Technology Windows in Sustainable Innovation Projects: Experiences with an Innovation Tool for Identifying Sustainable Application Domains

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Abstract

Emerging technologies are potentially interesting for sustainable innovation in high-technology firms and for 'techno-starters'. This article provides an innovation tool for sustainable technology-oriented innovation, as there are hardly any of these kinds of methods available. The Technology Window tool helps to find valuable applications and helps to evaluate if the application fulfils sustainability criteria. The window is a symbolic visualization, in which each side represents a key dimension: the strengths of the technology, one or two constraints that apply to utilizing these strengths in a sustainable way, and the technological drivers (trends and developments). This paper describes eight empirical cases used for evaluation and validation of the innovation tool. The technology window has been applied in student projects and used as a workshop tool in a professional setting. In most cases the innovation tool successfully structured the front-end of technology-oriented innovation. It was most effective in cases where the strengths of the technology were not obvious and when a new application domain was needed. In these cases the method resulted in surprising and innovative ideas. The method proved to be valuable to structure the front-end of technology-oriented innovation in sustainable innovation projects and for sustainable emerging technologies.

1 Introduction

Sustainable innovation is becoming a key driver for business development. Especially 'techno-starters' and high-technology firms see the potential of emerging technologies for sustainable new product innovation. Although there is no real method for innovation (Berkun, 2007) it helps to structure the process to increase the success factor (Buijs, 2005). Unfortunately most innovation tools and methodologies are developed for traditional manufacturing and non-high-technology firms (De Luca, 2010). It is well known that technology-push strategies often do not work, because customer-orientation is a critical success factor for innovation (Veryzer, 1998;

Cooper, 1999; Ulwick, 2002; Riel *et al.,* 2004; De Luca, 2010). However, customer-orientation is especially difficult for high-technology firms due to the engineering culture of these companies (Day, 1999; Slater and Mohr, 2006). In addition, classical market research methods are unreliable in such cases, because consumers are unfamiliar with the new technology (Hellman, 2007). And finally, despite the fact that the most important decisions for sustainable new product innovation are made in the Fuzzy Front End (FFE) (Brezet *et al.*, 2001), there is little focus in de FFE on identifying opportunities for developing products that are sustainable in function (Wever and Boks, 2007). For this reason, we developed the Technology Window: an innovation tool for identifying sustainable application domains for emerging technologies (Van Onselen *et al.*, 2007). The Technology Window helps to find valuable applications by taking consumer needs into account and helps to evaluate whether the application fulfils sustainability criteria. The aim of this paper is to describe the innovation tool and the empirical cases used for evaluation and validation of the method.

2 Opportunity identification

The tool forms part of what Van Onselen *et al.* (2007) called Sustainable New Product Development (SNPD): a combination of Environmental New Product Development, referring to function and system innovation (Berchicci, 2005), and Sustainable Development, defined as development that "contributes to the balanced continuation of the humankind-environment relationship for all and for the future" (Boutilier, 2005). SNPD can be defined as the sustainable development of completely new products by integrating social and environmental aspects into the development of a product (Berchicci, 2005; Boutilier, 2005). SNPD does not only focus on product improvement and design as do the other terms used for DFS, but also on innovation of new products. SNPD focuses on radical new solutions needed to meet the sustainability goals set by the different stakeholders in society. It often means that there will be a discontinuity with the former solutions or innovation processes. Perhaps functions should be fulfilled differently (Function Innovation) or even the whole system in which the function has to be fulfilled has to be changed (System Innovation) (Brezet and Hemel, 1997).

The investigated models of the FFE could be summarized in four steps: strategy definition, opportunity identification, creative thinking and assessing and substantiating (Van Onselen *et al,* 2007). The main difference of our method in comparison to other innovation models lies in the opportunity identification phase. During the opportunity identification phase, a lot of information is gathered and many decisions are made. Several diverging and converging steps are taken (see Figure 1). Speed and focusing are the typical characteristics of this phase.

The opportunity identification phase for technology-oriented innovation has a different order of steps compared to the traditional market-oriented innovation models. The opportunity identification for market-oriented innovation starts with analyzing and identifying opportunities in the market. Often, market segments are analyzed, which are (close to) familiar markets of the company to provide a workable view. Our approach starts with analyzing the technology and its competing technologies instead. The thought behind this is that technology-oriented innovation should not start with analyzing the market for opportunities. The lack of familiar markets would

result in too broad a perspective. The Technology Window provides a more suitable starting point by creating a framework based on the strong properties of the technology or its strengths.

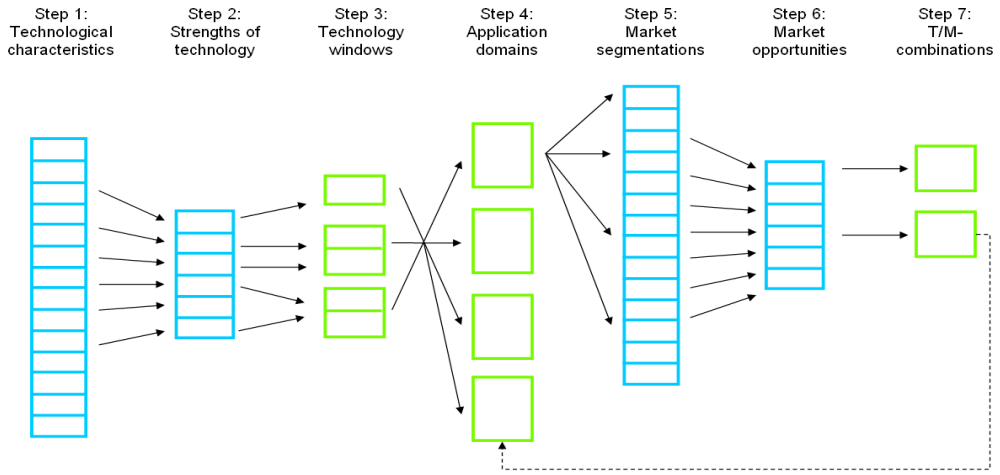

Figure 1. Opportunity identification phase

The analysis results in a list of properties of both the technology and competing technologies. Some of the characteristics of the technology are the strengths of the technology in relation to those of the competition. A strength, or a few strengths combined, can form a Technology Window (for more explanation see Section 3). The window acts like a framework for identifying application domains for which the technology solves a problem or provides additional value compared to existing solutions. It will be most likely that a few windows and application domains can be generated for each front-end cycle of an innovation project. It is important to focus as fast as possible on the most potential domain. When later in the process it becomes clear that a domain was not as potential as assumed, not too much time is lost and it is possible to iterate and focus on an alternative domain.

The selected domain should be analyzed to find markets for the technology. The potential of each market must be defined. Those markets that have more potential than others are called market opportunities. Sometimes, a market opportunity can be combined with one or more strengths of the technology; these combinations are often called Technology-Market (T/M) combinations or search areas. The focus should be on the most potential T/M-combinations.

3 Technology Window

The Technology Window helps to generate application domains in case of a technology-oriented innovation project. The window helps to understand what categories of products can be developed based on analyzing the technology first. After that, the window helps with the search for markets without getting lost in all the available market opportunities and ending up with a list of suitable T/M-combinations. With the strengths of the technology in mind, the market can be searched for new valuable opportunities.

A Technology Window is a symbolic visualization (see Figure 2) with each side representing a key dimension of the specific technology: the strengths of the technology, one or two constraints that apply to utilizing these strengths, and the technological trends. In Table 1 each side is explained with a definition and an example.

The number of sides of the Technology Window is not fixed. In Figure 2 an example is shown with one strength, one development, and two conditions. It is also possible to combine two strengths of the technology, or to use more trends and developments. It is not recommended to use more than six sides, because this might be too complex to generate fitting application domains. The risk might be that a side is forgotten and the generated application domain will not fulfil the conditions of the window. In Table 2 the steps to create and use a technology window are explained.

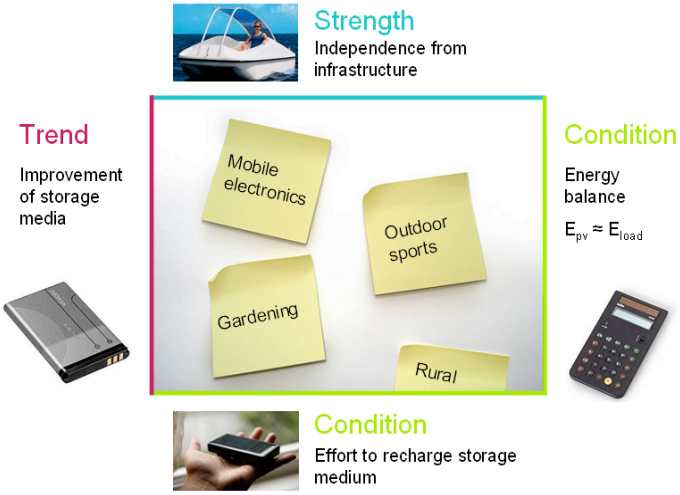

Figure 2. The Technology Window for 'independence from infrastructure'

Table 1. Explanation of the technology window terminology

Side	*Definition*	*Example solar cells*
Strength	A strong feature or property of the technology.	Independence from an infrastructure.
Trend/development	A market or technical development in a certain direction for the long term, that enables the technology or material to excel in its performance.	Improvement of storage media.
Condition	A requirement that needs to be met to enable the characteristic to work in a sustainable way.	User must be motivated to put effort to (re)charge the battery.

Step 4 should be explained more in depth. At this point it is not necessary to formulate very precise conditions, because the window is used mainly to stimulate creativity in order to generate several application domains. These conditions however still need to be formulated in such a way that afterwards they can be used to evaluate the generated domains. For example, a condition for solar cell technology can be that the user must be motivated to put effort in recharging the product's storage medium. This condition is formulated in such a way that it does not block the generation of application domains by being too specific. On the other hand, this condition is specific enough to be used to evaluate the generated application domains. In case of solar cell technology domains could be mobile electronics and outdoor travelling and sports. It is not

certain if consumers of mobile electronics want to put effort in recharging the battery. If this is compared to the outdoor travelling and sports domain, it is more likely that consumers are more dedicated to the environment and therefore more willing to put effort in recharging the battery of a product with solar cells.

Table 2. Creating and using a technology window

Step	*Explanation*
1. Drawing material	Take a large sheet of paper for developing the window.
2. Pick a strength	Take an interesting strength from the list of characteristics. Draw a line on the top of the paper and write the strength above it.
3. Select a trend/development	Search for consumer trends and technological developments that will make the strength excel even more. It should be promising for the next five years. Draw one of the side bars of the window and write the trend and/or development on the outer side. If you selected more trends or developments you can draw more side bars (and create a pentagon or hexagon).
4. Formulate conditions	Formulate conditions that are necessary to utilize the strength. It can be one or more conditions. Draw more side bars if necessary and a bottom bar to finish the window. Write the conditions also on the outside of the window.
5. Use the window	The window should be large enough to write all the possible domains you can come up with on the inside. Use the brainstorm technique to generate application domains. Postpone judgment: do not use the conditions for judgement while brainstorming.
6. Select the best fitting domain	If you have an extensive list of possible application domains you can select the best fitting domain by evaluating each domain on the conditions.

4 Research method

In order to test our approach, we conducted six workshops and two student projects based on the Technology Window method. These workshops and projects are treated as case studies to build up a body of evidence on the use of the technology window method (Eisenhardt, 1989). For each case, a number of different research methods were employed to collect data from the end-user and the facilitator perspective (see Table 3 and 5). The data were analyzed qualitatively by identifying themes and by cross checking these with other sources.

5 Cases: workshops

In the past years, six workshops based on the Technology Window method were conducted. All the workshops were organized during events with 15 to 30 participants. The participants were placed in groups from 4 to 6 people. In Table 3, the workshops are described.

The workshop contained elements of interaction, brainstorming and question cards. These elements stimulated creativity and inspiration. The workshop was designed for half a day (see outline Table 4). However, in some cases less time was available. Therefore, we were forced to shorten the steps or hand-over a specific step (consumer/market investigation) to a parallel workshop.

Table 3. Description of the workshops

Case	*Client/organization*	*Description*	*Aim*	*Data type*	*Participants*
1.	Network organization for sustainable designers (O2 Nederland)	Part of the O2 lustrum event with the theme playground	Find opportunities for NaBasCo, bio-polymers, nano-polymers	Field notes Pictures	4 groups: sustainable designers
2	Association of Dutch Designers (BNO) and network organization O2 Nederland	Part of *De Bloeiende Stad* during the Dutch Design Week	Find opportunities for Techwood, bio-polymers, bamboo and Pure Composite	Evaluation facilitators Pictures Blog report	4 groups: business people, designers and students
3	Pezy product innovation	Pilot workshop as preparation for *the Big Bang*	Find opportunities for bio-polymers	Field notes	1 group: Pezy employees
4	Association of Dutch Designers (BNO) and network organization O2 Nederland	Part of *Dinsdag* a network event for discussing sustainability	Find opportunities for bio-polymers, bamboo and NaBasCo	Evaluation facilitators Questionnaires participants Report by organization Pictures	5 groups: designers and business people
5	Cooperation of several organizations (DPI value centre, Pezy product innovation, O2 Nederland and Dusc innovation)	Organized during the Dutch Design Week as part of *the Big Bang*	Find opportunities for bio-polymers and self-healing materials	Evaluation facilitators Questionnaires participants Report by organization Pictures	4 groups: (sustainable) designers and business people
6	Industrial Design Business Fair (IOB)	Organized together with Aluminium Centrum	Find opportunities for different kinds of aluminium	Evaluation facilitators Pictures Blog report	3 groups: industrial design students

In case 3, 4 and 5 the step consumer/market investigation took place in a separate workshop guided by facilitators of Pezy Product Innovation. They are specialized in consumer insight research. The Technology Window and consumer insight modules were performed in parallel sessions. At the end of the two sessions the two workshop-teams were force-fitted together in an

extra step. The force-fit resulted in ideas combining the insights from both workshops. It was however difficult to split up at the right moment. In case 3 and 4 the domain for the consumer insight workshop was still vague. This led in some teams to very broad market definitions and unsurprising opportunities. In case 5, the domain was defined beforehand, which undermined the Technology Window workshop. *"Because of using a too specific problem statement the Technology Window was less useful."* The problem of vague or too descriptive domains did not occur when the workshop was performed chronologically.

Table 4. Workshop outline

Module	*Description*	*Duration*
Introduction and briefing	The technology window and outline of the workshop is explained. The facilitator expert briefs the teams on the aim of the workshop. The teams are describing their vision on sustainable product innovation.	15 min
Analyze technology	Each team analyzes the technology by questioning the expert and by exploring the internet and literature. The team can use 'question' or 'development' cards in order to find every detail there is to know about the technology. They fill in a table of properties and compare the characteristics with similar technologies. Then the team determines which characteristics are the real strengths of the technology.	30 - 60 min
Make windows	A window is based on a *strength*, a strong characteristic. After choosing the most promising strength, the team defines which trend is aiding the strength and defines on which conditions the strength will excel.	30 - 45 min
Application domains	When the window is finished, the team will generate application domains by using the brainstorm technique. It is important that the group will postpone judgment and uses creative thinking skills. Only after an extensive list of possible domains is generated, the conditions should be used to judge which domain fits the strength of the technology the best.	30 - 45 min
Consumer/ market investigation	When an application domain is chosen, the team should investigate the market in this domain and use consumer insights to find useful opportunities for the technology. (This phase can be performed separately to create more time, which was done in cases 3, 4 and 5). A technology/market-combination is chosen.	30 – 120 min
Idea generation	Based on the technology/market-combination, product ideas can be generated. (It is advised to perform this phase in another workshop as this increases the time that can be spent and therefore results in a wider range of innovative ideas).	30 min
Pitch	The ideas are presented and judged on the level of innovation and sustainability by an expert jury. (This phase is added as a concluding element for events or for workshops with more than one group).	15 min

In case 4 we received a lot of positive feedback and only a few negative responses on question 1 (see Table 5). The main critique concerned the explanation and the long learning time necessary for understanding the definitions and the rules of the game. Respondents were positive about the technology analysis and the knowledge available. In case 5 the feedback was less positive on the question for two reasons. Firstly, the self-healing material used as one of the cases had only one strong property and was therefore less suitable for the Technology Window approach to search for the strongest property. Secondly, the domain was already specified. In our method the domain is based on the strongest property that results from the technology analysis. This negative response indicates that the technology window method is only useful when the strengths of the technology are unclear and there is need for a new application domain.

Table 5. Results of the questionnaires

Case 4	*Yes*	*No*	*Maybe/Little*	*Don't know*	*Respondents*
1. Did this approach help you to integrate the strengths of the material into new applications?	11	3	4		18
2. Did this approach help you to integrate user benefits into new applications?	8	4	3	3	18
3. Did this approach help you to come up with more sustainable designs?	7	6	3	2	18
Case 5	*Yes*	*No*	*Maybe/Little*	*Don't know*	*Respondents*
1. Did this approach help you to integrate the strengths of the material into new applications?	2	5	3	1	11
2. Did this approach help you to integrate user benefits into new applications?	2	1	2	6	11
3. Did this approach help you to come up with more sustainable designs?	5	4	2		11

The respondents had mixed opinions on the subject of sustainability (question 3). About half of the respondents agreed for two different reasons. The first is *"because of the different thinking"* and *"because it can lead to totally new products in comparison with improving existing products."* The second is that the starting point is sustainable, but therefore *"depending on the conversation with the expert and the type of material."* A few of the respondents thought the method had potential, but they were not specific about what could be improved to make it more effective for generating sustainable designs. The second half of the respondents gave negative feedback to the question also for two reasons. The first is based on the same observation as above that the sustainable design depends on the technology or condition. The second reason is that the respondents did not see *"any connection to sustainable design."* We observed also that the results were not always sustainable. The facilitators tried to stimulate the participants to think

about sustainability and generate sustainable ideas, but the chosen ideas were not necessarily more sustainable.

6 Cases: student projects

The method was also used in two student projects from the University of Applied Sciences of Amsterdam (HvA) and Delft University of Technology. In both projects students received an explanation on the method and the paper by Van Onselen *et al.* (2007). The students interpreted and managed the method themselves without help of a facilitator. Semi-structured interviews were conducted to gain insight in their approach and experience (see Table 6).

Table 6. Description of the interviews

Case	*Interviewee(s)*	*Description*	*Data type*	*Technology*
7	Teacher HVA	In the course Innovation Management students need to find innovative applications for technologies.	Interview & reports	E.g. augmented reality techniques, LED, solar cells
8	Two students TU Delft	In the minor Sustainable Design engineering one student project was to develop a sustainable product for Helianthos.	Interview & report	Photovoltaic solar cells

The reason for using Technology Windows was in both cases that they had a technology as starting point for innovation. Using the tool helped to categorize the possibilities of the technology and provided a different perspective. The method quickly led to a concrete result. It is however not clear if the method led to more innovative and sustainable results than would have been without using the method. In case 7 the results of the projects also depended on the level of the students. In case 8 the students received a good mark, but the company who was their client did not use the ideas (yet) due to a change of project manager. Based on their experience the interviewees listed advantages and disadvantages of the method, which can be found in Table 7.

The method was used slightly differently in both cases. In case 7 the window was drawn on a large sheet of paper. Each side represented several strengths, trends and conditions. The window was used to find connections between the different sides. In case 8 they added an extra step in front. They made a reference book of good and bad product examples they had studied. After that they followed the steps described by Van Onselen *et al.* (2007), they replaced the window by a matrix in which application domains generated in a brainstorm were evaluated with the strengths of the technology.

Table 7. Advantages and disadvantages of the method

Case	Advantages	Disadvantages
7	The focus on the technology and the explanation what to do with it.	The article of Van Onselen et al. (2007) is only explaining the method. It does not work properly as a guideline.
	The use of a window is a fun and interesting way of getting insight into the technology.	There is not a structured approach to categorizing strengths, trends and conditions.
	The order of steps is clearly explained in the figure.	It is not clear how to find application domains and how to make connections between the different aspects.
8	The structured approach and different perspective. It is fast way of converging, narrowing down the possible alternatives.	The fast focus on the best alternative is also a downside. Good opportunities might be overlooked and it might be too restricted.
	It tells where to search for opportunities and helps to brainstorm in a structured way.	It is difficult to come to surprising ideas.
	It gives a clear start for the idea generation phase.	

The interviewees had suggestions for improvement of the use of the method. This most important remark was that it would help a lot if a trainer could teach the method in a correct way. Other suggestions are:

- Use the window as a complete overview of the strengths, trends and conditions. In this way correlations between them can be investigated.
- The term trends is limited, use instead the term technology drivers, which includes trends as well as other developments.
- Add a side with functionality of the technology, which could give a hint towards the application.
- There is need for a clear description how to step from the T/M-description to the creative idea generation phase.
- A clear description of all steps and definitions of the method.
- Allow more room for creativity.

5. Discussion

In most cases Technology Windows successfully structured the front-end of technology-oriented innovation. It was most effective in cases where the strengths of the technology were not obvious and there was need for a new application domain. In these cases the method resulted in surprising and innovative ideas. On the other hand, it has not yet been proven that it always results in successful market introductions and sustainable innovative products. More extensive research is needed to prove that the method results in successful and sustainable products in the long run.

The findings of the research (Table 5 and 7) do not fully support the claim that the Technology Windows tool aids in achieving development of sustainable products. Looking at the definition of

Sustainable NPD the tool supports the development of completely new products and integrates the technology strengths and social aspects into the development of a product. However, it does not explicitly integrate environmental aspects. One could argue that this method was developed to support the application and diffusion of emerging sustainable technologies. The current trend is that sustainable technologies are applied in useless, low quality products. Finding valuable and useful product applications for them is therefore more sustainable.

We also need to mention that the method was not successfully applied in all cases. In case 5, with a defined domain and with a material that had only one specific strong characteristic, the method was less convincing. Therefore, it is important to work with an open question and with technologies with many possibilities. In addition, in cases 1 to 4 a few participants did not approve of the workshop design, which in turn affected their opinion on the method.

6. Conclusion

The method proved to be valuable to structure the front-end of technology-oriented innovation in sustainable innovation projects and for sustainable emerging technologies. Although a lot of positive feedback was received, there still is room for improvement of the method. Especially, there is a need for improving the method on the environmental aspects of SNPD. The first six cases indicate it is possible to apply the method in a workshop. Yet, more depth might be reached if more time is used for each step. It is also important to explain the steps and definitions more clearly, which is attempted in this article. In addition, trainers can be used to explain the method to innovators or facilitators to guide a project team.

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