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TECHNOLOGY WINDOWS: A NEW METHOD TO DETERMINE VALUABLE PRODUCT-MARKET COMBINATIONS

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ABSTRACT
This paper describes the Technology Front End (TFE) method, which applies Technology Windows as a new approach to the front-end of technology-oriented innovation. The development of the TFE-method started with a review of the relevant literature, an analysis of technology-oriented innovation projects and semi-structured interviews with ten experts. This research confirmed that such a method should address technology push as well as market pull factors. The core contribution is the concept of Technology Windows, a new approach to generate applications in case of a technology-oriented innovation project. A Technology Window is a symbolic visualization of the strengths of a technology plotted against constraints and technological trends. This allows searching for suitable product-market combinations based on a thorough definition of the strengths of the technology. The TFE-method therefore enhances the process of the technology oriented front-end of innovation. The method was applied in three case studies in order to test it, of which two resulted in a set of innovative product-market combinations. Because of its generic structure, the method should also be applicable in other technology-oriented innovation projects to define innovative product-market combinations.

Keywords: design management, method development, design for sustainability, Fuzzy Front End

1 INTRODUCTION
In the last few years 'techno-starters' have been popping up. The trend of new, small companies placing new technologies and innovative products onto the market has been noticeable. These companies are often started by students, graduates or researchers of universities who are up to date with the latest developments of emerging or rapid developing technologies or innovative product ideas. However, bookshops and journals do not actually bulge from books and papers on this theme to fulfil the need of these 'techno-starters' for methods and tools useful for them to bring their innovative technologies and products on the market. Our impression is that existing methods and tools are often too theoretical and mainly addressing market driven developments. The existing innovation models do not provide enough practical tools for 'techno-starters', who are oriented toward innovative technologies, to help them identify market needs that can make their specific technology a success.
Researchers of a large research consortium called "SYN-energy"[1] experienced this lack of technology-oriented models in a project. The goal of the SYN-energy research group is to apply photovoltaic (PV) energy conversion technology in a product, which will then serve as a research example for the industry to stimulate the diffusion of the technology. The motivation to develop a method for a technology-oriented front-end process for new product development arose from the dissatisfaction with the front-end process of the project and the impression that it did not result in innovative product ideas. The researchers felt that the front-end had not been sufficiently structured and efficient, because existing innovation models did not provide enough practical tools for technology-oriented innovation projects. Therefore we developed a new methodological approach based on a study on the latest

[1] The SYN-energy project is a sub-program within the Energy Research Stimulation Program. Within this project, scientists from ECN3, University Utrecht, University Twente and Delft University of Technology are working on sub-projects. The sub-project of the Delft University of Technology is coordinated by the Design for Sustainability section of the Industrial Design faculty and originates from the need to develop good products applying photovoltaic (PV)-technology. For a good design, synergy is needed between the user, the product and the energy system.

innovation models and practical insights. The method can be applied to any kind of front-end of technology-oriented innovation to identify viable product-market combinations.
This paper describes the Technology Front End (TFE) method, which applies Technology Windows as a new approach to the front-end of technology-oriented innovation. The TFE-method integrates the two research areas, namely Sustainable New Product Development (SNPD) and Fuzzy Front End (FFE) (see for definitions of these terms in sections 2.1 and 2.2). Sustainability is becoming an absolute necessity for new product development. The most important decisions related to sustainability are made in the Fuzzy Front End of the process [1]. Sustainability is being perceived more and more as an inspiration instead of a hindrance for new product development. Unfortunately there is a gap between these two important research areas. The FFE field is a relatively new area of research, and SNPD researchers have mainly relied on older innovation models with a greater focus on development. A better integration of the two disciplines is therefore needed to create products that are sustainable as well as really innovative [2].

2 LITERATURE REVIEW

The first step of developing the TFE-method and Technology Windows consisted of deriving a theoretical framework from a review of the relevant literature, which is summarized below.

2.1 Sustainable New Product Development

Different terms that have similar meanings are used for Design for Sustainability (DFS) [2], [3]. All these different terms do not precisely cover the research area. Therefore a new term is introduced: Sustainable New Product Development (SNPD) which is a combination of Environmental New Product Development, referring to function and system innovation [2], and Sustainable Development, which is defined as development that "contributes to the balanced continuation of the humankind-environment relationship for all and for the future [3]. SNPD can be defined as the sustainable development of completely new products by integrating social and environmental aspects into the development of a product [2], [3]. 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) [5].

2.2 Fuzzy Font End

The FFE of innovation is the first step of the innovation process (see Figure 1) and can be defined as the messy ‘getting started’ period of product development, which comes before the formal and well-structured product development process, when the product concept is still very fuzzy [4]. This step is followed by New Product Development (NPD) and Commercialisation. The FFE generally consists of the first three tasks (strategic planning, concept generation, and, especially, pre-technical evaluation) of the NPD process. These activities are often chaotic, unpredictable, and unstructured [4].

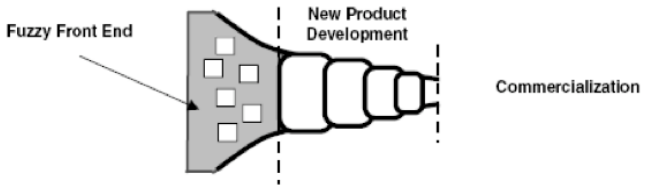

Figure 1. The stages of the innovation process [4]

The FFE is part of the innovation process, but what is innovation? Innovation is change that appears in different forms ranging from radical or discontinuous on one hand to incremental or continuous on the other [6] [7]. The change can be based on technology or product capability or both [7]. When the technology and the product only change slightly, it is called continuous innovation. It is called technological and commercial discontinuous when both change radically. If the goal is to be highly innovative, it is important to take the customer’s view of the product into account [7]. Many scholars

agree that the consumer perception on highly innovative products is an important success factor [8], [9], [10], [11], [12].

2.3 Market pulled versus technology pushed innovation

Technology push innovation is often more radical and of high importance during the first stages of the economical life cycle of products and product categories. Market pull innovation is mostly incremental innovation and influences the diffusion of innovations on the market [6], [12].
Other literature state that product development bridges the gap between market pull and technology push innovation [13], [14]. Focussing solely on market pull innovation or technology push innovation will reduce the chance in creating sustainable and successful products. The market pull only opens new target markets for existing or slightly different products, and solely technology push innovation will lead to confused customers rejecting the innovative product. Sustainable and successful innovation is therefore a combination of both market pull and technology push. True innovation meets the demand in the market place by applying emerging technologies in products.

2.4 Success factors

A product seldom fails for just one reason [15] and the list of possible reasons is long. Although these reasons or factors were identified in the seventies, innovation teams still fall into the same traps. Cooper [8] identified a problem with these factors: they are invisible and blocked for the project teams or designers. He investigated the reasons why the success factors are invisible and why projects seem to go wrong. By integrating the success factors in the process and by considering the action points the likelihood of successful innovation projects will be much higher [8], [15]. The action points are:

- ***Discipline:*** the project should be leaded in a managerial way. Consistent, timely, and stable project go/kill-points ought to be made and decisions have to be prioritized.
- ***Design and implementation of a process:*** each project has its own characteristics. Other processes and models must be critically studied. Adjustments to the processes and models are necessary most of the time and the processes and models must be used as guides through the innovation process.
- ***Overhauling the process:*** the processes of other (similar) products must be reviewed critically to provide valuable learning points for the new process. The weak areas, roadblocks and timewasters must be identified and eliminated. One should identify what works and consider suggestions for improvement from others.
- ***Definition of expected performance standards:*** Key activities and clear expectations regarding the nature and quality of work required must be defined. An explicit deliverable is a must and the gates in the process are to be used as quality control checkpoints.
- ***Evaluation of the process:*** it is important to reflect the process on a regular basis and review outsiders for their opinions to make sure the process is working.
- ***Tough go/kill decision points:*** carefully defined criteria for decision points must be used to be effective in focusing on the right alternatives.
- ***Usage of input from others:*** Innovation cannot be done in isolation. Inputs from others are to be used in a successful innovation process and it should be ensured that they are from various fields and functions.
- ***Training:*** All kinds of methods should be used to train members of the project team with the latest knowledge and tools of the innovation process.
- ***Cycle time should be reduced when possible.*** However, one needs be aware though not to become a speed freak. Flexibility must be build into the process to adjust it to each new situation. Key task such as stakeholder analysis however must not be deleted from the process, even when the answers might be obvious or thought to be known.

It can be concluded that one of the most important action point is to build in tough go/kill decision points. Carefully defined criteria are a necessity when focussing on the right project. Verloop [16] emphasizes that one should not be afraid to abandon some ideas. The primary reason is to select winners, not eliminate the losers.

Table 1. Tools for each phase of the FFE

Phase	Tool	Description	Actions
Strategy	Stakeholder analysis	Identify the stakeholders and the relationships.	- Conversations with at least two stakeholders; - Survey in case of a large group.
	3 radar sustainability dimensions model [22]	Prioritizes criteria at the 3 dimensions of sustainability: the environmental, the economic and the socio-cultural dimension.	- Fill in the questionnaire, the 3 radars, and draw conclusions.
Opportunity	SWOT-analysis	Identify strengths and weaknesses as a starting point for opportunities.	- Determine subject of analysis - Interview experts; - Analyze documents concerning the subject of analysis.
	Boston Consultancy Group-Matrix	Identify the product positions in the market. Instead of using it for strategy definition it can be used for mapping players in the market.	- Internet research; - Interview experts; - Visit distribution centres or retail.
	Focus group	An interview conducted by a moderator among a small group of respondents in an unstructured and natural manner.	- Prepare interview; - Invite respondents; - Conduct several focus groups; - Analyse data.
Creative Thinking	Brainstorming/creative sessions with consumer or expert involvement	Many ideas or solutions can be generated during a creative session with creative thinkers, users or experts.	- Prepare session; - Prepare stimuli; - Invite participants.
Assessing and substan-tiating	Scenario building (Janszen)	Predict step-by-step future situations (> ten years).	- Expert interviews; - Analysis of documentation; - Define scenario drivers; - Create scenarios.
	Business chain management (Smulders)	Planning the business chain necessary to produce the product and implement it on the market.	- Identify businesses relating to product idea; - Speak with key persons; - Create business chain.
	MET(A) matrix (Remmerswaal)	Identifies environmental problems in product development.	- Gather information; - Fill in the Matrix.

2.5 Relevant elements of innovation models from literature

Although the front-end of innovation is fuzzy and chaotic and the steps of the process are iterative and flexible [17], [18], a good routine or guiding model helps the manager or designer to innovate successfully [19].

Various innovation models were studied and compared to one another [4], [15], [17], [20], [21], [22]. Each model has its own unique elements. When combined, they can provide good insight into the FFE. The first lesson learnt from existing models is that clear steps need to be defined. These steps can be similar to those of an existing model, as long as they are adjusted to the requirements of a project. From the comparison of the innovation models a general outline of such models became clear. This general outline can form the basis of any front-end method:

1. ***Strategy definition:*** depending on the project the company strategy can be analyzed and (re)formulated. Sometimes only a project strategy (fitting in with the main strategy) needs to be formulated.
2. ***Opportunity analysis:*** many projects start with the identification of an opportunity, for example PV powered products. Subsequently the strategy needs to be formulated, as described in the previous step. The next step is to analyze the opportunity internally and externally. Internal analysis is the identification of the strengths or competences and weaknesses of the company or technology. Competitor, context, stakeholder and consumer research are part of the external analysis. The results from both analyses can form together search areas. The most potential search area must be selected and will be the starting point for the following phase.
3. ***Creative thinking:*** this phase starts with generating (clusters of) ideas. A quick selection can take place to focus on a few ideas. This step is not obligatory, but it depends on the project and how many ideas are generated. This is followed by analyzing or enriching the ideas to facilitate the final selection of the most potential ideas based on carefully formulated criteria.
4. ***Assessing and substantiating:*** the last phase consists of writing a business plan or design

brief. An important topic of the business plan or design brief is the justification of innovation. This can be achieved by assessing the ideas and substantiating the most potential idea with feasibility analyses.

2.6 Tools

Which tools to use during the process depends on the demands of the project, the preferences of the person or team, and the type of information needed. During the FFE it is important to have an overview of useful tools. In Table 1 various tools for the FFE can be found which are selected from different fields such as market research and SNDP. This is a selection of possible tools useful in the FFE process and is based on a few criteria. These tools are aimed at new product development rather than improving products that are already on the market. Tools that require quantitative data were not included because in the FFE such data or the resources to conduct research for this data are often not available. The selected tools can be used in a short time span. Table 1 describes each tool and indicates in which of the phases the tool could be used (see previous paragraph).

3. TFE-METHOD

The method was developed in two steps. The first step was a clarification of requirements, which originated from a review of relevant literature, analysis of technology-oriented innovation projects and semi-structured interviews with ten experts. These studies led to the conclusion that technology-oriented innovation should be a combination of market pull and technology push innovation, since true innovation meets the demand in the market place by applying innovative technologies. The innovation model of Buijs [17], [23] proved to be a valuable basis for approaches to the front-end of innovation. A procedure was formulated based on the requirements derived from the findings of the study.
The second step was applying the TFE-method in a case study in order to test the method. The case study focused on PV energy conversion technology and was conducted at the Faculty of Industrial Design Engineering at the Delft University of Technology. The case study resulted in a set of innovative product-market combinations for PV-technology and illustrated the process of applying the TFE-method. The method was evaluated in terms of the requirements, in comparison to the process of the previous project, and with a reflection on the process of applying the TFE-method in the case study. Some improvements were made to enhance the TFE-method. The result is described in the following paragraphs.

3.1 General background model

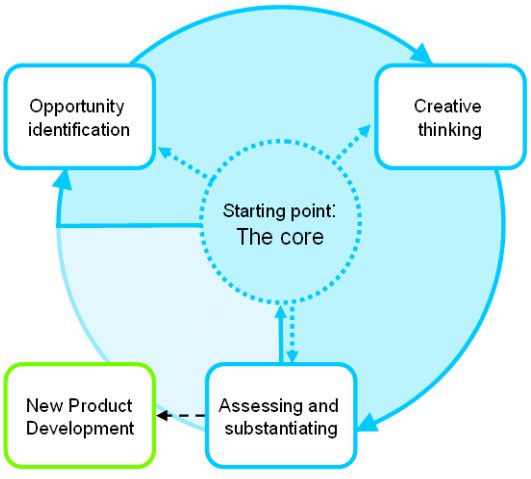

Figure 2. General background model

The TFE-method is based on a general background model, which explains the relation between four separated phases: the core, opportunity identification, creative thinking, and assessing and substantiating (see Figure 2). It is important not to see this general background model as the guidance through the FFE of technology-oriented innovation, because it does not explicitly describe the steps of the process. The steps, the character and the deliverables of each phase are therefore described in more

detail in the following paragraphs. The biggest difference to other models is in the opportunity identification phase in order to meet the demands of the technology-oriented front-end. The other phases are more similar to the steps or phases of other (market-oriented innovation) models. The main new element, the concept of Technology Windows, will be described in more depth in section 4.

3.2 The core

The core consists of analyzing the mission, vision or strategy of the organisation, typically a company or, as in this case, a research consortium (see Figure 3). The core influences every phase of the front end (see Figure 2). With each new start of the front-end cycle it is important to analyze the mission, vision and strategy of a company or, as in this case, a research consortium. This provides a solid basis for the selection criteria of the decision points in the other three phases, opportunity identification, creative thinking and assessing and substantiating.

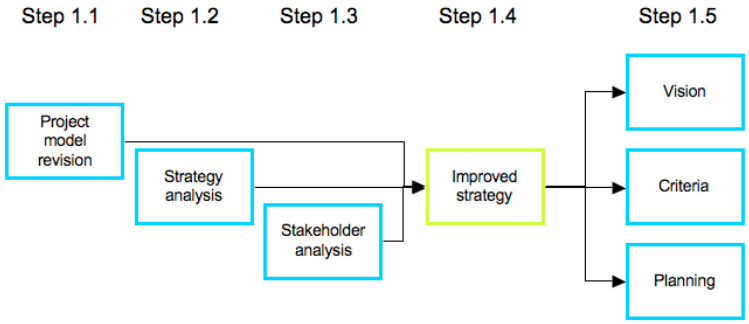

Figure 3. The core of the TFE-method

The first step is to analyse previous projects and to adjust the process, because it is important to continually update the plan, to eliminate time wasters, to rearrange steps to improve the flow and to integrate missed steps [8]. This is followed by an analysis of the present situation, which consists of a strategy and stakeholder analysis. A stakeholder analysis helps to understand the perspective of those involved and how they influence the project. The strategy can be improved on the basis of new insights resulting from the analysis of the present situation. If a strategy is not present yet, then a helpful tool to define a new (sustainable) strategy is the 3 Radar Sustainability Dimensions model (for a short explanation see Table 1). On the basis of this information, the criteria for decision points can be defined, the vision of the innovation project can be written and the planning for the innovation project can be made.

3.3 Opportunity Identification

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 4). Speed and focussing are the typical characteristics of this phase.

The opportunity identification phase for technology-oriented innovation has a different order of steps then in models for market-oriented innovation projects. Instead of conducting technology and market research in parallel, this method starts with analyzing the technology and its competing technologies. The analysis results in a list of characteristics 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. One of the strengths or a few strengths combined can form a Technology Window (for more explanation see Section 4). Through the window a select area of the world can be searched to identify application domains in which the technology solves a problem or provides additional value compared to existing solutions. In the case study one strength of PV- technology, its independence of infrastructure was considered a valuable strength, which then formed 'infrastructure independence window.' An application domain belonging to this window was 'emergency relief products.' After a disaster, the infrastructure of the electricity grid is often severely damaged. Disasters also occur in places where no grid was available in the first place. In these cases solar powered products might solve the problem of being out of electricity.

Probably 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 re-focus on an alternative domain.

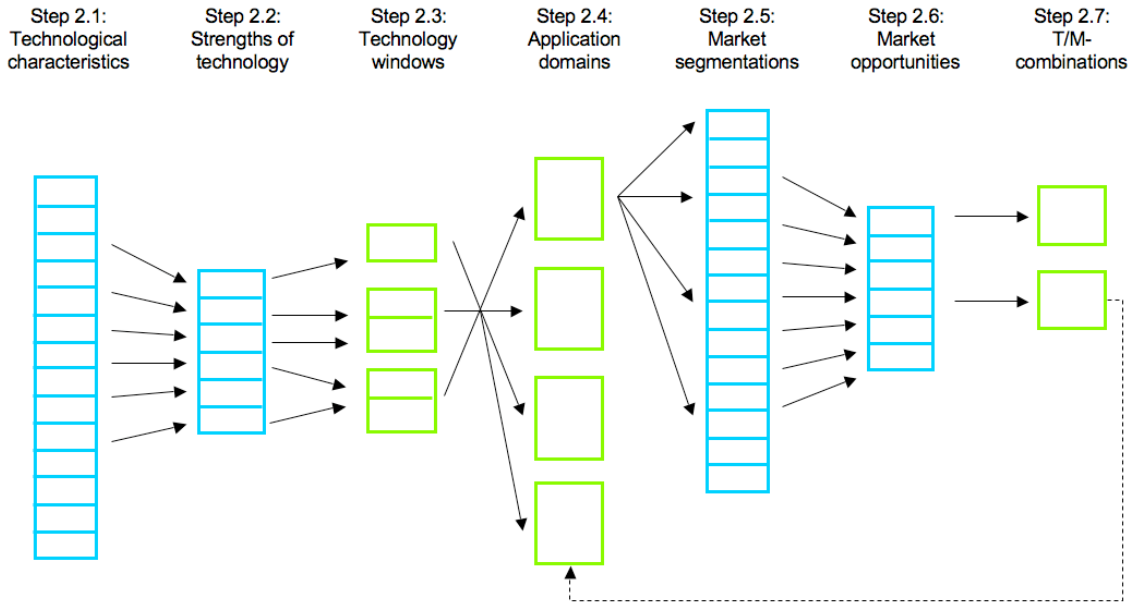

Figure 4. Opportunity identification phase

The selected domain should be analyzed to find markets for the technology. The potential of each market must be defined. The 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.

3.4 Creative Thinking

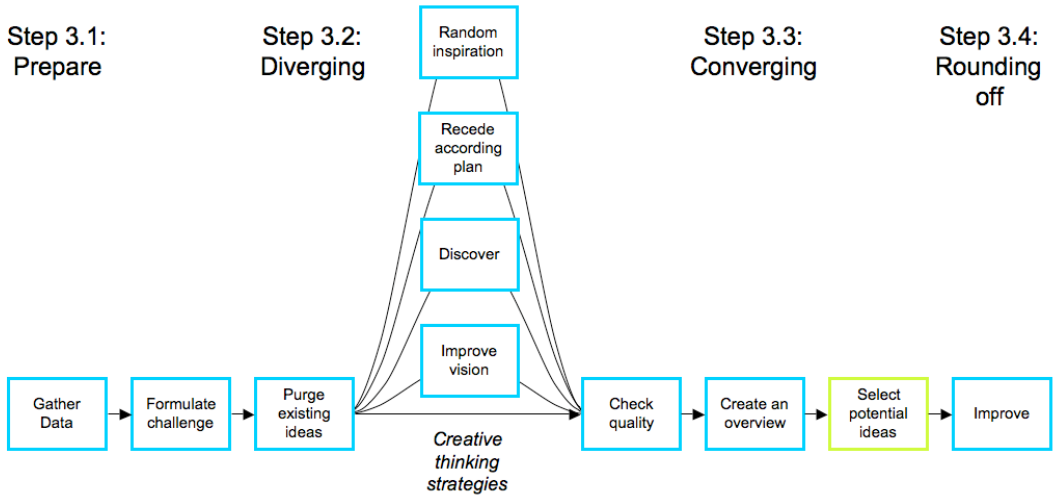

Figure 5. The model of creative thinking strategies [25]

The character of this phase is very creative as the name indicates. During this phase many product ideas should be generated following the principle of "quality through quantity" [23], [24]. Ideas can be generated with help of creative thinkers, creative sessions and generative sessions with consumers. Being creative can be very chaotic, but there are strategies to structure the creative thinking process. A company specialised in creative thinking, The Creativity Company [25], developed a model of these strategies (see Figure 5). First data must be gathered for the topic of the creative thinking. The search

area must be explored in order to formulate the challenge correctly. Helpful tools for gathering data are simple desk research or marketing research tools like focus groups, interviews, observations or surveys. Depending on the time and resources available one or more tools could be used. When the challenge is defined, the existing ideas must be listed and new ideas must be generated. This can be done with the help of brainstorming or other creativity techniques [24].
The deliverable of the creative thinking phase is a list of potential product ideas. A product idea is the most embryonic form of a new product or service. It often consists of a high-level view of the solution envisioned for the problem identified by the opportunity [4]. It clarifies what the product form will be, and what the technological aspects and target groups are.

3.5 Assessing and Substantiating

A simple list of potential ideas is not enough; they must be justified before writing a design brief or business plan. During this phase the ideas will be assessed and substantiated (see Figure 6).

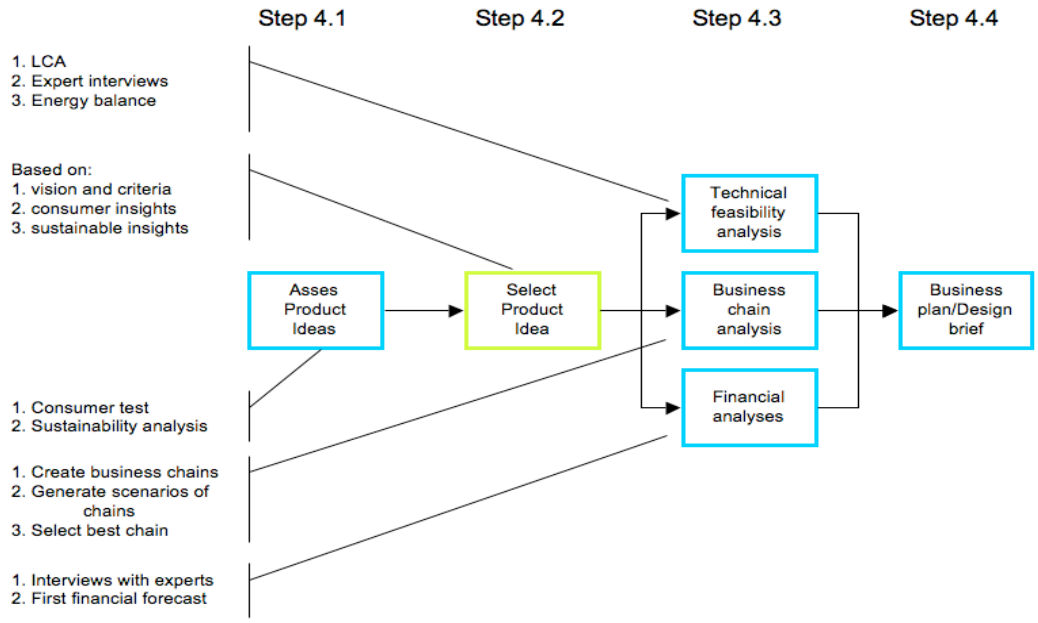

Figure 6. Assessing and Substantiating

The most promising product ideas are then tested on feasibility, on sustainability, and last but not least by consumers as shown in Figure 6. Based on the insights of these assessments and the selection criteria defined at the core, a product idea can be selected. This idea must be substantiated with all previously gathered data and with a technical, financial and business chain analysis. Tools that can be used in this phase are Business chain management, MET(A)-matrix and Scenario Building (see for an explanation Table 1).
Although one could write a business plan given this type of data, we generally advise not to do so at this point, because it would consume too much time and is based on too many assumptions (possible business chain, financials, production method, etc.). A 'justification of innovation' report, a simple version of a business plan, would be enough at this stage. If the project has been approved on the basis of this evidence, a more thorough analysis can be carried out and based on this additional information and then a business plan can be written as starting point for the next phase, new product development.

4. TECHONOLOGY WINDOWS

The Technology Window is a new approach to generate application domains in case of a technology-oriented innovation project. The windows help to understand what categories of products can be developed based on analyzing the technology first. After that the windows help 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.

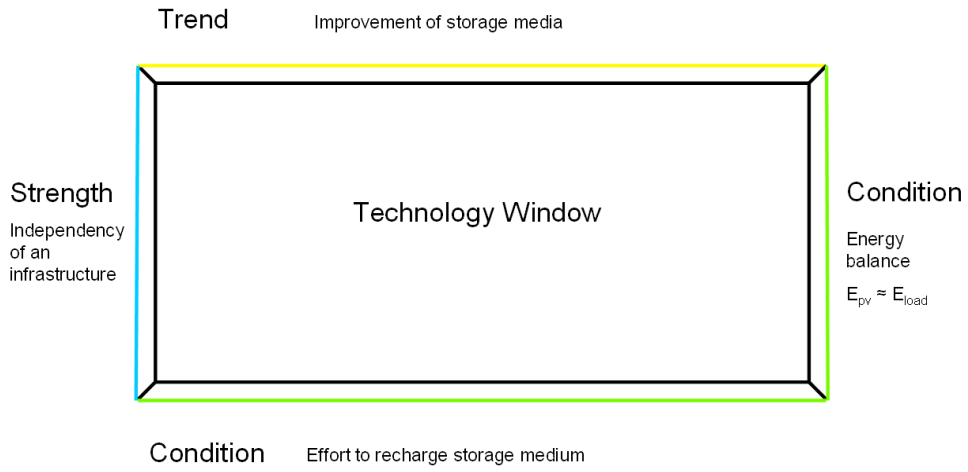

Figure 7. The Technology Window for 'independence of an infrastructure'

A Technology Window is a symbolic visualization (see Figure 7) with each side representing a key dimension of the specific innovation: the strengths of the technology, one or two constraints that apply to utilizing these strengths, and the technological trends. For example the first side of a window can be formed by one of the strengths of PV-technology, its independence from infrastructure. The second side can than be formulated based on a condition to enable this typical strength, e.g. for PV a storage medium is required to provide sufficient energy at any time of need. A second condition forms the third side, in this case that the user has to be motivated to put effort into recharging the storage medium for optimal usage of the product. The technological trend that completes the window is the improvement of storage media, which will alleviate the problem of the latter condition.

The number of sides of the Technology Window is not fixed. In our case study all the windows had four sides, but a window could also be constructed with three or five sides. More than six sides is not recommended, because it then might be to 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.

At this point it is not necessary to formulate very precise conditions, because the window is used firstly 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 was in this case that the user must be motivated to put effort in recharging the products 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 can be used to evaluate the generated application domain. For this case the statements would be that it is not certain whether users of mobile electronics want to put effort in recharging the battery and that consumers in the outdoor travelling and sports domain are more dedicated to the environment and therefore more willing to put effort in recharging the battery of a product with solar cells.

After the formulation of the Technology Window, the window is used as a framework to explore valuable market opportunities. The window is kept in mind when searching for application domains in which the technology could solve a problem or provide additional value compared to existing solutions. A useful tool to generate application domains is a brainstorming session alone or in a team.

6. EVALATION OF THE TFE-METHOD

The TFE-method was evaluated by applying the method in three projects. The first project was the case study of a technology-oriented front-end of PV mentioned before (see Section 3). This case helped to improve the TFE-method, which is described in the following paragraph. The TFE-method was also applied in two other projects. The evaluation of these projects can be found in paragraph 6.2.

6.1 Evaluation of the first case study

The TFE-method was successfully applied in the first case study. The final results were ten solid ideas regarded as valuable by the research consortium. The process of the case study was a learning process, which helped to revise the TFE-method to its current shape.

The TFE-method met nearly all requirements listed before its development. The method integrated both technology and market perspectives in the opportunity identification phase by starting with analysing the technology and ending with combining the results of this analysis with potential markets. For each phase it was possible to select tools conforming with the demands of the project. The TFE-method made it possible to select the right criteria and to write a vision at the end of the first phase. The method provided sufficient structure and integrated five go/kill-points. It also stimulated generating multiple alternatives, which is proved by the case study. It used existing models as a basis for the method development.
However, two requirements, integrating eco-innovation tools and business chain innovation, could not be tested in the time span of the project and the third, including others, was beyond the use of experts in the interviews not explicitly integrated into the method.
The process of the case study with the TFE-method was much more effective and structured than the process of the research consortium. Structure and focus had not been sufficient in the original process and thus resulted only in ideas that merely combined existing products with PV. The TFE-method helped to structure and shorten the process of identifying opportunities for PV by defining go/kill-points, writing a project vision, formulating criteria before making decisions and assessing only potential ideas with extensive analysis. This resulted in more valuable and innovative ideas ranging from continuous to discontinuous ideas confirm the mission of the research project.

6.2 Evaluation of the second and third case study

The two other projects were both applied by other researchers, which makes this evaluation more objective. The second project addressed solar technology in a broader sense than our case, which was aimed solely on PV technology. Another difference was that in the second case the general target area was already known, namely the bottom of the pyramid. Unfortunately this project was cancelled halfway due to personal reasons. The third project aimed to find applications for mobile ad-hoc networks. This technology is more complex then the technology in the other case studies. The TFE-method was applied in a slightly different manner from how it was intended. It resulted however in promising product-market combinations. Although the TFE-method was not appropriately applied in both projects, it was still possible to draw interesting conclusions from them.
The first conclusion is that the TFE-method is only applicable if technology is the starting point. This is however not true in many NPD projects for which the market is a starting point for innovation. Even more innovation projects start from a technology-market combination, like the second case study. Nevertheless, technology driven innovation models are rare in innovation literature and therefore the TFE-method is a valuable addition.
Secondly, the TFE-method can be further improved in several ways. At this stage the method has small, detailed steps with non-descriptive names, which makes it difficult to apply for newcomers. The TFE-method has to be learned and cannot be applied directly. Future research should improve the TFE-method and make steps more explicit, so that the method can be directly applied with very little training.
The last conclusion is that it is important to use the Technology Window as described in Section 4, otherwise the TFE-method has not so much added value compared to other methods. The third case used Technology Windows simply to identify applications rather than for generating application domains. It also combined Technology Windows to create application domains and not as framework to search the outside world for application domains. It is therefore strongly advised to follow the procedure described in Section 4 when applying the TFE-method.

7. DISCUSSION

Technology-oriented innovation needs a different approach of the front-end then market-orientated innovation. Market-oriented innovation starts the opportunity identification phase with analysing and identifying opportunities in the market. Often market segments are analysed that are (close to) familiar markets of the company to provide a workable view.
Technology-oriented innovation on the other hand should not start with analysing the market for opportunities, as then a lot of time would then be wasted on investigating opportunities that will not suitable for the chosen technology. It is therefore crucial to start off with analysing the possibilities and strengths of the technology. From these strengths Technology Windows can be formulated, which provide a helpful framework for addressing the market and a higher chance on finding opportunities

that fit the technology. During the first case study the focus was on the 'infrastructure independence window'. Keeping this window in mind only application domains were generated for which this independency was important. This approach makes it possible to find several fitting opportunities for a few Technology Windows in a short time without getting lost in all the available possibilities. It can therefore be concluded that the concept of Technology Windows helped to address the specific needs of technology-oriented innovation as opposed to market-orientated innovation.
Modelling the process to find valuable opportunities for product development is essential. Similar statements are proposed in literature, for example Cooper [8] states it is important to design and implement a process that can be used during the innovation process. Others developed models and methods for the front-end of innovation based on the thought that modelling the process is essential for improving the FFE.
The first case study also supported this statement. Comparing the process of the case study, which was structured by the TFE-method, to the initial process of the research consortium proves once more that developing a well-considered model is essential. The process of the case study was much more effective and structured than the original process and resulted therefore in more valuable and innovative ideas ranging from continuous to discontinuous innovation.
The case studies could not be applied to all aspects of the method due to the limited time of the projects. The fourth phase, assessing and substantiating, still needs to be carried in order to complete the validation of the method. Also further research is needed on the integration of eco-innovation tools and usefulness of business chain innovation in the fourth phase. The testing of the method should be extended with applying the TFE-method during future innovation projects focussed on other technologies.

8. Conclusion

It can be concluded that the TFE-method enhanced the process of the technology oriented front-end of innovation and was effectively applied during the first case study. As it is a generic method, it should prove useful not only for the three case studies, but also for other technology-oriented innovation projects. The biggest difference to other models lies in the opportunity identification phase with as main new element the concept of Technology Windows. Applying this method for technology oriented innovation projects will result in continuous to discontinuous innovative product-market combinations.

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