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Stingl, Verena; Fuglsig, Linea Vibe; Hoveling, Cecilie

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UNCERTAINTY MANAGEMENT IN CIRCULAR BUSINESS MODEL INNOVATION – THE CASE OF CIRCULAR PLASTICS

Stingl, Verena;
Fuglsig, Linea Vibe;
Hoveling, Cecilie

Aalborg Universitet

ABSTRACT

The transition towards circular economy means a radical systemic shift that requires re-design and innovation of business models. However, this radical systemic shift also creates high levels of uncertainty, which pose challenges to the circular business model innovation (CBMI) process. Using the transition towards circular plastics as a case context, this study aims to conceptualize different forms of uncertainty affecting CBMI, and to link them with approaches for managing these uncertainties. Based on interviews with incumbent manufacturing firms that have transitioned to circular plastics, or are in the process of doing so, we identified three domains of uncertainty: goal uncertainty, development uncertainty, and outcome uncertainty. We discuss the nature and sources of these uncertainties, and present different approaches chosen by manufacturers to manage these uncertainties in the context of their business. Our findings highlight the complex nature of uncertainty, and the importance of a nuanced consideration of uncertainty as a factor in the CBMI process. Moreover, our mapping of core uncertainties for CBMI and approaches to manage these uncertainties can guide practitioners in the innovation process.

Keywords: Business models and considerations, Uncertainty, Circular economy, business model innovation, manufacturing

Contact:
Stingl, Verena
Aalborg Universitet
Denmark
vstingl@mp.aau.dk

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1 INTRODUCTION

The transition towards a circular economy for plastics has become a political priority at national and international levels (European Commission, 2022; UNEP, 2022). The prevalence of plastics in modern economies and its substantial environmental impact (UNDP, 2022) render plastics an obvious candidate for more circular material streams. However, plastics as they are used in manufacturing today, are not naturally suited for circularity, given the immense variety of polymers and additives in the market, and the typical degradation of material properties during use and mechanical recycling (OECD, 2022a). The transition towards a circular plastics economy therefore posits a particularly uncertain situation with numerous challenges for value chain actors (Johansen et al., 2022; Milios et al., 2018) - against the backdrop of increasing political and societal pressure to increase circular use of plastics.

High levels of uncertainty can lead to hesitancy for engaging with novel strategic directions (Hahn et al., 2014) and more concretely hamper the willingness to pilot uncertain business models in the real world (Thompson and MacMillan, 2010). This is particularly true for incumbent manufacturers (Linder and Williander, 2017). Those manufacturers are important actors for the transformation towards circular plastics, as they drive the demand for recycled granules, and their design choices determine the reusability or recyclability of plastic components (OECD, 2022b). For these incumbent manufacturers, the transition towards circular economies often implies a substantial redesign of their business models (Pieroni et al., 2019, 2020). Such circular business model innovations (CBMI), call for a systemic and transdisciplinary view (Sakao and Brambila-Macias, 2018) and require the creation of new structures and value innovations that do not follow conventional "industry recipes" (Matthyssens et al., 2006). Thus, CBMI are fundamentally novel for most incumbent manufacturers, which increases the level of uncertainty that they face in the process of designing new business models (Santa-Maria et al., 2021) and renders CBMI more risky than conventional, linear business models (Linder and Williander, 2017).

Thus, the reduction and management of the uncertainties is central for the successful development of CBMI (Linder and Williander, 2017) - and hence the industry's transition towards circular models. However, effective management of uncertainty requires a differentiated understanding of the nature of uncertainty and the effect of different uncertainties on the novel business model and the firm in general, to tailor effective approaches (Schneckenberg et al., 2017). Yet, the current business model innovation literature, while acknowledging the important role of uncertainty, remains conceptually vague regarding the term "uncertainty" - offering either highly generic definitions (e.g. Massa and Tucci, 2013; Thompson and MacMillan, 2010), or investigating only the mechanisms through which managers cope with unspecified uncertainty (e.g. Schneckenberg et al., 2017). The aim of this paper is therefore to create clarity about different types of uncertainty in CBMI, and to connect them with approaches to manage and reduce the uncertainty or its effect on the firm. Specifically, our research asks: *How can we conceptualize uncertainty and its management in circular business model innovation for incumbent manufacturers of plastic goods?*

2 CHALLENGES IN A CIRCULAR PLASTICS ECONOMY

Plastics are ubiquitous owing to low costs and versatile material properties. However, there is an increasing concern related to the environmental impact in both production and disposal (UNDP, 2022), leading to increased public and political attention. National governments and international policymakers have initiated action through regulations and directives on the use of plastics (mainly targeting packaging), as well as schemes for extended producer responsibility from the European Union (European Commission, 2022). Furthermore, in March 2022, the United Nations Environment Assembly agreed on a resolution to end plastic pollution and create a global legally enforceable agreement by 2024 (UNEP, 2022). There are thus several drivers for manufacturing companies to transition towards more sustainable materials such as circular plastics.

However, research shows that only a small portion of plastics goes back into production processes due to challenges related to the underdeveloped and fragmented plastic recycling sector (Milios et al., 2018). Research has identified several challenges and barriers of transitioning to a circular economy and challenges in the recycled plastics value chain (Johansen et al., 2022; Milios et al., 2018; Paletta et al., 2019). A review of the academic and grey literature allows grouping the challenges into four common categories: Quality, regulation, economic, and market challenges (Table 1).

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Table 1. Known challenges in the transition towards circular plastics

Challenge	Source and impact of challenge	References
Quality	Heterogeneous waste fractions, risk of impurities, degradation through use and recycling processes with risks to product performance in use-phase	Baldassarre et al., 2022; Hennlock et al., 2015; Johansen et al., 2022; Milios et al., 2018; Paletta et al., 2019; The Danish Environmental Protection Agency, 2014; Baldassarre et al., 2022; European Commission, 2019; Paletta et al., 2019
Regulation	Regulations restricting use of recycled materials or hampering recyclability	
Economic	Fluctuating supply prices and availability and need for additional testing creating cost uncertainty	Baldassarre et al., 2022; Hennlock et al., 2015; Milios et al., 2018; Paletta et al., 2019
Market	Low consumer acceptance of recycled plastics; lack of willingness to pay for more sustainable products	European Commission, 2022; Johansen et al., 2022; Milios et al., 2018; Paletta et al., 2019; UNDP, 2022

The literature on circular plastics mainly addresses these challenges as barriers that firms that aim to move away from fossil-based virgin plastics need to overcome through technical innovations or that need to be addressed through policy changes or changed individual behaviour in waste handling. However, following the conceptualization by Schneckenberg et al. (2017) we propose to consider these challenges as interrelated uncertainties, that firms navigate through more or less formalized processes of circular business model innovation.

3 UNCERTAINTY IN CIRCULAR BUSINESS MODEL INNOVATION (CBMI)

Circular business model innovation is an emerging topic in the literature on business models, generally concerned with how firms create, deliver and capture value (Osterwalder and Pigneur, 2010). Specifically Geissdoerfer et al. (2020, pp. 7–8) define CBMI as "*the conceptualisation and implementation of circular business models*", whereas circular business models broadly refer to *"business models that are cycling, extending, intensifying, and/or dematerialising material [..] loops."* A further differentiation relates to the consideration and study of CBMI as the outcome - the new design and implementation of a business model - or as a process of organizational change through which such a design is developed (Foss and Saebi, 2017; Santa-Maria et al., 2021). The process view is interested in different stages of the process, and capabilities and activities that support the process, and in turn aims at developing tools to support the business model innovation. In a recent review of the CBMI literature, Santa-Maria et al. (2021) provided an overview of the recent literature adopting the process view, organizing them as research addressing the change process itself, its antecedents, moderators, and effects. Specifically, they identified the inherent CBMI uncertainty as an important, yet under-researched, moderator in the process.

Indeed, the literature on uncertainty in (C)BMI is relatively scarce and conceptually vague. For BMI generally, Thompson and MacMillan (2010, p. 293) defined uncertainty as a situation where "*almost anything can happen*" - and thus requires specific strategies for the creation of novel business models in high uncertainty environments. Massa and Tucci (2013) further suggested a generic differentiation between computational complexity (resulting from the large number of possible configurations) and dynamic complexity (resulting from non-linear interdependencies). Following research on BMI adopted these notions, yet with the purpose to identify approaches through which firms or managers cope with uncertainty (Schneckenberg et al., 2017) or make sense and enact the uncertainty (Moqaddamerad and Tapinos, 2022). In the domain of CMBI, Linder and Williander (2017) have underlined the importance of reducing and managing uncertainty and risk, however conflating those two concepts.

A differentiation between risk and uncertainty is important, as it highlights the connection between values at stake (objectives, outcome expectations), risks of possible deviations from expected outcomes, and the uncertainty of such deviations happening (Aven and Renn, 2009). Research on uncertainty in related domains, such as innovation management (Jalonen, 2011), or new product development (Fox et al., 1998) have attended to nuanced concepts of uncertainty, relating different types of uncertainty with different objectives, the context and appropriate approaches for management of the uncertainty. We thus propose that we need a better conceptualization of CBMI uncertainty, in order to study its moderating effect on the CBMI process and to design tools to support the management of CBMI uncertainty.

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4 METHODOLOGY

To identify different types of uncertainty and the firm's approaches to manage or reduce such uncertainty in relation to circular plastics, we follow a qualitative cross-sectional multiple-case study research design (Yin, 2009). Given the lack of theoretical foundation of uncertainty in CBMI, case studies were deemed appropriate (Saunders et al., 2015). Moreover, multiple case studies allow for thorough investigation and a stronger base for theory building and comparable and generalizable results (Eisenhardt and Graebner, 2007). We included seven Danish companies representing a broad spectrum of incumbent manufacturers of plastic products, present in different industries, with different product types, customer structures, and sizes. Moreover, the firms were at different stages concerning their circular business models, from early investigations to full adoption of circular plastics business models.

We collected data through semi-structured interviews both online and in person. We conducted 22 interviews of 45-90 minutes with respondents across seven companies. The respondents were affiliated with different departments, such as materials, operations, R&D, sales and sustainability. The interviews focused on the companies' experience working with circular plastics and their perceptions of key uncertainties and their approaches to manage these uncertainties. The interviews were conducted in both Danish and English and all were recorded and transcribed verbatim. The use of multiple researchers and frequent discussions and evaluations of the data helped to assure reliability.

We coded the interviews using the NVivo software, coding for statements relating to uncertainties and approaches (implemented, considered, or rejected) to deal with uncertainty. Thereafter, we iteratively grouped these statements, following the Gioia method (Gioia et al., 2013), arriving at a grouping of three categories of uncertainty, with six sub-themes (Table 2).

Table 2. Three categories of uncertainty in circular business model innovation

Category	Sub-themes	Examples of sources of uncertainty
Goal uncertainty	*Current goal uncertainty* Uncertainty that assumptions about value propositions are incorrect or based on wrong beliefs.	Lack of understanding how the customer processes a material/semi-finished product Uncertain customers' willingness-to-pay for sustainability Possible divergence between customers' and firm's value perception
	Future goal uncertainty Uncertainty caused by possible events or trends that can shift value propositions.	Compliance with new legislation might create new value propositions for sustainable products Competition's product might shift benefit expectations Societal developments might shift appreciation of lowered environmental impact
Development uncertainty	*Feasibility uncertainty* Uncertainty about whether the BMI offering is even feasible, and if so, how it can be best designed or developed.	Lack of research or in-house experience Lack of knowledge about technologies or materials Uncertain ability to improve environmental impact Uncertain material behaviour in long-term use or further processing Uncertainty of running circular operations cost-effectively
	Capability uncertainty Uncertainty about whether the firm is able to provide the right resources, knowledge, or other capabilities to develop the desired CBMI	Uncertain cooperation from other relevant departments Uncertain availability of resources for initiatives Uncertain support from relevant stakeholders Uncertain abilities for knowledge sharing Uncertain availability of external capabilities
Outcome uncertainty	*Environmental uncertainty* Uncertainty that possible changes to external conditions may affect the ability for value capture.	Variability and sudden shifts in recycled plastics market (price, availability, quality) Uncertain fit of product offering/production technology with requirements Uncertain future offerings of competition, that may reduce the effect of firm's value proposition
	Operational uncertainty Uncertainty whether the operational design allows value capture.	Uncertain ability to effectively control take-back systems or other waste streams Uncertainty of implementing novel internal processes & decision-structures

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5 FINDINGS

Through our analysis, we identified three categories of uncertainty, related to *Goals*, *Development*, and *Outcome* (Table 2). Whereas Goal Uncertainty captures the uncertainty of defining the right objectives for the CBMI, Development and Outcome Uncertainty capture sources of uncertainty during the development or deployment phase, which can have an effect on the achievement of the objectives. Approaches to deal with any of these uncertainties can either serve to avoid the uncertainty and its impact, to reduce the uncertainty, to reduce the possible effect of the uncertainty, to transfer the effect of the uncertainty to a partner, or to simply accept the uncertainty.

5.1 Managing goal uncertainty

Goal uncertainty relates to the question whether the objectives targeted through the CBMI process, i.e. the customer value propositions and internal value propositions, are suitable objectives. Through the interviews, we identified a wide range of value propositions concerning, for example, ease of material processing, product longevity, regulatory compliance, environmental impact, reputational gains, and so forth. However, the interviewees formulated substantial uncertainties related to the validity of these value propositions, addressing both *current goal uncertainty* and *future goal uncertainty*.

Current goal uncertainty relates to unknown or potentially wrongly presumed value propositions in the present. The interviewees partially addressed these uncertainties explicitly, for example through commonly expressed doubts about the customers' actual willingness to pay for products with an improved environmental impact. However, we also encountered examples where the firms assumed concrete customer benefits based on the firm's belief how the customer would use the product, only to learn in the process that these assumptions were wrong. Moreover, some interviewees were also concerned about customers' subjective value perception that was detached from an offering's objective properties or benefits. Concretely, some interviewees referred to the uncertainty that customers might consider a product made from recycled plastics as less safe or of lower quality than its virgin plastic counterpart, despite any objective differences.
To avoid potentially negative effects from current goal uncertainty, some firms targeted only market segments where they considered the uncertainty about value proposition as lower, either because areas of potentially biased perception were less relevant (e.g. non safety-critical components), or because the firm had more knowledge about customers' value perceptions. Talking about home-textiles, one interviewee stated "*in these areas, [producers] almost demand that we use recycled plastics [in our semi-finished product]. Not because it gets better by it [..] but because they get a different stamp and can charge a higher price for it."* Another avoidance strategy grounded in simply hiding the use of recycled plastics from their customers in cases where the properties matched the virgin material.
To reduce the uncertainty, firms acknowledged the need to build up more knowledge about the customers' needs. As one interviewee stated: *"You need to go to their shopfloor and be interested in [what they do]"*. These activities allowed them for example to identify those material characteristics that are most valuable to the customer and to focus their developmental efforts on these issues. Moreover, the engagement with the customers also allowed them to lobby for greener products and their related benefits. However, for products sold to a variety of customers, the effect of engaging with a single customer was limited and thus not pursued as an uncertainty reduction strategy by any of the firms in our sample with a diverse customer portfolio.

Future goal uncertainty concerns possible incremental or radical changes in legislation, societal preferences, or technology, which may influence the benefit perception of customers, and the firm's internal values. For example, interviewees suggested that novel regulatory requirements for use of recycled plastics can create an entirely new value proposition regarding the compliance with the novel regulation. Similarly, slow or sudden shifts in societal preferences can enhance or dampen the value proposition of a decreased environmental impact and shift the importance of having the reputation of an environmentally friendly organization.
To deal with future goal uncertainty, one interviewee suggested that they could either choose an avoidance strategy, waiting until the customers ask for sustainable products, or actively influence the customers' value perception by demonstrating the potential benefits of their recycled plastics products - thereby reducing the uncertainty. This interviewee also highlighted the potential of acting as a front-

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runner in the industry, and thereby shaping the expectations of the customers. Other firms negated the possibility for setting the agenda. For example, an interviewee from a firm delivering to the construction sector stated *"The contractor in our market is conservative. He does not care whether products are sustainable. He wants it as cheap as possible [..] because he has 28 competitors."* Thus, the firm could either only pursue an impact reduction strategy, for the case that customer requirements change. Examples of such impact reduction approaches were the development of a portfolio of products that serve different sets of plausible value propositions, or preparing solutions answering to potentially shifting value propositions through R&D activities.

5.2 Managing development uncertainty

Development uncertainty relates to reservations whether the firm can achieve the development of the CBMI – in particular concerning the development of novel offerings in line with the value propositions and concerning the design of suitable operational structures related to logistics, production technology, marketing channels and so forth. We identified two sources of development uncertainty: *Feasibility uncertainty* and *capability uncertainty*.

Feasibility uncertainty concerns the questions about whether it is – in principle – possible to design a solution satisfying the aspired value propositions within an acceptable timeframe and with acceptable use of resources. The main driver of this uncertainty is limited knowledge about current and future technical possibilities. Firms mentioned for example a current lack of research for their domain as challenging uncertainty in the innovation activities. Feasibility uncertainty also includes concerns about whether a circular business model could actually achieve a reduction in environmental impact, given the complex influences along the supply chain creating the impact. Finally, feasibility uncertainty also captures the concern that the CBMI would not allow offering products at a competitive price, considering uncertain development and operational costs.

A main difference in approaches between firms followed their perception of whether feasibility uncertainty is "given" or whether they actively can influence feasibility uncertainty. Firms that consider this uncertainty as given would avoid it altogether, when they perceived it as too high - sometimes formulating such perceptions in absolute terms. One firm producing medical equipment stated: *"Our hands are pretty much tied. We cannot use these plastics in [..] our applications. Simply because of the purity."* Other avoidance approaches only meant that firms turned towards working with materials, technologies, or partners for which feasibility was better understood.

However, other firms continuously aimed at reducing feasibility uncertainty, mainly by engaging in knowledge creation and knowledge sharing activities. To do so, they built up internal and external knowledge sharing structures, including sometimes even the competition. Such activities also increased the understanding about the possible solution space, thus shifting the perception of feasibility uncertainty (in some cases, however shifting this perception, rendering previously optimistic individuals more pessimistic). Moreover, R&D activities, testing, life cycle analyses, or research collaborations allowed firms to reduce feasibility uncertainty - sometimes even by pushing the current boundaries of technological feasibility. One firm described their current experimentation as such: *"The plan is that we will change some parts to recycled material, some will be virgin. If there's a problem, they can just switch over. [..] maybe in a year we'll know that its stable."*

For persisting feasibility uncertainty, some firms reduced the potential impact of the uncertainty through flexible goals, for example regarding the aspired percentage of recycled plastic used. Others suggested that they simply avoided making claims, about which they felt uncertain, to their customers.

Capability uncertainty addressed the question whether the firm would be able to provide the necessary capabilities to conclude the CBMI process. These uncertainties concern the availability of necessary competences and monetary resources to develop the solution, and the ability to collaborate with internal or external stakeholders. For example, individuals in technical functions often expressed doubt about the collaboration with sales or procurement departments, who they considered essential for an effective solution design. Also, interviewees highlighted the important – yet uncertain – ability to collaborate with external partners, such as suppliers or customers, for the solution development process. The underlying source of these uncertainties were often doubts about support for the innovation activities through important stakeholders, such as management, other departments, customers, or suppliers.

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Avoidance strategies for capability uncertainty were less common and mainly concerned the avoidance of CBMI directions for which individuals expected low managerial or organisational support. To reduce capability uncertainty, we encountered many examples of approaches to assure support, to build up capabilities, and to reduce dependence on specific capabilities. To assure support, some interviewees or firms actively managed stakeholders' perception of the initiative. These activities could take the form of typical change management or lobbying activities, involving key stakeholders, such as the sales department, customers, or suppliers in the development process. Several interviewees also highlighted the importance of strategic goals linked to the CBMI, to increase the probability of managerial and organizational support. However, we also encountered approaches that reduced the likelihood of adverse stakeholder reactions, by hiding the activities (or parts of the activities) from the stakeholders. One interviewee recalled the beginning of their recycled plastics journey: *"[Me and my colleague] started looking into the market […] we did a lot of testing. [..] Only when we were convinced, we went to the management. [..] And we proposed that it's this much we are going to get from CO_2, and other stuff. That's how it started."* Approaches that served to build-up capabilities were, for example, trainings that involved non-technical departments, to foster their understanding how they can contribute to the CBMI both during development and when it is implemented. Other examples were the creation of novel organizational structures – both internally and in collaboration with external partners – to enable knowledge sharing and collaboration.

5.3 Managing outcome uncertainty

Outcome uncertainty relates to concerns about the viability of the to-be designed circular business models once it is deployed. The CBMI outcome can be affected by two sources of uncertainty: *environmental uncertainty* and *operational uncertainty*.

Environmental uncertainties capture uncertainties resulting from variations or changes to the firm's environment. One of the most addressed environmental uncertainties was the future market of recycled plastics. One interviewee characterised the market as the "Wild West" with numerous small suppliers of recycled plastics entering the market, and large consumers of plastic unpredictably appearing, thus raising demand and prices. As such, most of the interviewees were uncertain about the future ecosystem of actors in the circular plastic supply chain, and the effect on future prices, supply volumes, and supply quality. Moreover, some interviewees also identified the emergence of new legislation or radically new offerings of the competition as factors that could affect the viability of their CBMI, depending on its fit with these external changes.

With the supply uncertainty as the most dominant environmental uncertainty, many of the approaches aimed to reduce the uncertainty through taking control of the supply stream. The approaches ranged from re-use of the firm's own scrap, over take-back systems involving customers, to novel form of partnerships with both conventional suppliers or unconventional new supply sources, such as other manufacturer's industrial waste. These approaches sometimes also included product and production re-design to facilitate the recycling of scrap or end-of-life products.

To reduce the impact of environmental uncertainties, firms sometimes designed for flexibility in their products and production technology - for example adjustable percentages of recycled plastics to account for supply and quality variations. Others focussed their CBMI on products or components that were less susceptible to variations in quality. Some firms also chose to make no claims about, for example, the percentage of plastic used, to avoid exposure to reputational damage when supply fluctuations forced them to lower the percentage. Finally, some firms aimed at transferring the risk of variable supply to their suppliers, through contracts that ensured agreed upon volumes and quality. However, firms that engaged in such approaches also acknowledged that such activities increased the costs for sourcing substantially.

Operational uncertainty relates to uncertain factors from operational activities that may affect the achievement of value capture. Effective operations of CBMI require the adoption of novel operational procedures, both in internal functions and at external partners (e.g., waste collection at the customer). Some of the interviewees pointed towards risks resulting from the uncertainty that these operational processes might not be carried out correctly, leading in turn to disruptions of material streams, procurement of unsuitable material, or operational decisions with negative environmental impact.

As operational uncertainty concerns activities largely within the sphere of control of the firm, we found predominantly examples of approaches serving to reduce operational uncertainty by increasing

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control over the processes and their execution. One main activity was change management activities that served to align understanding of the purpose of the novel procedures, and training of different departments on these procedures. Such activities could concern both internal employees, and partner firms. Some firms also explained the need for simplified or streamlined procedures to make it easier for employees to behave or decide in manners that supported the value capture.

6 CONCLUSION, DISCUSSION & OUTLOOK

The CBMI literature acknowledges the importance of uncertainty, yet treats uncertainty as a broad construct, without differentiation between sources or impact of uncertainty. To address this shortcoming, we have proposed a framework of three categories of uncertainty in CBMI, linked with explicit sources of uncertainty within these categories. The category *Goal Uncertainty* highlights the challenges to defining suitable value propositions in the dynamically developing context of circular economy. Goal uncertainty emerges from lack of understanding of the customer's preferences, general ambiguity of value perceptions, and unpredictable shifts of preferences and value perception in a dynamic environment. *Development Uncertainty* points to the challenges in an innovation process that may require a holistic redesign of products, operational and organizational structures, and modes of relating to the customer. It addresses thus uncertainty of whether such a CBMI is in principle achievable, how it can be achieved, and whether the firm has the right capabilities to do so. Finally, *Outcome Uncertainty* underlines the role of external and internal circumstances that may affect the ability to capture value, even if the CBMI was built on sensible value propositions and developed in an effective mode. It thus calls attention to the need for resilience, given the highly unpredictable future of any circular economy.

While the firms in our sample generally faced uncertainties within all three categories, we also observed differences in perceived importance or severity. Some of these differences relate directly to variations between their organizational or market contexts – such as applicable regulations, lifespans of products, or customer structures. While our sample of only Danish firms did not allow to investigate the role of contextual differences in the national environment, the local legislation and maturity of the plastics recycling system might also influence the perception of uncertainties. We also observed effects from organizational culture, prior experience, and values, which may vary between firms or even between units or hierarchical layers within a firm. Such different context have been suggested as the foundation of diverging perception of uncertainties within or across firms (Egfjord and Sund, 2020; Hahn et al., 2014). Finally, some of the different perceptions may also relate to the maturity of the circular plastic use, which can shift the type of uncertainty that firms attend to (Loch et al., 2007). Moreover, some of the interviewees appeared to conceptualize their innovation efforts mainly along the lines of product innovation: just a change in material or product design. However, the most substantial uncertainties they faced emerged from uncertainties that are idiosyncratic to business model innovation - uncertainties about value propositions and about structures to deliver and capture value. Thus, their understanding of the process as "just" a product innovation may limit their ability to identify and understand central uncertainties but also their view on the potential solution space beyond the product innovation itself.
These contextual and perceptual differences result in differences approaches for managing uncertainties in the development and design of the CBMI. While the differences in perceived importance guided which uncertainties firms attended to, their organizational context also shaped the boundaries for the design and choice of approaches to manage these uncertainties. Following these differences, we identified a broad range of strategies that firms adopted to manage their critical uncertainties – responding to their concrete uncertainty landscape within the solution space delimitated by their context.
By providing a conceptualization of CBMI uncertainty that attends to different categories and sources, we offer a conceptual foundation suited to study the role and impact of uncertainty in the CBMI process. Specifically, we propose the following research directions:

1. The conceptualization allows investigating which uncertainties dominate decisions in the innovation process, and whether these dominant uncertainties change throughout different stages of the CBMI process. Such insights could support the development of process support tools.
2. The framework of possible combinations between uncertainties and approaches provides the possibility to research the fit between uncertainty, organizational context, and approach, to support CBMI success. This equally would provide valuable insights for CBMI process support tools.

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3. The conceptualization also highlights differences in the nature of uncertainty – ranging from lack of knowledge, over ambiguity, to true unpredictability. Further research could investigate how CBM designers and decision-makers make sense of and enact these different uncertainties.
4. Acknowledging the important effect of uncertainty perception on behaviour in innovation and design activities (Cash and Kreye, 2018), the conceptualisation could also structure further research in how different uncertainty perceptions across the categories may influence the CBMI process.
5. Our data showed indication of dynamic interdependence between uncertainties and approaches – such as that some uncertainties show correlated emergence, or that some approaches may have contrary effects on different uncertainties and objectives. Future research could map out such interdependencies.

The framework as developed in this paper thus is an invitation for further research based on a novel conceptualisation of uncertainty in CBMI. However, it also presents a valuable tool for orientation for CBMI practitioners. As a structured view on typical categories of CBMI uncertainty, their sources, and potential approaches to manage the uncertainties, it can also act as a sensemaking tool for identifying, assessing, and enacting uncertainty in CBMI processes.

REFERENCES

Aven, T. and Renn, O. (2009), "On risk defined as an event where the outcome is uncertain", *Journal of Risk Research*, Vol. 12 No. 1, pp. 1–11, https://dx.doi.org/10.1080/13669870802488883.

Baldassarre, B., Maury, T., Mathieux, F., Garbarino, E., Antonopoulos, I. and Sala, S. (2022), "Drivers and Barriers to the Circular Economy Transition: the Case of Recycled Plastics in the Automotive Sector in the European Union", *Procedia CIRP*, Vol. 105, pp. 37–42, doi: https://doi.org/10.1016/j.procir.2022.02.007.

Cash, P. and Kreye, M. (2018), "Exploring uncertainty perception as a driver of design activity", *Design Studies*, Vol. 54, pp. 50–79, https://dx.doi.org/10.1016/j.destud.2017.10.004.

Egfjord, K.F.-H. and Sund, K.J. (2020), "Do you see what I see? How differing perceptions of the environment can hinder radical business model innovation", *Technological Forecasting and Social Change*, Vol. 150, p. 119787, https://dx.doi.org/10.1016/j.techfore.2019.119787.

Eisenhardt, K.M. and Graebner, M.E. (2007), "Theory Building From Cases: Opportunities And Challenges", *Academy of Management Journal*, Vol. 50 No. 1, pp. 25–32, https://dx.doi.org/10.5465/amj.2007.24160888.

European Commission. (2019), *A Circular Economy for Plastics : Insights from Research and Innovation to Inform Policy and Funding Decisions*, Publications Office, doi: doi/10.2777/269031.

European Commission. (2022), "Plastics", *European Commission*, available at: https://environment.ec.europa.eu/topics/plastics_en (accessed 28 November 2022).

Foss, N.J. and Saebi, T. (2017), "Fifteen Years of Research on Business Model Innovation: How Far Have We Come, and Where Should We Go?", *Journal of Management*, Vol. 43 No. 1, pp. 200–227, https://dx.doi.org/10.1177/0149206316675927.

Fox, J., Gann, R., Shur, A., Von Glahn, L. and Zaas, B. (1998), "Process Uncertainty: A New Dimension for New Product Development", *Engineering Management Journal*, Vol. 10 No. 3, pp. 19–27, https://dx.doi.org/10.1080/10429247.1998.11414992.

Geissdoerfer, M., Pieroni, M.P.P., Pigosso, D.C.A. and Soufani, K. (2020), "Circular business models: A review", *Journal of Cleaner Production*, Vol. 277, p. 123741, https://dx.doi.org/10.1016/j.jclepro.2020.123741.

Gioia, D.A., Corley, K.G. and Hamilton, A.L. (2013), "Seeking Qualitative Rigor in Inductive Research: Notes on the Gioia Methodology", *Organizational Research Methods*, Vol. 16 No. 1, pp. 15–31, https://dx.doi.org/10.1177/1094428112452151.

Hahn, T., Pinkse, J., Preuss, L. and Figge, F. (2014), "Cognitive frames in corporate sustainability: Managerial sensemaking with paradoxical and business case frames", *Academy of Management Review*, Vol. 4015 No. 1, p. amr-2012, doi: http://dx.doi.org/10.5465/amr.2012.0341.

Hennlock, M., zu Castell-Rüdenhausen, M., Wahlström, M., Kjær, B., Milios, L., Vea, E., Watson, D., *et al.* (2015), *Economic Policy Instruments for Plastic Waste*, 2014:569., Nordic Council of Ministers, https://dx.doi.org/10.6027/TN2014-569.

Jalonen, H. (2011), "The uncertainty of innovation: a systematic review of the literature", *Journal of Management Research*, Vol. 4 No. 1, https://dx.doi.org/10.5296/jmr.v4i1.1039.

Johansen, M.R., Christensen, T.B., Ramos, T.M. and Syberg, K. (2022), "A review of the plastic value chain from a circular economy perspective", *Journal of Environmental Management*, Vol. 302, p. 113975, doi: https://doi.org/10.1016/j.jenvman.2021.113975.

Linder, M. and Williander, M. (2017), "Circular Business Model Innovation: Inherent Uncertainties", *Business Strategy and the Environment*, Vol. 26 No. 2, pp. 182–196, https://dx.doi.org/10.1002/bse.1906.

https://doi.org/10.1017/pds.2023.368 Published online by Cambridge University Press

Loch, C.H., Solt, M.E. and Bailey, E.M. (2007), "Diagnosing Unforeseeable Uncertainty in a New Venture*: DIAGNOSING UNFORESEEABLE UNCERTAINTY", *Journal of Product Innovation Management*, Vol. 25 No. 1, pp. 28–46, https://dx.doi.org/10.1111/j.1540-5885.2007.00281.x.
Massa, L. and Tucci, C. (2013), "Business Model Innovation", in Dodgson, M., Gann, D.M. and Phillips, N. (Eds.), *The Oxford Handbook of Innovation Management*, OUP Oxford.
Matthyssens, P., Vandenbempt, K. and Berghman, L. (2006), "Value innovation in business markets: Breaking the industry recipe", *Industrial Marketing Management*, Vol. 35 No. 6, pp. 751–761, https://dx.doi.org/10.1016/j.indmarman.2005.05.013.
Milios, L., Christensen, L.H., McKinnon, D., Christensen, C., Rasch, M.K. and Eriksen, M.H. (2018), "Plastic recycling in the Nordics: A value chain market analysis", *Waste Management*, Vol. 76, pp. 180–189, doi: https://doi.org/10.1016/j.wasman.2018.03.034.
Moqaddamerad, S. and Tapinos, E. (2022), "Managing business model innovation uncertainties in 5G technology: a future-oriented sensemaking perspective", *R&D Management*, Vol. n/a No. n/a, https://dx.doi.org/10.1111/radm.12559.
OECD. (2022a), *Global Plastics Outlook: Economic Drivers, Environmental Impacts and Policy Options*, OECD, https://dx.doi.org/10.1787/de747aef-en.
OECD. (2022b), *Global Plastics Outlook: Policy Scenarios to* 2060, OECD, https://dx.doi.org/10.1787/aa1edf33-en.
Osterwalder, A. and Pigneur, Y. (2010), *Business Model Generation: A Handbook for Visionaries, Game Changers, and Challengers*, John Wiley & Sons.
Paletta, A., Filho, W.L., Balogun, A.-L., Foschi, E. and Bonoli, A. (2019), "Barriers and challenges to plastics valorisation in the context of a circular economy: Case studies from Italy", *Journal of Cleaner Production*, Vol. 241, p. 118149, doi: https://doi.org/10.1016/j.jclepro.2019.118149.
Pieroni, M.P.P., McAloone, T.C. and Pigosso, D.C.A. (2019), "Business model innovation for circular economy and sustainability: A review of approaches", *Journal of Cleaner Production*, Vol. 215, pp. 198–216, https://dx.doi.org/10.1016/j.jclepro.2019.01.036.
Pieroni, M.P.P., McAloone, T.C. and Pigosso, D.C.A. (2020), "BUSINESS MODEL INNOVATION FOR CIRCULAR ECONOMY: INTEGRATING LITERATURE AND PRACTICE INTO A PROCESS MODEL", *Proceedings of the Design Society: DESIGN Conference*, Cambridge University Press, Vol. 1, pp. 2119–2128, https://dx.doi.org/10.1017/dsd.2020.28.
Sakao, T. and Brambila-Macias, S.A. (2018), "Do we share an understanding of transdisciplinarity in environmental sustainability research?", *Journal of Cleaner Production*, Vol. 170, pp. 1399–1403, https://dx.doi.org/10.1016/j.jclepro.2017.09.226.
Santa-Maria, T., Vermeulen, W.J.V. and Baumgartner, R.J. (2021), "Framing and assessing the emergent field of business model innovation for the circular economy: A combined literature review and multiple case study approach", *Sustainable Production and Consumption*, Vol. 26, pp. 872–891, https://dx.doi.org/10.1016/j.spc.2020.12.037.
Saunders, M.N.K., Lewis, P. and Thornhill, A. (2015), *Research Methods for Business Students*, Seventh edition., Pearson Education, New York.
Schneckenberg, D., Velamuri, V.K., Comberg, C. and Spieth, P. (2017), "Business model innovation and decision making: uncovering mechanisms for coping with uncertainty", *R&D Management*, Vol. 47 No. 3, pp. 404–419, https://dx.doi.org/10.1111/radm.12205.
The Danish Environmental Protection Agency. (2014), *Hazardous Substances in Plastics*, Copenhagen.
Thompson, J.D. and MacMillan, I.C. (2010), "Business Models: Creating New Markets and Societal Wealth", *Long Range Planning*, Vol. 43 No. 2, pp. 291–307, https://dx.doi.org/10.1016/j.lrp.2009.11.002.
UNDP. (2022), *Transitioning to a Circular Economy Through Chemical and Waste Management*, United Nations Development Programme, New York.
UNEP. (2022), "What you need to know about the plastic pollution resolution", *UN Environment Programme*, available at: https://www.unep.org/news-and-stories/story/what-you-need-know-about-plastic-pollution-resolution (accessed 28 November 2022).
Yin, R.K. (2009), Case Study Research: Design & Methods, Vol. 5.

https://doi.org/10.1017/pds.2023.368 Published online by Cambridge University Press