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How do companies measure and forecast environmental impacts when experimenting with circular business models?

Ankita Das*, Jan Konietzko, Nancy Bocken

Maastricht Sustainability Institute, School of Business and Economics, Maastricht University, Tapijn 11 Building D, P.O. Box 616, 6200 MD Maastricht, the Netherlands

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ABSTRACT

Many companies have innovated their business models in their attempts to transition towards a circular economy. However, the label 'circular' does not necessarily mean better for the environment. How do companies measure the environmental performance of their business models? And as they alter them for a circular economy, how do they forecast the potential environmental impacts? These questions are important to better understand the impacts of circular business models. This study sets out to answer these questions through 29 semi-structured interviews and 39 survey responses, with business developers, managers, product designers and consultants from more than 10 industries. The results reveal that while most participants measure the impact of their current business models, they do not forecast the future impacts of their circular business ideas before implementation. The most popular measurement method was rules of thumb, followed by life-cycle assessment (LCA) or LCA-based tools. A lack of data, increased uncertainty during experimentation and a lack of knowledge are the common barriers that keep the participants from measuring environmental impacts. We also found that startups give a lower priority to measuring impacts than large corporates. However, despite the latter having more resources to measure impacts, results from impact assessment might not lead to direct design improvements in the same design cycle. An overarching finding was that the extent of positive impact of circular business models remains uncertain for many participants. Future research can work on developing methods or frameworks that resolve these issues.

1. Introduction

The need for a more circular economy is increasingly being recognised by both governments and the private sector (European Commission, 2020; Government of Canada, 2019; Government of the Netherlands, 2016; Lewandowski, 2016). Businesses are trying to become more sustainable by trialling circular business models (CBMs) that aim at longer product lifetimes and production of less waste (Bocken and Antikainen, 2018; Geissdoerfer et al., 2020). Companies often do this through business model experimentation (Bocken and Snihur, 2020), which tends to follow the – 'build, measure, learn' – Lean Startup approach (Blank, 2013; Ries, 2011). This is an iterative approach, where different business strategies are repeatedly trialled to find the best product-market fit (Chesbrough, 2010). In the circular economy context, business experimentation also focuses on addressing pressing sustainability issues, in particular to narrow, slow, close, and regenerate resource loops (Bocken et al., 2016a,b; Konietzko et al., 2020a).

However, the label 'circular' does not necessarily mean more sustainable, unless a business model is specifically designed to be so (Blum et al., 2020). Well-intended circular solutions can have unintended rebound effects with higher environmental impact (Siderius and Poldner, 2021; Warmington-Lundström and Laurenti, 2020). Previous empirical experiments have shown that consumers might consume larger quantities of products than usual, if they perceive it to be a more sustainable option (Catlin and Wang, 2013; Warmington-Lundström and Laurenti, 2020). Thus, it is important to keep track of the environmental impacts while innovating, to avoid rebound effects (Zink and Geyer, 2017) and missed opportunities.

Many environmental impact assessment approaches have been described in both literature and practice (Harris et al., 2021; Kravchenko et al., 2019; Moraga et al., 2019; Sassanelli et al., 2019). Some approaches are focused on ex-post assessment, or 'measuring after the event', while others are specialised for ex-ante assessment, or 'forecasting' impact before the event (Kravchenko et al.,

* Corresponding author.
E-mail address: a.das@maastrichtuniversity.nl (A. Das).

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2019; Pieroni et al., 2018). However, there seems to be a 'design-implementation gap' between the many sustainability and circularity impact assessment tools created by researchers (e.g., Bocken et al., 2019; Pieroni et al., 2019), and those used in practice. Many tools created by academics are not used in practice, in particular when they have not been tested with prospective users (Baumann et al., 2002; Tyl et al., 2015). This suggests an issue with the viability, feasibility and usability of the current environmental impact assessment tools (Baldassarre et al., 2020). There seems to be a disconnect between what researchers create, and what practitioners need and can use (Van de Ven, 2007).

Further, there is a surprising lack of empirical research on how companies currently assess their environmental impacts, and how they forecast the environmental impacts of their new circular business models (Bocken et al., 2018). Many recent studies have focused on using environmental impact assessment tools to measure the impact of new circular business models (e.g., Hoffmann et al., 2020; Jacobson et al., 2021; Johnson and Plepys, 2021; Lindahl et al., 2014). However, how companies use environmental impact assessment methods during the business model experimentation process is less clear. This leads to the research gaps this study aims to address: understanding how companies measure environmental impact of their current and future business models, and what barriers they face in doing so. The research questions of this study are:

RQ1. How do companies measure the environmental impact of their current business models?
RQ2. As companies experiment with circular business models, how do they forecast the potential environmental impacts?
RQ3. What are the barriers faced by companies when measuring environmental impact?

It is important to understand the answers to these questions, because only by measuring and forecasting impact can companies validate their assumptions about the environmental impacts of their business models. By showing how companies currently measure the environmental impacts of their business models, this study shares insights into common industry practices and barriers related to measuring environmental impact. The findings can benefit researchers working on impact assessment methods by filling a crucial gap in circular economy literature through empirical evidence. The results can also be of use to business developers, designers, and consultants, who are involved in the process of CBM experimentation, by bringing to light the areas that need more support in the environmental impact assessment process.

The following section gives an overview of the conceptual background (Section 2). Section 3 describes the methods, Section 4 reports the results, and Section 5 discusses the findings and limitations. This is followed by the conclusion in Section 6, and suggestions of future research avenues.

2. Conceptual background

In the following three sub-sections we first define circular business model experimentation. We classify companies that experiment towards circular business models into two broad categories, with examples. Second, some examples of the environmental impacts and rebound effects that can result from circular business models are reviewed. In the final section, we discuss the different types of environmental impact, and give an overview of the environmental impact assessment tools currently available for use to academics and practitioners.

2.1. Experimentation towards circular business models

Circular business models present a viable alternative to the current linear systems of production and consumption (Bocken et al., 2016a; Yang et al., 2018). Some examples of such business models include rental, subscription or leasing, refurbished, remanufactured and secondhand products. These types of business models have the potential to significantly reduce environmental impact if actively designed to do so (Tukker, 2004, 2015). While many definitions exist, for the purpose of this study, a business model is defined as the basic plan of how a business proposes, creates, delivers and captures value (Teece, 2010). Circular business models (CBMs) are business models that specifically target environmental and economic resource savings through narrowing, closing, slowing and regenerating resource loops (Bocken et al., 2016a; Konietzko et al., 2020b). Businesses do not necessarily need to close resource loops by themselves, within their own internal system boundaries, they can also be part of a system of business models that together close a material loop, and work towards a 'circular' goal (Antikainen and Valkokari, 2016; Mentink, 2014).

Companies typically test and validate these new business model opportunities through experimentation (Bocken et al., 2016c). Business model experiments can help reduce uncertainty, manage risk and test organisational capabilities in a controlled environment (Poortinga and Whitaker, 2018; Vandenbroele et al., 2019). This early trial phase tends to involve multiple iterative rounds of testing and pilots. Previous studies in product design literature have suggested that 80–90% of a product's environmental impact is decided in the design phase (Konietzko et al., 2020b; Millet et al., 2007). We hypothesize that the same is true for business models, since circular business models are not sustainable by default (Curtis and Mont, 2020; Tukker, 2004). Thus, it is important to forecast the potential environmental impacts of new business models at an early stage, to maximize their impact reduction potential.

Companies that experiment with circular business models can broadly be classified into two categories (Fig. 1). First, there are 'linear' firms that are experimenting with circularity. These are traditional established firms with linear business models, that are trialling new CBMs (Bocken et al., 2017; Weissbrod and Bocken, 2017). These firms still exploit their linear business models as the primary source of revenue, but they conduct business experiments to trial new ways of doing business to reduce their environmental impact. Some recent examples of this include IKEA's Buy-Back Program (IKEA, 2021), Volvo's car sharing and subscription initiatives (Volvo, 2021a, N. b) and Adidas's rental platform trial in France (Adidas, 2021).

The second category of companies are those that are 'born circular', that started out with circular business models as their core business strategy (Henry et al., 2020), but their business experiments can lead them in two directions. In the first case, experimentation could lead to new 'circular' revenue streams, value propositions and market niches. An example of this is Fairphone, a company that sells modular phones and encourages repair (Fairphone, 2021), has recently tested a new phone-as-a-service initiative where the company retains ownership of the phones (Circle Economy, 2017). Another example is the packaging reuse company Loop (Loop, 2021), that has trialled new zero-waste e-commerce systems (WEF, 2019). In the second case, some born circular companies can also conduct business experiments that lead them in the direction of linearity (Zink and Geyer, 2017). This might be the case because there is increased demand for their product offerings, and they are exponentially growing in size, resulting in higher environmental impact (Hamann et al., 2019; Hollingsworth et al., 2019). Another reason may be the pressure to create new revenue streams, and stay ahead of competition

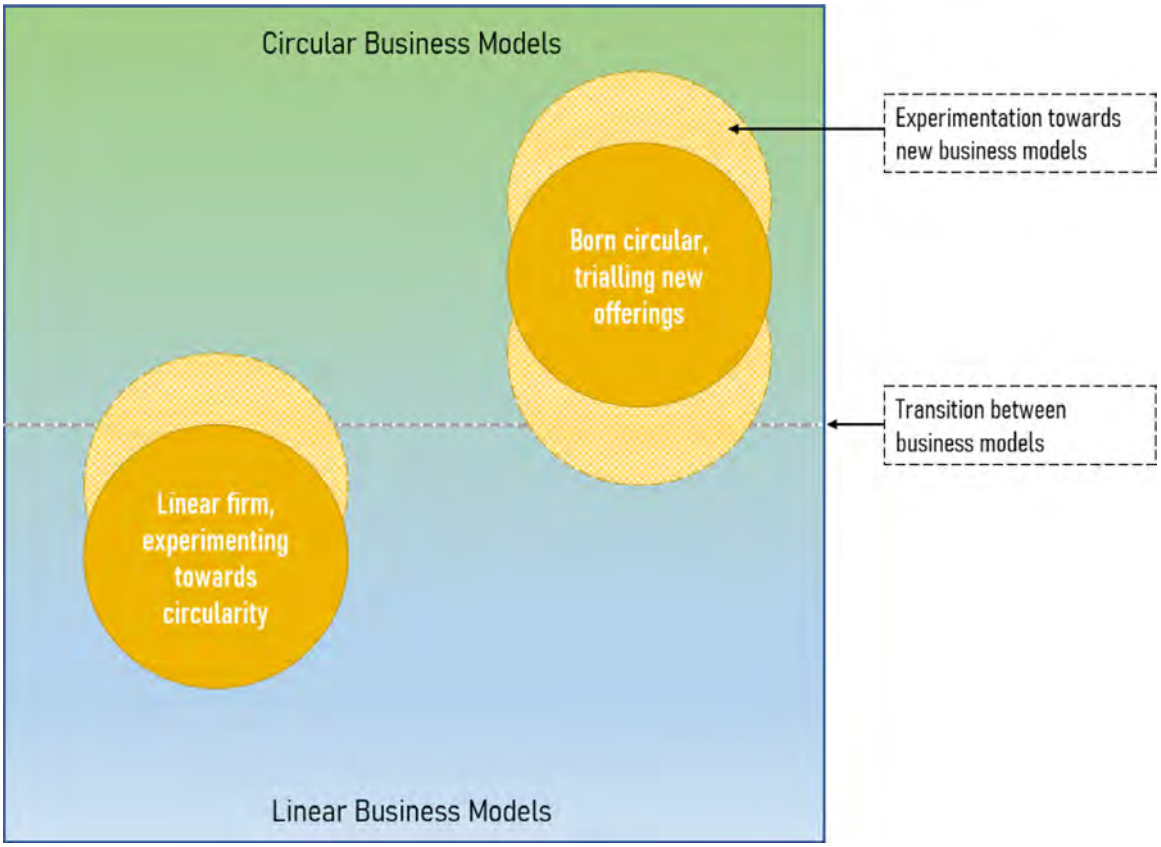

Fig. 1. Categorisation of businesses experimenting towards circular business models.

(Hamann et al., 2019). These 'linear' ventures, and resulting increased environmental impact, may be temporary or permanent, and they might be intentional or accidental. Such companies could be put in this situation because they are unaware of the environmental impacts of their new business ideas before implementation. An infamous example of such a case includes the Mobike bicycle graveyards created from exponential growth and oversupply (Haas, 2017). So, business experiments conducted by companies that may have started out as 'circular' or sustainable, could either create new 'circular' business opportunities, or move them towards linearity through unintended rebound effects (Zink and Geyer, 2017).

The above examples illustrate that business strategies can change quickly and iteratively with every step of the experimentation process (Bocken et al., 2017), as companies trial new ways of doing business to remain competitive. And with every step, they make implicit or explicit decisions on the environmental impact that follows. It is important to measure the environmental impact of these decisions during the experimentation phase itself, in order to prevent design lock-ins (Millet et al., 2007). So how are these experimenting companies keeping track of their environmental impact?

2.2. Environmental impacts of circular business models

As mentioned earlier, CBMs might not be more environmentally sustainable (Blum et al., 2020; Manninen et al., 2018). Perceived savings from circularity can sometimes lead to rebound effects by increasing consumption of other resources (Blum et al., 2020; Catlin and Wang, 2013). Moreover, consumers can sometimes be careless towards rental products, diminishing their potential lifetimes (Tunn, 2020). A 2013 experiment conducted by Catlin and Wang (2013) demonstrated rebounds of consumers who were given access to wastepaper recycling facilities at public restrooms. Based on the narrative that recycling is beneficial for the environment, consumers were later shown to use more paper towels, compared to the control group, when given the option to recycle them. The authors suggest that this might be due to consumers being unaware of the true costs of recycling, and that *"making recycling readily available at all times could actually boomerang such that in some cases people consume more than they otherwise would"* (Catlin and Wang, 2013, p. 123). This experiment shows that recycling can only be a means to an end, and that overall resource consumption needs to be reduced to derive environmental benefits.

Another recent study by Warmington-Lundström and Laurenti (2020) on a peer-to-peer boat sharing platform, showed that both the boat lessees and the lessors experienced rebound effects. In the case of some participants, the rebound effect contributed to losing about one-fifth of potential emissions reduction obtained from the resource sharing. Many study participants reported increased consumption of resources, enabled through economic savings. In some cases, more air travel was undertaken because of the financial savings. In other cases, a higher personal use of the boat than usual was reported. This resulted in a net increase of most of the participants' annual emissions, despite being part of a resource sharing business model. Such field experiments can be crucial in showcasing whether a perceived "green" activity actually has the intended environmental benefits. Therefore, it is important to keep track of environmental impacts while trialling new circular business ideas.

So how are businesses currently measuring their environmental impact? A brief literature scan for empirical studies on this topic was done using Web of Science and Google Scholar be-

tween February and May 2021. The search strings used a combination of the following keywords: “environmental impact measurement”, “environmental impact assessment”, “business model”, “circular business models”, and “empirical research”. For example, a search string used was, “environmental impact assessment” AND “business models” AND “empirical research”. The search included titles, abstracts and keywords, and was limited to journal articles and reviews. This revealed that most past studies (Epstein et al., 2018; Hörisch et al., 2015; James, 1994) have focused on showcasing the best practices for environmental impact measurement, and the efficacy of impact measurement tools. A more recent study by Braig and Edinger-Schons (2020) conducted some related empirical research. But their primary objective was to explore a group of companies’ motivations behind employing “impact measurement and valuation” methods to assess social and environmental impacts. The study did not conduct research from the perspective of businesses experimenting and transitioning towards CBMs. Apart from this, only the Moreno (2013) study conducted empirical research on this topic, as part of exploring a larger research gap on documenting the managers’ perceptions on integrating sustainability in business management. The study surveyed 192 Spanish companies on how they perceive measurement of the impact of their business activities on sustainability. However, this study only looked at the management accounting perspective and asked participating companies about their views on integrating “full cost accounting”. This is defined as identifying and quantifying the full range of direct, indirect, and intangible costs, of the product life cycle, product line, process, service, or activity. Moreover, this study was limited in its geographical scope and conducted in 2013, when the discussion within the private sector on advancing CBMs and assessing their impact just started. Thus, the short literature search did not find any empirical studies that investigated about the actual methods organisations employ to measure environmental impact.

2.3. Present state of environmental impact assessment

Environmental impacts can be created at the micro, *meso* and macro-levels (Harris et al., 2021; Johnson and Schaltegger, 2020). The micro-level is the level of the product or company, the meso–level refers to the level of industrial networks, and the macro-level is at the level of cities, nations, or society in general. Environmental impact assessment tools tend to be specifically tailored to one or more of these levels. For this study, we focus on the micro-level. The word ‘tool’ is used as an overarching term to describe frameworks, assessment methods, indicators, strategies, and tools that can be used by a company to determine the environmental impact of its business model.

Many types of tools exist in both academia and practice for assessing the environmental impact of business models (Pieroni et al., 2019). However, most of these existing methods focus only on the product or material-flow levels (Bocken et al., 2016b; Moraga et al., 2019; Walzberg et al., 2021). Some examples of commonly used impact assessment tools are Input/Output Analysis, Life Cycle Assessment (LCA), Material Flow Analysis, Recycling Efficiency Rate, Global Reporting Initiative (GRI), Greenhouse Gas (GHG) Indicators, and Internal Reporting Guidelines (Moraga et al., 2019; Sassanelli et al., 2019; Walzberg et al., 2021). Environmental impact assessment tools can be divided into two categories: ex-post or ex-ante (Bailey et al., 2002). Ex-post methods measure environmental impacts of the final outcomes after certain actions have been carried out by the company (Kravchenko et al., 2019). They can use lagging indicators, or reactive indicators like ‘amount of waste generated’ and ‘total water consumption’ to quantify impact. Many environmental impact assessment tools, such as the LCA and GRI fall into this category. Ex-ante assessment methods on the other hand, aim to predict impact before the events have occurred (Bailey et al., 2002; Kravchenko et al., 2019). They can use leading or proactive indicators such as ‘industrial efficiency levels’ and ‘types of vehicles used for transport’, to provide guidance and warning about proposed actions, hence giving companies the opportunity to improve on their strategies (Pojasek, 2009).

Several recent review studies (Table 1) have mapped the spectrum of current environmental impact assessment tools used by academia to assess the environmental sustainability of CBMs. The wide range of difference in numbers of reported studies below can be attributed to differing scopes and research questions of the review studies.

The above studies conclude that while existing methods can be adapted to measure environmental impact of CBMs, none of the current impact assessment methods are fully suited to encompass all aspects of circularity yet. Sassanelli et al. (2019) and Harris et al. (2021) identified that the most popular environmental assessment methods used in circular economy literature are LCA based. Most academic studies that try to assess environmental impact of CBMs, create their own adapted method from a combination of the LCA and Life-Cycle Costing methods (Sassanelli et al., 2019). Further, Pieroni et al. (2019) note that most environmental impact assessment tools still need expert guidance for measurement.

To the best of our knowledge, no studies have investigated how companies measure environmental impact of new circular business models in a comprehensive manner. There is a surprising lack of empirical studies on how companies are measuring the environmental impact of their business in practice (Section 2.2). Further, how are they forecasting the change in environmental impact if they experiment with new circular business strategies? We suspect there is a design-implementation gap between environmental impact assessment tools that have been created by researchers, and those that are actually used in practice (Baumann et al., 2002; Tyl et al., 2015). It is important to understand the state-of-the-art of environmental impact assessment from a practitioner perspective, as they are an important stakeholder in the circular economy transition (Tyl et al., 2015). This study aims to fill these gaps through interviews and a survey with key circular business innovators.

3. Methods

The research plan consisted of three steps (Fig. 2): 1) Data collection through a round of interviews and a qualitative survey, 2) Data analysis through qualitative coding in Atlas.ti, leading to the final 3) conclusions and recommendations. The following sections explain this process in detail.

3.1. Data Collection

Data collection followed a multimethod qualitative research approach (Mik-Meyer, 2020), involving two concurrent steps. Multimethod qualitative research combines multiple qualitative research methods within the same study (Mik-Meyer, 2020). They are typically used to complement each other and to expand on the breadth and range of enquiry (Greene et al., 1989; Schoonenboom and Johnson, 2017). In this study, semi-structured interviews and a qualitative survey were conducted with business practitioners, service designers, managers, and consultants. Qualitative surveys are a less well-known data collection method that are growing in popularity in social research due to the ease in distributing and administering them in the digital age (Braun et al., 2020; Clarke and Demetriou, 2016; Whelan, 2007). The wider scope available through qualitative surveys helps to reduce the risks that occur in the typically smaller samples from only interview research,

Table 1
A list of recent review studies that have attempted to map the environmental assessment methods currently used by researchers.

Authors	Number of studies reviewed	Number of unique impact assessment methods identified
Harris et al. (2021)	135	5 types of methods
Kravchenko et al. (2019)	52	270 indicators
Moraga et al. (2019)	14	20 indicators
Opferkuch et al. (2021)	–	15 methods
Pieroni et al. (2019)	94	92 approaches
Sassanelli et al. (2019)	45	22 methods
Walzberg et al. (2021)	–	7 methods

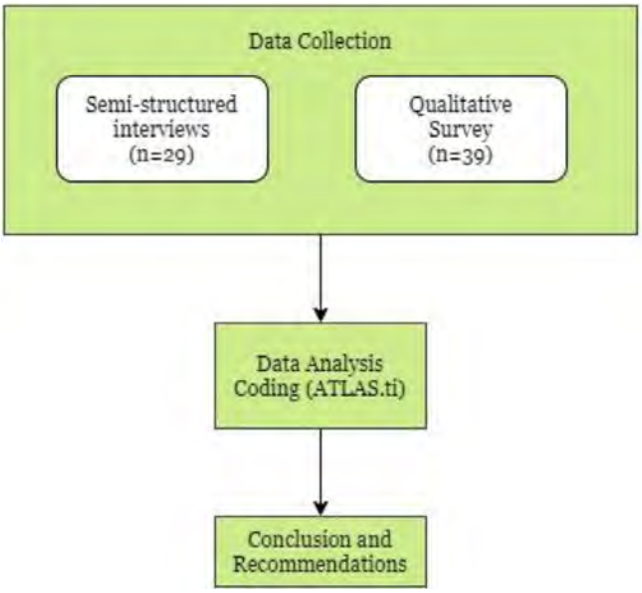

Fig. 2. Research Plan.

where the opinions of a few participants, who might speak from non-dominant social positions get treated as the 'spokesperson' for the group (Braun et al., 2020). That is why we opted to combine a survey and interviews.

In total, 68 data points were collected (29 interviews and 39 survey responses). Data saturation was observed three-fourths of the way into the data collection process, and no new significant findings were emerging (Saunders et al., 2018). All parts of the data collection process were completed between May 2020 to June 2021. Participation was voluntary and the interviewees and survey respondents were not compensated for participating. All responses collected from the interviews and the survey were anonymised.

3.1.1. Interviews

A purposive sampling, followed by snowball sampling method was used for data collection (Bryman and Bell, 2011). While there are disadvantages to snowball sampling like the difficulty of retrieving randomized samples, it is increasingly used in qualitative research (Kirchherr and Charles, 2018), and is a recommended method when the total cohort from which the data sample must be drawn is unclear (Bryman and Bell, 2011). In this study, we were faced with the difficulty of creating an accessible sampling frame for the total population of companies experimenting with CBMs, from which the data sample was to be taken.

Circular economy transition experts in business who were involved experimentation with new circular business ideas were initially identified through desk research. This was achieved by scanning company websites, online databases, and the authors' professional networks for potential interviewees. The primary inclusion criterion was that an organisation must display some form of experimentation towards circular business models. This meant that they had to be making active attempts to maximise the value of their products while minimizing the depletion of natural resources (Geissdoerfer et al., 2020). The target sectors were the furniture, clothing, food, built environment, energy-using appliances, mobility, and consumer goods sectors. These sectors were chosen because of their high environmental impact reduction potential (Tukker et al., 2010, 2016). Business consultants who assist companies in measuring their environmental impact were also considered relevant and included in the sample.

After the first round of interviews, participants were asked to identify further potential interviewees, who were then contacted by the authors. In total, $n = 29$ semi-structured interviews were conducted with practitioners. A complete list of participants and their organisational attributes can be seen below in Table 2. Interviewees were selected from small (1–10 employees), medium (10–250 employees), and large (>250 employees) enterprises (OECD, 2021), to include a wide range of views. The organisation listed as 'Other' under 'Organisation Size' in Table 2 represents a public administration organisation that is also involved in experimenting with new circular strategies. The list of interview questions used, and the protocol followed is available in Appendix A.

3.1.2. Survey

In addition to the interviews, a qualitative survey was conducted to broaden and diversify the sample size, and to supplement the emerging interview results. For example, 83% of the interviewees were from small and large-size organisations, and 97% of the participants were from Europe (Table 3). The survey made up these interview sample limitations by adding more respondents from medium-sized enterprises. The survey also included some respondents from other geographical contexts (Africa and Asia), that are often underrepresented in circular economy literature (Hofstetter et al., 2021). The Qualtrics application was used to conduct the survey. Construction of the questionnaire was based on the approach described by Choi and Pak (2005), to ensure lack of bias in the questionnaire. This was done by ensuring use of neutral language in the questions, and randomisation of some of the multiple-choice answers. The survey questions were a combination of multiple-choice answers and open questions. The survey was pre-tested and optimised with feedback from five respondents from academia and industry before being announced on social media. The full survey questionnaire, with the display logic is available in the Appendix B.

A broad social media sampling type approach was followed. The survey was shared on the authors' LinkedIN, Twitter and Facebook pages, and through the official channels of the research project under which this study falls. This was followed by distribution through targeted emails to mailing lists and CBM innovation groups. The announcement post included text such as:

Table 2
List of interviewees and their organisation attributes.

Interviewee	Industry Sector	Position of interviewee	Organisation	Organisation Size	Interview Mode	Duration
Interviewee #1	Furniture	Circular Service Business Designer	Organisation #1	Large	Zoom (video recording)	30m + 44m
Interviewee #2	Furniture	Sustainable Business Developer	Organisation #1	Large	Zoom (video recording)	46m + 1h
Interviewee #3	Furniture	Service Circular Business Designer	Organisation #1	Large	Zoom (video recording)	49m
Interviewee #4	Furniture	Project Leader of Circular Supply Chain Team	Organisation #1	Large	Zoom (video recording)	41m
Interviewee #5	Furniture	Circular Business Development	Organisation #1	Large	Email	–
Interviewee #6	Furniture	Circular Business Development Leader	Organisation #1	Large	Email	–
Interviewee #7 & #8	Clothing	Founder + Marketing & Social Media Manager	Organisation #2	Small (Startup)	Zoom (video recording)	25m
Interviewee #9	Clothing	Director of Second-Hand Ventures & Corporate Development	Organisation #3	Large	Zoom (video recording)	17m (in 36m call)
Interviewee #10	Clothing	Product Area Manager Circular Business Model Innovation	Organisation #4	Large	Zoom (video recording)	12m
Interviewee #11	Food	Sustainability Manager	Organisation #5	Medium	Zoom (video recording)	28m
Interviewee #12	Food	Global Content Creator	Organisation #6	Large	Zoom (video recording)	10m
Interviewee #13	Food	Global Sustainability Manager	Organisation #6	Large	Zoom (video recording)	18m
Interviewee #14	Food/ Built-environment	CEO	Organisation #7	Small (Startup)	Zoom (video recording)	22m
Interviewee #15	Construction	Community Affairs Officer (specialisation in climate, circular economy & energy transition)	Organisation #8	Other	Zoom (meeting notes)	10m (in 30m call)
Interviewee #16	Energy-using Appliances	Co-founder	Organisation #9	Small	Zoom (video recording)	08m
Interviewee #17	Energy-using Appliances	Co-founder	Organisation #9	Small	Zoom (video recording)	15m
Interviewee #18	Energy-using Appliances	Director, Circular Solutions	Organisation #10	Large	Zoom (video recording)	25m
Interviewee #19	Energy-using Appliances	Innovation Lead & Design Strategist	Organisation #10	Large	Zoom (video recording)	20m
Interviewee #20	Energy-using Appliances	Head of Environmental Impact Assessment Unit, Global R&D	Organisation #10	Large	Zoom (video recording)	18m
Interviewee #21	Energy-using Appliances	Program Manager for Circular Economy & Transformation	Organisation #11	Large	Zoom (video recording)	1h
Interviewee #22	Mobility	Head of Sustainability	Organisation #12	Large	Zoom (video recording)	26m
Interviewee #23	Mobility	Co-founder	Organisation #13	Medium	Zoom (video recording)	22m
Interviewee #24	Mobility	Environmental Impact Assessor	Organisation #13	Medium	Zoom (video recording)	27m
Interviewee #25	Mobility	Founder	Organisation #14	Small (Startup)	Zoom (meeting notes)	10m (in 1h call)
Interviewee #26	Business Model Design Consultancy	Partner & Service Designer	Organisation #15	Small	Zoom (video recording)	38m
Interviewee #27	Business Model Design Consultancy	Impact Entrepreneur & Designer	Organisation #16	Medium	Zoom (video recording)	20m
Interviewee #28	Business Model Design Consultancy	Climate Impact Consultant	Organisation #17	Small	Zoom (video recording)	23m
Interviewee #29	Consumer Goods	CEO & Co-founder	Organisation #18	Small (Startup)	Zoom (meeting notes)	10m (in 30m call)

Table 3
Sample profile of informants from semi-structured interviews and survey.

	Interview		Survey	
Sample profile	Number	Percentage (%)	Number	Percentage (%)
Company size				
Small (1–10 employees)	9	31	6	15
Medium (10–250 employees)	4	14	17	44
Large (>250 employees)	15	52	11	28
Other	1	3	5	13
Total	29	100	39	100
Sector				
Construction	2	7	4	10
Consumer goods	1	3	1	3
Consulting	3	10	19	46
Energy-using appliances	6	21	2	5
Food	3	10	–	–
Furniture	6	21	–	–
Mobility	4	14	1	3
Textile/Clothing	4	14	2	5
Waste Management	–	–	5	13
Other	–	–	6	15
Total	29	100	39	100
Geographical location				
Africa	–	–	2	5
Americas (North & South)	1	3	4	10
Asia	–	–	3	8
Europe	28	97	30	77
Total	29	100	39	100

"*Are you working on circular innovations? Are you unsure if 'circular' means more sustainable? Are you worried about environmental impacts of your business models? We are conducting a research study to explore these answers. If you are a consultant, innovator or business developer interested in these issues, then we would like to invite you to fill out this quick 5-minute survey*"

Respondents were allowed to self-identify as circular economy innovators. However, this might have been one of the limitations of the survey sampling approach, as respondents could have been subject to self-selection bias (Choi and Pak, 2005). A summary of the recorded survey responses can be seen in Table 3 below. The survey also collected some incomplete and /or non-relevant responses, which had to be discarded.

A first round of review of the survey responses was done to filter the sample to only include responses which were more than 50% complete. A manual scan of discarded responses showed that one response could be considered relevant due to the answers that had been filled for the open questions. This resulted in a total of 57 relevant responses. A second manual scan of the 57 relevant responses was done, for a closer review of the survey answers. The responses were further filtered based on the following criteria: answers were complete, relevant to the research questions, and respondents gave legitimate, verifiable answers to the questions about organisation name and their role. This resulted in a final total of 39 usable responses. The first part of the survey answers that identified the respondent's organisation and role were first used to ensure the legitimacy of the responses. These details were then anonymised to ensure privacy. This was done by the first author, and the subsequent results were checked by all authors to ensure validity and accuracy.

3.2. Data analysis

The findings from the semi-structured interviews and survey were analysed and reported together, as the nature of the respondents in both data samples is similar. The results from both data collection methods were found to jointly answer all three research questions. Data analysis followed an analytic induction approach (Bryman and Bell, 2011).

The interview transcripts were coded and analysed using the ATLAS.ti software by the first author. In order to follow a systematic approach, the coding method described by Patten and Newhart (2017) was followed. First, open coding of the most prominent themes was conducted. Next, axial coding was done, and the data was re-examined and reorganised to identify interrelationships between the different categories identified via open coding. Finally, core coding was done to develop main overarching categories, under which the other subcategories belong, to answer the research questions. For the survey, data analysis of the multiple-choice questions was first done using Excel. The responses were tabulated, and the results were compiled into descriptive statistics to provide simple summaries about the sample (e.g., in Sections 4.1 & 4.2). Then the responses for the open questions were coded using ATLAS.ti, using the same approach as for the interview transcripts.

Table 3 presents a profile of the organisations that participated in the semi-structured interviews and survey. The semi-structured interviews had 29 participants, representing 18 organisations; that is, some interviewees represented the same organisation. The survey included a sample of 39 respondents. The table details the characteristics of the different organisations based on company size, sector, and the geographical location they are headquartered in.

4. Results

Most of the participants reported that they measure the environmental impact of their current business model. However, the majority also indicated that they do not forecast the future environmental impact of new circular business ideas, before trialling them. The participants typically measured the environmental impact of their business models using rules of thumb and LCA/LCA-based tools. We also found that startups gave a lower priority to measuring environmental impact than large corporates. An overarching finding was that the extent of the positive impact of CBMs remains unclear to many participants. Section 4.1 details how organisations currently measure their environmental impact, including the tools and methods they use. Section 4.2 delves

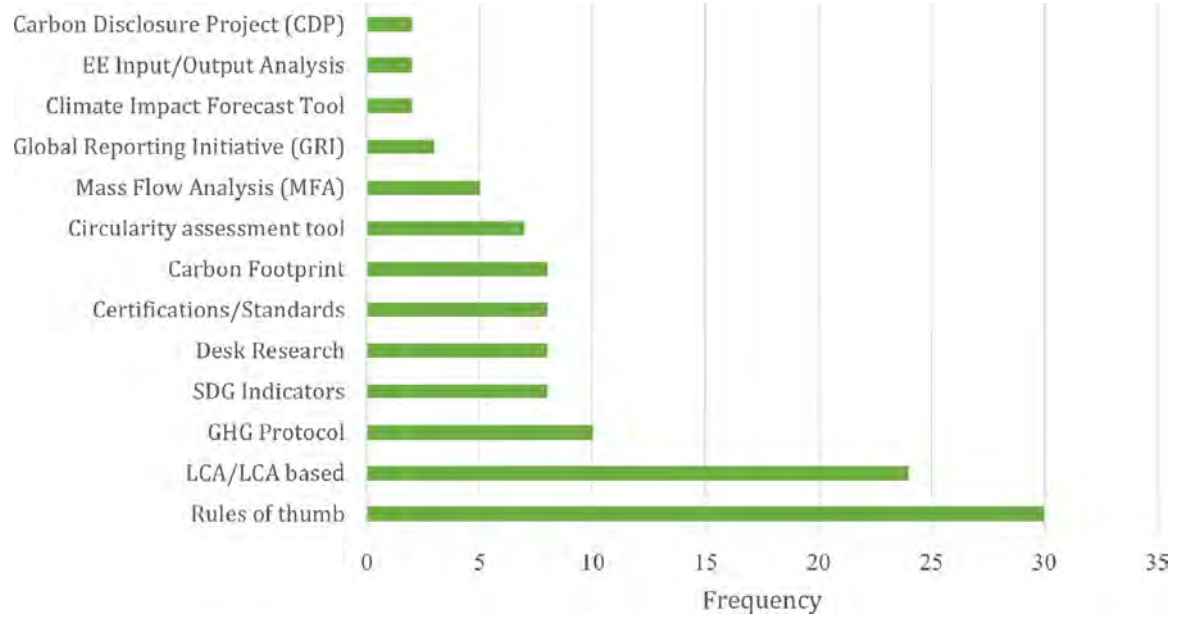

Fig. 3. Frequency of environmental impact measurement tools observed in data sample (SDG: Sustainable Development Goals; GHG: Greenhouse Gas; LCA: Life-cycle assessment).

into how organisations forecast the environmental impact of new circular business ideas. Section 4.3 describes some of the barriers to environmental impact measurement that we identified. Section 4.4 concludes with some remaining common open questions that the participants had.

4.1. How is the environmental impact of business models being measured?

In the first part of the interview and survey, participants were asked if their organisations measure the environmental impact of their current business model. Most of the participants reported that they measure the environmental impact of their business models (90% of interviewees and 64% of survey respondents). Three of the interviewees (10%) said they currently do not measure their impact but have tried and failed to do so in the past. This was attributed to the complicated and time-consuming nature of environmental impact measurement. Eight of the survey respondents (21%) said they do not measure their environmental impact, and six (15%) indicated they were not sure.

The participants who indicated that their organisation assessed environmental impact, were asked to specify the tools and methods used for this purpose. Some participants reported multiple different types of measurement strategies. This accounts for the higher number of reported tools (82) compared to the data sample size ($n = 68$). Fig. 3 shows a graph of the list of tools reported in the data sample, including the number of times they were mentioned by the participants. Analysis of the answers revealed that 'rules of thumb' was the most popular type of measurement method. This refers to the use of internal guidelines or policies regarding circular design, the measurement of customer use behaviour, or the rough estimation of emissions diversion from landfilling. These measurements could be based on expert input or on internal desk research by the employees. In some cases, organisations used sensors to conduct their own technical measurements. These measurements would then be compared over time to self-determine whether there is a net positive or negative environmental impact. The second most cited type of tool was 'LCA/LCA-based'. This either involved conducting a full life cycle assessment (LCA) or relying on quick-LCA tools. Some common quick LCA tools mentioned were SIMApro, GRANTA and Idemat. 'GHG Protocol' was the third most reported type of measurement method.

Some participants expressed concern about whether their current methods of assessment were accurate and robust (Interviewees #12, 13, 14). Others indicated that they only partially assessed environmental impact, of only a part of their business model or specific initiatives (Interviewees #11, 17). Survey respondent #8 said they use quick LCA-based assessments, but it *"still needs to find [its] way into all projects"*. In some cases, interviewees had conducted measurements using LCAs at a specific point in time and were using the single report as a reference point to make business decisions (Interviewees #14, 23, 24).

4.2. How do companies forecast the environmental impact of new circular business ideas?

Participants were asked if their organisations forecast the environmental impact reductions of new circular business strategies designed to improve sustainability. Most of the interviewees (96%) reported that they were not actively forecasting the environmental impact of their new circular business ideas during experimentation. The remaining one interviewee said that they tried their best to forecast the impact, but that it depended on the nature of a specific initiative. Interviewee #9 said:

> *"if possible, [we] measure things beforehand, so before we launch these initiatives. And if not, we measure them after the fact. So it totally depends on the business, on the venture, on the initiative."*

Some interviewees noted that they had sometimes achieved higher sustainability unintentionally through financial decisions, where reducing environmental impact was not the primary aim, but a consequence of a decision to minimize cost. For example, interviewee #17 who works for a company that provides white goods as a service said:

> *"We have our own operational sustainability, but that is also cost driven. We try to minimize the number of trips, which has a sustainable impact. But it's mostly driven out of cost [concerns]."*

Contrary to this, most of the survey respondents (64%) indicated that they forecast the environmental impact of new CBM

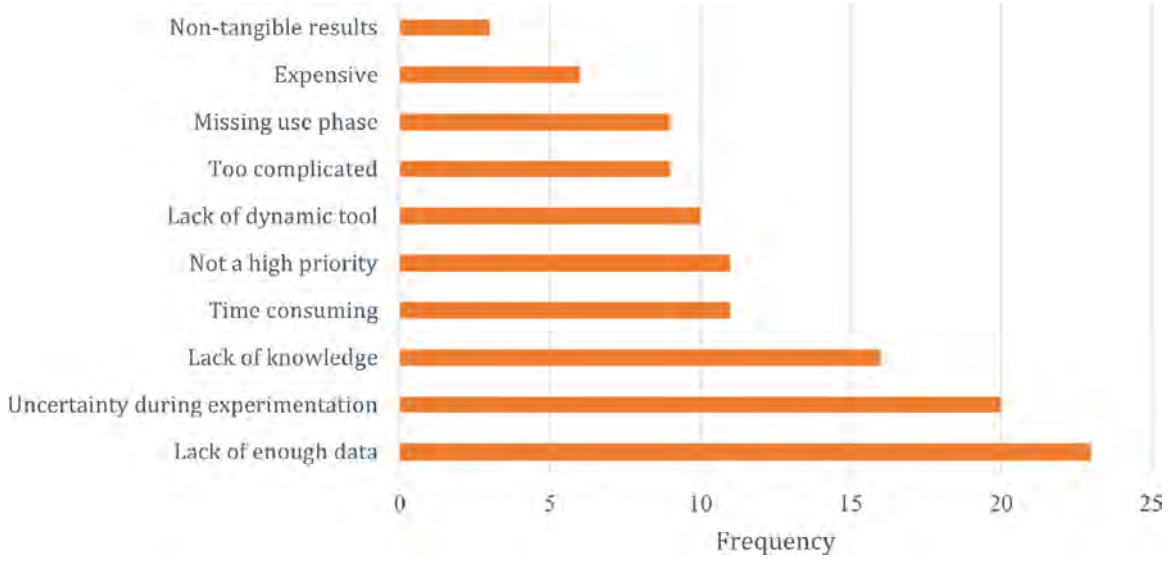

Fig. 4. Frequency of barriers to measuring environmental impact observed in the data sample.

ideas. The respondents reported that they typically achieved this either through LCA-based scenario analysis or through designing their new CBM ideas based on rules of thumb. For example, survey respondent #2 said that they *"design and engineer by three principles to activate circularity"*. Survey respondent #3 said *"Every project [we] take internal or external has to have ESG [Environmental, Social & Governance] goals that are aligned with universal frameworks (SDGs [Sustainable Development Goals] as minimum)"*.

The difference in interview and survey results regarding this question can perhaps be attributed to the different data collection methods. The survey respondents could have had a limited understanding of the question, as forecasting of environmental impact is not frequently talked about. In the case of the interviews, it was observed that interviewees often needed clarification on what 'forecasting' of environmental impact meant. This was not possible in the survey method.

4.3. Barriers to measuring and/or forecasting the environmental impact of circular business models

Participants were also asked if there are barriers associated with measuring and/or forecasting environmental impact of their circular business ideas. The three most common barriers we found are 'lack of enough data', 'uncertainty during experimentation' and 'lack of knowledge'. We detail them in turn. Sometimes, respondents reported multiple different barriers. This is the reason for a higher number of barriers (118) reported versus the participant sample size ($n = 68$). The complete list is reported below in Fig. 4, along with their frequency of occurrence in the data sample.

'Lack of enough data' was the most frequently cited barrier. Participants reported a lack of reliable and/or accessible data sources, with some stating that current databases can have a lot of assumptions and guestimates. On being asked about improving the accuracy of their environmental impact calculations, interviewee #13 said:

> *"I would love to do that, but the response I got from all of [our impact assessment consultants], is that our calculation is not exact or scientific enough. It is based on approximation, it is based on a FAO [Food & Agricultural Organisation] research, which they cannot guarantee"*.

Some participants also mentioned that *"gathering of data can be a challenge"* within companies. For example, interviewee #20 said

> *"most of our products are not designed to collect data useful for LCA. I think to know the use patterns of our products [would be] very very important"*.

The second most cited barrier was the high uncertainty of new business strategies during business model experimentation. This can hinder environmental impact assessment as companies often have to make a lot of assumptions and generalisations, which can make it hard to quantify environmental impact of all parts of their business idea. Interviewee #14 said:

> *"there are no numbers I could tell you now because…we guesstimate what it might be. But we don't know exactly as it is very difficult to calculate for us, because we have so many elements coming together…[our] product is dynamic and essentially changes based on what the client wants"*

The third most common barrier was the 'lack of knowledge' of participants (or their organisations). This leads to an inability to comprehensively measure the current environmental impact, and to accurately forecast environmental impact reductions from their business models in the future. Participants noted that the understanding of how to measure environmental impact tends to remain concentrated to a few trained individuals. This potentially prevents designers and business developers from incorporating lower impact choices during the design and experimentation phase.

The remaining barriers discovered are: 'time consuming', 'not a high priority', 'lack of dynamic tool', 'too complicated', 'missing use phase', 'expensive' and 'non-tangible results'. The code categories which don't have straightforward definitions are clarified below.

Not a high priority. This refers to the lack of laws compelling measurement of environmental impact. It also refers to the observed trend of environmental impact measurement having a lower priority for startups, as they have many other things to keep track of. In some cases, it also refers to the notion that the exact tracking does not matter, as most changes are perceived to be positive based on rules of thumbs.

Lack of dynamic tool. Many participants noted that some current environmental impact assessment tools (like LCA) give results for one product at a moment in time. They are not adaptive, reactive, and predictive for business models that are constantly changing.

Missing use phase. As companies trial product-as-a-service type of business models, they find it difficult to quantify and forecast the environmental impact reductions in the consumer use phase.

Participants reported that this does not seem to be covered very well by existing impact assessment tools so far, and assessments can only be done with a lot of assumptions right now.

Non-tangible results. These participants found it hard to translate results from current environmental impact assessment tools into actionable conclusions.

Another finding was that a majority of the startups and smaller companies (11 out of 15) tend to prioritize environmental impact measurement less than larger firms. This included startups that were trying to stand out from the rest by labelling themselves as 'circular'. They showed a high desirability to measure environmental impact, but often lacked the resources, time, and expertise to do so. For example, on being asked about measuring the environmental impact of their clothing product, interviewee #7 who works for a start-up said:

> *"I tried to in the beginning, but it's very hard and it wasn't that possible. I looked into how [to] wash it properly, where I should wash it. Should I wash it at home, or should I go somewhere and wash it, but that was a little hard".*

The interviewee's company also tried to commission an LCA, which failed:

> *"because it's really complicated to measure it and I searched for a lot of people, who would be able to do it. But, they told me that it's very hard and it's like a job. You need a lot of time".*

Interviewee #29 who runs a consumer goods company said:

> *"It is very hard. Initially a LCA was proposed. But the challenge with a LCA is that it is for one-product, at one point in time."*

In contrast, most participants from larger companies measured environmental impact in some form or the other. This can probably be attributed to a higher availability of resources to measure environmental impact in larger firms. But this might not necessarily translate into meaningful changes in the same design phase. Interviewee #20, an LCA expert working at a large multinational appliances manufacturer, noted that there is often a disconnect between the designers and the impact measurement experts. This leads to missed opportunities in terms of reducing environmental impact of new initiatives, as impact only tends to be measured at the end of the design phase.

4.4. Open questions

Finally, the data analysis also revealed some open questions that many participants had in common regarding environmental impact measurement.

First, as many of the study participants coming from linear firms were trialling new service-based business model strategies, they had questions about the use phase. These questions were around uncertainty about quantifying environmental impact reduction from changes to usage and the extended product lifetime. So, the way the consumer uses the service - also in relation to other products and services the consumer has access to - really influences the environmental impact.

Second, there was a concern about the trade-off between economics and environmental impact and how these two may be decoupled. Participants questioned how longer-term benefits or return on assets from adopting CBMs could be included in the core business valuation, while also keeping in mind the total cost of ownership for the company that might result from operational and repair costs (Interviewees #1, 2, 17, 15, 22). For example, interviewee #23, the co-founder of a bike mobility scale-up said:

> *"I'm pretty much convinced that we need to go to at least a net zero economy, and a net zero world, based on the climate impacts, [but] there is also a real business value [in adopting CBMs]….[However,] because we retain ownership over the product, we also have to take care of the waste, over the transport, over the insurance. Those kinds of warranties, so that's all the costs that you add. And you should not forget [when adopting CBMs] those because otherwise you will have a very loss-making business"*

Third, an overarching finding was that despite all the effort of innovation, the positive environmental impact of CBMs still seems uncertain in the minds of most practitioners. This amplifies the need for easy-to-use environmental impact forecasting tools. Interviewee #2, who works for a large multi-national furniture manufacturer said:

> *"I think still there is a big hole there. Because if we are saying that circular economy is one of the very important tool for us to reach climate performance. So how do we quantify that? Because today we're not talking about the use phase at all, except there will be a longer use phase, but how do we quantify how much the circular economy is contributing to the climate challenge."*

5. Discussion

To date, few studies have investigated empirically how companies assess and forecast the environmental impacts as they experiment with new circular business models. To this end, this study adds the following new findings.

First, we aimed to understand how companies measure the environmental impact of their business model. The findings showed that a majority of the participants measure environmental impact of their current business models. The most common types of tools used by practitioners for measurement of environmental impact are 'rules of thumb'. This refers to businesses designing new ideas based on internal guidelines related to circular design principles or using technology to conduct technical measurements of their environmental impact. This is in contrast with the most used environmental impact assessment tool by academics (LCA) that was identified by the review studies mentioned earlier (Harris et al., 2021; Sassanelli et al., 2019). The second most used type of impact assessment tool by practitioners was 'LCA/LCA-based tools', such as SIMApro, GRANTA, and Idemat. The third most used type of method was the 'GHG protocol'. While the use of LCAs could give a fact-based assessment, the use of the latter method could result in some inaccurate measurements. This can lead to design lock-ins and rebound effects (Blum et al., 2020; Manninen et al., 2018).

Second, we explored how companies forecast the potential environmental impact as they experiment with new circular business model ideas. We found that most of the study participants did not forecast the environmental impact of their new circular business ideas before implementation. The participants that did report forecasting environmental impact, did so through 'LCA-based scenario analysis' or based on 'rules of thumb'. Some participants also reported that they had at times unintentionally achieved greater environmental impact reductions through secondary consequences of cost-cutting financial decisions. In the uncertain experimentation phase, guidelines and rules of thumb are the type of assessments that practitioners seem to rely on most if they provide the necessary guidance before sufficient data can be obtained for a more in-depth assessment. Hence, there seems to be a gap between methods that academics use when assessing new circular business models such as LCA on behalf of companies (e.g., Lindahl et al., 2014) and the real or preferred methods during experimentation.

Third, we studied the barriers companies encountered when measuring environmental impact of their business models. The top three barriers that companies faced were, 'lack of enough data', increased 'uncertainty during experimentation' phase and 'lack of

knowledge' on how to comprehensively measure environmental impact of circular business models. Many participants felt that most current environmental impact assessment tools are not fit for the rapid business experimentation process. These findings corroborate inferences from existing literature on the barriers to adoption of circular business models (Guldmann and Huulgaard, 2020; Vermunt et al., 2019), that found a lack of adequate tools to assess and manage risks associated with circular business models. This showcases that a lack of understanding of environmental impacts is closely linked with reduced adoption of circular business models. In general, greater awareness of potential environmental impact reductions of new business models and the existence of appropriate methods during the experimentation phase could help guide better business model design for sustainability. While previous studies have identified and mapped circular business model innovation tools and methods (Bocken et al., 2019; Pieroni et al., 2019), there is a specific need for approaches to be used to measure environmental impact improvement during the experimentation phase with new circular business models.

Fourth, most study participants showed a high desirability to track environmental impact, but we found that startups often gave a relatively low priority to measuring the environmental impact of their business models, compared to large corporates. This was typically due to lack of resources, time, and the complex nature of environmental impact assessment. This also applies to startups that attempt to distinguish themselves by branding themselves as 'circular'. In contrast, large corporates measured environmental impact because they have more resources to do so. But the results from their impact assessments might not lead to design improvements in the same design cycle. Participants observed that the knowledge of measuring environmental impact tends to be concentrated with a few experts within the company, who are different from the product or business model designers. This led to a lack of environmental impact forecasting during the design phase, which could lead to rebound effects (Blum et al., 2020; Manninen et al., 2018). Better internal training and building synergies between the designers and impact assessment teams can help overcome these issues. Additionally, the availability and increased awareness of easy-to-use and quick forecasting tools catered towards the design phase could help designers track environmental impact while they are still in the experimentation phase. Such tools could also enable measurement of environmental impact amongst companies with limited resources.

Fifth, the companies in the sample that experiment with product-as-a-service types of business models struggled to quantify the environmental impact reduction generated from extending the consumer use phase. Some participants questioned how the long-term benefits and return on assets generated from adopting circular business models could be incorporated into their core business valuation before implementation of the new business models. In conclusion, the extent of potential positive impacts of circular business models remained unclear in the minds of many participants.

The study also has some limitations. First, it should be noted that the interviewees were selected through snowballing and the survey respondents through social media allowing them to self-identify themselves as circular economy innovators. This was done to expand the number of respondents but may have also resulted in a more heterogenous sample. Second, the survey method did not allow for direct clarification of questions, whereas in the case of the interviews, the interviewees had the opportunity to ask follow-up questions, and to have questions clarified to them by the interviewer. While we did remove some invalid questionnaires (i.e., those that were largely incomplete), a survey still has the inherent disadvantages of not connecting with the respondents directly to judge respondent suitability or clarify questions.

6. Conclusion

To conclude, the results of this study reveal important insights into how companies are currently measuring environmental impact, how they forecast impact of new circular business model ideas, and the setbacks they face while measuring impact. In doing so, we add empirical evidence-based answers to a crucial research gap. The findings reiterate the need for practitioners to recognise that forecasting environmental impact is necessary in order to avoid missed opportunities and rebound effects. Crucially, we found that currently most companies do not forecast the environmental impact of their new circular business ideas before implementation. This could lead to potential design lock-ins and unintended rebound effects. To avoid this, more effort needs to be made to facilitate easier measurement and forecasting of environmental impact during the experimentation phase for both small and large companies. This could be achieved through building simpler environmental impact assessment tools in consultation with business designers to adequately address the pain-points that were identified.

Further, this research also has high generalisability potential since it involved 68 practitioners from startups, small, medium, and large organisations from more than 10 sectors, operating across multiple geographical contexts. Some of these companies had circular business models from the start, while others were linear firms transitioning towards circularity through business model experimentation. In the future, more sector specific in-depth research can reveal specific barriers and enablers and operationalizable solutions. Since this field is actively changing, with new research, tools and assessment methods being created at a fast pace, future studies will need to be done at frequent intervals to check how the measurement of environmental impact is changing in practice as circular business models start to become the new norm.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.spc.2021.10.009.

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