INNOVATION PROCESS AND NEEDS OF SUSTAINABILITY DRIVEN SMALL FIRMS

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Abstract

Traditional approaches to sustainable consumption and production emphasized addressing issues related to the natural environment and sustainability through optimizing *existing* products, processes and businesses. Even though the conventional wisdom suggests that young and new firms have greater advantages in innovation, there are few studies that address exploiting sustainable product ideas through new organizations. Therefore, this paper seeks to explore and characterize the innovation process of sustainability-driven small and young firms in the Netherlands, and reports on the results of an explorative study that involves the use of generative techniques during individual semi-structured interviews with entrepreneurs and intermediary organizations. The results suggest that the novelty and radicalness of an innovation and the development phase of a firm are important factors that influence how firms organize for innovation, manage their network and in-source knowledge necessary for the innovation.

Keywords

Sustainable product development, small firms, entrepreneurs, intermediaries, the Netherlands.

1. Introduction

Traditional approaches to sustainable consumption and production are to make products and production processes cleaner and more efficient (Charter et al., 2008). This view reflected in the design domain through approaches like Design for Environment, Ecodesign and Sustainable Product Development. These approaches have emphasized addressing issues related to the natural environment and sustainability through optimizing *existing* products and processes. Although they increased our understanding of sustainable product development, the majority of these studies have resulted in normative and prescriptive approaches (Berchicci, 2005). In addition, these approaches have focused on established

organizations and how to design and develop more sustainable products within this context. While conventional wisdom suggests that young and small firms have a greater advantage in innovation (Acs & Audretsch, 1990), there are few studies examining how entrepreneurs translate sustainable product ideas into commercially viable businesses and how the entrepreneurial context influences this process. Therefore this paper seeks to explore and characterize the product innovation process in an entrepreneurial context driven by sustainability ambition.

The data that builds up the empirical evidence for answering the research questions raised by this study, were collected within the EcoMind project. The EcoMind project, funded by the European Union's Interreg IVA "2Seas" programme, aims to better understand and address the specific support needs of SMEs who are seeking to develop innovative products and services and to support them to take full advantage of the growing market for more environmentally acceptable products. The aim of the project is to ensure that SMEs within the cross-border area have the greatest chance of capitalising on amongst other things the generation of renewable energy by bringing innovative products and services within the environmental technology sector to market more quickly. By assisting more SMEs to become increasingly innovative, the project aims to stimulate sustainable innovation, increase economic growth and increase the capitalization of knowledge. Through this the project contributes directly to the EU agenda for Innovation and Knowledge Economy and helps deliver against the Gothenburg Agenda.

2. Literature review

2.1 Sustainability and product design

Design plays an important role in sustainable product development. Since designers link products to users they thus play a key role in integrating sustainable goals in the life cycles of the products they design (Charter & Tischner, 2001).

Since the Brundtland report appeared in 1987 different approaches to realising sustainable consumption and production have come into practice. In the 1980's and 1990's the focus was to reduce the negative side effects of production processes, which is reflected in end-of-pipe approaches. From the 1990's onwards the focus shifted to cleaner production and preventing pollution and waste at their source to minimize the risks to humans and the environment. Environmental consideration have been reflected in the design domain through approaches such as Design for Environment, Ecodesign and Sustainable Product Development with a focus on optimizing existing products and services. Design for Sustainability (DfS) is another approach to sustainable product design, taking into account social and economic concerns next to environmental concerns (e.g as reviewed in Crul, et

al., 2009). In addition to the approaches mentioned, some scholars called for more *radical* approaches with higher environmental gains, such as Product Service Systems (PSS) and system innovation for sustainability. While PSS focus on functions rather than products, and seek to combine tangible products and intangible services to fulfil user needs, system innovation requires technology development, and implies changes to the social and structural environment. However, these approaches often fail to offer studies of what radical innovation entails for the organization (i.e. explaining to a project team how to deal with the higher degree of uncertainty intrinsically linked to project radicalness) (Berchicci, 2005).

2.2. Product Innovation

While scholars in DfS literature define radicalness of an innovation based on the environmental performance of the *outcome*, the scholars of innovation literature link the degree of radicalness of an innovation to the levels of risk and uncertainty and implications of these on the innovation *process*.

The degree of novelty or riskiness of an innovation can be reflected based on the newness of the market and product/technology combination. Davis (2002) differentiated 4 types of innovation: 1) new ventures (radical innovations, innovations in both technology and market, new to the world), 2) new categories (moderate innovations, innovations in the market), 3) new platforms (moderate innovations, innovations in technology), 4) derivative products (incremental innovation, same markets and technologies, new to the firms). Davis (2002) states that a well-structured product development process can make the risks and uncertainties associated with increasingly radical innovation more measurable and controllable, since such robust innovation process create the premises for reflection.

The degree of novelty of an innovation has implications for the innovation process. There are two different perspectives of how the innovation process may unfold: rational and non-rational. The rational view of the innovation is typically observed in the field of New Product Development (NPD). The process is described at the firm level, consisting of a set of activities that are linked to one another through feedback loops (Berchicci, 2005). It is goal-oriented, linear and visualised in consequent steps. For instance, Roozenburg & Eekels (1995) identify four steps of convergence and divergence in a basic innovation cycle. These four main steps are policy formulation, idea finding, strict development and realization. Despite this logical linear representation, in practice the innovation process is more chaotic and unstructured (Buijs, 2003) and may require an experimental logic in contrast to the analytic logic of NPD models (Hellman, 2007). This non-rational view of the innovation process is illustrated as a learning process with intermediate outcomes (Lynn et al., 1996;

Schon, 1967) in contrast to a single product as in NPD models. Considering the technological and market uncertainties involved within radical innovations, the innovation process is characterized as a highly uncertain journey of exploration and learning and modeled as a dynamic process of parallel activities in technology development, early applications and continues learning (Hellman, 2007).

Even though there are different perspectives of innovation processes and each innovation process is unique, Van de Ven et al. (1999) in a study on 14 different innovations, found similar process patterns and common elements in the majority of cases. These include an initiation period, development period and implementation/termination period. *The initiation period* represents a gestation period lasting several years in which seemingly coincidental events occurred and set the stage for the initiation of innovation. It involves development of plans submitted to resource controllers to obtain the necessary resources needed to launch the innovation development (Van de Ven et al., 1999). This period is often called "Fuzzy Front End" in NPD literature. *The development period* typically involves proliferation of numerous ideas and activities that proceed in divergent and convergent path of development (Van de Ven et al., 1999). *The implementation/termination period* occurs when inputs have been converted into outputs or when the uncertainties have been translated into risks (Schon, 1967). It begins when activities are undertaken to apply and adopt an innovation regardless of who is developing, implementing or adopting the innovation. Innovations stop when they are implemented and institutionalized or when the resources run out (Van de Ven et al., 1999).

2.3 Entrepreneurship

The concern for the socio-ecological system and human wellbeing has given rise to the concept of sustainability as a broad social goal and entrepreneurship is increasingly seen to contribute to this goal (Parrish, 2009). Sustainability driven entrepreneurs can contribute to this goal since they are individuals who see environmental issues as opportunities in the market that need to be exploited (Berchicci, 2005).

According to Venkataram (1997) studies of entrepreneurship in general "seek to understand how opportunities are discovered, created, and exploited, by whom, and with what consequences." The entrepreneur is the individual who is responsible for this process of creating new value (Venkataraman, 1997; Bruyat & Julien, 2000). By this definition, an entrepreneur is not necessarily an individual who takes risks 'hunting' for opportunities to earn money and respect. Even though such an individual is often considered to be the prototypical entrepreneur, this type of entrepreneur only constitutes a very small percentage of all entrepreneurs in the Netherlands (Oosterbaan et al., 2010).

Entrepreneurs, in general, are founders of small businesses (Heunks, 1998) and face challenges in translating their ideas into successful products and services in the market due to their inability to internalize all elements of the innovation process (Maillat, 1990). SMEs and particularly small firms operate with fewer people, funds and time, are flexible, focus on the short term and have a lower degree of formalisation (see e.g Madrid-Guijarro, Garcia, & Auken, 2009; Kaufmann & Todtling, 2002; Scozzi, Garavelli, & Crowston, 2005; Freel, 2000; Kassicieh, Kirchhoff, Walsh, & Mcwhorter, 2002; Mosey, 2002; Hausman, 2005; Bos-Brouwers, 2009; Berchicci, 2005). Historically, small companies and new ventures have been good at looking for and identifying entrepreneurial opportunities but less effective in development stages and in sustaining the competitive advantages when exploiting those opportunities over time (Ireland et al., 2003). As a drawback, small firms are also subject to a lack of market recognition, a weak financial position and a lack of internal structure (Berchicci, 2005).

Related to sustainable innovation however, Bos-Brouwers (2009) states that characteristics of small firms do not always support sustainable innovation objectives. One of the reasons of this is the limited resources of firms in terms of capital, knowledge and skilled labour, which also limit the sustainable innovation capacity of firms. Secondly, the short-term focus of small firms conflicts with the long-term orientation needed to achieve sustainability goals. Moreover, Bos-Brouwers argues that innovations in smaller firms are generally incremental, whilst sustainable innovations are usually more radical.

Besides the advantages and disadvantages of an entrepreneurial context, the processes associated with entrepreneurship should be considered since such processes are studied within this research. A process view of entrepreneurship can be defined as “intentional act of new value creation in which opportunities are created and realised through various modes of organising” (Parrish, 2007, see Figure 1). In this definition, entrepreneurial intention (i.e. entrepreneurs’ value and motivation) is presented as an important dimension that guides their entrepreneurial actions.

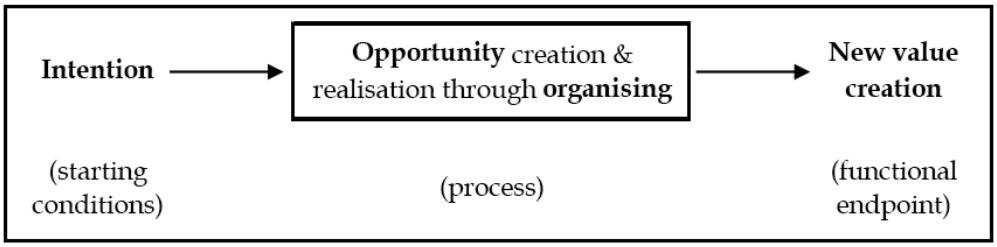

Figure 1: A process view of entrepreneurship (Parrish, 2007)

This process of new organization formation is characterised by three development stages: an Embryonic Stage, a Start-up Stage, and Growth Stage (see e.g Churchill, 2000; Benebo, 2008). The embryonic stage is the initial stage of the development of a venture, and is characterized by the development and validation of the product technology. In the start-up stage the capability of having and selling a product, and creating the business and its operations are most important. The Growth Stage generally focuses on marketing of the company and products for market entry into other target market-segments (Benebo, 2008).

3. Method and cases

3.1 Research design

Nineteen interviews were conducted within this research in order to understand the innovation processes and needs of sustainability driven small firms. Because relatively little research has been conducted regarding the innovation process and needs of sustainability driven firms, a qualitative approach has been chosen to identify themes and patterns which are relevant. Two studies were conducted to do so. In study 1, eight entrepreneurs were interviewed to get insights in their innovation processes and needs. In study 2, seven innovation intermediaries were interviewed to get insights on innovation processes and needs of sustainability driven entrepreneurs. The interviews lasted between one and two hours. In some cases follow-up interviews were held to further clarify issues.

The goal of the interviews was to explore and explain how sustainability oriented small firms organise for product innovation. In order to provide a description, rich information is required (Eisenhardt, 1989). This is collected combining generative technique with interviews.

3.2 Generative techniques

Central to this paper is to explore the innovation processes of sustainability driven small firms. The primary sources of data were main actors in small firms, commonly the owner entrepreneur. Traditional qualitative methods that could be used to research insights and experiences include focus groups, observation, interviews, field visits and ethnography. Methods that recently emerged from the design discipline to explore experiences and insights of stakeholders (and users of products in particular) are cultural probes and generative techniques (Sanders & Stappers, 2008). Such methods support elicitation of what people know, feel and dream (latent and tacit knowledge) by supporting people to become aware of their own experiences by using creative methods. Generative techniques are compared to other research approaches in Figure 2. Different research techniques give access to different levels of knowledge. Talking to people in interviews provides insights in knowledge that is explicit to these people. What people do can be observed. What people

know, feel and dream (latent and tacit knowledge) can be elicited in generative sessions (Sleeswijk Visser et al., 2005)

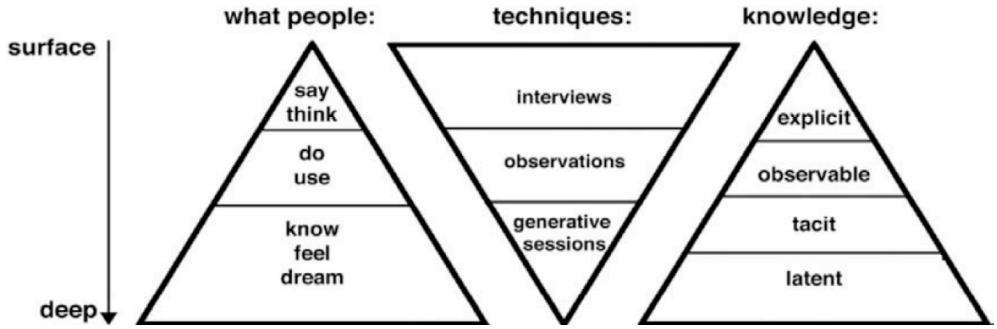

Figure 2: Different research techniques access different levels of knowledge (Sleeswijk Visser et al., 2005)

Sleeswijk Visser (2009) states that awareness and reflection of experiences are necessary for people to be able to articulate experiences and their context. Sanders (2001) argues that an experience takes place in a moment but is built on past experiences and generates future dreams. To make research participants aware of experiences generative techniques where participants say and make things stimulate them to employ their own creativity to become aware of and learn from their experiences (Gaver et al 1999; Mattelamaki 2006).

3.3 Research procedure

In this project generative techniques were used during individual semi-structured interviews with entrepreneurs. In study 1 eliciting exercises (from now on called interview tools), images (printed on stickers) and interview questions were used. The interview tools consisted of a visual framework to reflect the innovation process (Figure 3) and stakeholders involved (Figure 4).

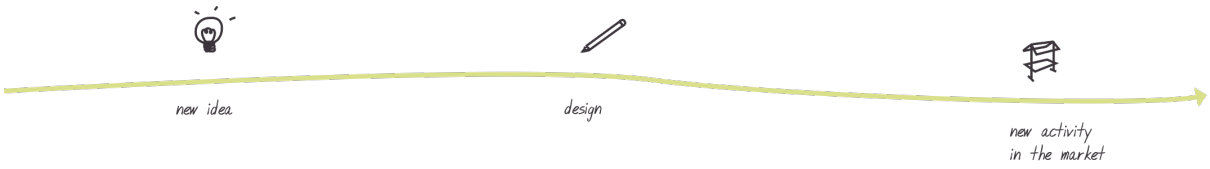

Figure 3: Interview tool to visualise the innovation process.

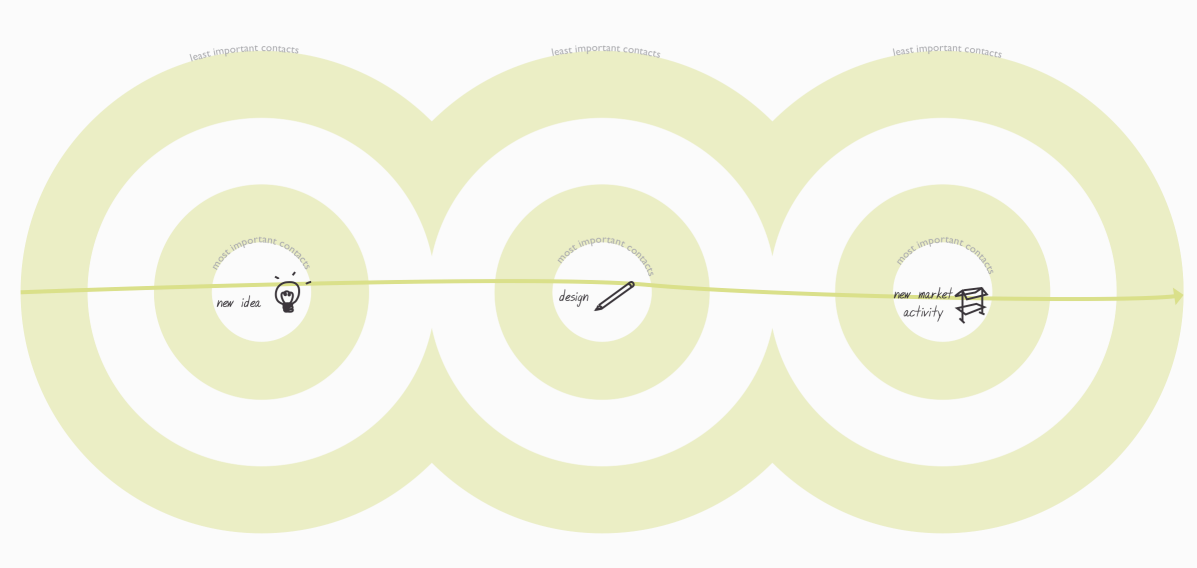

Figure 4: Interview tool to visualise the stakeholders necessary for innovation.

Based on the theoretical representation of the innovation process by Roozenburg and Eekels (1995) three stages of the strict product development process were incorporated in the visual framework: an *idea stage*, *design stage* and *market introduction stage*. Before and after these stages room was left open to incorporate *strategic orientation* before development and *evaluation* after introduction, if this was considered relevant by the entrepreneur. The exercise draws on both the past and the future of firms since the setup and ambitions are discussed, thus supporting elicitation of experiences (Sanders, 2001). Two researchers conducted the majority of these interviews

Simultaneously study 2 was carried out. In this study support intermediaries were interviewed about the innovation support offered to firms, and in particular small sustainability driven firms. Intermediaries were asked about innovation needs and network use of these firms, as well as the methods and tools used to support them. One researcher conducted the majority of these interviews.

The questions in both study 1 and 2 were adjusted somewhat across interviews in order to probe emerging themes and to take advantage of the interviewee's specific knowledge in different cases (Eisenhardt, 1989). All interviews in both studies were recorded and transcribed. The initial research questions and field notes supported devising an open coding scheme in which phenomena were named and categorised (Gray, 2004). The analysis tactic was used to select categories in the open coding scheme and look for similarities and differences across the cases (Eisenhardt, 1989).

3.4 Sample

Eight Dutch firms participating within the EcoMind project were interviewed in study 1. These consisted of spinoff companies of Delft University of Technology (DUT) as well as companies that are established differently, firms in different phases of the innovation process and firms covering different sectors: transport, housing, energy, entertainment (see table Table 1a on the next page: Case descriptions, firms).

To get insights in the experiences of those supporting the innovation processes of SMEs, innovation support intermediaries were interviewed as well (Table 1b). The intermediaries that were interviewed were involved in the Ecomind program or public and commercial organizations not involved in Ecomind. These intermediaries supported SMEs, and in some cases focussed on supporting sustainability driven SMEs.

Table 1b: Case descriptions, innovation support intermediaries

Support intermediary	**Country**	**type of intermediary**	**supporting SMEs/small firms**	**supporting sustainability driven firms**	**Informant**
Ecomind support 1	Netherlands	commercial foundation	SMEs/ small firms	sustainability driven	project manager
Ecomind support 2	UK	university	SMEs/ small firms	sustainability driven	project manager
Ecomind support 3	UK	public	SMEs/ small firms	also a sustainability orientation	project manager
Ecomind support 4	UK	public	SMEs/ small firms	also a sustainability orientation	project manager
Public support	Netherlands	public	SMEs	starting sustainable orientation	regional innovation manager
Incubator	Netherlands	incubator	Small firms/ start ups	sustainability driven	incubation manager
Commercial support	Netherlands	commercial	SMEs	starting sustainable orientation	intern, workshop visit

Table 1a:Case descriptions

Firm	***"Bike"***	***"Solar"***	***"Fun Power"***	***"Truck"***	***"Plug"***	***"Boat"***	***"Party"***	***"Lantern"***
Industry	transport	energy, lighting	energy, entertainment	transport	energy		energy, entertainment	energy, lighting
Product	Create cargo bicycle	Lighting in BoP communities	Create means for interactive domestic, energy	Make trucks more aerodynamic	Reduce energy consumption of appliances	A boat for living and working	Creat products for sustainble partying	Hhistoric LED street lighting
Start up year	2009	2009	2009	2008	2002	2004	2006	1924
DUT spinoff	yes	yes	yes	yes	no	no	no	no
Develop-ment phase	Embryonic phase product testing	Embryonic phase product development	Embryonic phase product development, market testing	Embryonic phase , market testing, preparing commercial launch	Start up firm, market phase	Start up firm, market phase, design iterations	Start up firm, market phase, product improvements realised	Established firm, new product in development
Sustainable goals	reduce emssions, make transport available to all	reduce emissions, improve living conditions, create employment	reduce energy consmption, create awareness in a fun way	reduce fuel consumption, economic gains	reduce energy consumption of household appliances	reduce consumption of resources (energy, water) in an alternate space for living	reduce energy consumption in clubs, create awareness amongst young people	reduce energy consumption of historic street lanterns
Informant	founder	founder	founder	founder	founder	founder	CEO	manager

4 Cross case analysis

For the cross case analysis, conditions for innovation at the start of the process, conditions along the process itself and the value created at the end of the process are considered (Parrish, 2007), see Figure 5. Initial conditions that were identified to be relevant are opportunity identification and sustainable ambition. *External factors* found to be most relevant for the innovation process are external validation of the opportunity, network and market orientation. The most relevant *internal factors* were found to be the type of innovation, human resources and innovation management. The type of opportunity and its external validation are most influential in the idea phase of the innovation process. Human resources, networking and managing the innovation process are relevant for all phases of the innovation process but particularly affect the beginning of the design phase. In the commercialisation phase the market and user orientation of the firms manifests the process.

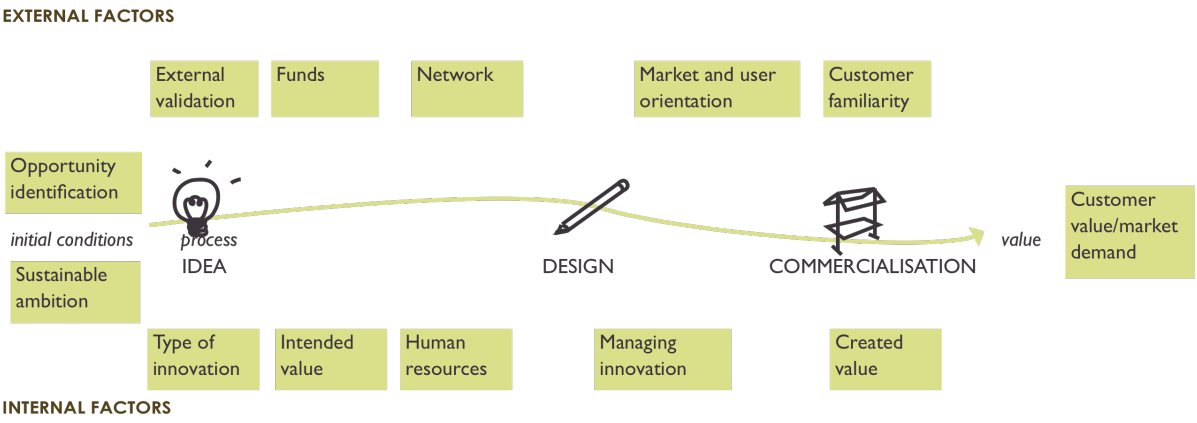

Figure 5: Internal and external factors that influence the initial conditions, innovation process and value created in new product development

4. 1 Initial conditions

Initial conditions that were identified to be relevant are opportunity identification and sustainable ambition. The findings per case are shown in Table 2.

4.1.1 Opportunity identification

Considering how opportunities are identified three different categories could be distinguished within the firms studied. The most dominant source for product ideas was the *entrepreneurs' own frame of reference*. Ideas originated from the owner's own frame of reference reflect the dominant character of firm owners in the innovation process (Madrid -Guijarro et al. 2009;

Table 2 : Initial conditions

	Firm	"Bike"	"Solar"	"Fun Power"	"Truck"	"Plug"	"Boat"	"Party"	"Lantern"
	Opportunity identification	user and sustainability problem, based on own frame of reference	user and sustainability problem, based on own frame of reference	user and sustainability problem, based on market and user reserach	economic goals, technology orientation, based on reserach	sustainability problem, based on own frame of reference	personal product use,	sustainability problem, own frame of reference, also researched	sustainability problmen, customer demand, somewhat reserached
Sustainability...	**... driver to start project?**	yes	yes	yes	no	yes	no	yes	yes
	... aspects (issues) adressed	social and environmental issues	social and environmental issues	environmental issues and creatign awareness	environemtnal issues	environemtnal issues	environemtnal issues	environmental issues and creatign awareness	environemtnal issues
	... in idea?	yes	yes	yes	yes	yes	no	yes	yes
	... in design?	yes	no	no	yes	no	yes	yes	yes
	... in sales?	intended	intended	yes	yes	yes	no	yes	yes
	difference intended and created value	higher sustainable value than intended	higher sustainable value than intended	sustainable value as intended	higher sustainable value than intended	lower sustainable value than intended	lower sustainable value than intended	lower sustainable value than intended	sustainable value as intended
	Sustainable ambition	high	high	medium	medium	low	very low	medium	medium

Scozzi et al., 2005; Hausman, 2005; Bos-Brouwers 2009). In such cases, the firm might become more dependent on the person for survival (Bos-Brouwers, 2009).

Another category of firms had started off on the *premises of research*. An example is "Truck" where the founders graduated researching the technology and potential of their ideas. In this case the founders of the firm used research as a means to build a network of relevant knowledge and develop contacts with clients. The research and resulting network compensated the lack of knowledge within the firm (Madrid -Guijarro et al. 2009; Scozzi et al., 2005; Hausman, 2005; Bos- Brouwers, 2009). In some firms an idea that is closely connected to the personal goals or interest of the founder is further researched within the idea phase.

4.1.2 Sustainable ambitions

The sustainable ambition construct is concerned with whether sustainability was a driver for innovation, how many aspects of sustainability were considered, whether this was integrated in all phases of the innovation process (idea, design, commericalisation), and whether the intended goals regarding sustainability were realised (see Table 2).

Bansal and Roth (2000) have identified legislation, social pressure and economic considerations to be the main drivers for sustainability in large companies. Van Hemel (1998) point to the lack of studies about sustainable drivers in smaller firms. Based on a literature study she claims that internal stimuli are important for small firms, next to economic drivers that help small firms cut the costs of innovation. In the sample of this study, internal drivers were indeed most relevant for small firms when considering sustainability. The most important internal drivers were environmental awareness, the prospect of green marketing, the opportunity to create new value and innovation. Ecomind intermediaries in the UK who were interviewed support that firms with a high sustainable ambition are driven by internal motivation to prove that their sustainable products will be successful.

All firms studied considered environmental aspects of sustainability through energy saving. Linked to energy saving is cost saving. To two firms ("Truck" and "Boat") in the sample found that the economic aspect was more important than the environmental aspect of sustainability. This orientation towards environmental aspects of sustainability and cost saving is in line with historic developments in the DfS research domain (Charter & Clark, 2007; Dewick & Pietikainen, 2008; Cohen, Smith, & Mitchell, 2008; Brink, Destandau, & Hamlett, 2009). However, breaking with historic trends, besides environmental orientation, about half the firms either explicitly strived to create awareness about sustainability ("Fun Power" and "Party") or strived for equity with their products ("Bike" and "Solar"). In these

firms innovation covered all three pillars of sustainability. Three of these firms (”Fun Power”, “Bike” and “Solar”) were developing product service systems (PSS), which are a more radical approach to sustainable innovation (Tukker & Tischner, 2006). These firms (”Fun Power”, “Bike” and “Solar”) were all DUT spinoffs, which could signify that knowledge of PSS is an effect of the education the founders of these firms have experienced. The level of education furthermore was considered to have a positive effect on sustainable orientation by an Ecomind intermediary in the UK.

Half of the firms studied were taking sustainability beyond the idea phase of their product by also taking into account materials used in the product and whole life cycle of products. Integrating sustainability in all phases of the innovation process seems to be difficult for many firms. This might be linked to the disadvantages of small firms, such as lack of resources in terms of time, knowledge and skills (see e.g. Van Hemel, 1998) and a focus on daily activities that found to impede innovation in small firms (Kaufmann & Todtling, 2002) and especially in start-ups (Freimann, Marxen, & Schick, 2005).

4.2 The innovation process

The previous section focused on the initial conditions for innovation and how this might influence the innovation process. This section will consider the external and internal factors that influence different phases of the innovation process.

4.3 Idea phase

The type of opportunity as an internal factor and its external validation as an external factor were considered to be relevant in the idea phase of the innovation process (Table 3).

4.3.1 Type of innovation

The innovation process is influenced by the novelty of an innovation. From the perspective of novelty in terms of market and product/technology (Ansoff, 1957; Davis, 2002), roughly half the firms in the sample are working with an existing technology in a new market. A majority of firms in the sample worked on moderate to radical innovations. These findings are supported by the notion that sustainable innovations (vs. green washing) tend to be radical rather than incremental (Bos-Brouwers, 2009; Tukker & Tischner, 2006; Berchicci, 2005; Brezet & Rocha 2001). Although Bos-Brouwers (2009) argues that small firms innovate more incrementally she identifies factors that play a role in motivating and supporting entrepreneurs in overcoming this, such as sustainable orientation management of the innovation process and networking capabilities of small business owners. The team and the capabilities acquired through networking, as well as the ability to manage (iterations) in the

Table 3: Idea Phase

Firm	*"Bike"*	*"Solar"*	*"Fun Power"*	*"Truck"*	*"Plug"*	*"Boat"*	*"Party"*	*"Lantern"*
Novelty of the innovation	existing technology, new market	existing technology, new market	new technology, new market	new technology, new market	existing technology, existing market	existing technology, new market	new technology, new market	new technology, new market
Partipation in competions?	Yes	Yes	Yes	Yes	No	Yes	No	No
Funding	competition prize money, sponsorhip	competition proze money	competition prize money, paid public presentations	competition prize money, subsidy, bank loan	investors	bank/investor?	sponsorhip, subsidies bank loan	firm capita, investor

innovation process will be considered in more detail in following sections. In the sample it did appear that firms innovating more radically had developed the means to better control these factors.

4.3.2 External Validation

Competitions were particularly important for embryonic firms in the sample. Without exception business plan and new venture like competitions have created a platform for ideas to be presented and tested by a (professional) audience for feedback. All embryonic firm owners said that competing in competitions and 'tasting' the enthusiasm and potential was the motivation to really start a business. A network of advisers and potential clients are built through these competitions. Furthermore participating in competitions gives embryonic firms and products more credibility, for example in negotiating a bank loan or applying for subsidies. The support intermediary at the incubator consulted in this research recognises the value of competitions in particular for building credibility. Competitions are however not found to be a topic of interest in the literature on SMEs or entrepreneurship. A limited number of studies argue that business plan contests within universities are a mechanism to transfer high tech knowledge of students into an entrepreneurial setting (e.g Derfoo et al., 2005; Nelsen, 1998; Dodt et al., 1999). In the Netherlands there are however also contests which provide established firms an opportunity to 'test' their ideas, get feedback from a jury, build credibility and win prize money (for example ' Het Ei can Columbus').

Besides credibility acquired through competitions, acquiring funding from external sources can also be a form of external validation. Competitions were the most important source of seed money for embryonic firms. As these firms developed they started generating income through public presentations and eventually subsidies and bank loans. Start up firms said to rely on investors or bank loans. A requirement for investors in the sample was proven external interest for the product, for example through statements of intent. It is recognised in the literature that especially small firms are confronted by the high costs of innovation, a difficulty to control costs and insufficient financial (government) support (Madrid-Guijarro et al., 2009; Kaufman & Todtling, 2002). This exhibits a weakness of smaller firms that do not have a product portfolio to generate a funding for development (Kaufman & Todtling, 2002).

4.4 Design phase

Human resources and innovation management skills as internal factors, and networking as an external factor are relevant for all phases of the innovation process but especially affect the beginning of the design phase (Table 4).

Table 4: Design phase

Firm	***"Bike"***	***"Solar"***	***"Fun Power"***	***"Truck"***	***"Plug"***	***"Boat"***	***"Party"***	***"Lantern"***
Human resources at start of development	2 designers	1 idea generator	1 engineer, 1 entrepreneur	2 engineers	1 engineer, 1 entrepreneur/ 2 idea generators	1 idea generator	1 entreprenuer, graduate students	mainly craftsmen, small sales force
Human resource expansion during development	none	none	none	1 entrepreneur, 1 engineer, 1	none	none	1 business developer 1 engineer, 1 finance, 1 sales,	expand to 20 people: managereer, sales, marketing .
Network needs	new network, business development, strategy, production	new network, business development, strategy, product development production	new network, build industry platform, software developers, designers, producers	new network, build industry platform, designers, producers	existing, old network of known designer, producer and distributor	existing network and some new contacts, new designers, producer	new and existing network, new engineers, designers, producers	new and existing network, new engineers

4.4.1 Human resource development and innovation management skills

Although human resources are relevant when starting up the firm, the need for capacity and expertise for innovation becomes more apparent during the development phase. Considering the expertise available in the team a distinction can be made between mono-disciplinary teams and multi-disciplinary teams. Mono-disciplinary teams are considered to consist either of one person or of partners that have worked together in the same industry for a long time ("Solar" and "Bike" amongst embryonic firms and "Boat" and "Plug" with the start up firms). In the mono-disciplinary firms various relations need to be managed by one or two firm owners. In the embryonic firms this leads to an overload of work. Managing various relations seems to be an issue for established firms with mono-disciplinary teams as well.

In the embryonic firms more balanced, multi-disciplinary teams consist of an engineer or designer and an entrepreneur since early stages of the company. In established firms balanced multi-disciplinary teams have generally grown with the firm (e.g. "Party" and "Lantern). In more balanced teams it appears that fewer tasks need to be outsourced, and the need to expand the team with different expertise is better identified. These teams seem to become relevant in the design phase of new product development since diverse tasks need to be fulfilled. Multi-disciplinary teams generally are favourable for innovation, since innovation processes are often more complex than one person can successfully handle (Van De Ven et al., 2008). The support intermediary "Incubator" encouraged embryonic firms to find a business partner with complementary skills. Moreover, "Incubator" stated that teams with three to four members were observed to innovate faster than smaller teams.

4.4.2 Network needs

New network building also becomes relevant early in the innovation process, and remains important throughout the process. DUT spinoffs in the sample were all founded by young graduates without connections in business and industry. Primarily contacts to support business development, strategic orientation, detail development and production were sought by these firms. Firms also sought contacts with business and strategy advisers to become informed about possibilities. Detail developers and producers were generally needed for outsourcing part of the product development. This is typical for many (student) embryonic firms according several intermediary organisations (e.g. by the Ecomind partner in the Netherlands, public intermediary and incubator consulted). Building a network is however a necessity for small firms because they need partnerships with others to complement their own skills (Roure, 2000; Stockley, 2000).

The start-up firms in general have networks they can use. The firms working on more novel innovations (e.g. “Party”, “Lantern”) however need to expand these networks and actively look for new knowledge and inspiration. New contacts are needed especially to develop new technology. Technology development is consequently either outsourced or done in cooperation with new contacts. Firm owners that do not actively look for new skills and knowledge amongst external contacts can have a negative effect on their firm, because they remain unaware of environmental changes and do not develop new or complementary insights to innovate (Madrid-Guijarro et al., 2009).

4.5 Commercialisation phase

In the commercialisation phase an important factor that was recognised in the sample was the degree to which markets and users are consulted (Table 5).

4.5.1 Market and user orientation

Embryonic firms have maintained relations with potential clients/users throughout their innovation process. This gives them both a channel for first sales as described above, and insights in market requirements. This can be described as a more pro-active approach in which market insights are gained and used right from the idea phase (and possibly before). This seems to be different in start up firms where relations with the market and users are more limited and concentrated around the commercialisation of a product. In this case firms operate in a more reactive way, guided by learnings from the market once the product is being sold (or fails to sell).

Close relations with customers were mentioned as strength of small firms (Madrid Guijarro et al., 2009, Scozzi et al., 2005; Hausman, 2005), but this study shows that customer relations can be managed in a pro-active or a reactive way. Since the firms responding to the market reactively change the course of their product development due to lack of sales (to the desired target group), it could be argued that reactive market approach is inferior to a pro-active market approach also in small firms. What makes this just an assumption however is that most start-up firms (with a pro-active market approach) are involved in the market by testing prototypes at most, and can not be considered to be fully commercial yet.

4.6 Value created

Previous sections gave an analysis of the factors influencing the initiation period and the innovation process. To conclude, the study examines the value created as the outcome of the innovation process.

Table 5: Commercialisation and value created

Firm	***"Bike"***	***"Solar"***	***"Fun Power"***	***"Truck"***	***"Plug"***	***"Boat"***	***"Party"***	***"Lantern"***
Market and user orientation	close cooperation with potential users	close cooperation with potential users	close cooperation with potential users and clients	close cooperation with potential users and clients	no	no	limited	limited
Complexity and value created	Easy to understand product, complicated service system to replaces less sustainable forms of commuter and passenger transport	Easy to understand, but slightly complicated service system. Social and financial model more imnportant than produc	Easy to understand but more intangible service system: no insight in consumption of appliances yet	First product tests seem succesfull. Easy to understand, saving energy, reducing costs, increased safety	Product sales are below expectation. Simple product but difficult to understand value of limited energy saving	Product sales are slow. Easy to understand product but difficult to understand value of living on water	Easy to understand, but too expensive to sell in intended market, rented instead.	Technical problems in design are beig solved. Easy to understand, but expensive
difference sustainable intended and created value	higher sustainable value than intended	higher sustainable value than intended	sustainable value as intended	higher sustainable value than intended	lower sustainable value than intended	lower sustainable value than intended	lower sustainable value than intended	sustainable value as intended

4.6.1 Product complexity and value created

The interaction with the customers and users reflects in the ease with which products can be understood and can deliver value. The products of DUT embryonic firms in the sample are all easy to understand, but insights in market and user requirements might have led to more complicated service systems. Whether this complexity impedes the development of successful products cannot be said because the products are not in the market yet.

Amongst the start-up firms with less of an orientation towards customers, there is a bit of a difference. “Plug” and “Boat” do not necessarily have complex products but the value to users is difficult to understand. “Lantern” and “Party” products are both simple to understand, but difficult to sell since they are expensive. This lack of product to user/customer match could be attributed to a lack of market-oriented management. For example, the owner of “Boat” says: *”People will buy our product as a yacht, office space and second home, but not as their primary living space which I anticipated. I lived like that and loved it, but people do not necessarily want it. Designing for myself is a problem and maybe the reason why we haven’t sold so much yet.”*

A market oriented management approach is however based on the premises that understanding (also before developing products) and satisfying customer needs to create customer benefits is the most effective means to create and sustain a competitive advantage in the market (Walker et al., 2006; Srivastava et al., 1999; Webster, 1994). Such a market orientation allows for adapting to market changes (Lehmann & Winer, 2005), which is considered to be an advantage small firms can have over larger firms (Madrid Guijarro et al., 2009, Scozzi et al., 2005; Hausman, 2005). Contrasting this market orientation is a production orientation. Especially “Plug” can be described as a production-oriented firm that sells what it can make, focusing on functionality, performance and cost. The product line is narrow and any research is technology focussed (Walker et al., 2006; Lehmann & Winer, 2005)

To conclude this section, the intended value in terms of sustainability is considered. The sustainable intended value was found to be lower for three of the firms in the sample, since the products offered only add to the number of products (and their impact) consumed by the users. In cases where sustainable value turned out to be higher, products designed replace products with a higher environmental impact or contribute to reducing this impact significantly.

5.1 Firm categorisation

Looking at the cross case analysis of the innovation opportunities, process and value created, characteristics which distinguish firms from each other emerge as well as

characteristics that seem to be common for firms. A framework is proposed in Figure 6 to characterize the firms in the sample. Key factors that seem to distinguish the firms are the type of innovation they are working on (moderate innovation or radical innovation), and the stage of innovation at which they are (embryonic or start up). In this section these characteristics are explained. Within the combinations of these characteristics four types of firms were distinguished in the sample. Firstly, 'Idea developers' are firms that are in the embryo stage of development, and working on moderate innovations (Bike and Solar, in the sample). Secondly, 'Integrated embryonic firms' are also in the embryo stage of development and working on more radical innovations (Fun Power and Truck in the sample). Third, 'Opportunistic entrepreneurs' are in the start up phase of development and work on moderate innovation (Plug and Boat in the sample). Lastly 'Integrated start up firms' are also in the start up phase, but work on more radical innovation (Party and Lantern in the sample).

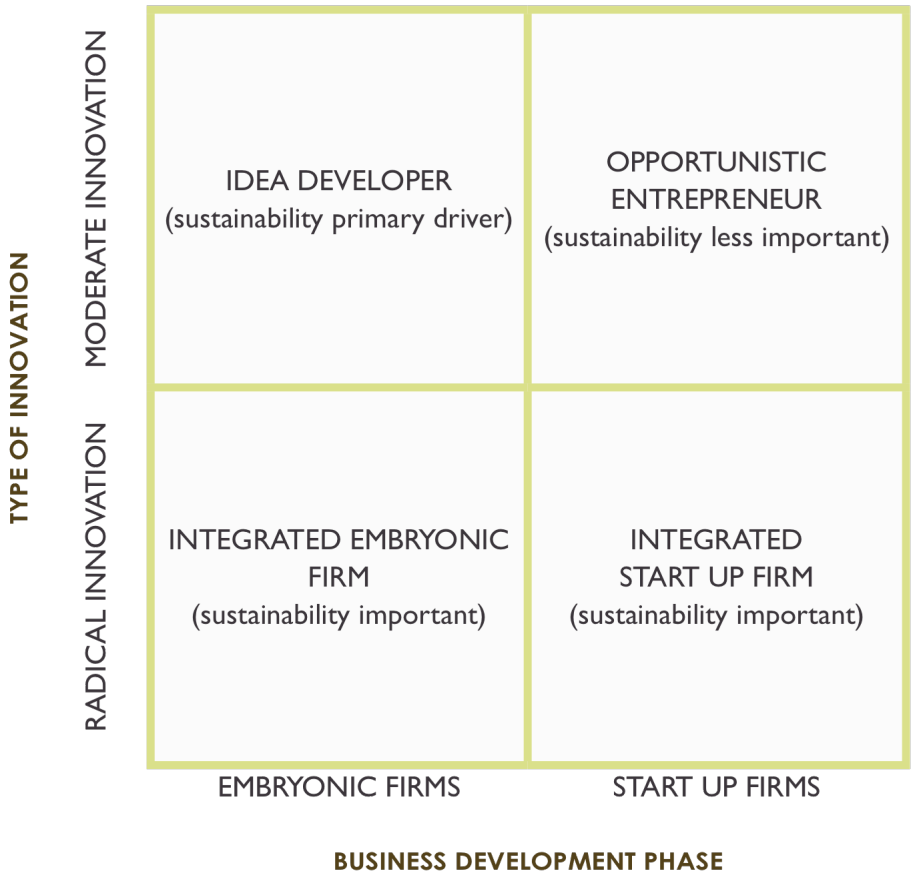

Figure 6: Framework to differentiate firms based on the type of innovation and business development phase.

5.1.1 Differences due to the type of innovation

The type of innovation firms are working on seems to be an important factor for product and business development. The novelty of an idea is categorised depending on the newness of the market and product/technology combination (Ansoff, 1957; Davis, 2002). Davis). Novel market and technology combinations in moderate and radical innovation however also seemed to be associated with other firm characteristics in the sample.

Characteristics that are found to be common within firms working on moderate innovation are:

- Opportunities identified based on the entrepreneur's own frame of reference. This makes the firm owner a dominant character in the innovation process, which is typical for small firms (Madrid-Guijarro et al. 2009; Scozzi et al., 2005; Hausman, 2005; Bos-Brouwers 2009).
- Mono-disciplinary teams consisting of one person, or two people who have been working together for a very long time (converging their knowledge, orientation and frame of reference). Such mono-disciplinary teams are less favourable for innovation, since innovation processes are often more complex than one person can successfully handle (Van De Ven et al., 2008). Because the innovations are moderate, there may however be a lower direct need for a bigger and more diverse team.
- Troubles in managing their many external relations. These entrepreneurs prefer either to be involved as little as possible with detail development or they simply cannot keep up with these external developments. This high workload and a focus on daily activities, which impedes innovation, is typical for small firms (Kaufmann & Todtling, 2002).

The moderate innovation of these firms decreases the potential of these firms to contribute to social and environmental sustainability (Bos-Brouwers, 2009; Tukker & Tischner, 2006; Berchicci, 2005; Brezet & Rocha 2001). However, because the environmental ambitions of the firms are different, it is difficult to determine the degree to which theses firms can contribute to sustainable development.

Characteristics that are found to be common within firms working on moderate innovation are:

- Some sort of preliminary market and/or technology research, which is favourable to increase the limited knowledge within a firm (Madrid -Guijarro et al. 2009; Scozzi et al., 2005; Hausman, 2005; Bos-Brouwers 2009). An expert who knows the market provides great value to a firm, according to the incubator consulted for this paper. Market orientation furthermore increases the degree to which customer needs can be recognised and met (Walker et al., 2006; Srivastava et al., 1999; Webster, 1994).
- Small teams, which have at least two disciplines represented within the team. Engineers or designers cooperate with people with entrepreneurial skills. These balanced teams are favourable for innovation, since a diverse group of people contribute to innovations with different skills, knowledge, enthusiasm and frames of reference (Van De Ven et al., 2008).
- Building new networks for their innovation. These firms are better in identifying the needs for a network (Roure, 2000; Stockley, 2000), especially in terms of product and technology development.

The radical innovations in new markets, using new technologies, increase the chance that innovations will substantially contribute to sustainability goals (Bos-Brouwers, 2009; Tukker & Tischner, 2006; Berchicci, 2005; Brezet & Rocha 2001).

5.1.2 Differences due to the firm's development phase

As mentioned previously the embryonic stage is the initial stage of the development of a venture. "Bike", "Solar", " Fun Power" and "Truck" are firms who are in this embryonic phase. In the start-up stage the capability of having and selling a product, and creating the business and its operations are most important. "Plug", "Boat", "Party" and "Lantern" can be described as start-ups.

Characteristics that are found to be common within firms in their embryonic phase are:

- Being reliant on competitions and sponsorships for seed capital, but are starting to obtain capital through paid presentations and banks/subsidies/investors. Although these small firms cannot rely on a product portfolio to generate innovation funds (Kaufman & Todling, 2002), they are using public events to build credibility and capital.
- Closer relations with clients and users to get insights in the target market. Consequently, these firms are influenced by feedback from potential clients but also juries at competitions to alter the focus of the firm. The involvement with the market and users may not necessarily be attributed to the development phase of these firms, however it can be concluded that this is influenced by the educational background of

these entrepreneurs at DUT, particularly at the Faculty of Industrial Design Engineering. Having design as background seems to influence the firms' degree of market-orientation.

Characteristics that are found to be common within firms in their start-up phase are:

- Sustainability considerations, which were taken further into the development of products by a majority of the firms, particularly through consideration on materials lifecycle of products.
- Being dependent more on bank loans and investors for funding.
- Lower degree of market orientation. Clients and users are not involved in the product development process to a large degree. Products are also not always tested before market introduction. A lack of sales furthermore often changes the directions of these firms, and considered to be a consequence of lack of user orientation. Lack of knowledge of how to deliver customer benefits, it is difficult to create good products that sell (Walker et al., 2006; Srivastava et al., 1999; Webster, 1994).

6 Conclusions and recommendations

Despite limitations of the research, this paper moves beyond the traditional DfS approach in which existing products and processes are optimized (Chater er al, 2008) to provide several initial insights in how sustainability driven entrepreneurs manage their innovation process.

Conclusions can be drawn that the sustainability driven firms in the sample are in general working on moderate to radical innovations. It is typical for sustainable innovations (vs. greenwashing) to be more radical rather than incremental (Bos-Brouwers, 2009; Tukker & Tischner, 2006; Berchicci, 2005; Brezet & Rocha 2001). Although small firms are believed to generally innovate more incrementally (due to a lack of resources in terms of capital, time, knowledge and skilled personel), factors Bos-Brouwers (2009) identified to play a role in overcoming this are the sustainable orientation, management of the innovation process and networking capabilities of small business owners.

First of all, considering the sustainable orientation of firms, this study could not prove a relationship between sustainable orientation and radical innovation. The findings do however show that the internal drivers (as opposed to external drivers) for sustainability in small firms play an important role. Small firm owners were driven by their own values and insights and used this to identify new opportunities, innovate, create new value, and promote a sustainable story. The firms in the sample attempted to take sustainable innovation beyond the traditional environmental focus, in order to incorporate social aspects, as well as create awareness for sustainable behaviour with their products. Sustainable innovations that

created a higher sustainable value than initially intended furthermore successfully managed to replace products that have a higher environmental impact.

Secondly, in the sample, how radical an innovation was appeared to be related to several other factors that were considered. For instance, if an entrepreneur was dealing with moderate (sustainable) innovation, the need for a multidisciplinary team appeared to be lower. This type of entrepreneurs furthermore had a lower need for extensive technology based research, and showed a lower ability to acquire and manage their network that can support such research. In addition, it remained difficult to manage both the complex (sustainable) innovation process and the network needed for innovation, because of a high focus on daily activities (Kaufmann & Todtling, 2002). Because these factors appear to be related to the type of innovation, opportunities for further research are to test whether this is actually the case.

Thirdly, in the innovation processes studied, the phase of development at which a firm resides seemed to influence the degree to which sustainable ambitions were realised in the innovation process. Firms at an embryonic stage of development were not able to incorporate sustainability in the detail development and (intended) commercialization of the product yet. These firms have not been able to manage their innovation processes to such a degree that the full product lifecycle and its implications for production and marketing could be considered. A challenge for further research is to find out whether such firms will be able to incorporate sustainability in their further development successfully. Next to that an opportunity for further research is how small firms can be better supported to incorporate sustainability in their innovation process and product realised.

This study attempts to examine the product innovation process within an entrepreneurial setting. The select number of cases enabled an analysis of innovation process of sustainability-driven entrepreneurs. However, this approach also poses several limitations. First of all, the research is based on a limited sample of eight firms making it difficult to generalise the findings. In addition, due to the scope and timeframe of this study, the data has been retrieved though interviews with entrepreneurs. A case study approach would yield an in-depth analysis of the sample, which would increase the accuracy of results. Second, another factor that complicated the analysis further is that all embryonic firms were spin-offs from DUT, and all start up firms were not. Conclusions for embryonic firms are biased by the sample consisting of just spin-offs. Furthermore, since these firms are in the embryonic stage of development the value created for clients is very difficult to judge. Any judgements about value created are primarily based on prototypes that are tested with a limited number of clients and users.

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