



Sustainable business model experimentation by understanding ecologies of business models

Nancy Bocken ^{a, b, c, *}, Frank Boons ^d, Brian Baldassarre ^{b, e}

^a Lund University, IIIIEE, Tegnérplatsen 4, 223 50, Lund, Sweden

^b Delft University of Technology, Industrial Design Engineering, Product Innovation Management, Landbergstraat 15, 2628, CE Delft, Netherlands

^c School of Business and Management, Lappeenranta University of Technology, Finland

^d University of Manchester, Sustainable Consumption Institute & Alliance Manchester Business School, Manchester, M13 9P, UK

^e THANKS, Amsterdam, the Netherlands



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ABSTRACT

Sustainable business model innovation is about creating superior customer and firm value by addressing societal and environmental needs through the way business is done. Business models require intentional design if they are to deliver aspired sustainability impacts. Scant research has been done on 'ecologies' of different business models in order to understand and improve these and create positive impact on the environment, society, economy and other key stakeholders. Hence, in this paper a novel framework is presented to enable a systemic form of sustainable business model experimentation. The framework is based on the recognition of three key issues which have not yet been sufficiently incorporated in the literature on sustainable business models: construct clarity, boundary setting and uncertainty about outcomes. These concepts are discussed first. Building on earlier work, the resulting framework incorporates potential side-effects and boundary setting based on the concept of an 'ecology of business models'. Second, an approach is proposed that could stimulate more profound forms of sustainable business model innovation: The Ecology of Business Models Experimentation map. Third, the approach is illustrated through two cases. The approach could help minimise symbiotic dependency on less sustainable business models; help destroy unsustainable business models by outcompeting them; and maximise contributions to favourable institutional infrastructures for more sustainable business models. This paper contributes to research on sustainable business model innovation, design and experimentation by providing a potential approach for 'business model ecology redesign'.

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1. Introduction

Sustainable business models are currently a major focus in academic literature, and also among business practitioners and policy makers dealing with the ecological and social impact production and consumption systems. Yet there is uncertainty about the outcome of business model innovations for sustainability (Mont, 2002; Tukker, 2004, 2015; Lüdeke-Freund and Dembek, 2017). Sustainable business model innovation is about creating superior customer and firm value through addressing societal and environmental needs (Boons and Lüdeke-Freund, 2013). To this end, a company should actively seek to create positive societal and

environmental value and optimise value for itself as well as for a wider network of stakeholders, including Society and Environment as stakeholders, thus optimising value for the 'system' (Stubbs and Cocklin, 2008). However, creating 'shared value' across stakeholders is difficult to realise in practice (Porter and Kramer, 2011). Tools such as the Triple Layer Business Model Canvas (Joyce and Paquin, 2016), Flourishing business canvas (Upward and Jones, 2016) and Value Mapping Tool (Bocken et al., 2013) have been developed to support a systemic view on sustainable business modelling.

We argue for a more inclusive perspective when experimenting with sustainable business models (Weissbrod and Bocken, 2017). This follows from considering three key issues: construct clarity, boundary setting and uncertainty about outcomes. These issues were identified from reviewing literature on sustainable business models and build on findings in earlier work of the authors in this

* Corresponding author. Lund University, IIIIEE, Tegnérplatsen 4, 223 50, Lund, Sweden.

E-mail address: nancy.bocken@iiee.lu.se (N. Bocken).

field (e.g., Boons, 2009; Boons, 2013; Bocken et al., 2013; Boons and Bocken, 2018). We argue that taking these into account in a meaningful way in the process of (re)developing business models, will increase positive societal and environmental outcomes, as well as financial viability.

The first issue is construct clarity: there is a lack of clarity concerning the context in which sustainable business model experimentation takes place and consequently on the sustainable business model construct itself (Boons, 2013; Schaltegger et al., 2016). Business model innovation potentially optimises only specific elements such as the value proposition, value creation and value delivery, and value capture (Richardson, 2008) rather than increasing systems-wide impact. This is related to the lack of clarity on what constitutes a business model, which has been identified in the literature on business models in general, as well as for business model innovation (Zott et al., 2011; Foss and Saebi, 2017; Ritter and Lettl, 2018). In the sustainable business model literature the problem is similar, with the added complication of multiple definitions of sustainability (Schaltegger et al., 2016; Boons and Lüdeke-Freund, 2013).

The second issue follows from the first one, and concerns boundary setting: since there is no fixed frame of reference on the context in which sustainable business model innovation takes place, it is extremely difficult to assess the impact of sustainable business models. In fact, the expected, unexpected and direct and indirect positive and negative impacts resulting from a business model vary depending on how boundaries are traced around the system of analysis. Here the lack of construct clarity complicates an adequate assessment of comprehensive impacts. This issue is not only an academic problem; it relates to expectations of sustainable business models in practice. This leads into process-oriented interpretations of sustainable business models, in which boundaries are not given, but rather become defined in the process of business model innovation. Thus, Boons and Lüdeke-Freund (2013) define sustainable business models as a process of engaging affected stakeholders to achieve consensus about what impacts should be considered rather than defining key indicators for impact from the start. This implies that boundaries are drawn in the process of defining, modifying and sustaining a business model, and implication that resonates with systems theory. This approach allows the inclusion of rebound effects in assessing impacts. Rebound effects refer to “a behavioural or other systemic response to a measure taken to reduce environmental impacts that offsets the effect of the measure.” (Hertwich, 2005, 86). A simple example would be taking the measure of installing energy saving lightbulbs. If this leads users to leave on lights longer than they used to, then the potential energy saving is offset by a behavioural change instigated by the measure.

The third issue is a consequence of the first two, and concerns uncertainty about outcomes: since it is difficult to assess the impact of sustainable business models, concrete outcomes cannot easily be predicted, and thus implementing a new business model can lead to undesired rebound effects. While recently studies question the size of rebound effects (Gillingham et al., 2013), the size of such effects depend on what system boundary is drawn (Sorrell, 2007), leading to uncertainty about outcomes. This relates to the extent to which desired impacts can and will be managed. For example, in a business model focused on ‘creating value from waste’, waste streams elsewhere may be sustained rather than reduced (Bocken et al., 2013). Regarding systems boundaries, the work of Flood (2002) is relevant. His approach allows organisations and stakeholder groups to critically assess their own system boundaries and those of actors they affect to develop more inclusive ways of dealing with shared problems and opportunities. We posit that this approach can be fruitfully employed in the process of business

model design and experimentation. This invokes a perspective where innovation is not a form of managerially controlled design (as is sometimes implicit in the business model innovation literature), but rather a process of collaborative learning and experimentation (Roome and Louche, 2016). In this process of experimentation, the system boundary becomes a topic of consideration, as it affects who is involved in the process of developing the business model for sustainability. Often sustainable business model innovation is initiated by a focal firm but will quickly involve other stakeholders such as customers, supplier and partners, NGOs, and the government, who jointly shape the new business model (Bocken et al., 2013; Keskin et al., 2013).

The aim of this paper is to develop and illustrate a framework for sustainable business model experimentation that addresses these interrelated issues. The framework enables sustainable business models that minimise negative impact and generate significant positive value for a network of stakeholders, including society and environment, and not only the firm (Stubbs and Cocklin, 2008; Bocken et al., 2013). Boons and Bocken (2018) present an ‘ecology of business models’ to create greater awareness of business model interdependencies in business model design. Building on this, and other work on sustainable business models and experimentation, and insights on changing interactions and boundaries and rebound effects in business models, this paper explores a novel method to help design and experiment with business models that create greater positive environmental and societal value overall. The approach is illustrated with two case companies of start-ups aiming to pursue sustainable business model innovation.

2. Literature review

We review the literature on sustainable business models to clarify how the three interrelated issues introduced above have been dealt with up till now. Section 2.1 deals with the impact of sustainable business models and uncertainty about outcomes. Section 2.2 is about the sustainable business model construct and boundaries and Section 2.3 is about ways to develop new business models using (joint) experimentation. Business experimentation is about businesses exploring the diverse possibilities they could create value from and understanding what works in which particular situations in a real-life business context (Bocken et al., 2017, 2018b) and relevant as an approach to deal with the three issues. Drawing on this, in Section 2.4 a conceptual framework is created that could support sustainable business model design and experimentation.

2.1. Impact of sustainable business models

Sustainable business models arguably hold the promise to deliver ‘systems-level’ innovation (Boons and Lüdeke-Freund, 2013), but such models need to be designed with upfront intent to deliver the desirable impacts (Mont and Tukker, 2006). Several categorisations of sustainable business models have been created by academics and business practitioners ((Boons (2013), Bocken et al. (2013), Clinton and Whisnant (2014) and Wells (2013), Accenture (2014), Bakker et al. (2014), and Bocken et al. (2016)). Building on this work a more profound understanding is needed about the actual impacts of such business models. Table 1 summarises potential positive and negative effects associated with sustainable business models and shows that despite the potential environmental or societal benefits of each innovation, unintended negative consequences are materialise, which, through greater awareness, may be mitigated.

Business models come with intended and unintended consequences, of which rebound effects are of particular importance

Table 1
Summary of sustainable archetypes and impacts (adapted from Lüdeke-Freund et al., 2017, based on Bocken et al., 2013 and Ritala et al., 2018).

	Environmental			Social			Economic		
	1. Maximise material & energy efficiency	2. Closing resource loops	3. Substitute with renewables and natural processes	4. Deliver functionality, not ownership	5. Adopt a steward-ship role	6. Encourage sufficiency	7. Repurpose for society/ environment	8. Inclusive value creation	9. Develop sustainable scale up solutions
<i>Short definition</i>	Do more with fewer resources, generating less waste, emissions and pollution	Reuse materials and products; turn waste into feedstocks for other products/ processes.	Use of non-finite materials and energy sources	Provide services that satisfy users' needs without having to own physical products	Proactively engage with all stakeholders to ensure their long-term health and well-being	Solutions that actively seek to reduce end-user consumption	Seek to create positive value for all stakeholders, in particular society and environment	Sharing resources, knowledge, ownership and wealth creation, inclusive value generation	Delivering sustainable solutions at a large scale to maximise benefits for society and the environment
<i>Innovations within this archetype</i>	Lean manufacturing Dematerialization Increased functionality	Cradle-to-cradle Industrial symbiosis Extended producer responsibility	Cleantech Renewable energy (e.g. solar, wind) Biomimicry	Rental/lease Pay per use Product-service combinations	Community development Biodiversity protection Choice editing	Consumer education Demand management Slow fashion Frugal businesses	Social enterprises and b-corporations Non-profits Hybrid models Net positive initiatives	Collaborative platforms Collaborative consumption Peer-to-peer and Sharing models	Open Innovation platforms Incubators Slow/patient capital
<i>Typical positive impacts</i>	Enhance efficiency and improve resource use Cost savings	Reduces waste Turns waste into value/ new business lines Generate new revenue streams	Reduces use of finite resources, waste and pollution Supports long-term energy supply Contributes to 'green economy'	Can encourage the right behaviours with manufacturers and users Can reduce the need for physical good	Ensuring long-term well-being of planet (e.g. forests) and society (e.g. health) Ensuring long-term viability of the value network	Actively reduce consumption Encouraging community sufficiency, sustainable living Long-term customer loyalty, and new repair and service markets	Deliver positive societal (e.g. community development) value Deliver positive environmental (e.g. afforestation) value Prepare for a resource capacity for long-term business sustainability	Sharing resources, skills and knowledge and distribute wealth Leverage resources and talents Create new business opportunities	Achieve scale – from small sustainability pilot or start-up to large scale project or business Create industry-wide change for sustainability Create breakthrough innovation
<i>Possible negative side-effects</i>	May generate incremental change only May lead to rebound effects May lead to job losses	May lead to quicker sales cycles and more material use May sustain waste streams because 'waste = value'	'Carbon lock in' and NIMBY prevent uptake Embedded footprint of production (e.g. solar panels) Lack of recyclability consideration of (solar-based) products	More product/service usage If not combined with efficiency improvements, it may have negligible environmental impact improvement	More product/ service usage If not combined with efficiency improvements, it may have negligible environmental impact improvement	Potential price premium for consumers Remaining niche because it goes against "growth" principles	Potential to remain niche without policy changes Potential to remain niche within current capitalist framework	If not combined with efficiency improvements, it may lead to limited environmental improvement May induce more product/service use due to wider accessibility	Focus on scale might detract from sustainability purposes Risk of unproven radical innovation

(Hertwich, 2005). The size of rebound effects depend on what system boundary is drawn, but in areas like space heating and personal automotive transport direct rebound effects have been observed across different studies, indicating that energy savings in one area will lead to ‘energy spending’ in other areas (Sorrell, 2007). Therefore, consumers who are saving money through a car sharing business model, might spend more money on other ‘stuff’ or flights (see e.g. Chitnis et al., 2013; Verboven and Vanherck, 2016). Second, companies rely on other business models to sustain theirs. Maxwell et al. (2011) in Verboven and Vanherck (2016) refer to the necessity for resource intensive infrastructures (e.g. telecommunications) for product service systems. However, while the boundaries of the business model expand, the total impact might be mitigated if the company chooses the most sustainable alternatives. The company Tesla for example has been contributing to the market for electric vehicles through supporting the development of an electric charging infrastructure together with, and benefitting public and private actors (Wieland et al., 2017). The startup company Riversimple is moving away from car ownership to access aiming to replace fossil-fuel based car technology with hydrogen-fuel based technology through its business together with various stakeholders (Wells, 2018; Bocken and Short, 2016). The business model innovation thus has to be viewed in its wider influencing context (Boons and Bocken, 2018). We argue that designing better business models requires insight in relevant rebound effects and the potential for companies to influence these impacts.

2.2. Sustainable business model innovation and boundaries

Boundary setting is essential to any innovation challenge for a business: in which areas does a company want to innovate and how far can (and should) its impacts reach? Boundaries are also essential in areas such as Life Cycle Assessment (LCA), a systematic approach to understand and manage an organization’s impact on sustainable development by using a life cycle perspective that can prevent negative impacts from being shifted elsewhere within the life cycle (ISO, 2016). A limited number of studies have used LCA (principles) to assess the environmental impact of new sustainable business models (e.g., Goedkoop et al., 1999; Lindahl et al., 2014; Manninen et al., 2018). However, more work is needed to assess the full impacts of sustainable business models (Tukker, 2015).

It is almost impossible to draw a clear line on where responsibility of a business lies, especially in the context of business model innovation, which implies that system boundaries will be redrawn. Critical systems theory (Ulrich, 2003) provides an approach to deal with the complexities of human interaction where system boundaries are an issue that require ongoing work. It builds on the work of Habermas and Luhmann (1971) which posits that human beings necessarily reduce the complexity with which they are confronted, by employing system boundaries which exclude actors, interests and contextual events from consideration. In social interaction, system boundaries are relevant as they may not overlap completely, or even conflict, resulting in miscommunication and lack of understanding and legitimacy. Based on this work different strands of theorizing on social systems, Flood (2002) describes an approach which allows organisations and stakeholders to critically assess their own system boundaries and those of actors they affect, to develop inclusive ways of dealing with shared problems and opportunities. This approach could assist in the process of business model innovation, being a multi-stakeholder and value-stream process, where business boundaries are challenged, new value is created and partnerships are formed in a process of collaborative learning and experimentation (Kraaijenhagen et al., 2016; Roome and Louche, 2016).

In the context of business models, intentional design combined with continuous attention to system boundaries as employed by stakeholders, is needed to deliver sustainability; and in assessing impact, it is crucial to acknowledge that business models are intertwined, and their sustainability impact is affected by other business models (Boons and Bocken, 2018). To this end, Boons and Bocken (2018) introduced the idea of an ‘Ecology of Business Models’ arguing that business models would need to be understood in their wider context:

- The shaping of individual business models takes place in an *institutional* context, which provides rules that are conducive to *certain forms* or providing products and services.
- Such shaping occurs in the *context of other* business models
- Some of which *compete* with the new business model, while others are complementary, or even provide *vital inputs* for the new business model.
- The ecological impact of a business model is difficult to assess as this impact is *shaped by the interaction* with other business models.
- This eventually determines the material, energy and labour flows associated with the provision of products and services.
- To understand how the provisioning of goods and services impacts on the natural ecosystem a closer look is taken at a localized business ecosystem rather than an individual business model.

This list was based mainly on a critique of ‘sharing business models’ (Belk, 2014), which feed on the existence of other (potentially unsustainable) business models. However, it is argued here that this list is also suitable in the broader business model context, as business models are interdependent by nature. Business model design considerations are thus influenced by interactions with other business models; the value chains, products and infrastructures used, sustained and competed with (see Table 2).

2.3. Experimentation with new sustainable business models

Experimentation is an important trigger for sustainability transitions (Hildén et al., 2017) and has been regarded as a key component of transitions research (Schot and Geels, 2008), Business experimentation for sustainability is context-sensitive and aims to either explore the diverse possibilities that a business could create value from (inside-out view) or understand how context factors pose specific requirements to new business models (outside-in view) (Lüdeke-Freund et al., 2016; Bocken et al., 2017). It is a systematic approach to identifying, testing and learning about value creation strategies that could be adopted by a business (Weissbrod and Bocken, 2017). The label ‘experimentation’ highlights the iterative nature of a process of trial and error, a reality which is absent from terms such as business model design and business model innovation.

Business experimentation is rooted in fields such as effectuation, a set of decision-making principles that can help entrepreneurs to operate in situations of high uncertainty (Sarasvathy, 2009; Keskin, 2015), start-up work (e.g., Ries, 2011), and research on organisational change (Chesbrough, 2010). Within practice, business experimentation has been applied to create better value propositions for customers in a low resource/time/cost way for start-ups (Ries, 2011; Blank, 2013). Rather than performing a full-scale pilot, companies would engage in smaller activities such as A/B split testing (e.g. running two different advertisements to investigate which one gets most traction), mock-up web pages (to test demand for a new service) or focus groups (Ries, 2011; Osterwalder et al., 2014). Schuit et al. (2017a) applied these

Table 2
Ecologies of business models – business model design considerations. Adapted from Boons and Bocken (2018).

Business model design consideration	Examples
Product design	<ul style="list-style-type: none"> - Design for low embedded carbon footprint (material/resource use per product) - Product reusability (e.g. reparability) - Product use phase (e.g. energy and water use in the product use phase)
Value chain	<ul style="list-style-type: none"> - Forward logistics - Reverse logistics
Infrastructure	<ul style="list-style-type: none"> - Dependency on existing infrastructures (e.g. buildings, networks) - Building 'sustainable infrastructures' (e.g. electric car charging network)
Business model dependency	<ul style="list-style-type: none"> - Dependency on other products (e.g. mobile phones) - Dependency on existing value chains (e.g. delivery networks) - Dependency on infrastructures (e.g., public spaces)
Interactions with existing business models	<ul style="list-style-type: none"> - Neutral – A and B do not affect each other - Mutualism – growth in A stimulates growth in B - Symbiosis – A benefits from presence of B - Competition – A detracts from growth in B and vice versa - Parasitism – A is harmed by presence of B - Dominance – A controls the resource flows to B, C, D
Rebound effects	<ul style="list-style-type: none"> - Any unforeseen negative (or positive) effects not yet captured in the above considerations

techniques to a range of sustainable start-up firms, pursuing sustainability as part of their business purpose. More recently business experimentation has been suggested and applied to a sustainable business context as a key capability to transition to a sustainable business (Antikainen et al., 2017; Weissbrod and Bocken, 2017). Chesbrough (2010) also suggested that large businesses need to experiment with their business models to remain competitive. Such experimentation would need to take into account sustainability goals to address the world's most pressing sustainability challenges.

The purpose of experimentation is to test assumptions about the future business; build legitimacy across stakeholder groups (internal and external) by joint collection and dissemination of information; and have a low resource, low visibility to others, and low-cost method to do so, in turbulent business environments with increasing pressures (Miller, 2016; Schuit et al., 2017b). In a business setting, experiments focus on testing 'hypotheses' about the potential future business: e.g. what type of customers are interested in a new service and how does the proposition need to be formulated? (Ries, 2011). While business model experimentation is traditionally described through a build-measure-learn loop (Blank, 2013; Ries, 2011), it has also been framed as an iterative interplay between analysis and design (Baldassarre et al., 2017; Keskin, 2015). Keskin (2015) explicitly refer to 'stakeholder interactions and design experiments' while Baldassarre et al. (2017) introduce a 'talking, thinking, testing' experimentation loop. Furthermore, according to Keskin (2015) and Schuit et al. (2017a) this experimental interplay takes place through specific practices of analysis and design.

Moving beyond a focus on start-ups, experimentation is expected to become increasingly important in turbulent business environments. Recent literature suggests that experimentation building on lean start-up principles of 'build, measure, learn & pivot', an iterative approach to trialling new business models, could be a useful starting point for sustainable and circular business model experimentation (Antikainen and Valkokari, 2016; Weissbrod and Bocken, 2017).

2.4. Research gap and framework

To date, research on sustainable business models has largely focused on conceptualizing sustainable business models through a strategy perspective (Boons and Lüdeke-Freund, 2013; Bocken et al., 2013; Upward and Jones, 2016; Joyce and Paquin, 2016).

However, work from more than a decade ago (Mont, 2002; Tukker, 2004) argued for the need to 'design' better business models (in particular, product service systems), which has been reiterated as a research agenda (Tukker, 2015). To achieve the most beneficial environmental and social effects through a viable business model with a superior value proposition (Boons and Lüdeke-Freund, 2013), the business model needs to be consciously set up to do so. Yet in a dynamic and complex environment (Eisenhardt and Martin, 2000), this requires experimentation to ensure long-term business competitiveness (Chesbrough, 2010) and start addressing sustainability issues as fundamental ways in which business is done (Stubbs and Cocklin, 2008).

2.4.1. The Ecology of Business Models Experimentation map

The Ecology of Business Models Experimentation (EBME) map (Fig. 1) brings together the notion of interaction and influence in product/service and business model design from Boons and Bocken (2018) and ISO (2016), as well as insights from sustainable business modelling and experimentation for sustainability (Schuit et al., 2017a, b).

The EBME map seeks to address the issues of construct clarity, boundary setting, and rebound effects associated with sustainable business model design identified in this paper as follows. The experimentation process starts with an input, which could be a new sustainable business idea or a current business model to improved. The experimentation process starts with an analysis of dependencies with other business models. Here, the purpose of the firm is stated or reiterated: e.g. what are the aims and how can the business pursue these? (Stubbs and Cocklin, 2008). The notion of an 'Ecology of business models' forms the basis to experiment by analysing and designing sustainable business models. The relationships between the 'organisms' in an ecology are routed in the fact that they make use of an interrelated set of resources and infrastructure (Boons and Bocken, 2018). This can be defined in terms of dependencies. To explain, businesses may depend on other products (e.g. mobile phones for apps), existing value chains (e.g. delivery networks) or on infrastructures (e.g., public spaces) to exist (Table 2). After the analysis phases, design phases follow, where potential options to modify, destroy or create dependencies and innovate sustainably through new partnerships are explored. Ultimately, these lead to a revised business model, put in context within and ecology of business models, which represents the output of the process. It has to be kept in mind that the experimentation process is iterative nature, meaning that there is

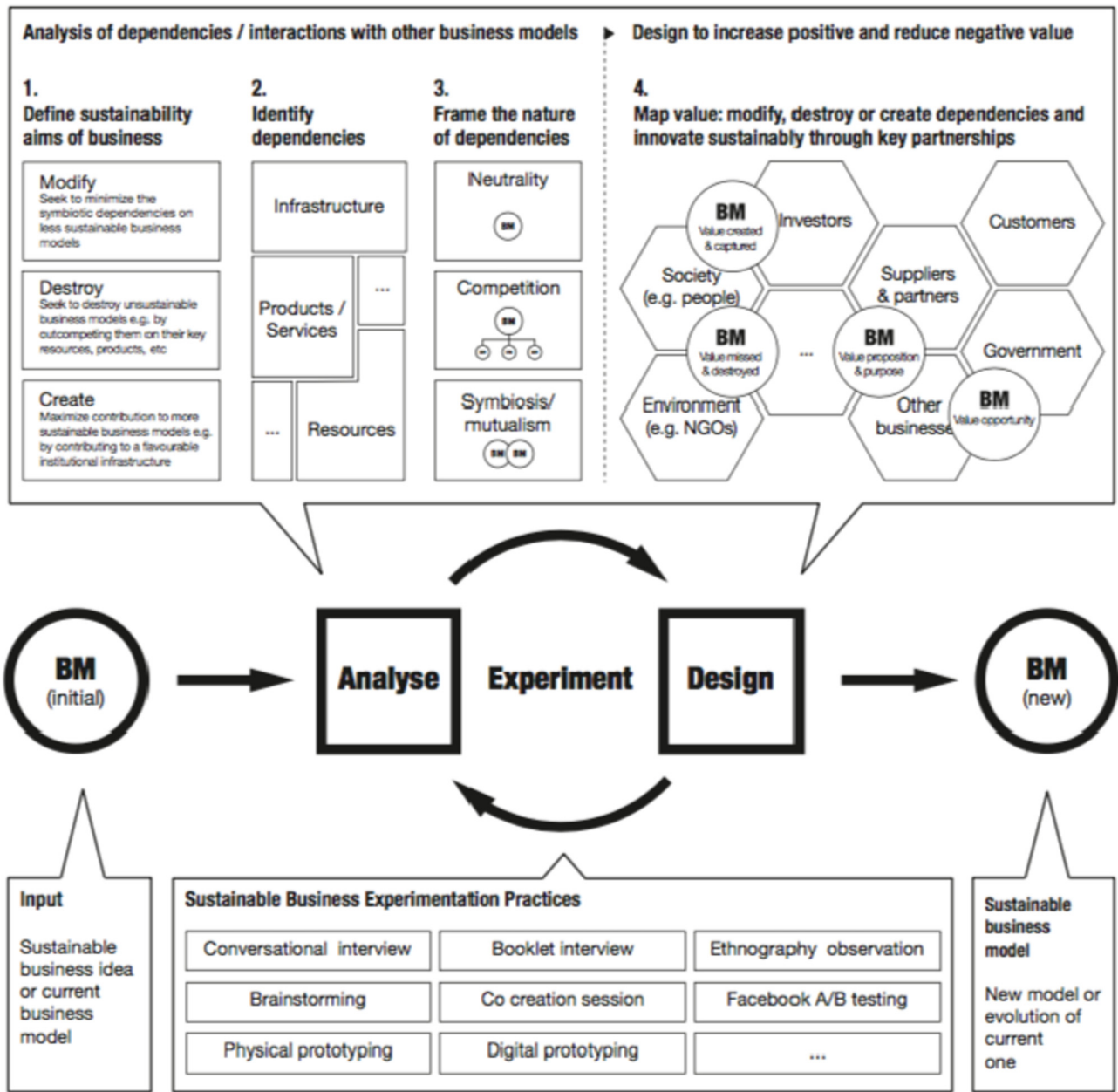


Fig. 1. The Ecology of Business Models Experimentation (EBME) map. Developed from Pfeffer and Salancik (1978); Boons (2002); Maxwell et al. (2011); Stubbs and Cocklin (2008); Boons and Bocken (2018); Bocken et al. (2013); Ries (2011); Schuit et al. (2017a, b), and Weissbrod and Bocken (2017). Note. BM refers to Business Model.

constant interplay between analysis and design based on a set of experimentation practices.

Step 1: What are the sustainability aims of the business?

The first step is about defining the sustainability aims of the business. Such aims can be defined by exploring, managing and reconfiguring dependencies through business experimentation - a key idea from the management literature (Pfeffer and Salancik, 1978). It is proposed that dependencies can be destroyed, modified or created:

1. *Modify*: Reduce dependency on less sustainable business models (e.g. is it possible to use electricity from renewables instead of fossil fuels within the business model of an electric car sharing service?);

2. *Destroy*: Seek to destroy unsustainable business models by outcompeting them on their key resources (e.g. Can we develop up a car sharing service to destroy the car ownership model?);
3. *Create*: Maximise contribution to favourable institutional infrastructure for more sustainable business models (e.g. Can we create a platform-based business model to boost adoption of existing car sharing services?)

These concepts are used in a novel way to frame the company's purpose or aims (Step 1, Table 3 and Fig. 1).

Step 2: To what extent does the business model depend on others and how?

The second step is about identifying the types of dependencies in place from existing infrastructure, products/services and

Table 3
Key questions associated with different steps.

Phase	Questions/steps	Relevant sources
Analyse	<p>1. <i>What are the sustainability aims of the business?</i> This question is about the business purpose in light of which business models it seeks to replace or 'destroy' which contribution it wants to emphasise, or symbiotic dependencies (e.g. on fossil fuels) the business seeks to minimise.</p> <p>2. <i>To what extent does the business model depend on others and how?</i> This question helps to identify the key dependencies between the focal company's business model and others it depends on? (building on the idea of interlinkages between business models)</p> <p>3. <i>What is the nature of the dependencies, i.e., what are the interactions with those business models?</i> (building on concepts such as competition, symbiosis and other ecological relationships)</p>	<p>- Stubbs and Cocklin (2008); Bocken et al. (2013)</p> <p>- Pfeffer and Salancik (1978); Maxwell et al. (2011); Boons and Bocken (2018)</p> <p>- Pfeffer and Salancik (1978); Boons and Bocken (2018)</p>
Design	<p>4. <i>How can positive value be increased and negative value reduced?</i> The current value captured, negative value (value missed, destroyed) and potential new value opportunities are identified here (building on the value mapping tool in). Here, an exploration of potential partners also takes place: Who can you partner up with to create more positive value through your business model?</p>	- Bocken et al. (2013, 2017)
Experiment	Use activities such as conversational interviews, co-creation sessions, or A/B Facebook or website testing as practices to experiment by discovering and testing new business model possibilities.	- Ries (2011) Weissbrod and Bocken (2017); Schuit et al. (2017a, b)

resources (Table 1). The most profound dependencies relate to existing infrastructures: the fact that business models are embedded in the same institutional infrastructure. This infrastructure is to some extent a result of the presence of the particular business models in the ecology. For example, an electric car sharing service is dependent upon the infrastructure of electricity production and distribution and this context determines the actual impact. Business models are embedded in a particular context of governance mechanisms through which they become linked (Iaione, 2016). This notion stems from the observation that dependencies are seldom symmetric. Given that asymmetric dependency translates into risk and reduced bargaining power, the dependency perspective on supply chain relations is based on the idea that dependencies need to be managed in a way that reduces risks and improves stable access to resources at the lowest (transaction) costs possible. Using the purpose and aims as a basis, the current business dependencies are explored (Step 2, Table 3 and Fig. 1).

Step 3: What is the nature of the dependencies?

The third step entails giving a closer look at the dependencies that were identified and determine their nature. According to Pfeffer and Salancik (1978) and Boons (2002) and Boons and Bocken (2018), three high-level forms of dependencies are possible. The first is *neutrality*: when both business models do not affect each other. The second is *competitive dependency*, a situation in which business models compete for the same resources, including time of users. A third form is *symbiotic or mutualistic dependency*. This occurs when the output of one business model constitutes an input for another or when the presence of one business model leads to growth in another. Such dependency occurs for instance between business models that deliver smart devices, the provision of wireless services, and the designers of software for such devices (apps). Growth in each of these facilitates further growth in the others. Step 3 in Table 3 and Fig. 1 deals with such dependencies.

Step 4: How can positive value be increased and negative value reduced?

While the first three steps are about analysing business model dependencies, the fourth and final step is about business model design and it is done by exploring how positive value can be increased and negative value reduced, around the four business model dimensions from the value mapping tool (Bocken et al., 2013), namely value created, captured, missed, destroyed, and

new value opportunities (Step 4 in Table 3 and Fig. 1). The different forms of value are related to multiple stakeholders at the same time, also including society and the environment. This final design step is geared towards the generation of new business models based on partnerships and collaborations that foster shared value dimensions for multiple stakeholders across multiple business models. For example, a web platform to access innovative car sharing services can stimulate sales of individual car sharing companies; or a partnership between a public transport company and a bike sharing company in cities can increase the uptake of both services. In this example, negative value is potentially reduced because the combination of bike sharing and public transport constitutes a viable alternative to the use of self-owned cars for commuting. The result is an ecology of sustainable business models that represents context, gives a frame of reference for a more realistic sustainability assessment and ultimately reduces uncertainty about outcomes in the design phase.

The next section will lay out the case studies that were developed to demonstrate the approach in Fig. 1.

3. Methodology

This paper explores how organisations can design and experiment with sustainable business models to optimise sustainable value creation for a network of stakeholders, by creating and building on a greater level of consciousness about the dependencies and interactions between business models. The research objective is addressed through a case study methodology, which is the preferred strategy for exploratory research on contemporary issues (Yin, 1994). To gain an understanding of the business experimentation process two illustrative cases are presented: THANKS and HOMIE. These are also used to explore the application and usefulness of this the EBME map. The two case companies had gone through multiple experiments for sustainability and are analysed from two angles:

- 1) What constituted the process of experimentation? What practices did actors use to explore opportunities for value creation and capture and how did sustainability enter into those practices?
- 2) What dependencies with other business models are important for the business model as it unfolded?

The two cases are illustrative in nature and build on various sources: the recollections of the authors about the process and practices, company data, public data (e.g. company website) and discussions with stakeholders (e.g. co-founders) to verify the process and practices, based on the logic on cases presented by Thomas (2011). Two of the authors are co-founders of the start-ups analysed, which provides an opportunity for unusual data access. This allowed for an understanding of the processes and practices of experimentation as well as the dependencies with other business modes considered. A limited number of cases may be justified when cases are unusually revelatory or provide unique access (Eisenhardt and Graebner, 2007; Yin, 1994).

The case approach was retrospective (Thomas, 2011) and investigated whether design and experimentation with sustainable business models took into account the broader perspective presented in Fig. 1. The analysis consisted of plotting the case company activities, processes and rationales onto the EBME map. The text in section 4 and Figs. 3 and 4 were verified with others involved in the start-ups (other co-founder plus the CEO at HOMIE and a service designer and concept developer for THANKS) for validation purposes. The multiple inputs helped create a rich picture of the processes of experimentation, taking into account the multiple viewpoints from those most closely involved with the start-ups.

3.1. Sample of case companies: THANKS and HOMIE

THANKS is a new venture which started in 2014 at Delft University of Technology within the framework of the Climate-KIC Netherlands. Background research revealed a market opportunity for energy saving solutions focused on sustainable behavioural change within large office buildings. The objective of THANKS was to develop the business model for a new venture providing a service to encourage energy saving behaviour at the workplace. The idea eventually evolved into a business model built around the following concept: empower office workers to make an impact by making a small donation to NGOs (using the sustainability budget of their company) every time they perform a sustainable action (e.g. taking the stairs instead of the elevator). This mechanism simultaneously brings a benefit to NGOs, who receive donations, and to companies, who engage their employees and improve their public image. In parallel, data about sustainable actions is collected and sold by THANKS to company clients through a monthly service subscription.

HOMIE is a new venture which started in 2016 as a spin-off of Delft University of Technology. It is also part funded by the Dutch government (STW Take-off grant). The aim of HOMIE is to provide consumers access to high quality appliances while stimulating sustainable consumption patterns through a pay per use business model. HOMIE started with offering customers washing machines on a pay per use basis: washing machines are installed in customers' homes for free and they only pay each time they use the washing machine. The company thus adopts a pure pay per use business model and only charges the customer when the washing machine gets used. A low temperature wash costs less than a high temperature one to stimulate sustainable consumption. Moreover, paying per wash aims to make people more conscious about often they wash.

4. Results

4.1. THANKS case

4.1.1. Sustainability aims and starting point

THANKS aims to provide a service to encourage energy saving actions at the workplace, while creating broader interest and

engagement into sustainability issues. Its starting point was an identified market opportunity for energy saving solutions centred on sustainable behavioural change within large office buildings. This environmental objective is coupled with the social objective of creating awareness on broader sustainability issues while fostering healthy practices at the individual level.

4.1.2. Business experimentation practices

The business model was developed through an iterative interplay of analysis and design phases based on a set of experimentation practices (Blank, 2013; Keskin, 2015). The experimentation practices were carried out in a series of three iterations, which gradually saw the initial idea developing into a more structured business model. The first iteration entailed the following practices: interviewing the energy manager of a company, creating booklets to gather feedback from twenty office workers, conducting a day of ethnographic observations into an office space, conducting a creative session with ten office workers, running a brainstorming session. The second iteration entailed the following practices: digital service prototyping to test the concept, conducting follow up interviews with ten office workers, interviewing the sustainability manager of one company, interviewing a manager from a non-profit organization, running a brainstorming session. The third iteration entailed the following practices: physical service prototyping to test the concept, conducting follow up interviews with four office workers, interviewing five sustainability managers from different companies, running a brainstorming session. All the practices within these three iterations were periodically complemented with additional online market research.

4.1.3. Analysis of dependencies and interactions with other business models

During the analysis phases, the experimentation practices aimed at gradually uncovering and understanding potential dependencies and interactions of the business idea with other existing business models (Boons and Bocken, 2018). Specifically, the focus was put on dependencies and interactions of the prospective service and business model aiming to nudge employees into energy saving actions at the workplace. It was progressively learned that for many companies, energy saving is part of a broader Corporate Social Responsibility (CSR) strategy, which is a key business model activity to foster long term competitive advantage through employee engagement and improved public image. It was learned that donations to NGOs are often an important part of CSR next to all those energy efficiency initiatives that were found as complimentary or in competition with the idea under development. THANKS started exploring how it could contribute favourably to existing business models (such as those by NGOs) rather than detracting from these. Furthermore, employee engagement also emerged as a key activity of the Human Resources department (HR), which is interested healthy behavioural patterns beyond simple energy saving actions. Hence, THANKS wanted to increase positive contributions within the business. From the HR's perspective, tracking sustainable/healthy behaviour provides a financial business case, because such metrics can be related to health insurance fees for the employees. Finally, NGOs also have a business model of their own. A large part of their revenue streams relies on company donations but their value proposition to society and the environment involves as well raising individual awareness. There was a possibility for THANKS to strengthen the internal business prospects as well as better supporting complimentary business models (NGOs).

4.1.4. Increasing positive and reducing negative value

During the design phases, the experimentation practices aimed

at gradually embedding triple bottom line sustainability into the business model using a value mapping lens (Bocken et al., 2013; Hall, 2011). Specifically, the focus was put on constructing mutually beneficial interactions amongst the business model of donating companies, beneficiary NGOs and the new venture being started.

The value opportunity was found in a gap of value missed inside CSR activities belonging to the business model of companies donating to NGOs. Specifically: such donations aim to foster employee engagement but fall short here because employees are not directly involved with transactions. In parallel, experimentation activities highlighted a strong drive from their side to make a sustainable impact on a personal level, presenting an opportunity to engage them individually. This was achieved by empowering them to donate small amounts from the CSR budget to NGOs every time they made a sustainable or healthy action (taking the stairs, going vegetarian for lunch). Consequently, a sustainable value proposition was defined: on the environmental side, measuring and reporting the impact of employees' sustainable actions inside office buildings; on the social side, raising sustainability awareness of employees, empowering them to make an impact and encouraging them to perform healthy actions on a daily basis; and on the economic side, making a more efficient use of the companies' CSR budget (Baldassarre et al., 2017).

Value creation largely builds upon pre-existing CSR processes and related business interactions with NGOs. Concerning infrastructure, experimentation practices with prototypes highlighted the need for a physical interface to allow employees making the donations. This point was addressed through the design of a hardware-software combination based on employee badges and a network of NFC sensors designed ad-hoc in order to partly leverage onto existing infrastructure and behavioural patterns. This was necessary to foster acceptance but also resulted in value destroyed, namely the physical resources needed to build the sensor network. Finally, value capture is based on charging service costs to companies.

4.1.5. Sustainable business model output

The output of the sustainable business model design and experimentation process consisted of the development of THANKS - the name for the new venture and related business model. The main feature of the business model of THANKS is that it is based on a dependency. Without NGOs, this business model could not exist and at the same time, it strengthens the business model of NGOs and company clients by reinforcing a symbiotic relationship. The business model of THANKS builds upon the mutually beneficial interaction of these two other business models: the business model of donating companies and the business model of recipient NGOs in the context of CSR. By plugging into this interaction with its own business model, THANKS reinforces the mutualistic interactions and creates two more, namely the interaction between THANKS and companies and the interaction between THANKS and NGOs. In the first mutualistic interaction, THANKS provides employee engagement and data to companies, receiving service subscriptions in turn. In the second mutualistic interaction, THANKS gives mission support to NGOs receiving in turn sales channels to better reach its target customers. This interaction of three business models (Fig. 2) fosters triple bottom line shared value creation, where THANKS and its company clients represent the economy-oriented stakeholders whereas the employees and NGOs represent society and the environment. Fig. 3 summarises the THANKS case using the EBME experimentation map.

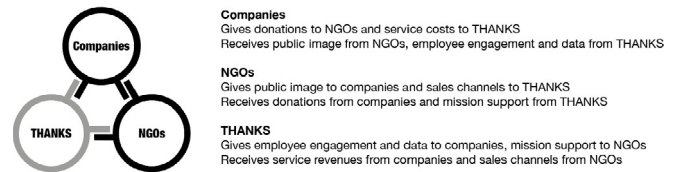


Fig. 2. THANKS business model and symbiotic dependencies in a schematic way.

4.2. HOMIE case

4.2.1. Sustainability aims and starting point

HOMIE started off with an environmental proposition – a circular business model that aims to drive sustainable consumption as well. However, it quickly started to develop a social proposition too by purposely offering affordable high-quality appliances and also catering for lower-income households. Its customer groups roughly include customers who care about sustainability; those looking for affordable options; those who are looking for flexibility; and those who do not value product ownership and are seeking for alternatives.

4.2.2. Business experimentation practices

The experiments at HOMIE centred around the following high-level work streams: *technical prototyping* and *value proposition refinement* (e.g. advertising experiments, desk research, mailings, washing habit interviews, and pay per use pricing) to create a fitting customer proposition while stimulating sustainable behaviour (Bocken et al., 2017).

The first *technical* experiments were focused on developing a prototype that works, i.e., developing a connected washing machine that enables a pay per use business model. While the company did not have a direct partner yet, and mainly focused on testing new potentially 'risky' business models for incumbents to stimulate sustainable consumption and the circular economy, HOMIE decided to buy an existing quality washing machine and 'hack' it to enable pay per use. This meant that for the time being, design for a circular economy (e.g. design for easy repair and remanufacturing) was out of scope as the company focused on testing the user case and driving sustainable consumption (see also Manninen et al., 2018). However, through being close to the customer and through its pay per use business model, it could easily facilitate good use practices, maintenance and repair.

The *value proposition* experiments initially included workshops and testing of different advertisements to investigate which value proposition would appeal most to the customer. Variations on advertisement focus (e.g. saving money, the environment, and combinations) were tested online for best fit with the business model and customer traction. Furthermore, based on interviews with prospective customers, a pricing scheme was developed to encourage customers to wash at lower temperatures. For example, a cold wash is significantly cheaper than a hot wash, to stimulate to stimulated lower temperature washes. By paying per use, it was expected that customers would also wash less due to increased awareness and salience (Thaler and Sunstein, 2009). While many experiments of those experiments happened at the same time, each customer received similar interventions as part of the experimentation process (Table 4). The interventions in Table 4 are aimed at finding out whether the pay per use business model could actually reduce the number of washes and could stimulate lower temperature washes. Each customer would go through the same cycle to be able to compare the data and interventions which are based on

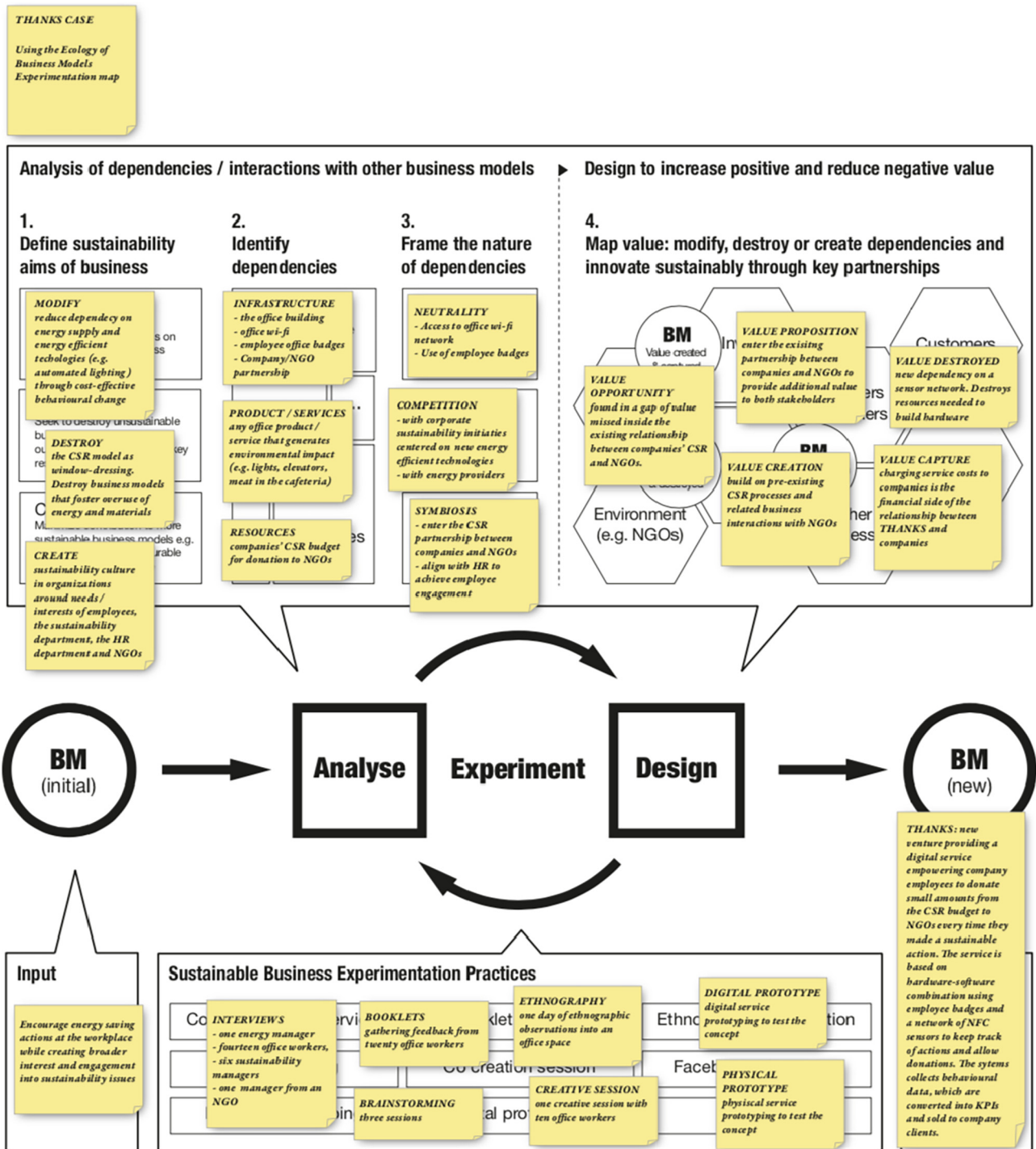


Fig. 3. THANKS case using the EBME experimentation map.

behaviour change and sustainable consumption research (Bocken et al., 2018a). In this way, the impact of introducing a pay per use business model coupled with interventions and the impact on sustainable consumption can be tested.

4.2.3. Analysis of dependencies and interactions with other business models

During the experimentation phase, the scope of HOMIE's business experimentation practices became more focused, because of

the lack of time and resources to test everything. HOMIE's focus in the first year was on investigating whether the pay per use business model works in general (with customers, practicalities etc) and whether it would drive sustainable consumption patterns. Because HOMIE is a start-up, it could not yet influence all aspects like product design, which is done by large incumbent appliance manufacturers; due to the lack of facilities, resources and R&D capabilities to redesign existing appliances, so this is yet out of scope.

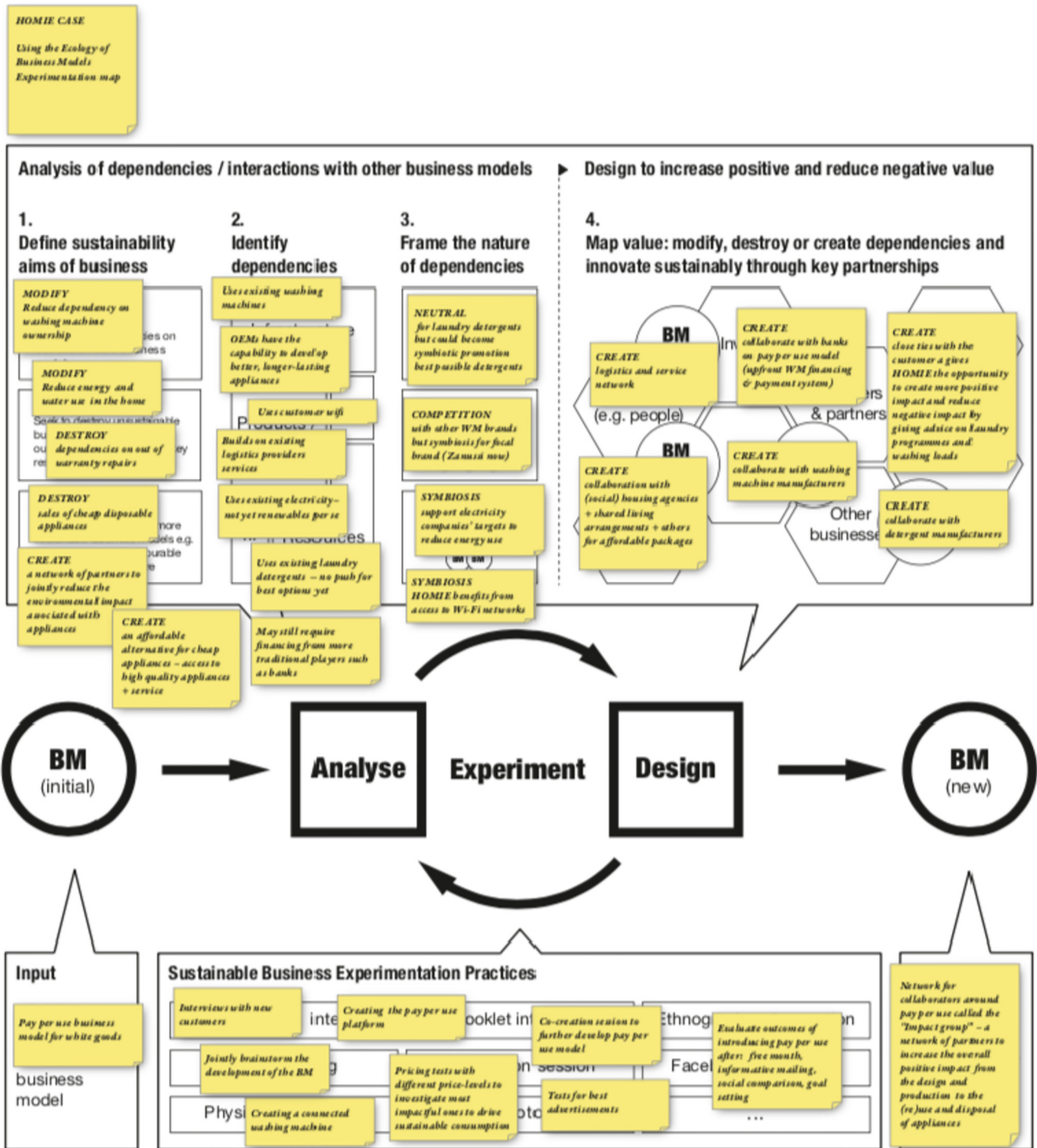


Fig. 4. HOMIE case using the EBME experimentation map.

HOMIE through its business model now creates parasitic dependency: the business model relies on OEM manufacturers. Furthermore, although HOMIE wants to challenge existing take-make-dispose business models, by experimenting with a pay per use business model, HOMIE also keeps in place existing business models by creating dependencies: it acquires existing washing machines via retailers and manufacturers and develops a 'pay per use' model using these. It also started off using customers' WiFi networks, creating another dependency. However, because the

WiFi dependency is less reliable, HOMIE is looking into developing its own connectivity with partners.

4.2.4. Increasing positive and reducing negative value

During the business model design phases, experimentation focused on driving sustainable consumption patterns (Table 4). The experiments started with interviews to test user behaviour, followed by a free month, then introducing the pay per use model, followed by providing informative mailings, social comparisons,

Table 4
HOMIE - Sample of customer interventions for each HOMIE customer (based on Bocken et al., 2018a).

Timing	Design intervention	Description summary
Pre-wash	Interview	Before washing machine installation, customers are interviewed to gain insight on their washing behaviour.
Month 1 (M1) Feedback M1	Free month	The first month is considered a test month, in which users get a full month of washing for free. No specific feedback. Customers can access their usage information on the website but this information is not proactively shared.
Month 2 (M2) Feedback M2	Introduce pay-per-use	The first paid month of washing.
Month 3 (M3) Feedback M3	Introduce informative mailing	Feedback received: Washing behaviour basics: Amount of washes, Temperature, Types of washes The second paid month of washing.
Month 4 (M4) Feedback M4	Comparison current vs previous month	Feedback received: Washing behaviour basics + Comparison washing behaviour (Individual compared washing behaviour between M1 and M2)
Month 5 (M5) Feedback M5	Introduce social comparison	The third paid month of washing. Feedback received: Washing behaviour basics + Comparison Washing Behaviour + Social Comparison (Individual washing behaviour compared to average of your user type)
	Introduce goal setting	The fourth paid month of washing. Each user receives specific & personalised washing goal, aiming to lower the number of washes and total energy consumption.

introducing goals, and then multiple feedbacks simultaneously. By using knowledge from sustainable design and behaviour change literature on effective interventions (e.g. Bhamra et al., 2008, 2011; Thaler and Sunstein, 2009) interventions were gradually introduced starting with relatively basic ones (information) to more 'advanced' ones (social comparison and goal setting) after having introduced 'pay per use'. Each customer is compared against him or herself – hence the months of intervention correspond to when the customer enters their contract with HOMIE.

Information about user behaviour is regularly collected to verify the sustainability outcomes of the business model and interventions. An earlier conference paper demonstrated that the pay per use business model led to more sustainable consumption patterns, but the introduction of mailings showed mixed effects (Bocken et al., 2018a). Through its business model experimentation and close contact with the customer HOMIE also found out that customers have a lot of questions about how to do the laundry. This initial value missed was turned into an opportunity: the close ties with the customer and mailings gives the company the opportunity to create more positive impact and reduce negative impact by giving advice on the laundry process. In some cases, the aspired sustainability benefits led to (accidental) misuse of the washing machine – a form of value destroyed. Customers sometimes overloaded machines to reduce the number of washes (saving money and the environment), which led to failure of the machine. However, this knowledge was used in later mailings to educate customers.

Although HOMIE does not design and (re)manufacture, it does try and influence longevity of the washing machines in other ways. As a form of maintenance and cleaning the washing machine, HOMIE started to offer a free 90 °C wash once every so often to improve the longevity of the washing machine. In this way, HOMIE seeks to influence product longevity and further stimulate sustainable behaviour.

4.2.5. Sustainable business model output

The (ongoing) output of the experimentation process is the startup 'HOMIE', a business operating a business-to-consumer pay per use business model for home appliances in the Netherlands installing appliances in people's homes for free. While the business has largely focused on building its own infrastructure and capabilities, the next stage of the business consists of partnering. HOMIE is exploring partnerships with washing machine manufacturers (to streamline the business model and influence product design),

tracker designers (to reduce reliance on customer WiFi), banks (financing and facilitating pay per use) and various other societal actors (e.g. building societies, student associations etc.). The partnering work is the important next phase of experimentation in the business model to optimise positive value creation in the start-up's network. Fig. 4 summarises the HOMIE case using the EBME experimentation map.

5. Discussion and conclusions

Sustainable business models are a popular theme in academic literature as well as with business practitioners and policy makers (Lüdeke-Freund et al., 2016; Lüdeke-Freund and Dembek, 2017). While experimentation has been recognised as an important trigger for climate change transitions (Hildén et al., 2017) and is an important feature of transitions research (Schot and Geels, 2008), the research on sustainable business model experimentation as the driver for resolving societal and environmental issues is still emerging (e.g. Antikainen et al., 2017; Bocken et al., 2017) and has roots in business experimentation as a recent field (e.g. Chesbrough, 2010). In addition, the impact of 'ecologies of business models' and the wider context in which business model innovation takes place to create positive impact is poorly understood (Boons and Bocken, 2018). This paper presents a novel framework, "The Ecology of Business Models Experimentation map" to enable a systemic form of sustainable business model experimentation and create positive impact across networks of organisations. Through its orientation on extended experimentation rather than instantaneous design, the proposed framework resonates with a processual perspective on sustainable business models, i.e. the sequence of events through which a firm, in conjunction with other actors, shapes the business model along a shared definition of sustainability (Roome and Louche, 2016; Schaltegger et al., 2016).

We argue that the three key issues identified in this paper - construct clarity, boundary setting and uncertainty about actual outcomes - need to be at the heart of such an experimentation, or learning process (Roome and Louche, 2016). Building upon Flood (2002), we provide guidelines to support practitioners in the process of experimentation and joint sustainable business model innovation:

1. As a multi-actor process of shaping future outcomes, individuals (representing organisations) involved in the joint development of a sustainable business model need to critically assess the

system boundary they (implicitly) draw on when thinking about their activities. This means that they need to clarify their notion of the business model and see how it aligns with other stakeholders. This requires mental models and framings to deal with such complexity. Our approach in Fig. 1 provides such a mental model: building on an ecology of business models it serves as a tool to acknowledge and work with this complexity.

2. As a multifaceted process, involved actors need to develop ways of *integratively* working on and periodically assessing the evolving business model in terms of efficiency, effectiveness, value created, and fairness. This includes the precise definition of these terms, i.e. they need to find joint understandings of value created, fairness, efficiency and effectiveness. This relates to work on sustainable business experimentation (Weissbrod and Bocken, 2017) which calls for regular 'check-ins' to understand whether key sustainability goals are still being met through the evolving business model innovation process. The EBME experimentation map may be used for such joint assessments.
3. As a process in time, involved actors need to be aware of the relevance of *timing* of activities, as well as the reality that it takes time to develop, and some involved actors have a different sense of time that needs to be accommodated. This relates in part to different time horizons: it may take a longer time for customers to adopt new behaviours than firms are used to in assessing the viability of an offering. It also relates to the fact that involved firms may have different investment timelines. In that case, the boundary work involved in business model experimentation is about findings ways of accommodating such differences.

The questions below (also in Table 3) provide a starting point to reflect on the fundamentals of the business and interactions with others, while helping to identify ways to collaborate with stakeholders and improve sustainable value creation systematically.

1. *What are the sustainability aims of the business?* This question is about the business purpose in light of which business models it seeks to replace or 'destroy', which contribution it wants to emphasise or create, or negative dependencies the business seeks to modify or minimise.
2. *To what extent does the business model depend on others and how?* This question helps to identify the key dependencies between the focal company's business model and others it depends on.
3. *What is the nature of the dependencies, i.e., what are the interactions with those business models?* This step considers neutrality, competition and mutualism as overall dependencies.
4. *How can positive value be increased and negative value reduced?* The current value captured and created, negative value and potential new value opportunities are identified here. An exploration of potential partners also takes place: Who can you partner up with to create more positive value through your business model?

Taken as reflective steps in a multi-actor experimentation process, these questions provide an input to sustainable business model development.

The illustrative cases of THANKS and HOMIE shed light on how such questions are addressed in the business model development processes of two start-ups. Through experimentation and greater awareness of the ecology of business models in which they are situated, they are able to contribute to greater levels of value creation. Whereas start-ups have been identified in the literature who take such an integrative approach, such as Riversimple (Wells, 2018), the framework in Fig. 1 could support future development of sustainable business models with greater overall sustainable

value creation.

5.1. Limitations and future research

A small number of start-up cases operating only in the Dutch context constitutes an empirical limitation of this work. Furthermore, the EBME map has only been used as an illustrative tool to map cases retrospectively and as such provides an illustration of the approach rather than a compressive assessment of its merits. In future research, it could be explored and applied as a brainstorming or action-research type of tool and method to support redesign of ecologies of business models and businesses more generally. Although challenging, this could be done as a multi-actor approach, common in transitions research (Kemp et al., 2007), involving stakeholders from adjacent businesses, but also public actors to explore barriers and opportunities. Finally, the EBME map was initially developed with an environmental focus in mind because issues such as rebound effects have predominantly been explored from an environmental perspective. While the cases also include examples of practices of social sustainability, the approach could be extended to more prominently include social impacts.

To conclude, this work aims to contribute to research and practice on sustainable business model design and innovation. Perhaps analogously to the work on life cycle thinking and assessment, it calls for a broadening of systems boundaries and taking a systems-view on such innovation. The framework and process presented in Fig. 1 would provide just the starting point to achieve this. Future work can expand on the frameworks and processes explored in this paper to develop better business models with a wider positive societal and environmental impact. This calls for further research on sustainable business model design and experimentation taking a systems-level perspective. While the topic of experimentation is not new and has been discussed in business (Chesbrough, 2010) and entrepreneurship literature (e.g. Blank, 2013), transitions research (e.g. Schot and Geels, 2008) and as an overall approach to start necessary climate change mitigation transitions (Hildén et al., 2017), this paper has provided an experimentation approach with a central role for business actors in sustainability transitions. Fruitful future research avenues could be the integration of this work with transitions management literature, which has proposed the embedding of a business model perspective to elucidate the dynamics of innovation (Sarasini and Linder, 2018). Finally, it is recommended that sustainability assessment, design and experimentation work take into account ecologies of business models to create systems-level change for sustainability.

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