



Product innovation processes in sustainability-oriented ventures: A study of effectuation and causation

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ABSTRACT

New ventures are increasingly recognized as candidates for creating novel sustainable products that challenge existing practices. Yet, succeeding in product innovation for such ventures is challenging due to various uncertainties pertaining to product development, potential demand and sustainability impact of their products. This study investigates how sustainability-oriented ventures engage in product innovation processes; in doing so, it builds upon the theory of effectuation, as a useful approach to decision-making under uncertainty. A longitudinal case study on four sustainability-oriented ventures revealed two different approaches to product innovation in such ventures, namely *adaptive* and *exaptive* approaches. While an adaptive approach is characterized by a long-term value proposition a venture engages in, and high fidelity design experiments used to get the commitment of a select number of stakeholders to develop this predefined value proposition, an exaptive approach is characterized by short-term multiple value propositions a venture engages in, and low-fidelity affordable design experiments used to test market potential of these propositions through various stakeholder interactions. Moreover, the way new ventures define their value propositions in relation to sustainability appears to influence the approach they adopt for the product innovation process. While the ambition to transform a particular market towards sustainable practices causes ventures to anchor on a target market, which appears to stimulate an adaptive approach, the ambition to develop a product that can replace existing products or provide similar sustainability benefits in a number of markets causes firms to anchor on a product idea, which appears to stimulate an exaptive approach. We conclude that future studies should explore the implications of different approaches in order to identify best practices for new ventures engaged in product innovation for sustainability.

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1. Introduction

New ventures are increasingly proposed as candidates of creating new, more socially and/or environmentally sustainable¹ products due to their ability in dealing with high levels of uncertainty (Dean and McMullen, 2007; Hockets and Wüstenhagen,

2010; Schaltegger and Wagner, 2011; York and Venkataraman, 2010). In this respect, there has been growing interest in academia and practice for sustainability-oriented ventures that aim to create viable businesses based upon environmentally and/or socially sound products (Choi and Gray, 2008). Yet, for such ventures succeeding in product innovation (i.e. translating a sustainable product idea into a viable business) is challenging. They are confronted with uncertainty pertaining not only to the potential demand and new product development (O'Connor, 1998), but also to the sustainability impact of their innovations. Therefore, the challenge of such ventures is not only related to 'what products to develop for which markets', but also 'with what social and environmental consequences'.

Recent work suggests that the simultaneous pursuit of social, environmental and financial goals creates tensions between

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¹ Sustainability in this paper is defined as a broad societal concept and approach aimed at contributing to the 17 Sustainable Development Goals of the United Nations (UNEP, 2015). However, no translation to operational indicators and scores is foreseen in this study; more a generic, subjective attitude of the involved new ventures with respect to the environmental, social and economic aspects of the concept is considered.

'creating a viable business' versus 'staying true to ideals' (Dixon and Clifford, 2007), which, in turn, increases the complexity of decision making process, in particular, with respect to the value proposition of the emerging firms (Berchicci, 2005). In addition, sustainability-oriented ventures face additional uncertainties that stem from the sustainability impact of their products and businesses. As a consequence, it is often challenging for such ventures to define a viable and sustainable value proposition at the outset of the venturing process. In that respect, some scholars have highlighted the role of experimenting with value propositions in identifying target groups that might be interested in the sustainable value offered, and sharpening the purpose of the firm (Baldassarre et al., 2017; Bocken et al., 2018, 2019).

However, current research offers little insight into this experimentation process, in particular, in the context of product innovation and sustainability-oriented ventures, and how it can be managed effectively. To advance our understanding, we synthesize research findings in sustainable and conventional product innovation literatures to conceptualize the product innovation process in sustainability-oriented ventures. Subsequently, we employ effectuation theory in order to advance the understanding of the dynamics of this process. Effectuation emerged as a theory of expert decision making within entrepreneurship literature (Sarasvathy, 2001), and is proposed as a useful approach to decision-making under uncertainty (Wiltbank et al., 2006). In this regard, it is a useful theoretical lens in the context of product innovation in sustainability-oriented ventures. Effectuation is conceptualized as the inverse of causation, which is a decision-making logic predominantly used by novice entrepreneurs (Sarasvathy, 2001). By building on the causation-effectuation dichotomy, we aim to investigate how sustainability-oriented ventures engage in product innovation. The research questions this study aims to answer are: (1) What type of approaches to product innovation process can be observed in sustainability-oriented ventures? and (2) What are the implications of sustainability-orientation on this process and the type of approach adopted by new ventures?

The contribution of this article is as follows. First, we contribute to an understanding of the product innovation process by synthesizing different literature streams, which is useful in describing and analyzing the product innovation process in sustainability-oriented ventures. Second, our case study reveals two different approaches to product innovation in sustainability-oriented ventures, namely *adaptive* and *exaptive* approaches. The adaptive approach, predominantly driven by causal logic, is characterized by long-term engagement in a particular value proposition and high-fidelity design experiments used to get the commitment of a select number of stakeholders to develop a predefined value proposition, which is set at the outset of venturing process. The exaptive approach, predominantly driven by effectual logic, is characterized by short-term engagement in various value propositions and low-fidelity affordable design experiments used to test market potential of multiple value propositions through various stakeholder interactions. Third, our analysis shows that the way entrepreneurs define their value proposition in relation to sustainability appears to influence the approach they adopt for the product innovation process, and consequently the degree of the focus on and flexibility with a particular value proposition.

2. Theoretical background

For studying the product innovation processes in sustainability-oriented ventures, we build upon the following literatures: sustainable entrepreneurship, sustainable and conventional product innovation, and entrepreneurial decision-making. In Section 2.1, we

rely on sustainable entrepreneurship literature to discuss the challenge of decision making with respect to pursuing multiple goals simultaneously, and the implications of sustainability-orientation for the decision-making process. In Section 2.2, we turn to sustainable and conventional innovation literatures to discuss how product innovation might evolve in sustainability-oriented ventures. Finally, in Section 2.3, we deploy entrepreneurial decision-making literature, and discuss the implications of causation versus effectuation, as two distinct decision making logics, for product innovation processes in sustainability-oriented ventures.

2.1. Sustainability-oriented ventures

Entrepreneurship has been recognized as an important means for the development of novel products and services that can address the social and environmental issues we face as society (Hall et al., 2010). There is a growing interest in academia for sustainability-oriented ventures that aim to create viable businesses based upon environmentally and/or socially sound products (Choi and Gray, 2008).

The literature at the intersection of sustainability and entrepreneurship can be categorized into social, environmental and sustainability entrepreneurship, based upon the type of societal issues entrepreneurship aims to address. While social entrepreneurship is mainly associated with non-profit activities that have a social mission (Mair and Martí, 2006), environmental entrepreneurship puts emphasis on profitable opportunities that create environmental value (Schaltegger, 2002), and sustainability entrepreneurship integrates all three elements of sustainability (Young and Tilley, 2006). Whether the focus is given on social and/or environmental goals, or whether the relative importance of social or environmental goals is equal or outweighs financial goals, the scholarly interest in social, environmental and sustainable entrepreneurship implies "an expanded view of entrepreneurship beyond firm performance" and "a broader concept of value creation" (Cohen et al., 2008, p. 108). Accordingly, in this paper sustainable entrepreneurship is viewed as 'individual or simultaneous pursuit of social and environmental goals in addition to financial goals'. In other words, sustainability-oriented ventures engage in a process of 'sustainable value creation' by combining their social and/or environmental mission with a product idea and create potentially sustainable and financially viable new businesses (cf. 'sustainability-rooted SMEs' in Klewitz and Hansen, 2014).

This simultaneous pursuit of social and/or environmental goals in addition to financial goals is likely to increase the complexity of the decision-making process. Especially the strategic decisions concerning the value proposition of the venture are likely to influence the social and/or environmental impact of the venture and its business model, as the value proposition is the core of a business and defines how it creates value for its customers, as well as the environment and society (Bocken et al., 2014a). For instance, a product in one particular market might not reveal similar sustainability benefits in another market due to different requirements or use scenarios (Paech, 2007). As such, a decision to shift to another market for increased commercial revenues might come at the cost of losing the social and/or environmental benefits (e.g. 'mission drift' as proposed by Battilana and Dorado, 2010). Alternatively, a commitment to a particular product concept or target market due to psychological rewards associated with sustainability might jeopardize the economic viability of a new venture (Berchicci, 2005). In other words, serving a particular market might not be financially viable in the long-term. Accordingly, sustainability-oriented ventures are continuously confronted with trade-offs between multiple goals of sustainability (Hahn et al.,

2010), and tensions between “running a viable business and staying true to the ideals” (Dixon and Clifford, 2007, p.328). This is likely to increase the complexity of the decision-making process, in particular, with respect to the value proposition of the emerging firms. As a consequence, it is often challenging for sustainability-oriented ventures to define a viable and sustainable value proposition at the outset of the venturing process. Considering this challenge, we in the following section employ conventional and sustainable innovation literatures to discuss how the product innovation process might unfold in sustainability-oriented ventures.

2.2. Product innovation processes in sustainability-oriented ventures

Innovations for sustainability, in comparison with conventional innovation, entail additional uncertainties stemming from their long-term impacts, as well as the additional environmental and/or social dimensions. Sustainable innovations require firms to “consider issues outside their area of expertise, far beyond the boundaries of the individual firm and over time periods much, much longer than the typical product-planning horizon” (Thurston, 1999, p.50). This implies that innovating for sustainability is typically more complex and ambiguous in comparison with conventional innovation (Goodman et al., 2017), and might require firms to adopt a more experimental approach to innovation development. For instance, Bocken et al. (2018) suggest that value proposition experiments help firms with identifying target groups that are interested in the sustainable value offered, and sharpening the purpose of the firm.

An additional challenge for the innovators for sustainability is a lack of consensus on the meaning and definition of the concept of sustainability (Faber et al., 2005). The terms ‘social’ and ‘sustainable’ are perceived differently by customers, suppliers, firms, knowledge institutes and other stakeholders. Sustainability is a multi-dimensional concept that needs to be continuously negotiated between multiple stakeholders concerned (Hall and Vredenburg, 2003). In this respect, stakeholders are at the heart of the challenge of creating new, more socially and/or environmentally sustainable products (Goodman et al., 2017). Interaction with multiple actors is an enabling mechanism for innovations in the context of sustainability for accessing novel ideas, new information and resources (Klewitz and Hansen, 2014; Boschma, 2005), as well as creating a shared understanding of and vision for sustainability (Aragón-Correa et al., 2008). An informal, open innovation approach (i.e. working together with suppliers, customers and knowledge institutes) appears to better fit firms’ approach to sustainable innovation (Bocken et al., 2014b). In a similar vein, the more recent business model innovation literature suggests that firms develop their value propositions through learning and experimental approaches, at least until the definition of the product and customer segment gets crystallized (Andries et al., 2013; Reymen et al., 2017). Within this process, stakeholder interactions are emphasized as an important activity that drives the goal of the emerging venture (Dew et al., 2011; Reymen et al., 2017; Sarasvathy, 2001; Wiltbank et al., 2006). New ventures usually engage in a number of stakeholder interactions to learn about potential markets and their business environment, as well as to secure the necessary finance for product development (Reymen et al., 2017).

Furthermore, the organizational context where innovation unfolds has implications for the innovation process. New ventures differ from large organizations and accordingly have particular strengths and weaknesses. On one hand, they possess quicker decision-making processes (Damanpour, 2010), are more flexible (Fiegenbaum and Karnani, 1991), and as such, take rapid action in

responding to evolving contingencies (Chen and Hambrick, 1995). On the other hand, new ventures usually suffer from limited resources, liabilities of newness (Stinchcombe, 1965), liabilities of smallness (Freeman et al., 1983) and a short-term outlook (Vanhaverbeke et al., 2018). These weaknesses, in turn, are likely to increase the level of uncertainty with respect to product development and potential demand. In that respect, some scholars have been suggesting that small firms, such as new ventures, are likely to apply radical innovation approaches even if they are engaged with incremental innovations (Berends et al., 2014). Small firms make decisions and engage in activities based upon limited and available resources, instead of predefined goals; the decision-making process is driven by a series of prototypes and a broad vision instead of concrete goals or well-defined product concepts (Berends et al., 2014). For instance, various effective management practices are described in literature, such as prototype tests with potential customers (Cooper and Kleinschmidt, 1986), demonstrations of a new technology (Jolly, 1997), experimenting with real products (Tidd et al., 1997), and probe and learn (Lynn et al., 1996). These practices are characterized by a process of experimentation and learning. Experiments often encompass the embodiment of product ideas into physical applications and vary in terms of their fidelity. Fidelity refers to the degree of accuracy to which an experiment represents reality (Thomke, 2008). The fidelity of an experiment has implications for the speed and cost of an experiment, as well as the learning it provides. While low-fidelity experiments, such as mock-ups and models, generate rapid feedback in validating designs and detect errors at low cost (Thomke, 2008), high-fidelity experiments, such as working prototypes and early versions tested in the market, are useful for communicating the final appearance and functionality of a product, as well as validating its aesthetics and technical performance (Pei et al., 2011).

A synthesis of these ideas suggests that product innovation in sustainability-oriented ventures is characterized as a process of action and interaction and learning from those. New ventures typically engage in a number of ‘design experiments’ (e.g. prototype tests with potential customers, demonstrations of a new technology, or experimenting with real products) and ‘stakeholder interactions’ to understand the potential of markets, the suitability and limitations of certain product ideas and concepts, as well as the social and/or environmental implications of the potential product-market combinations (Keskin, 2015). New ventures define their value proposition over time on the basis of the outcomes of design experiments and stakeholder interactions. Accordingly, in this study we conceptualize the product innovation process on the basis of three constructs: *value propositions*, *design experiments* and *stakeholder interactions*. ‘Value propositions’ in this conceptualization refers to the goals of the venture, and encompasses the decisions related to ‘what *products* to develop’, ‘for which *markets*’ and ‘how a *sustainability issue* is addressed’. The main argument here is that design experiments and stakeholder interactions are the main activities that drive the goals of the emerging venture.

To better understand how this process precisely happens, in particular, how new ventures progressively define a viable and sustainable value proposition over time on the basis of a series of design experiments and stakeholder interactions, we use the theory of *effectuation* as the theoretical lens, as it describes a problem space characterized by uncertainty and a decision-making logic that is suitable in addressing uncertainties linked to product innovation, sustainability and new ventures. In the following section, we discuss effectuation, and its inverse *causation*, as well as the implications of these two decision-making logics for the product innovation process.

2.3. Causation versus effectuation, and their implications for product innovation

Effectuation is a decision-making theory that has been developed within entrepreneurship literature as an alternative to the rational economic theories of decision-making, also referred to as causation (Dew et al., 2011; Read et al., 2009; Sarasvathy, 2001). The fundamental difference between the two decision-making logics is their assumptions with respect to *goals* and *means*. In causal processes, the goals are taken as given, or predefined at the beginning of the process. As such, causation is about selecting the right means to achieve a predefined goal. Effectuation, on the other hand, reasons from a set of given means. Accordingly, effectual processes are about selecting between goals that can be achieved with a particular set of means (Sarasvathy, 2001).

The predictive rationality of causation implies a process, in which opportunities are identified at the beginning of the process. These are then followed by a number of linear steps, such as market research, competitive analysis, business plan development, and resource acquisition for implementing a business plan and adapting it based on feedback from stakeholders in the emerging environment (Read et al., 2009). In causal processes, a considerable amount of time and resources are spent on analysis and planning type of activities in an effort to succeed in a predetermined market with a predefined product idea (Sarasvathy, 2008). In contrast, an effectual process starts with a set of means available to the entrepreneurs, such as the prior knowledge and aspirations of the entrepreneurs, and his or her personal and professional network. Pragmatically, entrepreneurs start thinking of what they can do with their existing means. They begin to imagine and implement possible effects that can be created and are worth creating (Sarasvathy, 2001). They move directly into action and interaction with other people. Those who commit to the new venture bring in new means and goals. This results in an expanding cycle of means and a converging cycle of goals. Thus, stakeholder commitment is an essential mechanism in the creation of new products and markets (Sarasvathy, 2008).

The two decision-making logics have different implications for how product innovation might evolve in new ventures on the basis of our conceptualization. While goals and stakeholder interactions are central to effectuation, this study also includes design experiments since the focus here is on product innovation, which involves the design, development and implementation of product ideas through various forms of design experiments, such as prototypes, demonstrations and early versions (Cooper and Kleinschmidt, 1986; Jolly, 1997; Tidd et al., 1997). First, the two views fundamentally differ in terms of their assumptions regarding the goals of the venture. While causation suggests that goals are predefined at the outset of the process, effectuation claims that goals emerge from the process itself. Therefore, it is likely that entrepreneurs who predominantly use an effectual logic are more flexible and iterative with the value propositions of the venture, and engage in short-term value proposition throughout the innovation process to identify business opportunities (Chandler et al., 2011). Contrarily, entrepreneurs who predominantly use a causal logic are likely to be less flexible with and more focused on the value propositions, and engage in long-term value propositions throughout the innovation process, since the goals of the venture are set at the beginning of the process. Accordingly, the ultimate product or service offered by a venture is likely to be similar to the original conception of entrepreneur (Chandler et al., 2011). Second, in both causal and effectual processes new ventures engage in a number of stakeholder interactions; however, the nature of these interactions are likely to be different in essence. In both processes, feedback received from stakeholders influences the future actions of the

venture, although effectuation fundamentally recognizes a more important and dynamic role for stakeholders. In other words, entrepreneurs who are using predominantly an effectual logic are more likely to let the stakeholder drive the goals (Sarasvathy, 2001). Contrarily, entrepreneurs who predominantly use a causal logic engage in stakeholder interactions primarily to attract the necessary resources to develop a particular business idea since the goals of the venture are set at the beginning of the process (Sarasvathy, 2001). Third, although the construct 'design experiments' is not central in effectuation theory, this study expects to find that experiments have a fundamentally different role for product innovation driven by a causal and effectual logic. Experiments in causal processes are likely to be used to fine-tune a predefined business idea, and as such, the outcome of the experiment does not influence the overall value proposition of the venture (Silberzahn, 2011). In other words, the experience and feedback gained in design experiments influence subsequent decisions, enabling firms to adapt their course of action to increase the chances of a desired outcome. Hence, design experiments in causal processes are characterized by generating variation based upon adaptation (Van de Ven et al., 1999). On the other hand, experiments in effectual processes are likely to be used to generate new value propositions (i.e. new product ideas/concepts for a variety of potential customer segments), and stimulate stakeholder commitments to the emerging venture (Sarasvathy, 2008). In other words, design experiments in effectual processes involve generating variation based upon experimentation, which is about finding solutions for various problems and other types of use (Sarasvathy, 2008).

A synthesis of these ideas suggests that the product innovation process will look different in terms of the number of *value propositions*, as well as the driver and outcome of *design experiments* and *stakeholder interactions* depending upon the underlying decision-making logic used by entrepreneurs. This study investigates how entrepreneurs use these distinct decision-making logics for product innovation process. Notably, although causation and effectuation are conceptualized as two distinct and contrasting decision-making logics, recent studies show that entrepreneurs adopt causation and effectuation simultaneously and sequentially for strategic decision-making (Reymen et al., 2015), marketing planning (Crick and Crick, 2015), and business model development (Reymen et al., 2017). As such, it is expected to observe these two decision-making logics simultaneously and/or sequentially in one venturing process. Finally, given our focus on sustainability-orientation, we aim to explore the implications of simultaneous pursuit of different sustainability goals. In particular, we are interested in how entrepreneurs make their decisions regarding the value proposition of the emerging ventures, since these decisions are likely to influence the social and/or environmental impact of the new venture and its business model, and the approach entrepreneurs adopt for the product innovation process.

3. Research methodology

To fully understand how new ventures create sustainable value by translating product ideas into new businesses, a process-oriented perspective has been adopted in order to investigate the unfolding of events over time (e.g. Langley, 1999; Van de Ven et al., 1999). A longitudinal case study of product innovation process was conducted to recognize patterns in the way new ventures create value propositions, and engage in design experiments and stakeholder interactions. Following Eisenhardt's (1989) suggestion that some degree of a priori specification of constructs enables more accurate measures for data collection and analysis, we used the conceptualization presented in Section 2.2 as a guideline for data

collection and analysis. This way prior theories were extensively and iteratively used to guide the case study, the data collection and the analysis of the results.

3.1. Case selection

The case selection relies on theoretical sampling. The cases were selected to extend extant theories (Eisenhardt, 1989) on product innovation process through identifying different patterns of this process and exploring the implications of different decision-making logics and sustainability-orientation. Four new ventures were selected based on three sets of criteria. First, they had to be innovative ventures in the process of developing a new product with potential sustainability benefits. Second, the ventures had to display variety in terms of product innovation processes, in particular the number of value propositions they engaged over time, to result in generalizable insights (Eisenhardt and Graebner, 2007). As mentioned in Section 2.3, the number of value propositions a venture engages is likely to be different in causal and effectual processes. Entrepreneurs who predominantly use an effectual logic are more flexible and iterative with the value proposition of the venture, which is likely to yield higher number of value propositions, whereas entrepreneurs who predominantly use a causal logic are expected to be more focused on the value proposition of the venture, which is likely to yield lower number of value propositions (Chandler et al., 2011). Although variation over the other two constructs of the conceptualization is plausible, it was not possible to gain an overview of the design experiments and stakeholder interactions of case companies before in-depth interviews. Therefore, the cases were selected based on the number of value propositions they engaged over time, as depicted in Fig. 1. Third, the selected ventures had to be active in different industries to allow for variation in order to ensure that the scope of findings is not limited to one single industry. Table 1 provides an overview of the case characteristics and data sources, and Table 2 gives a brief summary of the cases.

3.2. Data collection

Data were gathered through semi-structured interviews with entrepreneurs and product managers of the ventures, and covered the period that started with the emergence of the sustainable product idea until the data collection was finished (Table 1). Accordingly, the period we covered for each firm was different in duration. For instance, Solar Dew's innovation process entailed a longer timeframe compared to the other three cases. In this case, interviews with the product manager previously involved provided additional insights to the earlier phases. Similarly, interviews with the founder of Sustainable Dance Club who is not actively involved in the venture anymore, and the previous product manager provided valuable insights into the earlier phases of the product innovation process. In the first interview, entrepreneurs were asked about the history of their firm. Main topics discussed during these interviews were entrepreneurs' ambitions related to sustainability, the initial product idea and how it evolved, design experiments and learnings they provided, and most influential stakeholders and their involvements. These first interviews lasted 2 h on average. Based on the initial analysis of these interviews, main design experiments and influential stakeholders were identified and in a second interview, and in some cases a third interview, entrepreneurs or other employees were asked for further details. Data triangulation was achieved through interviews and complementary company documents (Yin, 2009). These consisted of patents, newspaper articles, company presentations, progress reports, balance sheets and web articles.

3.3. Data analysis

In order to organize the large amount of data produced through interviews and various archival documents, this study relies on multiple strategies. The activities conducted to analyze the data are described below. Although the data analysis procedure may seem as a linear process, the approach taken was iterative in nature, going 'back and forth' between activities, as well as empirical observations and theory (Dubois and Gadde, 2002).

First, we documented the product innovation process for each case on the basis of the conceptualization presented in Section 2.2. For this, we created case descriptions and visual maps (Langley, 1999) of product innovation processes. In order to avoid researcher bias and increase construct validity, informants were invited to review the initial case descriptions and visual maps (Gibbert et al., 2008).

Second, in order to observe and analyze the product innovation process of the ventures, a coding scheme was developed (Table 3). *Value propositions* consist of variations in the definition of products and market segments a firm engages over time, as well as the sustainability issue addressed. The decisions that require the development of applications with totally different architecture and product variants, and the shifts to different markets and market segments, as well as the sustainability issue addressed are considered to be a different value proposition. *Design experiments* entail the embodiment of a product idea into a physical applications and experimentation with it, whether in a controlled environment, in the field, or in a real market. *Stakeholder interactions* encompass interactions with stakeholders (e.g. partner, potential customer, investor, supplier) that might or might not result in actual commitments. Here commitments are considered in the form of time, knowledge, capabilities, as well as financial means. Interactions that do not include commitments are also included since they might influence the decisions concerning the value proposition of the firms (e.g. negative/positive feedback from potential customers). As a next step in the data analysis procedure, the interview data were coded based upon the coding scheme (Table 3). For each case, the coding was visualised in a timeline representing the value propositions ventures engage over time (Langley, 1999).

Third, the product innovation processes of the cases were analyzed to establish whether and when effectual or causal logics were used by entrepreneurs at different parts of the process. In doing so, we first identified the focused and iterative periods in each process. Focus periods are those where entrepreneurs engage in one or two value proposition(s) for a long duration, while iterative periods are those where entrepreneurs engage in a number of short-term value propositions (Chandler et al., 2011). Then, we analyzed these periods further with respect to the role of means (i.e. resources) in order to see whether the focused and iterative periods were characterized indeed by a causal and effectual decision-making logic, respectively. In causal processes, it is expected that resource commitments follow goal setting, while in effectual processes, resource commitments precede goal setting (Berends et al., 2014). Therefore, we analyzed stakeholder interactions in each period to see whether the driver of entrepreneurs was to insource the necessary resources for a particular value proposition (i.e. representing a causal logic), or insource ideas that leads to resource and stakeholder commitments and consequently a shift in the value proposition of the venture (i.e. representing an effectual logic) (Sarasvathy, 2008). Subsequently, we analyzed the design experiments in causal and effectual periods to characterize design experiments in causal and effectual processes, and identify patterns in the product innovation processes of the ventures in our sample.

As the final step in the data analysis procedure, the decisions with respect to changes in value propositions were further

analyzed in relation to the sustainability orientation of the entrepreneurs. In doing so, we first analyzed entrepreneurs' initial and emerging goals to address an issue related to sustainability via the products they develop and markets they engage in (i.e. how they create social and/or environmental value). We then analyzed the changes in the definition of the value propositions, and whether and how entrepreneurs' sustainability orientation influenced these decisions. The findings section starts with a descriptive account of the innovation processes of the ventures in our sample, and continues with discussing the two approaches emerged from our analysis. We finally discuss the implications of sustainability orientation for the product innovation process.

4. Findings

4.1. Product innovation processes of the firms

The analysis of number and duration of value propositions firms engage over time, and the drivers of stakeholder interactions provided qualitative empirical evidence to entrepreneurs' use of causal or effectual logic in different periods of the innovation processes. We observe that while some firms are more focused on a particular value proposition, others are more flexible and iterative with the value proposition of the venture. Furthermore, firms' innovation processes in terms of focused versus iterative periods changes over time. Fig. 2 illustrates the value propositions case firms engage over time. The dashed lines are used to illustrate the shifts from a focus to an iterative pattern, or a shift from an iterative to a focused pattern.

The comparison of the timelines of the cases as depicted in Fig. 2 reveals that four ventures differ significantly in their approach to innovation process. All firms start with a particular value proposition, however, follow different patterns of value proposition development. Evening Breeze displays a focused pattern to the design and development of its value proposition throughout the whole innovation process. The initial value proposition (VP1) of the firm is to offer an air-conditioned four-poster bed to eco-resorts in tropics with the aim of decreasing their environmental impact. The product reduces the cooled space and cooling time by focusing on the bed area and nighttime. The firm commits to this proposition throughout the whole innovation process, and develops a suspended version of the system for the same market with the same environmental goal (VP3) in 2011. In addition, in 2008, the firm starts focusing on the high-end of the Dutch consumer market and develops a luxury version of the system to be offered to Dutch households through bed manufacturers (VP2). However, the environmental benefits of this value proposition are considerably lower considering the number of days per year the product is being used and the chances of selling a luxury product to consumers who previously did not own an air-conditioner. In that respect, between 2009 and 2012, when the focus was given on the consumer market, the firm puts more emphasis on financial goals than environmental goals. The main stakeholders Evening Breeze interact throughout its innovation process are investors or potential clients within the target market to make these particular propositions successful. The firm's commitment to the air conditioning bed system and its variations within two main markets, namely the eco-resorts and consumer market, suggests that entrepreneurs predominantly adopt a causal logic throughout the innovation process.

Sustainable Dance Club displays both a focused and an iterative pattern to its innovation process in the early phases. Between 2005 and 2009, the firm appears to simultaneously use causal and effectual logics. On one hand, the firm has a strong focus on the clubbing market, and focuses on the development of an energy-generating dance floor. Various clubs are contacted and design

experiments are conducted to make this particular idea successful, suggesting a causal logic. On the other hand, in parallel to the focus on clubs, the firm explores a variety of markets that an energy-generating dance floor can be applied to, such as events and fitness clubs. Moreover, the entrepreneurs develop a portfolio of other product concepts for clubs, such as a zero-waste bar and a sustainable sound system, and interact with a variety of potential partners and suppliers to get their commitment in further co-developing these ideas. Although the majority of these interactions do not lead to any successful spin-offs, the firm starts renting the dance floor to large organizations who are interested in showcasing sustainability in their events (VP2). This way Sustainable Dance Club's sustainability goals evolve from decreasing the environmental impact of clubs to increasing the sustainability awareness among young people who visit events and interact with the dance floor. This explorative search and firm's willingness to adopt its product or develop new ones to different markets and their needs suggests an effectual logic. For example, the firm was developing a number of product concepts through affordable design experiments, such as a mini dance club (VP3) and an energy-display (VP4), and interacting with potential clients, partners and suppliers who could be willing to co-develop these ideas further. This suggests that entrepreneurs simultaneously use causal and effectual logics until 2009. In 2009, the firm's focus shifts to the development of an energy-generating floor with a focus on public spaces, such as stadiums, airports, railways, shopping centers, public buildings, and city squares. The period between 2009 and 2013 is characterized by a focused development of the energy-generating floor and a series of stakeholder interactions with potential customers (VP5).

Solar Dew's and Vrachtfiets' timeline display a mixed pattern in terms of focused and iterative periods of value propositions. Both firms start with a focused pattern and engage in the same product and its variations within one or two markets. After a considerable amount of time (i.e. about three to four years), the innovation processes of the firms display an iterative pattern. These iterative periods are characterized by a series of stakeholder interactions and changes in the value proposition of the firms based on the feedback of stakeholders. After the iterative periods, both firms engage in a focused pattern again, mainly engaging in one or two product categories in one or two markets. Solar Dew's initial value proposition is to offer an affordable desalination device for agro-businesses in solar rich areas, where infrastructure cannot provide a solution. Between 1998 and 2000, Solar Dew develops two different product concepts, namely an irrigation mat (VP1) and a gutter system (VP2) for agro-businesses. After its founding in 2000, the firm continues to develop the gutter systems in several design experiments. This period is characterized by a focused development of a water desalination device in a series of design experiments and interactions with potential customers within the target market. This suggests that entrepreneurs adopt predominantly a causal logic. In parallel to the development of the gutter system, between 2002 and 2005, the firm explores other markets with a variety of applications, such as thermodes (VP3) and water house (VP4) for the treatment of industrial wastewater for companies who are interested in thickening chemical waste and reducing the cost of chemical waste disposal, flat collectors for military purposes (VP5) and solar dew dropper for producing drinking water for low-income households in emerging markets (VP6). This iterative development of value propositions suggests an effectual logic used by the entrepreneurs of the firm. In this period, the main focus of the firm is to develop a business case on the basis of the unique properties of its membrane technology, decrease the uncertainties related to technology development and develop a working prototype. As such, the firm prioritizes the financial goal over the social

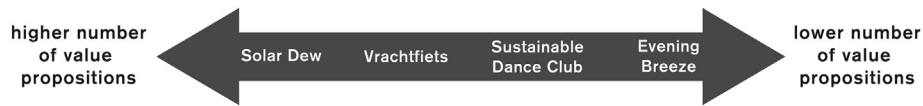


Fig. 1. Case selection based on variation in the number of value propositions.

mission of developing an affordable irrigation device. In 2004, with the start of solar dew dropper concept, the firm shifts its focus back to its social mission. The period that follows between 2005 and 2013 is characterized by a focused pattern of value proposition development. The firm develops two main concepts, namely black top collector (VP7) and flex-bag (VP8), as an affordable water

application to be offered to low-income group in emerging market. The firm's social mission and strong focus on this particular market lead to a series of design experiments conducted with the aim of developing a working prototype, and no significant stakeholder interactions. Accordingly, in this period the entrepreneurs appear to adopt causation as the main decision making logic.

Table 1
Case characteristics.

Venture	Industry	Sustainability issue addressed at the end of period covered	Initial value proposition	Value proposition at the end of period covered	Period covered	Data sources
<i>Solar Dew</i>	Consumer (Low-income countries)	Serving people who are in need of affordable water	An irrigation mat for agro-businesses	An affordable household water application for low-income markets	2000–2013	- Interviews with co-founder, product manager and investor (9) - Documents (progress reports, scientific articles, sketches and pictures of various products, presentations, patents, balance sheets) (64)
<i>Sustainable Dance Club</i>	Entertainment	Creating awareness about sustainability among young people	Various sustainable product ideas for clubs	An energy generating floor for multiple markets	2008–2013	- Interviews with co-founder, manager, two product managers (7) - Documents (product sheets, video, web articles, presentations, sketches and pictures of various products, patent, student reports) (41)
<i>Evening Breeze</i>	Hospitality & Consumer	Reducing energy consumption in the hospitality and consumer market	An air-conditioning system for eco-resorts in tropics	An air-conditioning system for eco-resorts in tropics and consumers in Dutch market	2006–2013	- Interviews with two co-founders, product designer (7) - Documents (magazine articles, business plan, white papers, sketches and pictures of various products, patents, student reports) (99)
<i>Vrachtfiets</i>	Mobility	Reducing the environmental impact of current mobility solutions	A cargo bike for students	Custom-made cargo bikes for multiple markets	2009–2013	- Interviews with two co-founders (4) - Documents (project proposals, videos, brochures, business plan, web articles, product and prototype pictures, student reports) (71)

Table 2
Brief summary of cases.

Solar Dew was founded in 2000 as a joint venture between Akzo Nobel, a venture capital firm, Wageningen University and a private investor. The firm's vision has been to develop affordable water applications for low-income markets based on unique properties of a patented non-porous membrane technology, developed for clothing applications in the laboratories of Akzo Nobel in 1990s. Since the firm was founded, the idea has evolved from a technological innovation to an independent firm called 'Solar Dew International'. Throughout this period, the membrane technology, product concept and the target markets have undergone a variety of changes.
Sustainable Dance Club was initiated in 2005 as a project by a Rotterdam-based network organization Enviu and the architecture firm Döll, with the aim of making the clubbing scene more sustainable through reducing the environmental impact of clubs. Sustainable Dance Club started as a firm in 2007 when, amongst others, an energy generating dance floor was selected as the most promising product idea by the team. Since 2008, Sustainable Dance Club's main activity has been the development of the dance floor, as well as an energy floor to be offered in a number of markets in a rental model.
Evening Breeze was established in 2006 by two industrial designers and two eco-tourism experts. The firm was founded with the vision of making the tourism industry more sustainable with a focus on energy use within eco-resorts. The firm had been developing an alternative to conventional air conditioning for tropical resorts, which are confronted with high energy prices, high overnight temperatures and the presence of insect based diseases. Evening Breeze offers air-conditioned bed systems that significantly reduce the cooled space and cooling time by focusing on the bed area and nighttime. Evening Breeze's slogan illustrates this ambition: "cool dreams for a better planet". The target market was initially selected as the hospitality market in tropics due to the high saving potential linked to the climate throughout the year. Currently, the firm offers solutions for the consumer market as well.
Vrachtfiets , a name that combines the Dutch words for 'cargo' and 'cycle', is a spin-off firm from the Delft University of Technology, the Netherlands. The firm was founded in 2009, with the vision of developing a sustainable and affordable mode of transport for the university students in Delft. Two industrial designers started the firm based on a problem they had often experienced during their studies: transporting voluminous goods. They aimed at developing a cargo cycle with the idea of offering an affordable alternative to existing mobility solutions, and making students less dependent on motorized vehicles. A Vrachtfiets is an electric assisted modular cargo cycle that enables custom-made mobility solutions. Since its foundation, the firm has developed different modules in order to provide fitting mobility solutions for a diversity of markets.

Table 3
Coding scheme.

Code	Definition
<i>Value proposition</i>	A particular product offering aimed at a certain market with potential sustainability benefits
<i>A change in the value proposition</i>	Includes decisions: - To develop a different product (or portfolio of products) - To target an alternative market segment - To address a different sustainability issue
<i>Number of value propositions</i>	Number of value propositions a firm engages in
<i>Duration of a value proposition</i>	Absolute time in years
<i>Design experiment</i>	Embodiment of a product idea into physical applications in a controlled environment (e.g. trial, lab/field test, prototype) or in real markets (e.g. early version)
<i>Stakeholder interaction</i>	Stakeholder interactions that a firm engages (with or without commitment)

Similarly, Vrachtfiets displays a focused pattern of value proposition development until 2011. The firm starts with the ambition to develop an affordable and environmental-sound cargo-bike for university students in Delft for transporting voluminous goods, and targets retailers as the main channel this solution can be offered (VP1). In this period, the firm also develops a different version for the mobility of tourists to be sold to holiday parks on Dutch islands (VP2). This period is followed by an iterative pattern. The firm identifies a number of markets on the basis of entrepreneurs' personal network and develops various versions of the bike for these markets with the ambition to offer a more sustainable solution that can replace or decrease the use of motor-vehicles, such a parcel bike for inner city distribution (VP3), a people mover for public transport (VP4), a pick-up version for city maintenance services (VP5) and a people mover for daycares (VP6). In this period, the firm engages in a series of design experiments and interactions with potential clients to find a viable business, which results in various value propositions. This suggests that entrepreneurs predominantly rely on an effectual logic. After this iterative period, entrepreneurs decide to focus on only two value propositions: the parcel bike for inner city distribution (VP3) and the pick-up bike for city service (VP5). The aim of the team in this period is to redesign these two versions of the bike and attract potential clients from the target markets. This suggest that a causal logic is used by the entrepreneurs.

Consequently, an in-depth analysis of these focused and iterative periods, with a focus on the shifts in value propositions, as well

as drivers and outcomes of stakeholder interactions and design experiments led us to identify two distinct approaches to product innovation: 1) *adaptive approach*, characterized by a focus on a specific value proposition, experimenting with it for several years and adapting it based on design experiments and stakeholder interactions, leading to no change in the overall value proposition of the firm; and 2) *exaptive approach*, characterized by a flexible attitude towards the value proposition and the use of design experiments instrumentally for generating alternatives and facilitating stakeholder interactions. An exaptive approach leads to more frequent changes in the value proposition of the emerging firms. In the following sections, we explain each approach in terms of value propositions, role of entrepreneurs' means, design experiments and stakeholder interactions, and with examples from the case study.

4.2. Two approaches to product innovation in sustainability-oriented ventures

4.2.1. Adaptive approach

All case firms in our sample initially focus on particular value propositions early on for several years and experiment with the same proposition, hoping that the business idea would become viable. For instance, Solar Dew's initial ambition is to develop a water desalination device for agro-businesses and engages in a series of design experiments in the early years to develop a proof of concept. As one of the entrepreneurs of the firm explained: "The

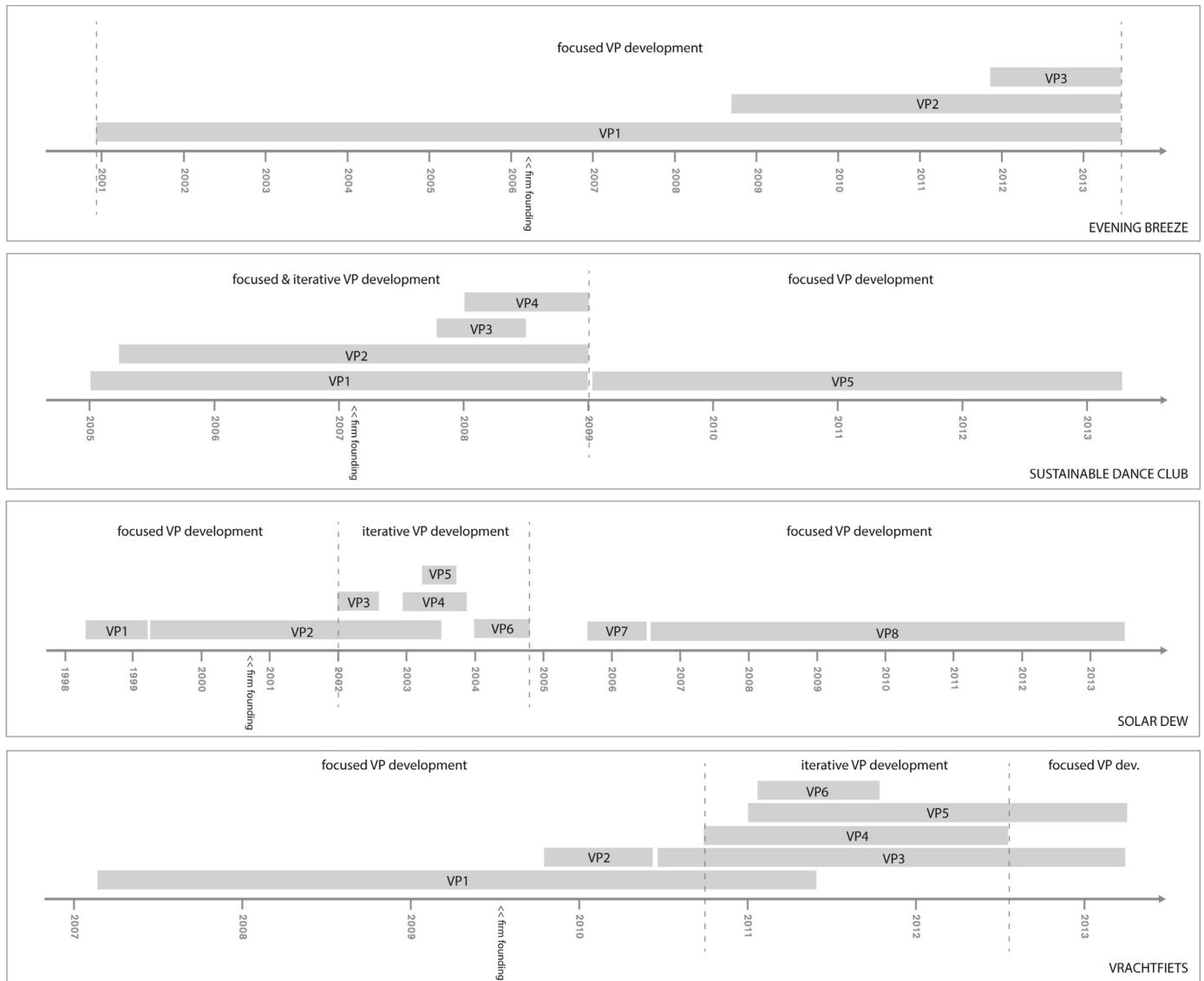


Fig. 2. Overview of value propositions case firms engage in over time.

concept of Solar Dew is from a brainstorm session within Akzo Nobel based on possible applications, what else this polymer could do. Outcome of this brainstorm session was: 'well isn't this a good idea', 'yes, let's make a prototype'. Because it was the research director, he immediately decided to make a little scoping program. So, they made a prototype in a sandbox and tested the idea; various configurations. And this prototype seemed to work in the lab, so they decided: 'let's do a field trial'. Because field trial comes close to showing the business 'this is worthwhile', but also because it is the sun and weather and all kind of complications, you cannot predict in the lab as the same as in the field.' Meanwhile, the main interactions of the firm in this period are with investors and potential customers from the target market, with the driver for acquiring the necessary resources for and generating market feedback on this particular value proposition. Likewise, in early years, Sustainable Dance Club's initial value proposition is a portfolio of products for clubs to decrease their environmental impact. The firm's innovation process in this period is characterised by a number of experiments that are conducted with the aim of testing the feasibility and sustainability potential of these ideas, as well as a number of interactions with potential

customers and partners to acquire the necessary means to develop this value proposition further. As business developer of Sustainable Dance Club explained: "Club Watt [first client of Sustainable Dance Club] was very important for the development of the floor. Because throughout 2006, I was looking for money for the floor. And everybody was interested in the floor, all the media but nobody had money to invest. It was very difficult to get subsidies, sponsorship, because sponsors want to sponsor only something which is there. We had talks with Low Land Festival, really big festival, they wanted to have Sustainable Dance Club. They also did not have money to invest. And then finally we got this project for Club Watt and part of this project was the floor, then we finally had the money to build a prototype."

In the case of Evening Breeze, the firm's initial assumptions appear to be correct as the firm is able to reduce technological and market uncertainties through the development of a working prototype, getting positive feedback from the potential customers within the target market, and eventually attracting investors within a time frame of two years. As the founder of Evening Breeze explained: "We had beautiful pictures from the resorts in Bonaire and South Africa that the product was there and it looked really great. We had very positive

references from the people sleeping there and the resort owners. We had the prize from Shell. So, that was a package, which was very positive." This appears to explain the firm's continuation with the same approach throughout the process. The firm adaptively develops the air-conditioning system for eco-resorts on the basis of the learning from design experiments and potential customers, resulting in no change in the value proposition of the firm. However, in the cases of Solar Dew, Sustainable Dance Club and Vrachtfiets, the outcome of design experiments and stakeholder interactions reveal that the initial assumptions were incorrect, or there are other ways to approach the market. For example, the founder of Vrachtfiets observed: "We had a lot of ideas about the Vrachtfiets, and we thought it would be easy to just design one because we thought it is just a bicycle with four wheels. Looking back, that was a big mistake." Similarly, the founder of Sustainable Dance Club explained: "I am always optimistic. At that time, at the end of 2005, I thought that halfway through 2006 we are going to have the floor. That was very naïve, of course." Consequently, following the initial adaptive period, Solar Dew and Vrachtfiets adopt an exaptive approach to product innovation, and Sustainable Dance Club pursues an exaptive approach in parallel to adaptive approach.

In summary, an adaptive approach is characterized by a commitment to a particular value proposition for a longer period of time, and a focused development of this proposition based on learning from high-fidelity design experiments, as well as feedback from investors and potential customers from a specific market segment. In this regard, an adaptive approach primarily represents a causal logic, since the main driver for conducting design experiments is to test the feasibility, viability and sustainability of a predefined value proposition. That also appears to explain the resources committed to these high-fidelity experiments. The main driver for stakeholder interactions is primarily to generate feedback from potential clients within the target market, and acquire resources from investors for the development of a predefined value proposition (i.e. insourcing resources for a particular value proposition). While positive outcomes provide reassurance for the initial value proposition, mixed and negative outcomes are likely to result in subsequent design experiments and stakeholder interactions, not leading to major changes in the value proposition. If the firms are not able to decrease uncertainties via design experiments and stakeholder interactions for a longer period of time, entrepreneurs appear to eventually shift to an exaptive approach.

4.2.2. Exaptive approach

Following the initial focused periods, the innovation processes of Solar Dew and Vrachtfiets are characterized by an exaptive approach and a flexible attitude towards the value proposition development. In the case of Solar Dew, a high technological uncertainty stemming from the challenge of translating a new technology into applications, appears to have necessitated an exaptive approach between 2002 and 2005. As one of the entrepreneurs recalls: "Everybody was very excited, but what it turned out was that in the wind sand and dust, that plastic did not deliver enough water." In this period, Solar Dew deploys the unique properties of its membrane technology (a crucial mean of the firm) into a wide range of applications in a diverse range of markets, in search of viable value propositions: "What we were trying to achieve was drinking water for solar rich rural areas, where people are far away from where you have mass markets. What we tried to find is: what are the product-market combinations that could make these technologies, and how do we make prototypes for that?" Similarly, after the focused development of the cargo-bike idea, Vrachtfiets engages with an exaptive approach, with the realization of alternative markets based upon the feedback from various stakeholders in a variety of markets. Within this search process, the founders of Vrachtfiets mainly rely on their personal network as a means to

identify target markets and get in touch with potential clients within those markets. One of the founders of Vrachtfiets explained: "He [the uncle of the entrepreneur] lives near a camping and they have contacted us to do something with Vrachtfiets. So, now I am thinking of another project to get funding from the municipality of Castricum, in this case to launch the project together with the camping." During the period between 2010 and 2012, the firm engages in simultaneous value propositions, and conducts a number of design experiments, with the aim of getting the commitment of potential customers in a variety of markets, and testing which markets would take off.

In contrast to the other three case firms, Sustainable Dance Club appears to adopt both an adaptive and exaptive approach simultaneously in early years. Although the firm has a strong focus on clubs in this initial period, the entrepreneurs are flexible with the definition of product and service concepts. During the period between 2005 and 2009, the firm engages in a variety of product concepts on the basis of their sustainability ambition of making the clubbing scene more sustainable (one of the main means of the company), and conducts affordable design experiments without necessarily committing to a specific product idea. These design experiments were conducted with the goal of attracting potential clients and partners, who would be willing to co-develop the 'sustainable dance club' idea further. As the business developer of Sustainable Dance Club explained: "The other products, like a bar that produces no waste, still have to be developed further together with the partners." In that respect, the firm aims to insource ideas from stakeholders that might eventually lead to resource and stakeholder commitments for one particular idea. After 2009, the firm is able to decrease the uncertainties stemming from product development and potential demand, and adopts an adaptive approach to innovation process with a focus on the energy-generating floor for public spaces.

In summary, an exaptive approach is characterized by short-term simultaneous value proposition experiments with various product concepts and/or target segments, without necessarily committing resources to one particular value proposition. In this case, low-fidelity affordable design experiments are instrumental in generating alternative value propositions, and facilitating the self-selection process of stakeholders and potential customers from various market segments, in order to co-develop value propositions further (i.e. insourcing ideas that might lead to resource and stakeholder commitments). Thereby, an exaptive approach primarily follows an effectual logic, as firms are likely to be more open to redefining their value proposition (i.e. shifting to alternative product ideas and/or target segments) based on the feedback from design experiments and stakeholder interactions. Table 4 illustrates the differences between the two approaches in terms of the constructs of the conceptualization presented in Section 2.2.

4.3. Implications of sustainability-orientation

Further qualitative analysis of decisions with respect to the value propositions, in particular how a venture addresses an issue related to sustainability, revealed that sustainability-orientation influences the pattern of value proposition development, especially the degree of focus on and flexibility with a particular product or market, and consequently the approach they adopt for product innovation process. While the ambition to transform a particular market towards more sustainable practices causes firms to anchor on a target market, the ambition to develop a product that can replace existing products in a diversity of markets appears to cause firms to anchor on a product idea. Consequently, anchoring on a specific market appears to stimulate an adaptive approach, and anchoring on a specific product idea appears to stimulate an exaptive approach.

Firstly, if an opportunity has emerged from the ambition to

transform a market, new ventures appear to be more reluctant to shift to alternative markets, even though the market signals and design experiments indicate to do so. The ambition to transform a market appears to increase the commitment of entrepreneurs to that particular market. Consequently, this prolongs the duration of the initial, or a particular, value proposition. In that respect, ventures appear to interpret the outcome of design experiments and stakeholder interactions in a different manner. They appear to ignore a negative outcome of a design experiment or negative feedback from a stakeholder interaction, and follow their own preferences and ambitions. This finding supports the argument that environmental ambition (i.e. “doing the right thing” for the environment) may be a non-rational factor that results in the escalation of commitments for a particular value proposition, even when faced with poor or unclear performance indicators (Berchicci, 2005). For instance, during the initial years Sustainable Dance Club has the ambition to transform the clubbing market, which is reflected in the desire to create a worldwide network of sustainable clubs, as well as efforts put into the exploration of franchising as a business model. Similarly, the founders of Evening Breeze are initially interested in the ‘sustainabilisation’ of tourism, and targeted eco-resorts in tropical regions. This ambition is reflected in the vision statement of the company in 2006: “By 2025 all tropical tourists enjoyed their holiday in the most sustainable way and slept comfortably in an AircoBed.” This is also the case for Solar Dew between 2006 and 2013. During this period, the firm’s focus is bringing affordable water to households in low-income countries. Despite the challenges of translating the technology into applications, Solar Dew develops two different product concepts for this market throughout the seven-year period. The three cases suggest that the ambition to transform the practices in a particular market appears to prolong the duration and focus on particular value propositions. In the case of Sustainable Dance Club, in the early years the firm postpones the decision to shift to alternative target segments that are positively reacting. As the product manager of the venture explains: “We were too idealistic, focusing on the club owners instead of focusing on the floor. And it really took a long time to accept that the floor was the thing. If we would have shifted earlier, maybe it would have been different.” In the case of Solar Dew, sustainability-orientation influences the go/no-go decisions, as the co-founder of Solar Dew recalls in an interview: “All the suppliers that have collaborated in this are all special people. And they were all very sure business people, or technical people with a lot of professional pride and esteem, and they all risked that for this application for the similar reason, because normally you would have cut this project several times.” Similarly, the focus of Evening Breeze on eco-resorts between 2001 and 2008 can be explained by the team’s ambition to decrease the environmental impact of the hospitality market. In this case, the long-term focus on eco-resorts appears to also be driven by the positive feedback of potential clients in the target market and technical challenges overcome in design experiments.

Second, in cases where the focus is given on a specific product applicable in multiple segments, the case firms appear to be more opportunistic and alert to market signals, and make the shift to alternative markets segments easier. Apparently, how entrepreneurs identify an opportunity in relation to sustainability influences the ease of justifying sustainability claims for alternative markets. Product ideas that can potentially replace existing products in a diversity of markets appear to ease the justification of similar sustainability claims for alternative markets. For example, Solar Dew and Vrachtfiets are not founded with the ambition to transform a particular market. Instead, Solar Dew had the ambition to exploit the unique properties of a polymer for developing an affordable water application for solar rich areas. The firm initially starts with agro-businesses and

iterates in diverse markets in an attempt to find a promising value proposition. Similarly, Vrachtfiets is founded with the idea of offering an alternative sustainable solution to students in transporting voluminous goods for short distances and soon after focuses on the cargo-bike concept, which can be applied in a diversity of markets. Having a focus on a specific technology or product with potential sustainability benefits in a diversity of markets appears to explain short-term focus on a range of markets. In addition, it can also be argued that developing products that are applicable in a broad scope of markets eases the justification of the social or environmental claims for alternative market segments, consequently increasing the number of target segments a firm engages in over time. For Solar Dew and Vrachtfiets, it appears that developing products that could potentially replace existing products (i.e. a cargo-bike replacing motor vehicles, or a solar powered desalination device for areas or people where existing infrastructure cannot provide solutions) was easier, at the least in the entrepreneurs’ mind, to justify that similar sustainability claims would also account for other markets.

Finally, the case study suggests that balancing multiple objectives for new ventures, which are often constrained with resources, is a delicate act, as suggested by Hahn and his colleagues (Hahn et al., 2010). When the sustainability benefits of a particular product cannot be justified through design experiments, or when stakeholders are not willing to adopt the innovation, firms appear to redefine their value proposition. This appears to be easier in cases where ventures develop products that can replace existing products, such as Vrachtfiets (i.e. offering cargo bikes that replace motor vehicles in a diversity of markets), and in cases where there is an urgent and similar need in a diversity of markets, such as Solar Dew (i.e. offering affordable water purification products in a diversity of markets). However, the case of Sustainable Dance Club shows that firms can also creatively redefine their value proposition in cases initial sustainability goals are not met. The firm was redefining its value proposition from ‘selling dance floors that can partly power clubs’ to ‘renting energy floors that can increase sustainability awareness among young people’. Finally, the case of Evening Breeze shows that firms can redefine their value proposition by prioritizing financial goals over social or environmental goals for a certain period of time, until the innovation is developed to its full potential, and the firm survival is no longer perceived to be crucial. In 2008, the focus of Evening Breeze shifts from hospitality market to the consumer market in the Netherlands, where the sustainability gains of the air-conditioning system were significantly lower compared to the resorts in tropics. Air-conditioning is needed only for a short period in summer in the Netherlands, whereas it is needed and used throughout the year in the tropics. As such, the environmental gains are significantly lower in the Netherlands, which might not actually justify the environmental costs of producing such a system. However, this shift is perceived to be necessary for the financial sustainability of the firm until the focus is given to the tropics again in 2012.

5. Discussion and conclusions

This study investigated how the product innovation processes unfolds in sustainability-oriented ventures in a case study on four new ventures. The focus has been given on the types of approaches to product innovation processes in sustainability-oriented ventures, and the implications of sustainability-orientation. For this reason, we have drawn on literatures on sustainable entrepreneurship, sustainable and conventional innovation management and entrepreneurial decision making, in order to extend the theory

Table 4
Characteristics of the two approaches.

Approach	Adaptive	Exaptive
Underlying logic	Causation	Effectuation
Value propositions	Focused pattern of lower number of long-term value propositions	Iterative pattern of higher number of short-term simultaneous value propositions
Role of means	Means are used to realize a particular value proposition	Means are used in search for various value propositions
Design experiments	High-fidelity experiments conducted for testing the feasibility, viability and sustainability of a predefined value proposition, leading to no change in the value proposition	Low-fidelity experiments conducted for generating alternative value propositions, leading to changes in the value proposition
Stakeholder interactions	Mainly with investors and potential clients within the target market to generate feedback on and acquire resources for the development of a predefined value proposition, leading to no change in the value proposition	Mainly with potential clients, partners and suppliers from various market segments in order to co-develop value propositions further, potentially leading to changes in the value proposition (depending on the commitments given to stakeholders)

on the product innovation processes in new ventures. In Section 2.2, we proposed a framework to describe and analyze the product innovation process in sustainability-oriented new ventures. This framework is visualised (Fig. 3) and suggests that the product innovation process in new ventures can be described by capturing the way new ventures define their value propositions over time, and the way they engage in design experiments and stakeholder interactions.

Our findings demonstrate that identifying a sustainable and viable value proposition at the outset of product innovation process is indeed a challenging task for new ventures (Berends et al., 2014). Although the ventures in our sample show variation in terms of the number of value propositions they engage over time, they all experiment with their value propositions, and the design experiments in the form of prototypes, demonstrations or early versions of products and stakeholder interactions with potential customers, partners or investors have a significant role in driving the value proposition of emerging ventures. These findings are consistent with previous work on sustainable and conventional innovation, which highlights the crucial role of stakeholder interactions (Saravathy, 2001; Goodman et al., 2017; Bocken et al., 2014b) and design experiments (Cooper and Kleinschmidt, 1986; Jolly, 1997; Tidd et al., 1997) in co-creating the value in terms of products, target markets and the sustainability issue addressed (Bocken et al., 2018; Baldassarre et al., 2017). Learning from experiments and co-creating with stakeholders help firms to progressively define their value offerings. The framework proposed, therefore, is useful for studying the historical dynamics of the product innovation processes driven by sustainability.

Furthermore, by drawing on recent theoretical perspectives in the field of entrepreneurial decision-making (Dew et al., 2011; Read et al., 2009; Saravathy, 2001), and applying them to the product innovation process, this article contributes to the literature on product innovation by contributing to an understanding on the dynamics of product innovation processes in sustainability-oriented ventures. The framework proposed provides opportunities to explain the behaviour of firms with respect to the patterns of value propositions and actions drive them, thereby shedding light on the differences among firms' product innovation process (i.e. adaptive versus exaptive approaches). In this regard, this study also adds to research that aims to translate effectual logic into effectual behaviour (Chandler et al., 2011; Fisher, 2012). The actions in effectual processes can be explained by a number of decision-making principles, such as creating something with existing means, limiting investments into affordable losses, and the influential role of stakeholders and emerging contingencies for the decision-making process (Saravathy, 2008). Ventures that adopt

an exaptive approach display these principles by engaging in short-term value propositions that are primarily driven by their existing means (such as sustainability ambitions or existing network), and conducting low-fidelity 'affordable' design experiments, which are used to test the market potential of multiple value propositions through various stakeholder interactions. Ventures that adopt an adaptive approach, on the other hand, engage in long-term value propositions, and conduct high fidelity design experiments, which are used to get the commitment of a select number of stakeholders to develop a predefined value proposition. Both approaches contribute to defining the value proposition of ventures over time; however, an exaptive approach is likely to yield in new goals at the level of strategic decisions (i.e. product offerings, target markets, and sustainability issue addressed).

Moreover, our study contributes to effectuation research by extending it into the context of product innovation in sustainability-oriented ventures. We expand the dynamic model of effectuation (Saravathy, 2008) with the act of designing, and consequently shed light on the nature of the design experiments. First, this study has observed that not only stakeholder interactions, but also design experiments have a significant role in the evolution of value proposition of ventures. The design experiments are likely to be the trigger for the development of new applications or shifts to other markets. Second, the nature of design experiments is different in effectual processes than in causal processes. When ventures use an adaptive approach (which represent a causal logic), they conduct design experiments to test the technical feasibility and market viability of a particular value proposition. In that respect, they engage high-fidelity design experiments, such as working prototypes or demonstrations (Jolly, 1997) and early versions of products tested in the market (Tidd et al., 1997; Lynn et al., 1996). When ventures adapt an exaptive approach (which represent an effectual logic), design experiments are used instrumentally to create alternative ideas, and consequently influence the self-selection process of stakeholders, which may result in actual commitments. Therefore, they engage in low-fidelity design experiments, such as mock-ups and models (Thomke, 2008) and prototype tests with potential customers (Cooper and Kleinschmidt, 1986). Design experiments in effectual processes are likely to result in higher level goals regarding the definition of products and markets and how sustainability issues are addressed. We add to the findings of Chandler et al. (2011) by offering a more detailed insight into how new ventures experiment with value propositions in identifying business opportunities. Third, our findings show that the way entrepreneurs define their value proposition in relation to sustainability influences the approach they adopt for product innovation process, and consequently, the

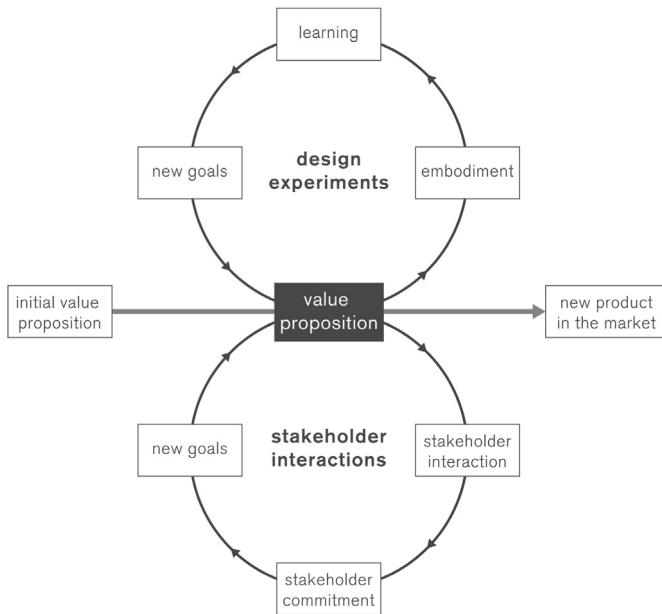


Fig. 3. A framework for product innovation processes in new ventures.

degree of the focus on and flexibility with a particular value proposition. While the ambition to change a specific market towards more sustainable practices causes firms to anchor on a specific market, the ambition to develop a product that can replace existing products in a diversity of markets appear to cause firms to anchor on a product idea. Consequently, anchoring on a specific market appears to stimulate an adaptive approach, and anchoring on a specific product idea appears to stimulate an exaptive approach. This suggests that besides the level of expertise of entrepreneurs and the level of uncertainty they are confronted with (Sarasvathy, 2001; Reymen et al., 2015), entrepreneurs' sustainability orientation and the way they define their value proposition in relation a sustainability issue has important implication for the logic they adopt for the innovation process.

Finally, this article contributes to the literature on sustainable entrepreneurship. A number of scholars suggest that the simultaneous pursuit of social and/or environmental goals in addition to financial goals is likely to increase the complexity of decision-making process (Hahn et al., 2010; Battilana and Dorado, 2010; Paech, 2007; Berchicci, 2005). Our findings show that the way entrepreneurs define their value proposition in relation to sustainability has implications for this complexity. In particular, value propositions based on the premises of a product as a sustainable alternative to existing products in the market appear to create less tensions for entrepreneurs, since it is easier to justify similar sustainability benefits in a variety of markets. However, value propositions based on the ambitions to transform unsustainable practices in a particular market appear to create more tensions for entrepreneurs, especially when the stakeholder interactions in this particular market reveal negative outcomes. This finding confirms the suggestion that a strong commitment to a particular value proposition might jeopardize the economic viability of a new venture (Berchicci, 2005). Nevertheless, the ventures in our sample show that in case of financial survival, they creatively redefine their value proposition or postpone their commitment to a particular value proposition until the firm's survival is not perceived critical.

The case study approach adapted in this study has enabled an in-depth analysis of the product innovation process, however, it entails several possible limitations and opportunities for future

research. First of all, this study has analyzed a small sample of case firms, which limits the generalizability of the findings. In order to further research sustainable product innovation processes and validate the findings, a larger sample of cases across settings (e.g. conventional versus sustainability-oriented ventures; corporate versus university spin-offs, sustainable product innovation in established firms versus new ventures; product versus service innovation in sustainability-oriented ventures) is recommended. Promising avenues of research concerns the combined effects of sustainability-orientation and other organizational factors on the type of approach adopted for product innovation. Second, although this study has benefited from following new ventures in real time for an average of three years, it mainly relied on retrospective data, which has implications for the accuracy and completeness of the data, particularly for the early phases of case firms. To deal with the retrospective bias, this study has used a variety of complementary documents as data sources, such as patents, websites, business model documents and email conversations and interviews with the founders. In order to increase the accuracy and validity of future studies, following new ventures in real time by making use of ethnographic research methods would be recommended. Finally, it is too early to evaluate the success or failure of the cases in terms of financial, social and environmental outcomes. At the end of the data collection process, the case firms prepared for subsequent design experiments and stakeholder interactions, thus the value propositions of the firms were still evolving. Furthermore, although some firms were successful in achieving their first sales, the firms' long-term success, as well as the social and environmental impact of their products, are yet to be determined since these firms did not yet enter the growth phase at the end of the data collection process. As a result, another limitation of this study is the limited analysis of the success and failure of the firms, as well as the social and environmental consequences of their products. A future ex-post study of the case firms may give insight into the consequences of different approaches in different conditions, resulting in the identification of 'best practices'. Another potential line of inquiry concerns the tensions arising from the difficulty of balancing financial, social and environmental goals. For example, which strategies entrepreneurs employ in dealing with these tensions? What are the implications of these strategies in terms of sustainability outcomes?

In conclusion, it is evident that more research in this area is necessary to be able to formulate and test hypotheses and potentially develop a further theoretical framework. Due to the present global and structural pressure regarding sustainability issues and ambitions (e.g. climate change, circularity, resources depletion), it is the general expectation that data on innovation attempts from the sustainable innovation and venturing will be available in abundance.

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