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AN APPROACH FOR A RECYCLING ORIENTED PRODUCT DESIGN

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1. Introduction

For the lasting entrepreneurial success product and process innovations are indispensable. Shorter innovation cycles, more complex products, higher customer requirements increase the pressure on enterprises to concentrate ever more on the development and realisation of sound and economically secure innovations. However, innovation includes however not only the generation of new product and process ideas, but concentrates much more on the successful implementation of the developed ideas. Therefore, innovations have to be always measured at the appropriate market success.
Although the importance of a company's ability and capability to generate innovations is widely acknowledged, innovation processes are often not seen as routine processes. The innovation process takes place beside the daily business, instead of being defined as a core process. Companies must meet the challenge to master the high technical and economic risk of an innovation and to use the chance offered by applying cutting edge concepts and technologies. However larger enterprises must also solve the problem of increasing the innovation outcome using the same R&D capacities.

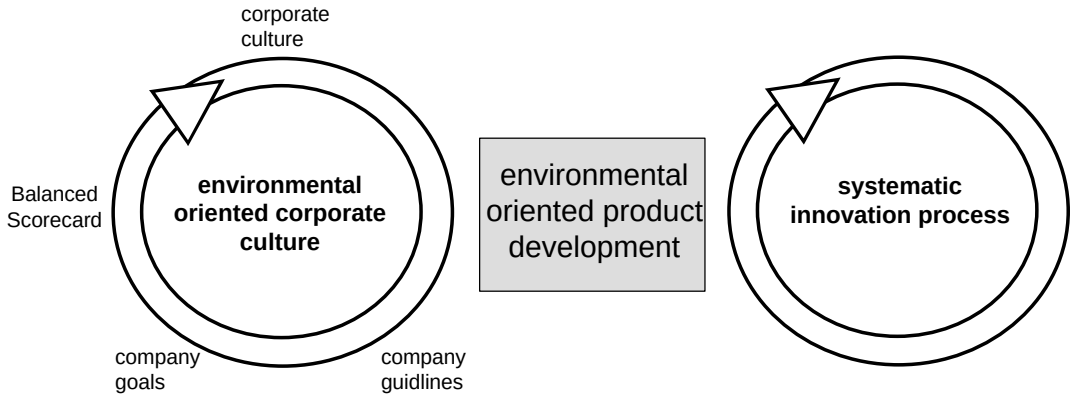

Figure 1. The basis for an environmental oriented product development: corporate culture and systematic innovation process

Of special interest is the electric and electronic industry. Electric and electronic products are an important part of everyday life and crucial to the quality of life we enjoy. These are on the one hand households appliances and consumer equipment and on the other hand products belonging to IT and telecommunication equipment with constantly increasing amounts due to the transition to an information society. Besides, the industry is characterised by shorter and shorter innovation cycles as well as by an increasing competition between enterprises. At the same time the life time of many

electrical products decreases. Here, economic and ecological challenges as well as new legislation can be used to implement new process and design strategies that have innovations as a major driver.
A fundamental precondition for the success of an innovation is a systematic methodology and the implementation of a defined innovation process into the enterprise. Further, for an environmental oriented product development an appropriate corporate culture has to be created (fig. 1).

2. Implementation of an environmental oriented product development

A corporate culture is the whole set of criteria, which contains the moral conceptions and conviction of the management and sets clear standards for its business behaviour. The corporate culture represents values and standards as well as knowledge and convictions, which influence the behaviour of the employees. A corporate culture cannot be given by management. However, how can a corporate culture be created, which embodies the environmental care and preservation of resources as an important value into the mentality of the employees?
A reasonable way to an environmental oriented corporate culture is the definition of a set of company guidelines. Company guidelines can be defined as fixed predicates to the basic purpose and the conceptions of the company. Therefore, all stakeholders should to be considered. Furthermore, environmental protection should be seen as an equivalent item as product quality, customer orientation and employees satisfaction. An example are the guidelines of the *Vorwerk* Company: "Environmental protection is for *Vorwerk* an independent company target. That means, that all management decisions are checked under the criterion of the environmental compatibility. *Vorwerk* intends to do more for the environmental care than the legislator requires. [...]"
Now, more precise company goals can be derived from the enterprise guidelines. In the next step differentiated goals for environmental oriented product politics and product development can be developed from these company targets. Their contents, their dimension and their degree of the achievement of goals should be specified. Thereby, the Balance Scorecard is an appropriate approach.
The basic idea of the Balance Scorecard is the implementation of strategic goals into the enterprise.
Financial characteristic figures are extracted from the company goals and are connected with non-financial characteristic figures to a holistic numbers system (fig. 2). This system contains four specific perspectives: Finance, business processes, customer, organisational development. Environmental oriented characteristic figures can be integrated into all of the perspectives. Examples for appropriate environmental oriented figures are the reduction of disposal costs or the reduction of energy consumption. In the next step the found characteristic figures must be broken down up to the smallest reasonable organisational unit in order to make the (environmental oriented) company goals transparency for the single employee. Furthermore, the Balance Scorecard can be combined with incentive systems, in order to evaluate and award the achievement of the goals.

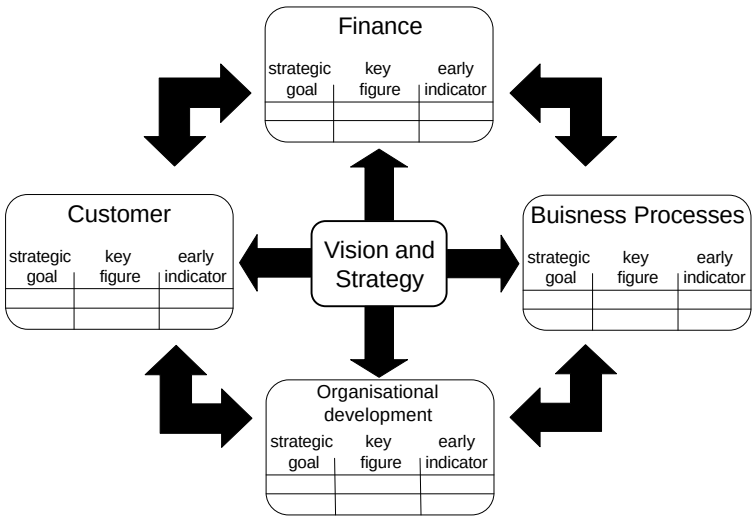

Figure 2. The perspectives of the Balance Scorecard [Kaplan, Norton 1997]

3. Innovation Process: The Five Steps to an Environmental Oriented Product

The other important item for the performance of a environmental oriented product development is the implementation of a systematic innovation process. As picture 1 shows an innovation process consists of five steps.

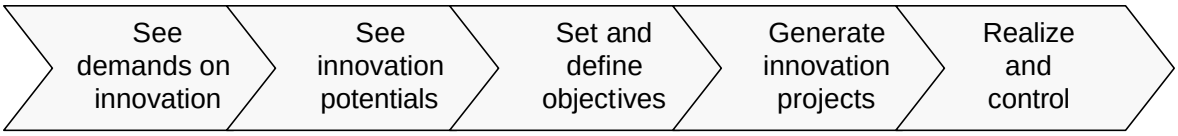

Figure 3. The five steps of the innovation process

3.1 See Demands on Innovation

Detecting the innovation requirement represent the beginning of the innovation process. Starting point is a problem, which results from the not fulfilled needs of the customers, from the general market and technology developments or the developments of the enterprise itself. The purpose of this phase is problem recognition, i.e. the perception of chances and possibilities to overcome it. The result does not necessarily have to be the definition of a concrete project idea, but the formulation of the scope of the problem which must be solved.

To identify innovation demands concerning environmental aspects an analysis of the demands within the company as well as an analysis of the market has to be performed. Over the last decade the importance of protecting the environment has come more and more into focus. Along with this growing understanding of the need to protect the environment has come the desire to move towards sustainable development. As a consequence, restrictions and environmental related legislation come more and more into force [Legener 1999]. Due to the nature of electr(on)ic products, aspects such as combination of different plastics, complex composite materials and new materials as well as increasing consumption of those products and a limited supply of natural resources and their related environmental challenges reflect in the current environmental legislation world wide. As figure 4 shows, the recycling oriented product development is addressed by four legislative initiatives.

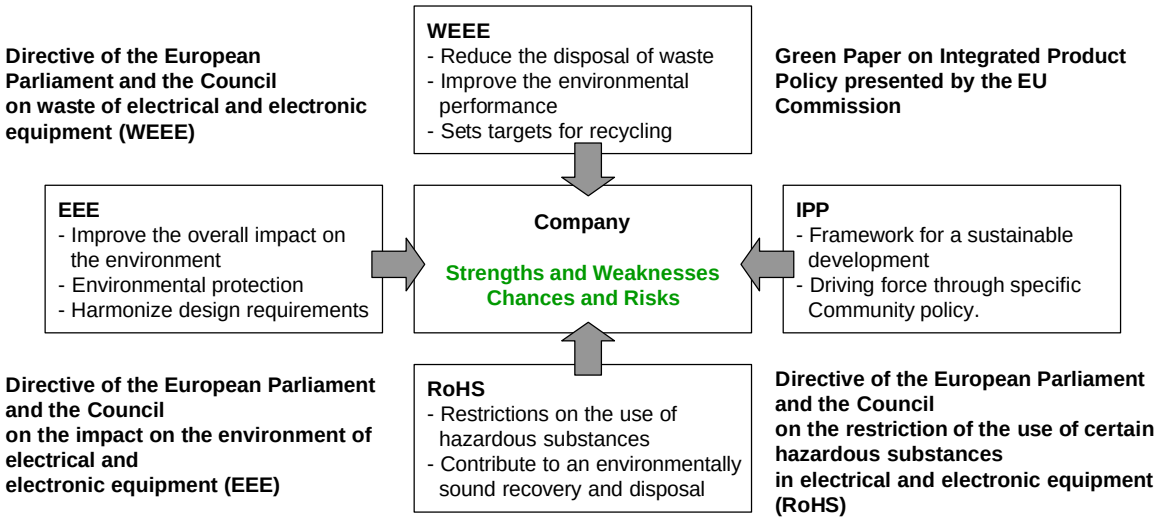

Figure 4. Changed legal settings in the electric and electronic industry

3.2 See innovation potentials

In this phase the analysis and evaluation of the detected innovation requirements take place. The evaluation criteria, which extensively describe the potential and the risk of the planned effort of innovation must be defined. The target is to filter the success-promising beginnings as early as

possible. The less promising alternatives are dropped. The evaluation is a function of the management and must be carried out very carefully, because false estimates can have an economic disadvantage for the enterprise. It is necessary to confront the identified requirements with the strategic orientation of the enterprise in order to concentrate on the innovation functions crucial for the long-term enterprise development. The potential and resources of the enterprise shouldn't be used for unimportant functions.
The problem perception as well as the potential evaluation are not included in the innovation process by many authors. However, they are an important and indispensable basis for the identification of ideas and the following work stages.

3.3 Goal definition and assessment method

In this phase the concrete goals and functions for the necessary research and development activities are to be formulated. This should be executed on base of an established analysis of the current situation. The purpose of this analysis is the definition of actions and measures for the enterprise, which are to be executed in order to fulfil the detected innovation requirements and potentials. The products, process and services should be evaluated regarding the strategic company targets defined by the management. Furthermore, these should be benchmarked against competitors products and if necessary against companies from other branches. The result is the definition of research and development targets, which form the base of a program planning. The detailing as well as the prioritisation of strategy and key projects take place afterwards, using a project roadmap. But attention has to be paid to the fact that apart from the product development process, service developments are to be started up.
The next step of the proposed process concerning environmental oriented innovations in the electric and electronic industry is to define the objectives and quantitative statement (if possible) that have to be achieved. This is the base for the assessment method used to determine the position of the company or of the companies products within the objective system.
For a qualitative recycling-oriented assessment suitable and relevant evaluation criteria must be selected. Due to the take-back obligation of the manufacturers and the involvement of the municipalities in the collection from private households, the improvement of the return system for waste products offers no competitive edge neither in Europe nor in other countries. Thus, the return system is not suitable for a evaluation criterion. Also, the basic recyclability of a product is only a weak competitive advantage, since this feature is increasingly expected by the consumer. Therefore, the high influence of the product design on the achievable recycling rate and end-of-life costs have to be considered. Furthermore, the evaluation of the basic recyclability has to be part of an assessment taking into account, that a process evaluation such as recycling rate and costs depends on real data. Therefore, these evaluation results are linked with an uncertainty. The used method is divided into [Hesselbach et al. 2000]:

3.3.1 Product assessment

Real data such as disassembly times or proceeds for secondary raw materials, which vary due to permanent market fluctuations, can contribute to uncertainty in the assessment results. The product assessment method presented aims to evaluate the basic recycling ability of a product. For this, the so-called recycling potential is determined using a multi-criteria product evaluation [Hesselbach et al. 2000]. This procedure evaluates product properties which are relevant for recycling and disassembly such as product structure, materials, joining techniques basing on a set of predefined criteria [Hesselbach et al. 1999].

3.3.2 Process assessment

A closed loop economy is aiming at a high recycling ratio and a maximum economical efficiency. The disassembly level describes the scale of operations in the disassembly process [Kang et al., 1999]. Components which can be recycled together are processed as recycling segments. The criteria for the determination of the disassembly level are the separation of toxic and pollutant substances, the

consideration of access restrictions as well as the comparison between disassembly costs and attainable proceeds for a reused part or a recycled material. The attainable proceeds require relevant information of the secondary raw material markets. Using the disassembly level, the recycling ratio can be determined as the weight fractions of the product which will be reused or recycled related to the total weight of the product.

3.3.3 Portfolio analysis

After the product and process performance assessment, the position of a product within the target system has to be determined.

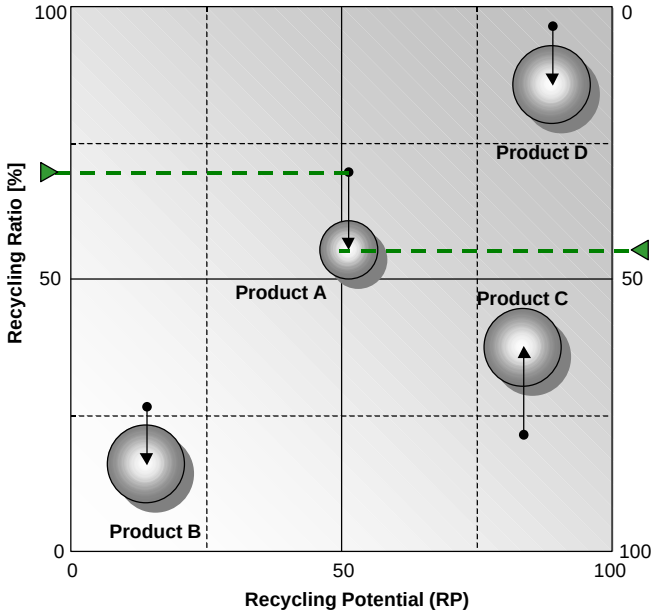

Figure 5. Recycling portfolio

The position of the company's products in relation to the competitor's products is of importance, as well. The recycling ratio and the recycling potential are factors of major importance, which are determined as aggregated results on the assessment level. The recycling ratio (RR) can be determined as the weight fractions of the product which will be reused or recycled (WR) related to the total weight of the product (WT). The recycling potential includes an evaluation of product properties which are relevant for recycling and for disassembly such as product structure, material, joining techniques, means for disassembly and reutilization properties basing on a set of predefined criteria.
Here, the portfolio technique offers the possibility to summarise and to represent the different evaluation dimensions within a model and perform a product benchmark [Legner, 1999]. Therefore, the recycling ratio and the recycling potential are represented as key factors in a co-ordinate system, in which the products can be arranged (fig 5). Additionally, the weight fraction of the analysed product can be represented by varying the diameter of the circle which represents the product's group [Hesselbach et al., 2000; Schlegelmilch, 1999].

3.3.4 Product process roadmap

Based on the performed innovation steps a combined product process roadmap can be developed. The roadmap should summarise the demands and potentials identified as well as goals derived from the assessment level presented above. All development goals for a new product generation should be transferred into the roadmap. The time axis should cover a long term strategic view.
With the proposed roadmap the transparency of further developments increases and interdependencies can be seen. The roadmap contributes to a process and project view instead of only a product view. Furthermore, the communication between the product and process development is supported.

3.4 Generate innovation projects

This phase starts with the actual creation of ideas, within a strategically limited field. The existing concepts resulting from the innovations demand, which were developed in the first phases of the innovation process, must be further prepared. Ideas for concrete innovation projects must be collected. However, the project ideas must have matured so far that they have strong economic and technological chances of success for the company. A differentiated success and investment calculation do not take place in this phase yet.

The development of new project ideas takes a high level of creativity. The idea identification during the creative phase can take place in two ways: intuitive or discursive thinking (fig 6). By intuitive thinking one understands excursive thinking flows. New ideas are developed subconsciously by associations, analogy formation, structure transferring and stimulation. They are perceived as sudden incident or thought lightning. Along the well-known brainstorming methods one can also use different creativity methods such as synectics, bionics, morphologic box or design guide. On the other hand discursive thinking can be defined by consciously dividing the problem into independent steps. These steps are solved separately. In this way existing solutions are questioned and thinking blockades are dismantled. Examples of creativity methods, which support discursive thinking, are TRIZ or lateral thinking by de Bono. An extensive collection of creativity methods is in [Schlicksupp, 1999].

The idea collection with the help of intuitive thinking is suitable in the case of the environmental oriented product design for innovations with a relative low novelty and complexity degree, e.g. part integration, selection of a alternative material. Discursive methods of thinking should be applied when the product ideas should be searched outside of a fixed solution area, e.g. finding a complete new solution for Printed Wiring Boards, for example based biodegradable materials or to assemble and fix the parts of a product without using joining elements.

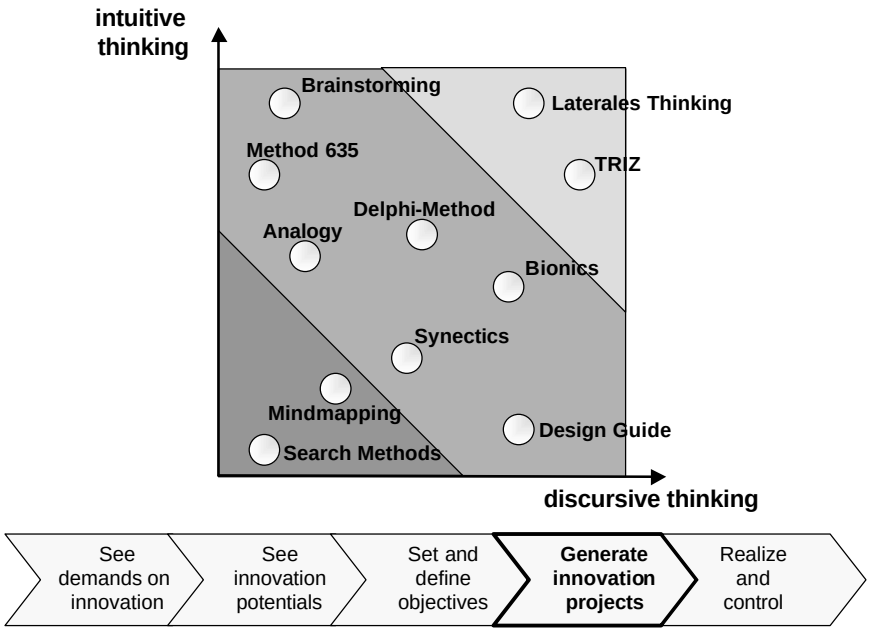

Figure 6. Classification of creativity methods [Gausemeier et al, 2000]

3.5 Realise and Control

The realisation of the R&D activities starts with a development order given by the management. The assignment determines, in which financial limits and time framework the innovation project is to be executed. Therefore, a concept must be developed for the execution of the project by the development department. In this concept, beside project manager and project members, a differentiated cost budget, a schedule as well as other important limiting conditions (e.g. used methods, CAD programs) must be set.

Afterwards the actual research and development start. Product, manufacturing and marketing concepts are acquired and transferred. The implementation can take place on the one hand via own research and development. On the other hand the necessary results can be acquired from other enterprises, research establishments etc. by transfer of technology or by license agreement. If the realisation requires a relatively large resources expenditure or a high novelty value is present, one should carry out the R&D activities in an independent project. In other cases the implementation in the routine processes appears more favourable.

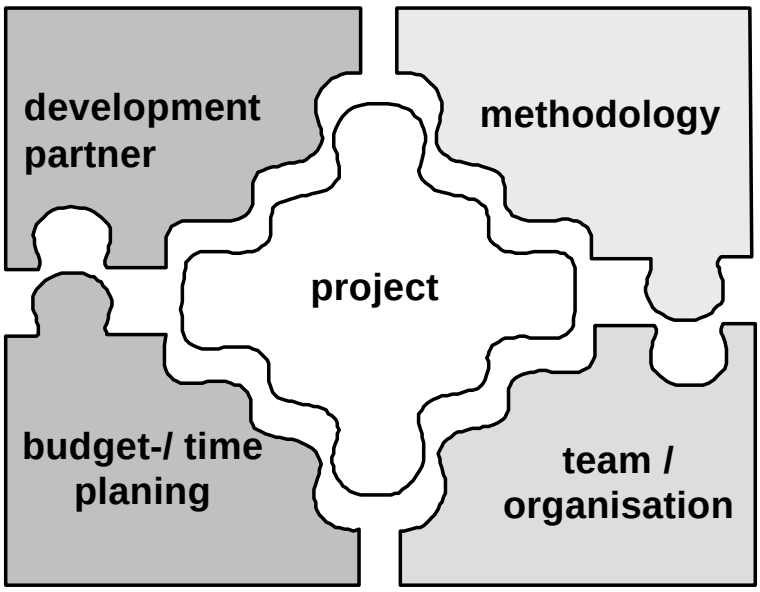

Figure 7. Components of the realisation

An important item concerning the environmental oriented product development is the integration of knowledge about recycling and disassembly processes. While assembly and manufacturing aspects are already considered in simultaneous engineering approaches, experts on disassembly and recycling processes are not integrated in design teams so far. Along the use of DFE Tools it is necessary to adapt the organizational structure so that it allows the consideration of end of life problems. A possibility is the integration of an external expert or consultant with solid knowledge about recycling and disassembly processes or the use of an expert system. Further, cross functional teams are also a suitable approach. These teams consist of employees coming from different departments. So, in the case of the environmental oriented product development, disassembly and recycling experts can also be included in the respective teams. On the one hand creativity potentials can be set free by this interdisciplinary composition, which would miss in a functional oriented structure. On the other hand these teams offers the possibility to see the different request of the functional areas of an enterprise as a whole.

4. Conclusion

This paper has focused on the integrated view of a closed loop economy and economical efficiency. Global trends in legislation based on an extended product responsibility require an environmental oriented corporate culture, the implementation of a systematic innovation process and methods for the development of adapted strategies for both, products and their related processes. Support is needed especially in the early development stage to set up the entire product strategy. The presented benchmark method contains the following steps: product assessment, process assessment, product portfolio analysis, and strategy selection. The distribution of a company's products within the product portfolio reflects the company's situation for an efficient closed loop economy. To achieve future competitive advantages, strategies can be developed considering processes and products as well as the product life cycle.

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