Reviewing and Defining Productization

Arho Suominen*

University of Turku, Ylhäistentie 2, 24130 Salo, Finland
E-mail: arho.suominen@utu.fi

Jussi Kantola

Department of Intelligent Service Engineering, KAIST 335 Gwahangno (373-1 Guseong-dong), Yuseong-gu Daejeon 305-701, Republic of Korea.
E-mail: jussi@kaist.edu

Aulis Tuominen

University of Turku, Ylhäistentie 2, 24130 Salo, Finland
E-mail: aulis.tuominen@utu.fi

Abstract: While New Product Development (NPD) is widely used a new term productization has to some extent been used in literature. The term is actively used in Finnish debate, but also in more widely, to describe something ambiguous. This paper reviews the usage of term in different contexts and presents a definition for the term. The paper also presents how a productization process, based on the definition given, was used in the development of a portable fuel cell.

Keywords: Productization, New Product Development

1 Introduction

In the academic discourse new product development (NPD) has gained substantial attention. In describing process that strives to develop new products we often read about product development processes. At the same time a new term *productization* has been, at least in the Finnish debate, widely used to describe something still ambiguous. The article aims to describe productization, which is strongly focused on understanding what is meant by NPD. In addition to this the authors will elaborate the definition of the term productization by presenting a review on the usage of the term.

This article also pursues to define the term productization in the context of product development. The key focus is to give the term a standardized meaning and open the academic discussion on the use of the term. Currently, the writers argue, that the term is used in different context without appropriate definitions. The definition of productization is also elaborated by demonstrating the use of a productization process in the development of portable fuel cells.

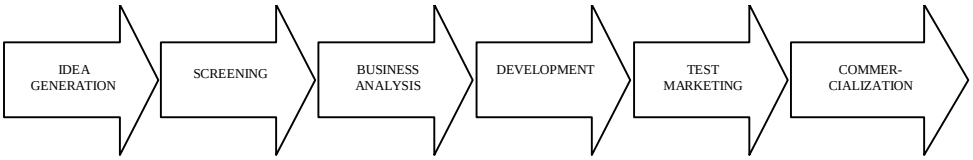
The paper is divided into six chapters. Chapter two will focus on elaborating the context of productization. The third chapter the authors will review the relevant literature and this is followed by a definition of productization in chapter four. Chapter five will present the productization case study and chapter six will make a summary of the paper.

2 Context for Productization

By the Oxford dictionary, a product is defined as "an article or substance that is manufactured or refined for sale". While Parkin [1] defines goods and services as all the things that we value and are willing to pay for, we can to some degree accept that product is a good or a service. By definition it's now understandable that product development strives to develop a good or service for sale by refining or manufacturing an article or substance. With these definitions we try to assess what the term *productization*, which is clearly derived from the word product, adds to previously used terms.

In this paper, we argue that productization is more than commercialization or new product development. The argument is made by analyzing the definition of commercialization, NPD and showing that this new term can be seen as helpful. The Dictionary of Business and Management defines commercialization[1] as the stage in the development of a new product during which a decision is made to embark on its full-scale production and distribution. NPD[2] is defined as "a marketing procedure in which new ideas are developed into viable new products or extensions to existing products or product ranges". In these definitions, commercialization is defined as a part of NPD. When defined as a graphical definition in Figure 1, it can be seen that commercialization can be defined as the last phase of a NPD process.

Figure 1 *New Product Development, Adopted*[1]



This definition implies that a new product can be developed to a prototype phase without commercialization. Only if a new product development process completes test

[1] The stage in the development of a new product during which a decision is made to embark on its full-scale production and distribution. "commercialization" *A Dictionary of Business and Management*. Ed. Jonathan Law. Oxford University Press, 2006. *Oxford Reference Online*. Oxford University Press. Turku University. 6 February 2008 http://www.oxfordreference.com/views/ENTRY.html?subview=Main&entry=t18.e1274

[2] "new product development" *A Dictionary of Business and Management*. Ed. Jonathan Law. Oxford University Press, 2006. *Oxford Reference Online*. Oxford University Press. Turku University. 6 February 2008 http://www.oxfordreference.com/views/ENTRY.html?subview=Main&entry=t18.e4333

marketing process successfully, commercialization is viable. We argue that, in a broad sense, commercialization should be an active part of NPD process, done in parallel with technical development aspects.

When attempting to define NPD we understand it to be a process which starts from ideas and ends on a viable product. This process can be phased differently depending on the process model used. In contrast, NPD can also be looked as a set of activities that lead to a successful product. Cooper and Kleinschmidt [2] analyzed activities found to be common in NPD projects. They found that most projects used, even though systematic processes are in use, apply only a fraction of the tasks seen as possible in the process. With this it can be concluded that reality differs from an academically written "ideal model" substantially. It also suggests that activities and processes are different between companies. While it has been seen that companies use different activities in their processes, the need for a blueprint for NPD is apparent. [2, 3].

While understanding that NPD is a process that consists of activities that lead to a viable product and that these activities are different between companies, we strive to find the key activities that make or break the project. On several occasions Cooper and Kleinschmidt [2, 4] have demonstrated the key activities separating winners from losers. Cooper demonstrates these as a list of thirteen key activities [4]. Literature regarding the factors found to drive NPD success has been also reviewed and analyzed by Montoya and Calatone [5].

Calatone, Vickery and Dröge [6] have later pointed out that it is however possible to construct a framework of success that is industry specific. It has been seen that when analyzing a specific industry, top performers put strategic emphasis on eight activities. These are customization, new product introduction, design innovation, product development cycle time, products technological innovation, product improvement, new product development and original product development [6].

In a series of two articles published in 1984, Cooper also points out that NPD success and strategy can be linked [7, 8]. From 19 strategy dimensions Cooper formed "clusters of companies that have similar strategies". As a result five distinct strategy types were found: 1) The Technologically Driven Firm, 2) The Balanced Strategy Firm, 3) The Defensive, Focused, Technologically Deficient Firm, 4) The Low-Budget, Conservative Strategy and 5) The High-Budget, Diverse Strategy. Through the concept of these strategy models Cooper showed that companies with a balanced strategy, which combine strong technological capabilities with a strong market orientation, achieved exceptional results in NPD processes. [8]

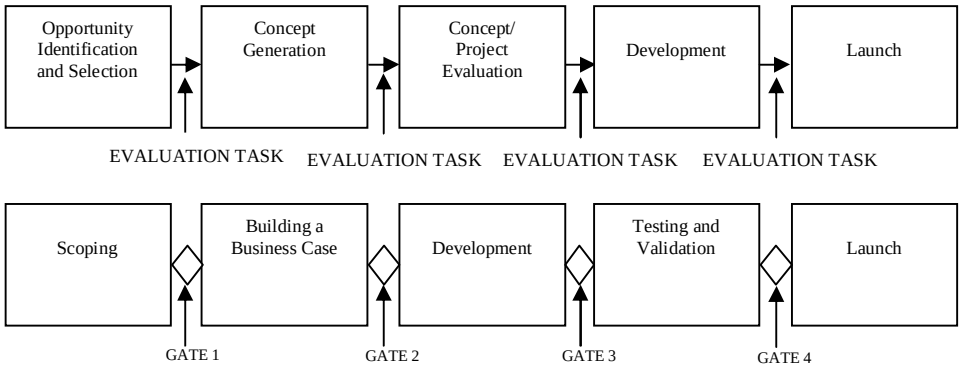
Paladino [9] has approached the NPD success and strategy through companies' market and resource orientation. Paladino found that companies with a strong resource orientation enable the company to provide the customer with a product that is valuable to the customer. Resource orientation is related significantly and positively, among other factors, to NPD success. On the other hand, strong market orientation enables the development of products that fit the customer better. It is obvious that a strong positive correlation to customer value is found with market orientation. In addition to this it was

found that market orientation was significantly and positively related, among others, to overall performance. [9]

Although in this paper NPD is approached from an activity point of view, it is important to note that these activities and orientations form a process. NPD discipline has gathered a substantial amount of scholars researching different types of processes. As in all actively researched subject's, there has been different views on and evolution in regard of these processes. From the first-generation linear and static models like Phase Project Planning developed by NASA in the 1960's we have moved towards wider and less functional processes [10]. Processes which are recursive or chaotic have been emerging to offer alternatives to the traditional linear processes [11]. Cooper [10] has also pointed out that formal stage-gate systems are evolving to the third-generation processes. Even in the second-generation new emphasis points such as cross-functionality and Marketing and Manufacturing was pointed out. In the third-generation process efficiency aspects are added to the mix. [10] When defining today's Stage-Gate Cooper [12] emphasizes loops, iterations, parallel activities and overlapping activities inside stages.

Although we have been presented with various different aspect and ways to manage the NPD process, it can be seen as containing several distinctive parts. These are presented in Figure 2 and also outlined by Crawford & Di Benedetto [13] and Cooper [4]. This distinctive sectioning is going through an evolution to the “third generation” processes also described by Cooper [12].

Figure 2 *New Product Process, Adopted [13, 4]*



Buijs [14] pointed out that the concept of developing a new product has two very different aspects, these were the engineer perspective and commercially oriented point of view. As Buijs writes "There was little or no contact between these two worlds - the engineers were talking about the product creation process; the marketeers were talking about new product development." [14] This bipartition can still be seen in the definition of NPD, described earlier in the text. By definition NPD is a marketing procedure. It should be noted that for example Cooper [12] points out that Stage-Gate system is not an R&D or a marketing process. The process is strictly a business process. It is however still

clear that in many countries where NPD is engineer driven, a clear bipartition exists. Productization as a term hopes to integrate these two subjects.

3 Literature review on Productization

To our knowledge there has been only one literature review on productization made by Simula, Lehtimäki & Salo [15]. We have attempted to update and complement this work. Our literature review has attempted to find relevant literature, which would contribute to the definition of the term productization. We are focusing on the use of the term in the context of product development, innovation, organization and commercialization. Literature referring to productization is presented in Table 1.

Although the term productization, or productisation, has been used in literature widely it isn't an official word in the English language. For example the Oxford Dictionary of English doesn't recognize either one of the terms productization or productisation. In the scientific literature there have however been a few attempts to define productization. Rautiainen, Lassenius & Vuornos [16] have defined, in the context of software development, productization process as a product release process. They make the argument that product development process is a part of the productization process; clearly indicating that productization is something more than just developing new products. Hietala, Kontio, Jokinen & Pyysiäinen [17] have also defined productization in the software context. They are referring to productization as "standardization of the elements in the offering". If we understand that Hietala *et al.* [17] use the term offering as product launched to the market, we can, to some extent, find similarities in product release process and the term offering. Alajoutsijärvi, Mannermaa & Tikkanen [18] have had similar understanding of the term productization. They have used the term in the context of software marketing. Although not actually defining the term they suggest that productization as a concept makes a change from "unique service-intensive customer projects" to standardized mass market products. In the context of software, the earlier mentioned definitions are in our opinion summed up by the definition used by Lassila, Jokinen, Nylund, Huurinainen, Maula and Kontio [19]. They use the term productization to describe "the degree of standardization".

As well as in software, the term productization has also been used in relation to other fields of business and development. Ojanen, Salmi & Torkkeli [20] have used the term in the service industry. They refer to the work of Vaattovaara [21] in their definition of productization of professional services. They point out that even though service is seen as a unique event, there can be substantial advantage gained from productization of service. They see productization as, yet again, standardizing the parts of a service that aren't unique and re-using them in new service projects. Baines *et al.* [22] use the term productization in the context of services. They see productization as an evolution of the service component. In this a product or a new service component is included in an already existing service component. These together are marketed as a new product.

Tiensuu [23] has also used the term productization in the service domain. Tiensuu sees productization as an innovation process, where ideas are transferred to the form of sellable product concepts. Simula et. al. [15] have been one of the first to broaden the scope of productization from the software and service domains to describe the "complimentary tasks and activities a firm should perform in order to perform real value to customers".

Nr.	*Definition*	*Context*	*Reference*
1	"...process can also be called 'productization,' which refers to the process of analyzing the needs of customers in the target market, designing the product and developing the ability to produce it (Flamholtz and Randle, 2000)." *Refers to Flamholtz, E. and Randle, Y. (2000) Growing Pains: Transitioning from an Entrepreneurship to a Professionally Managed Firm. Jossey-Bass, San Francisco, CA.*	Competitive Advantage	Searching for Competitive Advantage in the Black Box, Flamholtz, E.; Hua, W.; European Management Journal, Volume 21, Issue 2, April 2003, Pages 222-236 Organizational success and failure:: an empirical test of a holistic model, Flamholtz, E.; Aksehirli, Z.; European Management Journal Volume 18, Issue 5, October 2000, Pages 488-498
2	"In the final stage called productization a series of deliverables are produced to ensure effective reuse of the component in different (both FPGA and ASIC) target technologies. The main goal of productization phase is to define all deliverables that are necessary to make the use of the virtual component in the larger design easy."	Hardware development	A systematic development of virtual components compatible to standard ICS (An industrial experience), Bandzerewicz, M.; Sakowski, W.; Wrona, W.; The International Workshop on Discrete-Event System Design, DESDes'01, June 27-29, 2001, Poland.
3	productization – as a phase in process	Hardware development	Automation of user-specific ASIC library development, Kurosawa, A.; McNelly, A.; ASIC Conference and Exhibit, 1991. Proceedings., Fourth Annual IEEE International 23-27 Sept. 1991, Page(s):P14 - 7/1-5.
4	"It is understood that much of the RED in our fabs today is driven not only by our current internal factory manufacturing methods but also by our product portfolio selection, product sign, Introduction productization and equipment selection"	Hardware development	Semiconductor business, process, product and fab influence on throughput, cycle time and chip cost Kraft, C.; Advanced Semiconductor Manufacturing Conference and Workshop, 1996. ASMC 96 Proceedings. IEEE/SEMI 1996 12-14 Nov. 1996 Page(s):119 - 139
5	"The R&D projects results exploitation which includes the Productisation making commercial products from R&D prototypes and the business integration processes innovation planning and deployment processes ..."	Innovation	The advanced information technology innovation roadmap, Segarra, G.; Computers in Industry, Volume 40, Issues 2-3, November 1999, Pages 185-195

6	"One of the main challenges of project management is the minor and tangled accumulation of knowledge. The content and quality of the knowledge created vary, as well as the ability of organisations to utilise it. In this study, knowledge management in a project is considered to consist of four groups of activities: 1. Knowledge creation, for example collection, combination and refinement. 2. Knowledge administration, for example storage, organisation and retrieval. 3. Knowledge dissemination within and outside the project. 4. Knowledge utilisation and productisation, for example integration into products and decisions, and application in other projects."	Project Management	Managing knowledge and knowledge competences in projects and project organisations, Kasvi, J J J.; Vartiainen, M.; Hailikari, M.; International Journal of Project Management, Volume 21, Issue 8, November 2003, Pages 571-582
7	"Productization Stage - Produce marketable (internally or externally) product. Focus on documentation, training, port to production environment. Variable duration depending on product size. "	Knowledge-Based System Development	The LQMS research project: a case study in knowledge-based system development O'Neill, D.M.; Mullarkey, P.W.; Gingrich, P.C.; Managing Expert System Programs and Projects, 1990. Proceedings., IEEE Conference on 10-12 Sept. 1990 Page(s):61 - 69
8	"A second task facing the organization involves 'productization' - the process of analyzing the needs of current and potential customers in order to design the products or services that will satisfy their needs. "	Organization	Managing organizational transitions: implications for corporate and human resource management, Flamholtz, E.; European Management Journal, Vol. 13, No 1, 1995, Pages 39-51.
9	"The second challenge or strategic building block involves the development of products and/or services. This process can also be called 'productization,' which refers to the process of analyzing the needs of customers in the target market, designing the product and developing the ability to produce it. "	Organization	Strategic Organizational Development and the Bottom Line:: Further Empirical Evidence, Flamholtz, E.; Hua, W.; European Management Journal, Volume 20, Issue 1, February 2002, Pages 72-81
10	"One possible approach for providing IP is to start development from existing modules, which requires productization of these modules to reusable cores."	Product Development	Design methodology for IP providers, Haase, J.; Design, Automation and Test in Europe Conference and Exhibition 1999. Proceedings 9-12 March 1999 Page(s):728 - 732
11	"The motivation of this paper is to broaden the perspective beyond the product development per se and to pinpoint those complimentary tasks and activities a firm should perform in order to provide real value to customers. We introduce term productization to describe those activities. "	Product Development / Innovation	Re-thinking the product: from innovative technology to productized offering. Simula, H.; Lehtimäki, T.; Salo, J.; Proceedings of the 19th International Society for Professional Innovation Management Conference, June 15-18 2008, Tours, France.
12	"In essence, then, you have the formation of a team whose sole purpose is to carry a program/project/product from development	Product Develpment / Organization	Matrix Management a Primer for the Administrative Manager Wright, Norman H.; Engineering

	through "productization""		Management Review, IEEE Volume 10, Issue 3, Sept. 1982 Page(s):65 – 68
13	"The main objective of productization is therefore utilizing and re-using the know-how that has been gained from previous projects. "	Service Products	Innovation Patterns in KIBS Organizations: A Case Study of Finnish Technical Engineering Industry, Ojanen, V.; Salmi, P.; Torkkeli, M.; System Sciences, 2007. HICSS 2007. 40th Annual Hawaii International Conference on Jan. 2007 Page(s):228b - 228b
14	"Similarly, 'productization' is the evolution of the services component to include a product or a new service component marketed as a product. "	Service Products	State-of-the-art in product-service systems, Baines, T S.; Lightfoot, H W.; Evans, S.; Neely, A.; Greenough, R.; Peppard, J.; Roy, R.; Shehab, E.; Braganza, A.; Tiwari, A.; Alcock, J R.; Angus, J P.; Bastl, M.; Cousens, A.; Irving, P.; Johnson, M.; Kingston, J.; Lockett, H.; Martinez, V.; Michele, P.; Tranfield, D.; Walton, I M.; Wilson H.; Engineers, Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture Volume 221, Number 10 / 2007 Pages 1543-1552
15	"Thus, 'new' new product development process has been proposed (Kim, 2006 **Authors note: Referenced in the original source**). The first stage is the development of a dramatic technology, the second stage is the timely 'productization' and the third stage is directly launching the 'new' new product in the market without test marketing as 'Time-to-market' strategy."	Service Products	A feasibility test model for new telecom service development using MCDM method: A case study of video telephone service in Korea Expert Systems with Applications, Oh, Y.; Suh, E.; Hong, J.; Hwang, H.; In Press, Corrected Proof, Available online 22 July 2008
16	"The product release process is the productization process, in which all stakeholders contribute to making a product release. The product development process is part of the product release process and comprises the software engineering efforts done by the R&D team. "	Software Development	An experience in combining flexibility and control in a small company's software product development process, Rautiainen, K.; Vuornos, L.; Lassenius, C.; Empirical Software Engineering, ISESE 2003. Proceedings. 2003 International Symposium on 30 Sept.-1 Oct. 2003, Page(s):28 - 37
17	"We developed guidelines with our experience and domain knowledge in the digital AV domain mainly focused on reusability, maintainability and flexibility. We believe that concrete design principles and guidelines can significantly enhance those attributes in the productization. "	Software Development	Building Software Product Line from the Legacy Systems "Experience in the Digital Audio and Video Domain", Kim, K.; Kim, H.; Kim, W.; Software Product Line Conference, 2007. SPLC 2007. 11th International 10-14 Sept. 2007, Page(s):171 -

			180.
18	"Productization means standardization of the elements in the offering. The term productization includes several technological elements from the very early stages of designing a product (i.e., managing requirements, selection of technological platforms, design of product architecture etc.) to the commercial elements of selling and distributing the product (i.e., delivery channels, positioning of the product and the company, and after sales activities)."	Software Development	Challenges of Software Product Companies: Results of a National Survey in Finland, Hietala J.;Kontio, J.; Jokinen, J-P.; Pyysiäinen, J.; 10th IEEE International Symposium on Software Metrics (METRICS'04), 2004, Page(s) 232-243.
19	"We are using the term "productization" in this report to refer to the degree of standardization..."	Software Development	Finnish Software Product Business: Results of the National Software Industry Survey 2006, Lassila A.; Jokinen J-P.; Nylund, J.; Huurinainen, P.; Maula, M.; Kontio, J.; Centre of Expertise for Software Product Business 2006
20	"Last phase of Extreme Programming..."	Software Development	Integrating business and software development models, Wallin, C.; Ekdahl, F.; Larsson, S.; Software, IEEE Volume 19, Issue 6, Nov.-Dec. 2002 Page(s):28 - 33
21	"Based on the resulting pilot solution, the Productization stage can be entered. The pilot solution will be further developed by the responsible business partner to a commercial product complete with product documentation, marketing material, price, training, support etc."	Software Development	Three aspects of successful software development projects "when are projects canceled, and why?" Wallin, C.; Crnkovic, I.; Euromicro Conference, 2003. Proceedings. 29th 1-6 Sept. 2003 Page(s):368 - 374
22	"...productization typically includes a shift from unique service-intensive customer projects towards tangible standardized products aimed at international mass markets."	Software marketing	Customer relationships and the small software firm: A framework for understanding challenges faced in marketing, Alajoutsijärvi, K.; Mannermaa, K.; Tikkanen, H.; Information & Management, Volume 37, Issue 3, 1 April 2000, Pages 153-159

Clearly a process view of productization is presented in the work of Flamholtz [24] and Flamholtz and Aksehirli [25]. They have used the term to describe a process where customer needs are analyzed, the product is designed and the ability to produce it is developed. This productization process can be seen as having similar process steps as in a NPD process. Other scholars on the other hand see productization as a part of the process on developing new products. For example O'Neill, Mullarkey and Gingrich [26] see productization as being as stage where the marketable product is produced. They see it as stage where focus is given to "documentation, training, port to production environment". With this we can understand it being a market launch stage. This is quite similar to the point of view presented by Wallin and Crnkovic [27] as they see the productization as a

stage which is entered after a successful pilot solution is made. In this stage the pilot solution is further developed. Similarly to the view of O'Neill *et al.* [26] the product is completed with "documentation, marketing material, price, training, support, etc."

Productization is, in addition to the definitions given above, used as a term without a clear definition in several papers. There are also several papers where the definition isn't given, but the reader is given an idea of the context of the use. The terms however are only used in individually with no definite context so they are not included in this review.

4 Defining Productization

We define the term as a *standardized process which aims to produce a high quality commercial good or service viable in the market from produced information.* We argue that productization as a process adds value as a dynamic capability[1] by exploiting company specific cross-functional resources at an early stage to the NPD project. These can be seen by the emphasis of commercial and technology driven aspects in the project. Productization, as it is defined in this paper, emphasizes quality, customer demand and market orientation throughout the process. The focus is on complementing a technology based NPD processes with a value-creating productization strategy. The emphasize points in productization can be derived from the definition. These are:

- Starting from produced information.
- Product is viable in the market.
- Product is of high quality in relation to the cost.
- Product is the result of a standardized process.

In our context, the starting point to productization is produced information. This doesn't exclude reuse of earlier information, but has a definite focus on new exploratory technology. If thought from the point of Entrepreneurial strategies view [31], productization could be seen as being an innate capability to companies that strive to "being fustest with the mostest".

The very foundation of productization is created by thoroughly enhancing and upgrading the emerged idea. The idea and innovativeness of a product plays a crucial role in the success of the product. Products with mediocre innovativeness are the least successful products in the market [32]. Products innovativeness, and hence its viability, is analyzed within productization from two points of view. These follow the distinction

[1] Mäkelä [28] has argued that productization, in the context of software, can be seen as a dynamic capability. We are expanding the argument to electronics as well. Dynamic capabilities, as the term is used in this context, follow the definition that dynamic capability is a routine that uses resources to create new forms of resources which can address the changes in the environment. [29,30] Dynamic capabilities can be seen as the driving force of new competitive advantage.

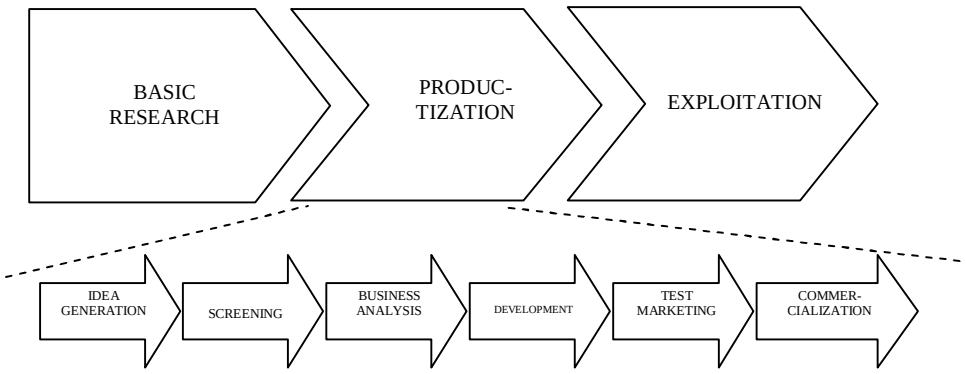
made by Buijs [15], who pointed out there are two distinct points of view in NPD. A clearly market and customer orientated view and technology driven point of view. The need to tackle NPD at an early stage from both of these viewpoints is emphasized in a rapidly developing market, such as most markets are. The need to take immediate use of emerged new technology and service opportunities, without the possibility of performing a traditional market studies, is important. This emphasizes the use cross-disciplinary teams, also emphasized by Cooper [10], and the need to learn to work with uncertainty.

Uncertainty can be seen as an information defect, in the sense that there isn't enough information to complete a specific process [33]. In NPD, uncertainty is seen as a daily problem and the decision making process under uncertainty has been widely researched [34, 35]. Mullins and Sutherland [36] have researched NPD in rapidly changing markets. They specifically studied the telecommunications market but to some extent we can generalize their results to the electronics field. They found that a manager in NPD processes generally struggled with three different types of uncertainty: First they found that potential customers have a difficulty in articulating their needs. With the rapid advancements in technology it is increasingly difficult for the customer to see the possibilities of the technology. Secondly, managers are uncertain in the means of modifying the new technology in to viable products. Thirdly this uncertainty effects the higher level decision making process, as it is hard for assess the amount of investment made to a specific new technology. With the productization process, new scientific information is molded to a form that is more suitable for commercial use by a cross-disciplinary team. Marketing involvement at an early stage help in articulating customer needs, technological molding is done by engineers and industrial designers. Produced information is summarized to serve the needs of higher level decision makers.

High quality is something from which the customer is willing to pay [31]. Productiziced product is defined to be of high quality and as such it should include something the customer is willing to pay extra for. The rapid introduction of new cycle has shortened the time of product development. This has cumulated to a smaller window for product testing time. At the same time, we have seen an increase in corporate responsibility for products as extended warranty times. This creates pressure for the development process to use rapid testing methods, done continuously during development [37] to insure good technical quality and avoid the need for after sales services. So in addition to the high quality that Drucker [31] referred to as being something customers would pay extra, there is a bottom line effect to quality as well. Productization aims at molding the produced new technological information in a way that the negative bottom line effect is minimized.

If we look at purely the innovation process as a standardized process, we see that it can be divided into three domains. These are producing scientific and technological

Figure 3 *Productization in the innovation process in the context of NPD*



information, molding information to a form of a product, and responding to the demand on the market [38]. If we simplify these three points to basic research, productization and exploitation, we suggest that productization can cover the "molding information to a form of a product" domain. The innovation process can be described as a pipeline where new scientific knowledge is transformed to commercial goods. This pipeline, first drawn by a technology expert at Tekes (The Finnish Funding Agency for Technology and Innovation), can be seen in Figure 3. It illustrates in a simplified way the value of productization in the innovation process

Figure 3 is also complemented by illustrating, how NPD would be situated in the productization definition. Our view is similar to the view of Rautiainen, Lassenius and Vuornos [16], who also argue that productization includes NPD. We make the argument that NPD is only a part of productization.

The definition presented in the paper is to some extent similar to those presented earlier by other scholar. Similarly as Tiensuu [23] we see that productization has a role in the innovation process. We on the other hand emphasize that productization doesn't form the whole innovation process. Our arguments view of productization has also similarities with the work of Flamholtz [24] and Flamholtz and Aksehirli [25]. In our work we also have an idea of productization as a process. This process is later described through the case study of productization of portable fuel cells.

5 Case Study: Portable Fuel Cell Development

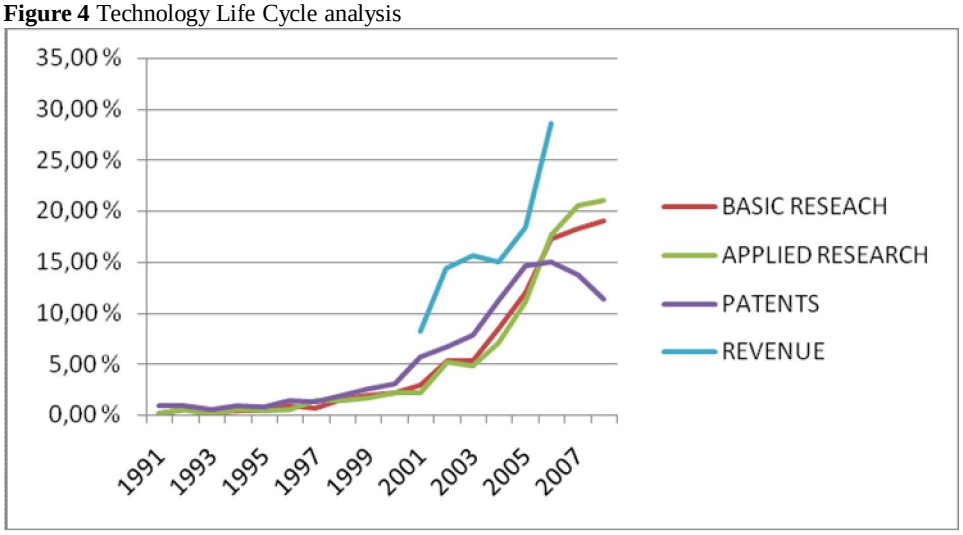
The ever increasing climate change is driving the transition towards alternative solutions in energy production. One of these alternative solutions is to use fuel cell technology in replacing more CO_2 intensive energy production methods. To this goal, much effort and funding has been given in recent years. Large scale government funded programs in Europe, Asia and US have been started. As an example of this is the EU 7th framework program fuel cell and hydrogen development.

Fuel cell was presented by Christian Friedrich Schönbein in 1830's. After the concept was presented the first demonstrational model was produced in 1840's. Since

these breakthrough developments it took significant time for the technology to gather significant interest by scholars. The first commercial fuel cells can be said to be used in the US space program. Recent developments, most significantly in the efforts on reducing CO_2 emissions, have made fuel cells a viable choice as an energy producing technology. However it is noted that it is unlikely to replace other technologies in the near future. Fuel cells are seen as complementing the existing technology. [39]

In assessing the possibilities of the technology we can to some extent rely on a bibliographical evaluation on the possibilities of the technology. Watts and Porter [40] has presented a Technology Life Cycle model to give an insight to this. If we use this to analyse the development in fuel cells, we can present a figure such as Figure 4. In the Figure 4 the evaluation has only taken into consideration fuel cells that use methanol as a fuel, but it can be seen as giving an assessment for the technology as a whole.

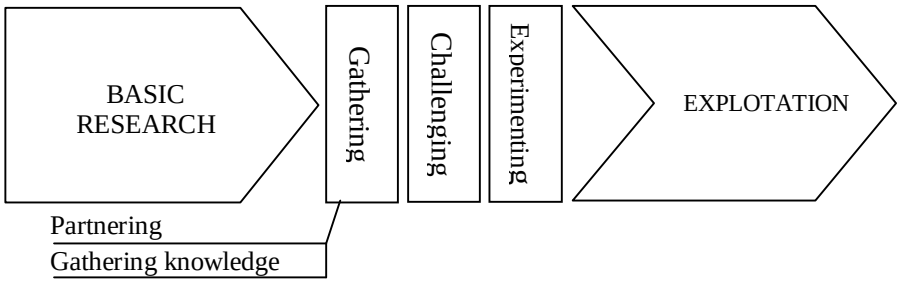
Figure 4 Technology Life Cycle analysis



As seen in Figure 4 development efforts in the recent years have increased in numbers. In all measurable values, which include basic and applied research, patents and revenue gained we see a strong increase. This gives a strong indication on fuel cell development. The development is seen as facilitating also commercial exploitation and as such the efforts to productize the technology have been started.

With the above mentioned understanding a fuel cell productization process was started in the University of Turku in late 2007. The goal was to develop and productize a fuel cell in the range of 1 W- 100W. The project was funded by The Finnish Funding Agency for Technology and Innovation and industry partners. As a starting point, as seen in Figure 3, the basic research done was set. This was done by gathering as partners and knowledge significant to the subject field. This can be seen in Figure 5.

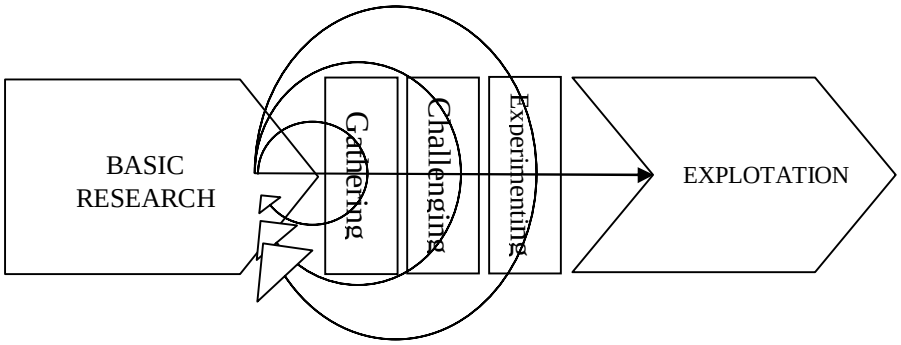
Figure 5 Productization process



The process described, starting from gathering followed by challenging and experimenting, are based on Learning Capacity (LC) described by Day & Schoemaker [41]. LC is characterized by Day and Schoemaker as having three distinguishable points: “Encouraging openness to Diverse Viewpoints”, “Challenge the Prevailing Mind-Set” and “Continuous Experimentation”.

However the process is not seen as being linear. The process has an iterative process with several links to basic research before ending in the end result. As such Figure 6 gives a better understanding on the process.

Figure 6 Productization process with feedback



In order to understand how the productization process presented differs from tradition NPD development process presented in Figure 1, we argue that the tasks mentioned are done in parallel and as such adding value to traditional NPD processes. We divide the steps taken in parallel, involving commercial and design aspect at an early stage to the development. In the presented case study, these aspects were added already in the applied research stage.

The project group working on the research project was gathered so that three key aspects seen as important to productization were to be covered. These areas of focus were

commercial, technical and design aspects. The group was formed on the basis of having one principal researcher on technical aspects and on commercial aspects. There was also active involvement on design aspect. These were however outsourced. In addition to the principal researcher there were assistants hired for both commercial and technical research work. The work of the group was managed by a management group formed from the funding partners. This cross-functional team was seen as facilitating the diversity of viewpoints mentioned by Day and Schoemaker [41].

As a requirement for the human resource hired for the project specific knowledge on fuel cells was not seen as a prerequisite. Knowledge on basic economics in the commercial research and chemistry and electronics was seen as important, but specific knowledge was seen as constricting. It was seen that the ability to "Challenge the Prevailing Mind-Set" was lost if the researcher has significant amount of knowledge before the project started.

Project steps

After the research group was formed the project started with a knowledge gathering period. Basic restrictions for the type of fuel cell were given for the purpose of focusing the gathering efforts. The efforts were focused on developing a fuel cell which would be

- Active or passive PEM (Polymer Exchange Membrane) fuel cell,
- Hydrogen or methanol fuelled
- Portable in the range of 1 W – 100 W

The decision on the context of the research was made while applying for the project in the basis of the current knowledge at that time. Project group hoped to take into consideration the constraints given by physical and knowledge restrictions.

The commercial research focused on gathering knowledge on the current status of the fuel cell market. The process was mostly done by launching a Delphi study [42] on the future development of fuel cells. To complement the Delphi effort studies on venture start-ups and patents was conducted. This was seen to gather significant amount market knowledge. Technical focus was put to gathering knowledge on the restrictions by technology. This was seen as important in defining the scope of development.

After the first round of gathering information, gained knowledge was challenged and experimented on. The groups' knowledge on chemistry and electronics gave several points of interest which challenged the prevailing mind-set. After several experiments on the first round of commercial research results the group narrowed its scope on

- A passive PEM fuel cell,
- Using methanol as a fuel,
- In the range of 1 W – 5 W.

The scope was narrowed in the basis of knowledge gathered from different point of view. From a technical aspect, researcher found that as a starting point PEM technology

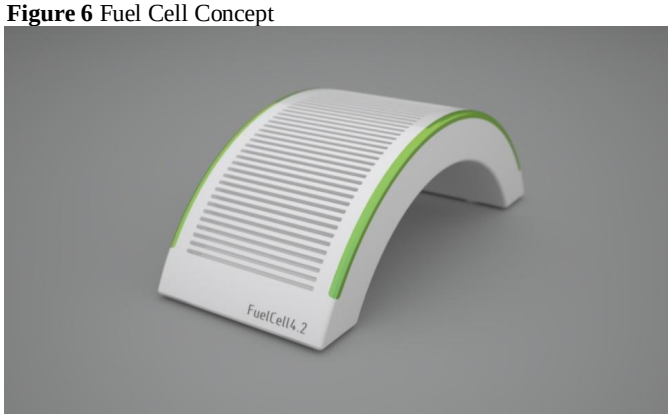
was one of the possibilities for portable solutions. A low operating temperature was one of the deciding factors for the technical researchers. From a technical point of view the possibility of using a liquid fuel was seen as a easy starting point, while keeping options open for the possibility of a hydrogen based end product. The commercial aspect narrowed the scope of the research in its power range. Through the first round of the Delphi study, it was apparent that a solution in the range of 1-100 watts was an unlikely product. There was however possibilities seen in a smaller scale. The increasing ubiquitous electronics require a small but efficient energy source. Although it was pointed out that fuel cells are just one possibility with its own pros and cons, but the wide range of future ubiquitous electronics was seen as facilitating niche fuel cell solutions.

After the scope of development was narrowed a second iteration round was started. To this round also the early involvement of an industrial designer was taken. The decision was made that with this round a proof of concept model was to be produced based on the cumulated knowledge. It was also seen as important to identify in an early stage the possibilities of beyond state of the art development.

With the above mentioned emphasis the group focused on furthering the project towards a tangible product. Commercial focus was given in identifying the key factors inhibiting the wide range application of portable fuel cells as well as commercial applications of portable fuel cells. It was seen that the immaturity of the technology and as well the first fuel cell bubble 15 years ago effected to the market penetration of the technology. It was also seen that effort of using fuel cells for everything and not to specific applications had a negative effect in the way the technology was seen. Commercially the project was directed towards pointing out the need for a niche application. From a technical point of view the researchers focused on a solution which would be easy an inexpensive to manufacture. The researchers pointed out that the group had possibilities moving beyond the state of the art by taking advantage on their cumulated knowledge on electronics and manufacturing. This was seen, however, to ever narrowing the end result to a disposable small energy source which could be used for future ubiquitous applications.

The second round of the process ended at a proof of concept model seen in Figure 7 being presented in FC EXPO 2009 in Japan. The proof of concept is a passive direct methanol fuel cell with the nominal power 3 watts. It’s based on a unit bi-cell configuration which is inexpensive to manufacture and has only limited control electronics. The designer took advantage of the freedom given by a strip solution in comparison to the constraints of a fuel cell stack

Figure 6 Fuel Cell Concept



In the development efforts the cross-functionality in the group had substantial effects on the direction of the work. Active dialogue between technical, commercial as well as design aspect in a early stage promoted rapid results. In the course of the development project, the ability to "challenge prevailing mind-sets", as there wasn't fuel cell experts in the group, produced a novel fuel cell membrane electrode assembly and a novel solution for condition monitoring of fuel cells. The development project is further continued by designing a manufacturing process for the developed cell type and working on the reproducibility and reliability of the fuel cell.

6 Conclusions

Since 2004 the Electronics Productization Research Group has worked on defining the term productization. While widely used in Finnish literature and to some extent to literature in general, the definition of the term isn't clear. In the context used in this work we focused on presenting the term as something larger as the concept of NPD, which is on the other hand widely used. Most significantly the authors see productization widening the concept of product development into contains a strong commercial and design aspect with the technical development efforts.

The authors presented a definition of productization as being a *standardized process which aims to produce a high quality commercial good or service viable in the market from produced information.* This was seen as a dynamic capability in which companies use their cross-functional capabilities in product development. The definition was seen as clarifying the wide scope of definitions given to the term. The definition is however seen from the point of view of a university research group and as such is seen as needing an industry view point. The authors to some extent also point out that the need for such a term can be made obsolete by focusing on developing the concept of NPD.

The usage of a productization process was demonstrated with a fuel cell development project. The benefits of cross-functionality was seen as producing rapid

results in the project, as the project produced a novel solution for a direct methanol fuel cell in the time frame of 2 years.

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