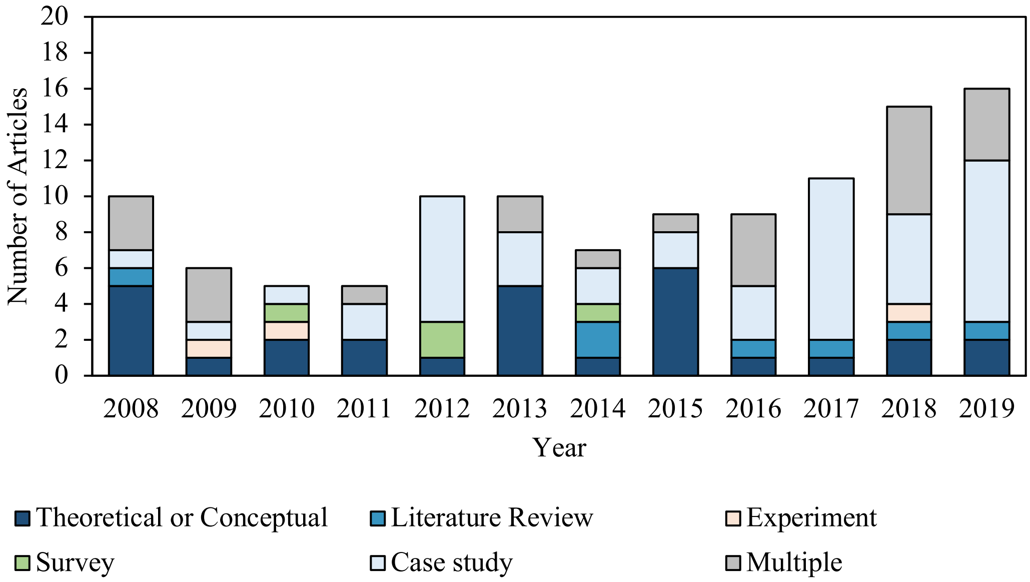
*Includes 11 cross-referencing articles

Findings

Descriptive findings

The final sample comprises of 113 articles from 40 different journals. Most of the articles were published in environmental and sustainability related journals (74 papers), such as Journal of Cleaner Production and International Journal of Life Cycle Assessment. Figure 1 shows the distribution of articles during the studied period and by implemented research method. The final sample consists of 29 theoretical or conceptual works, 7 literature reviews, 3 experiment articles, 4 survey papers, 45 case studies and 25 multiple method articles. The last category was conceptualised to differentiate articles that are testing conceptual/mathematical models or frameworks through case studies from articles that only develop a case study without theoretical or conceptual contributions.

Figure 1: Distribution of articles over time and by research method



Life cycle costing research has been developed mainly in industrialised countries – for example, Germany, Italy, China, United States, Australia and Portugal are responsible for 64 articles of the total sample – this is not surprising, as LCC was first conceptualised in the United States and has been used as a costing method to support product decision-making (Asiedu & Gu, 1998). LCC has been applied to several industrial sectors, from agriculture to defence and health sectors. In the reviewed sample, the construction and electric and electronic sectors have the highest number of articles (12) followed by the automotive sector (11).

Strengths and limitations

This section introduces the main strengths and limitations of life cycle costing in assessing the economic benefits and impacts of CBMs, considering LCC's main characteristics: life cycle perspective, stakeholder's perspective, cost allocation, externalities, and data availability and quality.

Life cycle perspective

Most of the studies implementing life cycle costing take a 'cradle-to-grave' approach (i.e. from raw material extraction to end-of-life) (23 articles). In a CE context, this approach should be replaced by a 'cradle-to-cradle' approach – accounting for costs associated to circular systems, in which reverse logistics operations are applied to bring end-of-life materials or products to manufacturers. In the reviewed literature, there is a clear lack of empirical studies following a 'cradle-to-cradle' approach (3 articles). Several authors have argued the need to use life cycle perspective for evaluating CBMs (Lindahl, Sundin, & Sakao, 2014; Rosa, Sassanelli, & Terzi, 2019; Settanni et al., 2014). When implementing CBMs, the value proposition of companies should shift from a "pay-per-own" to "pay-per-use" approach (Urbinati, Chiaroni, & Chiesa, 2017). In this scenario, the main purpose is to satisfy customers' needs, while companies retain ownership of products (Tukker, 2015; Urbinati, Chiaroni, & Chiesa, 2017). Therefore, a life cycle perspective that can be provided through life cycle costing is relevant to provide a broader perspective and cost information over time. Additionally, a life cycle costing approach can provide (at least) financial information about other actors within the value chain (Kambanou & Sakao, 2020). Despite companies retaining ownership of products, implementing LCC is still relevant to identify potential cost savings for customers and other actors in the value chain that can be a source of competitive advantage (Dunk, 2012) or influence customers in choosing eco-innovative products over conventional products (Deutsch, 2010; Kaenzig & Wüstenhagen, 2009).

Stakeholder's perspective

The stakeholder perspective is a key aspect of life cycle costing, since direct and indirect costs are met by several actors during the life cycle of an offering. According to Hunkeler et al. (2008), life cycle costing assesses the costs relevant to multiple stakeholder's, however 62 of the analysed articles followed a single stakeholder perspective (mainly producer or provider). The adopted perspective not only influences the scope and boundaries of LCC by determining the most relevant costs, but also the final results (Korpi & Ala-Risku, 2008; Wood & Hertwich, 2012). The implementation of CBMs requires an increase and improvement of cooperation between actors in the value chain (Urbinati, Chiaroni, & Chiesa, 2017). Therefore, requiring a multiple stakeholder perspective, mainly because what constitutes an economic benefit for the producer/provider might not be a benefit for the consumer or society (Krozer, 2008; Neugebauer et al., 2015; Traverso et al., 2012). The lack of studies considering multiple stakeholders is a clear limitation of the current research in the LCC field.

Cost allocation

In life cycle costing, the allocation of costs affects indirect costs and costs associated with different components within a single product. For example, environmental LCC can minimise indirect costs, such as overhead costs (e.g. building rent and insurance fees) by using a system view and converting them into direct costs associated with an offering (Hunkeler et al., 2008). Activity-based costing can also be integrated within life cycle costing to better account for these costs. However, the allocation of the correct fraction of cost between multiple stakeholders is still a challenge in life cycle costing (Albuquerque et al., 2019). Circular Economy not only increases the complexity of cost estimations by requiring multiple stakeholder perspective, but also because products (or at least, components/materials) are expected to have multiple life cycles. As Linder and Williander (2017) pointed out CBMs have a higher business risk than their linear counterparts, because companies can only validate a circular business model when recirculated products/materials have re-entered the market (i.e. second life). So far, only Bradley et al. (2018) has addressed cost allocation in multi-generational products by proposing a post-recovery allocation technique. Therefore, the inclusion or omission of multiple life cycles of products or materials in CBMs, as well as their implications in life cycle costing results are potential future research topics and clearly reveal a gap in the extant literature.

Externalities

Current business models are design to fit in a linear economy paradigm, in which environmental and social externalities are not included in the resources and products' prices (Nußholz, 2017). In a Circular Economy, prices should reflect the full cost (i.e. including negative externality costs) to be effective (Webster, 2015). However, the full cost may not always be transparent due to the various actors at play and their various perspectives. According to Linder and Williander (2017), CBMs have higher costs per physical item when compared with the corresponding linear business model, because these require investments to implement reverse logistics operations (e.g. costs associated with remanufacturing). Thus, contributing to a higher business risk associated with CBMs, and potentially making them unattractive from a business perspective to managers. This challenge could be overcome by internalising externalities, and thus accounting for the full costs related to a linear economy.

The environmental and social LCC approaches have been developed to account for externality costs (Hunkeler et al., 2008). Externalities have been barely included in LCC assessments (only 19 articles have included externalities in their analysis), mainly due to difficulties in quantifying and monetising these factors (Hoogmartens et al., 2014). Nonetheless, this might change with the publication of the ISO Standard 14008:2019 "Monetary valuation of environmental impacts and related environmental aspects" (ISO, 2019). This standard provides a methodological framework to monetise environmental impacts.

Therefore, future research focusing on the internalisation of externalities and their impact on decision-making related to CBMs is needed.

Data availability and quality

The lack of available costing data sets, the low quality and reliability are two challenges often mentioned in the LCC literature (Albuquerque et al., 2019; Bierer et al., 2015; Neugebauer et al., 2015; Sala, Farioli, & Zamagni, 2012; Settanni et al., 2014). However, little research has focused on data availability and quality, and its impacts on life cycle costing assessments. In fact, only Ciroth (2009) has discussed factors that influence data quality and proposed a matrix to manage data quality issues. This is clear a limitation of the LCC research that needs to be addressed in order to avoid undermining the potential use of LCC information in decision-making related to CBMs. Recent developments and innovations in autonomous data generation would suggest that the Industry 4.0 with its mechanisms (e.g. Internet of Things) offer obvious opportunities to address the data gap (Rosa et al., 2020).

Final remarks and future research

This study has analysed the literature associated with the field of life cycle costing and identified the strengths and limitations in using LCC as a quantitative method for support decision-making associated with CBMs. As described, life cycle costing gives the necessary life cycle and multiple stakeholders perspective to overcome identified challenges, which are associated with circular business models. In addition, environmental and social LCC can provide economic information related to externalities associated with business activities. Notwithstanding, the study confirms that paucity of empirical studies of life cycle costing applied to a CE context (particularly related to CBMs). Several limitations have been identified that need to be addressed due to their relevance to the topic. Therefore, future research should focus on empirical studies that:

- Apply life cycle costing considering multiple stakeholder perspectives;
- Include multiple life cycles of products or materials within circular business models, and evaluate their implications in life cycle costing results and decision-making at company level;
- Identify and monetise externalities associated with circular and linear business models, and assess their impacts on price strategy and decision-making within companies;
- Apply Industry 4.0 mechanisms to address data gaps and identify strengths and limitations in minimising the impacts data quality issues on life cycle cost results.

Acknowledgements

This study is part of the project ReTraCE that has received funding from the European Union’s Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie European Training Networks (grant agreement ReTraCE No 814247).

References

Albuquerque, T. L. M., Mattos, C. A., Scur, G., & Kissimoto, K. (2019). Life cycle costing and externalities to analyze circular economy strategy: Comparison between aluminum packaging and tinplate. *Journal of Cleaner Production, 234*, 477-486. doi:10.1016/j.jclepro.2019.06.091

Asiedu, Y., & Gu, P. (1998). Product life cycle cost analysis: State of the art review. *International Journal of Production Research, 36*(4), 883-908. doi:10.1080/002075498193444

Bierer, A., Götze, U., Meynerts, L., & Sygulla, R. (2015). Integrating life cycle costing and life cycle assessment using extended material flow cost accounting. *Journal of Cleaner Production, 108*, 1289-1301. doi:10.1016/j.jclepro.2014.08.036

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

Bradley, R., Jawahir, I. S., Badurdeen, F., & Rouch, K. (2018). A total life cycle cost model (TLCCM) for the circular economy and its application to post-recovery resource allocation. *Resources, Conservation and Recycling, 135*, 141-149. doi:10.1016/j.resconrec.2018.01.017

Ciroth, A. (2009). Cost data quality considerations for eco-efficiency measures. *Ecological Economics, 68*(6), 1583-1590. doi:10.1016/j.ecolecon.2008.08.005

De Angelis, R. (2018). *Business models in the Circular Economy - Concepts, Examples and Theory*. Exeter, UK. Palgrave Macmillan.

De Menna, F., Dietershagen, J., Loubiere, M., & Vittuari, M. (2018). Life cycle costing of food waste: A review of methodological approaches. *Waste Manag, 73*, 1-13. doi:10.1016/j.wasman.2017.12.032

Denyer, D., & Tranfield, D. (2009). Producing a Systematic Review. In *The Sage Handbook of Organizational Research Methods*.

Deutsch, M. (2010). Life Cycle Cost Disclosure, Consumer Behavior, and Business Implications. *Journal of Industrial Ecology, 14*(1), 103-120. doi:10.1111/j.1530-9290.2009.00201.x

Dunk, A. S. (2012). Assessing the Contribution of Product Life Cycle Cost Analysis, Customer Involvement, and Cost Management to the Competitive Advantage of Firms. In *Advances in Management Accounting* (pp. 29-45).

Ellen McArthur Foundation. (2015). *Towards a Circular Economy - Business rationale for an accelerated transition*. Isle of Wight: Ellen McArthur Foundation. Available online via https://www.ellenmacarthurfoundation.org/publications [25 March 2020]

Geissdoerfer, M., Morioka, S. N., de Carvalho, M. M., & Evans, S. (2018). Business models and supply chains for the circular economy. *Journal of Cleaner Production, 190*, 712-721. doi:10.1016/j.jclepro.2018.04.159

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, 114*, 11-32. doi:10.1016/j.jclepro.2015.09.007

Govindan, K., & Hasanagic, M. (2018). A systematic review on drivers, barriers, and practices towards circular economy: a supply chain perspective. *International Journal of Production Research, 56*(1-2), 278-311. doi:10.1080/00207543.2017.1402141

Gusmerotti, N. M., Testa, F., Corsini, F., Pretner, G., & Iraldo, F. (2019). Drivers and approaches to the circular economy in manufacturing firms. *Journal of Cleaner Production, 230*, 314-327. doi:10.1016/j.jclepro.2019.05.044

Hoogmartens, R., Van Passel, S., Van Acker, K., & Dubois, M. (2014). Bridging the gap between LCA, LCC and CBA as sustainability assessment tools. *Environmental Impact Assessment Review, 48*, 27-33. doi:10.1016/j.eiar.2014.05.001

Hunkeler, D., Lichtenvort, K., Rebitzer, G., Ciroth, A., Huppes, G., Klöpffer, W., . . . Swarr, T. E. (2008). *Environmental Life Cycle Costing* (1 ed.). Florida, USA. SETAC Press: CRC Press.

Ilg, P., Hoehne, C., & Guenther, E. (2016). High-performance materials in infrastructure: a review of applied life cycle costing and its drivers – the case of fiber-reinforced composites. *Journal of Cleaner Production, 112*, 926-945. doi:10.1016/j.jclepro.2015.07.051

ISO. (2019). ISO 14008:2019 - Monetary valuation of environmental impacts and related environmental aspects. https://www.iso.org/standard/43243.html [12 May 2020]

Kaenzig, J., & Wüstenhagen, R. (2009). The Effect of Life Cycle Cost Information on Consumer Investment Decisions Regarding Eco-Innovation. *Journal of Industrial Ecology, 14*(1), 121-136. doi:10.1111/j.1530-9290.2009.00195.x

Kambanou, M. L., & Sakao, T. (2020). Using life cycle costing (LCC) to select circular measures: A discussion and practical approach. *Resources, Conservation and Recycling, 155*. doi:10.1016/j.resconrec.2019.104650

Korpi, E., & Ala-Risku, T. (2008). Life cycle costing: a review of published case studies. *Managerial Auditing Journal, 23*(3), 240-261. doi:10.1108/02686900810857703

Krippendorff, K. (2013). *Content Analysis - An Introduction to Its Methodology* (3rd ed.). SAGE Punlications.

Krozer, Y. (2008). Life cycle costing for innovations in product chains. *Journal of Cleaner Production, 16*(3), 310-321. doi:10.1016/j.jclepro.2006.07.040

Lewandowski, M. (2016). Designing the Business Models for Circular Economy—Towards the Conceptual Framework. *Sustainability, 8*(1). doi:10.3390/su8010043

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

Lindahl, M., Sundin, E., & Sakao, T. (2014). Environmental and economic benefits of Integrated Product Service Offerings quantified with real business cases. *Journal of Cleaner Production, 64*, 288-296. doi:10.1016/j.jclepro.2013.07.047

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., Gold, S., & Bocken, N. M. P. (2018). A Review and Typology of Circular Economy Business Model Patterns. *Journal of Industrial Ecology, 23*(1), 36-61. doi:10.1111/jiec.12763

Miah, J. H., Koh, S. C. L., & Stone, D. (2017). A hybridised framework combining integrated methods for environmental Life Cycle Assessment and Life Cycle Costing. *Journal of Cleaner Production, 168*, 846-866. doi:10.1016/j.jclepro.2017.08.187

Naves, A. X., Barreneche, C., Fernández, A. I., Cabeza, L. F., Haddad, A. N., & Boer, D. (2019). Life cycle costing as a bottom line for the life cycle sustainability assessment in the solar energy sector: A review. *Solar Energy, 192*, 238-262. doi:10.1016/j.solener.2018.04.011

Neugebauer, S., Martinez-Blanco, J., Scheumann, R., & Finkbeiner, M. (2015). Enhancing the practical implementation of life cycle sustainability assessment – proposal of a Tiered approach. *Journal of Cleaner Production, 102*, 165-176. doi:10.1016/j.jclepro.2015.04.053

Nußholz, J. (2017). Circular Business Models: Defining a Concept and Framing an Emerging Research Field. *Sustainability, 9*(10). doi:10.3390/su9101810

Osterwalder, A., & Pigneur, Y. (2010). *Business Model Generation*. Hoboken, New Jersey, USA. John Wiley & Sons Inc.

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

Rosa, P., Sassanelli, C., & Terzi, S. (2019). Towards Circular Business Models: A systematic literature review on classification frameworks and archetypes. *Journal of Cleaner Production, 236*. doi:10.1016/j.jclepro.2019.117696

Rosa, P., Sassanelli, C., Urbinati, A., Chiaroni, D., & Terzi, S. (2020). Assessing relations between Circular Economy and Industry 4.0: a systematic literature review. *International Journal of Production Research, 58*(6), 1662-1687. doi:10.1080/00207543.2019.1680896

Sala, S., Farioli, F., & Zamagni, A. (2012). Life cycle sustainability assessment in the context of sustainability science progress (part 2). *The International Journal of Life Cycle Assessment, 18*(9), 1686-1697. doi:10.1007/s11367-012-0509-5

Settanni, E., Newnes, L. B., Thenent, N. E., Parry, G., & Goh, Y. M. (2014). A through-life costing methodology for use in product–service-systems. *International Journal of Production Economics, 153*, 161-177. doi:10.1016/j.ijpe.2014.02.016

Swarr, T. E., Hunkeler, D., Klöpffer, W., Pesonen, H.-L., Ciroth, A., Brent, A. C., & Pagan, R. (2011). Environmental life-cycle costing: a code of practice. *The International Journal of Life Cycle Assessment, 16*(5), 389-391. doi:10.1007/s11367-011-0287-5

Traverso, M., Asdrubali, F., Francia, A., & Finkbeiner, M. (2012). Towards life cycle sustainability assessment: an implementation to photovoltaic modules. *The International Journal of Life Cycle Assessment, 17*(8), 1068-1079. doi:10.1007/s11367-012-0433-8

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

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

Webster, K. (2015). *The Circular Economy: A wealth of flows*. Isle of Wight. The Ellen MCArthur Foundation.

Werning, J. P., & Spinler, S. (2020). Transition to circular economy on firm level: Barrier identification and prioritization along the value chain. *Journal of Cleaner Production, 245*. doi:10.1016/j.jclepro.2019.118609

Wood, R., & Hertwich, E. G. (2012). Economic modelling and indicators in life cycle sustainability assessment. *The International Journal of Life Cycle Assessment, 18*(9), 1710-1721. doi:10.1007/s11367-012-0463-2

Wouters, M., & Morales, S. (2014). The Contemporary Art of Cost Management Methods during Product Development. In *Advances in Management Accounting* (pp. 259-346).