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HIDDEN PATTERNS OF INNOVATIVE ENVIRONMENTAL DESIGNED PRODUCTS

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Abstract

Numerous examples of established environmental aware products prove that such products increasingly win recognition in the market. It is to be observed that these products in particular often are quite well to market, because in the course of a consistently environmental fair product design often further product properties are considerably improved, which initially have no connection with the environmental characteristics. Just these also improved characteristics, however, convince potential customers and thereby lead to a sales success.

If, however, a consequent environmental fair product development does not only lead to environmental fair or more sustainable products but also to further product innovations as well, enterprises would be well advised to arrange their products consequently environment-friendly. It is, however, extraordinarily important to know the relevant changes in the product design or the success factors in the design of these products, which indicate successful products because it is sure that not every small change of details in a product design, which improves the environmental profile of the product, does lead to substantial advantages going beyond it.

Environmentally Innovative Product Design, Life-Cycle-Design, Design for Environment

1 Introduction

The environment-friendly design of products becomes increasingly important for enterprises as, in the last years, environmental aspects have moved both in the eyes of the customers and in legislative regulations more and more into the centre of attention.

Beyond that, it is proven by numerous examples of environment-conscious products, that just by an ecologically aligned product development, characteristics can be achieved, which offer rich and also economic advantages far beyond the environmental aspect. These benefits are advantageous for both the participants of economic life and the final customers. For this reason, the market is prepared for an establishment of environmental friendly products.

For this reason, development patterns and restraints in the design of environmental friendly products will be analyzed in this paper. From this point of view suggestions for the application in an environmental innovative product design framework will be derived.

2 Examinations and Results

2.1 Basic conditions for successful product innovation

In order to successfully master the tasks in the daily design practice, the designer has to be integrated in an efficient organisational structure and supported by efficient methods and tools in synthesis and analysis. Thereby he is to be merged into a design methodological proceeding [1]. An integrated consideration of the factors mentioned is pursued by an integrated product development (IPD). For this see Figure 1.

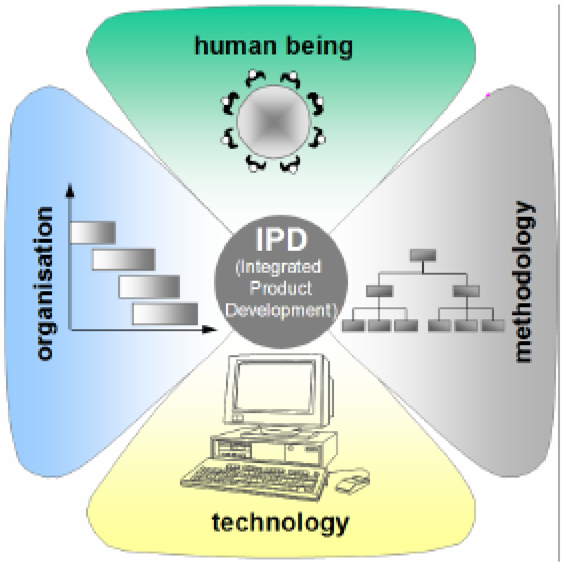

Figure 1. Elements of an Integrated Product Development [3].

The support of the innovation process is, however, considerably affected by the organization of the basic conditions in the design and development practice. To work out such development obstacles, practice inquiries in German enterprises were analyzed and complemented with the analysis of so called innovatory mega trends. From this, requirements for a successful innovation activity were derived, which just as well apply to an environmental innovative product development.

In German industry, which is shaped by the middle class industry, the lack of specialists, organizational problems and high expected development costs as well as bureaucratic obstacles play a more than average role as innovation obstacle. This results from the annually representative questioning of the Center for European Economic Research which, since 1995, is accomplished at each case in 2500 enterprises of different industries [7]. In this, the situation in the different industries differs altogether only insignificantly.

2.2 Characteristics of environmental oriented product innovation

For the derivation of substantial starting points for the improvement of the environmental performance of products during the development process, successful environmental aware products already present on the market were investigated and the reached improvements were examined in a product analysis. The classification according to the kind of change, compared to appropriate conventional products permits the determination and abstraction of development patterns as a basis of a target system to a successful methodical support. These classifications again allow focussing on substantial product properties, whereby the complexity of the development task will be reduced.

Regarding the design strategies of successful environmental aware products, it is necessary to differentiate between products according to their complexity.

- Products of less complexity / passive products: In this group, improvements are reached by material adaptation, possibly combined with changes in the product structure.
- Products of higher complexity / active products: In addition to the modifications of the first group of products, improvements of active products are mostly reached by further development and accordingly the use of well-priced function principles and solutions which are newer or based on technical advancements and therefore and above all more efficient.
- Complex products are often shaped through the application of functional modules from a very different area of expertise.
- Innovations are often accompanied by a development that decreases environmental burdens of products by the application of a product integrated environmental technique. Contrary to so called end-of-pipe technologies, environmental burdens are downsized by avoiding certain function principles, which are the source of the environmental burdens, and without the input of additional material or energetic resources.

The coherence between environmental oriented advancement and thereby parallel accompanying product innovations is impressively representable by the example of starter alternators. The development of these integrated devices allows the abdication of the alternator module, the v-belt and the starter. This leads to a light weight and compact construction. The fast motor start potential enables a start-stop-mode by which a reduction of the fuel consumption at city-traffic of approximately 5% can be achieved. Due to dynamic characteristics these modules increase the travelling comfort. The higher attainable operating voltages in the electrical system permit the employment of new technologies - x-by-wire systems - as well as smaller cross-sections of a line profiles.

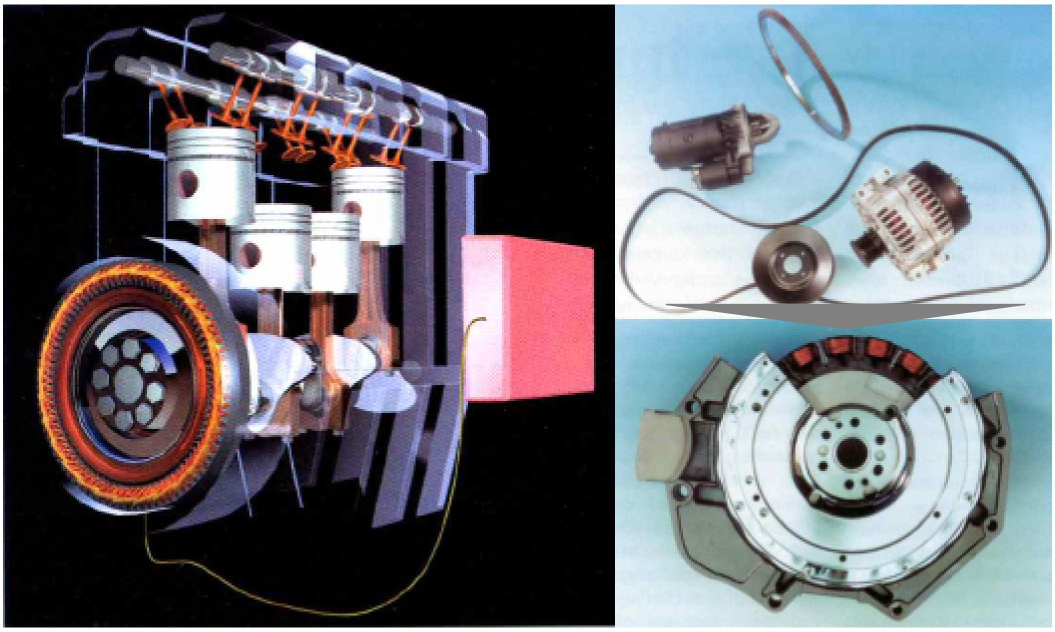

Figure 2. Starter-alternator for the electrical power supply system future cars is an impressing example of env i-ronmental aware product, which offers additional non environmental oriented advantages.

2.3 Fundamental relations between products and their associated ecoprofile

If one analyzes the results of accessible life-cycle-assessments and environmental product declarations, statements can be found, which ones of the influential impacts during the product development make a substantial contribution to the environmental profile of the products. These can be generalized as follows:

- Regarding active products, the use phase dominates the impact on the environment already from a nominal power of the devices lower than 1kW. This coherence becomes very clear with increasing nominal power (Figure 3)

Direct Current Machine ABB DMI 180 (rate of environmental impacts of the use phase)	**% of all**
Global warming potential	99,92
Acidification potential	99,96
Oxidant depletion potential	99,90
Photochemical oxidant creation potential	99,70
Ecotoxicological classification factor for aquatic ecosystems	99,99

Figure 3. Example for the environmental importance of the use phase in relation to other life-cycle-phases.

- Products with an increasing portion of electronics lead to a shift of the major part of the environmental burdens to the production phase respective the pre-production phase.
- The environmental burdens of passive products are primarily determinated by the production phase.
- The environmental burdens of the after use phases recycling and disposal are negligible in respect to the production and use phase, but they have a high importance for the establishment of closed substance cycles.
- Transport processes between different production locations and internal transport processes in the fabrication comes to the back at consumer goods.

3 Consequences for environmental oriented product innovation projects

In connection with the results of the analysis of freely accessible ecological product evaluations, which could be generalized in relation to the described influences, the determination of main influences as a function of a product classification permits a definition of substantial design strategy.

3.1 Methodology

For an environmental innovative product development in the frame of a design methodology the following conclusion are derived:

- For the relevant improvement of active products the energetic effect chain, which obtains the function realization has to be analyzed to identify and, by redesigning, considerably improve the most important sub functions.
- In order to minimize the influences of the pre-production and the production phase, the selection of the basic materials is to be accomplished with the help of an ecological evaluation of possible alternatives.
- For the establishment of closed material cycles a material homogenization in the product structure as far as possible should be acquired to enable a fast separation of the recyclable material fractions.

Thereby the relevant early phases of the product design can be done without the execution of a time and resource intensive life-cycle-assessment, which needs life-cycle-data that can not be defined at this stage anyway (Figure 4).

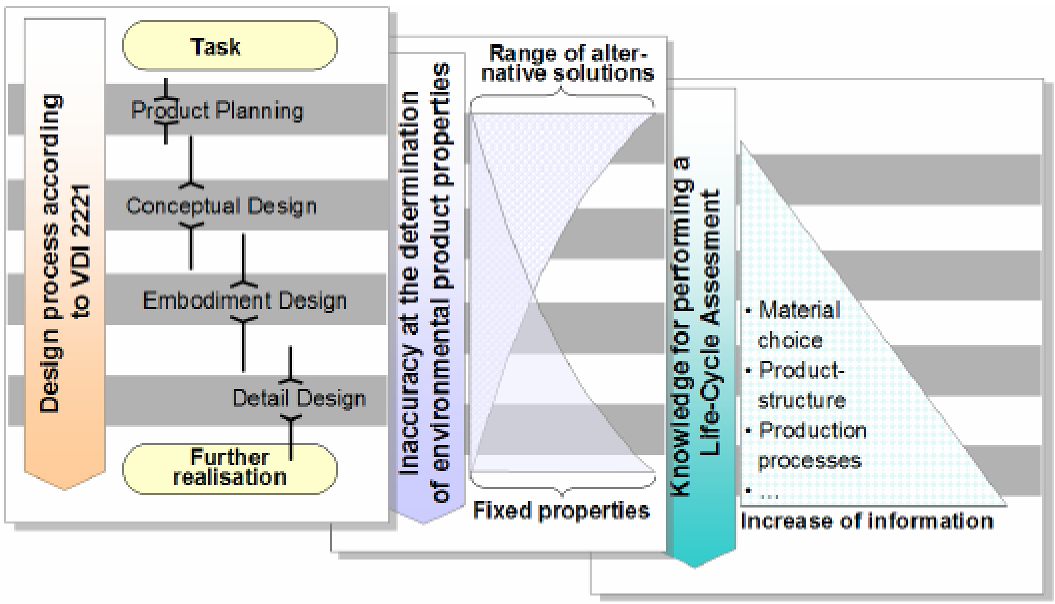

Figure 4. Design phases and data availability for performing a life-cycle-assessment.

3.2 Organisation

Modern and leading products increasingly consist of complex combinations of highly integrated components using electronic, mechanic and information technologies. This increasing assignment to the product design is one of the reasons for the extensive gain in the need of a special know-how of various disciplines. Additionally, the consideration of the whole product life-cycle during the product design process as prerequisite for the development of ecologic conscious products strongly indicates the difficulties of and the considerable time frame needed for the product development.

Not to miss important developments, controlling the technology complexity is a success factor of the future, which makes it necessary to very exactly pursue the development tendencies with world-wide horizon for the respective product group, to learn or complete new abilities and knowledge.

These requirements leads to a complexity, which becomes controllable for small and medium sized enterprises only through bringing together, project- or product-related, the necessary authority for redesigning mechatronic products and consider ecologic properties at the same time. For these enterprises it is not possible to fulfil the necessary wide knowledge requirements with own personnel.

3.3 Technology

Changes of successful environmental innovative products are characterized by conceptional changes in the functional realization, by the application of a new working principle and/or technology or a bundle of measures regarding the energetic chain of acting elements. Together, these changes lead to a significant reduction of energy consumption.

During the implementation of new working principles, often the familiar knowledge areas have to be left. Therefore, the solution identification can today be supported by a multiplicity of computer aided engineering techniques, which supports know-how and offers time and cost advantages in connection with conventional methods.

3.4 Human Being

Work-psychological factors, thinking and work behaviour in co-operation in differently composed teams are of very high importance. However, due to the complexity of this field, these factors are not treated in this contribution.

4 Example pilot-project results

How successful the concentration on substantial aspects of an environmental innovative product development can be, was impressively demonstrated in the IPP (Integrated Product Policy) pilot project BEnefiT promoted by the Bavarian State Ministry for State Development and Environmental Affairs. BEnefiT is an acronym of the Bavarian development net for innovative technologies. This network built of university and industrial authorities is led responsible by the Chair for Engineering Design (Prof. Meerkamm) at the University of Erlangen-Nuremberg and pursues the approach of an integrated product policy (IPP) [6].

The extensive improvements are quantitatively measurable, by setting the degree of fulfilment of different product-related environmental criteria of IPP fair products or services in relation to conventional kinds of fulfilment. These criteria, however, are partially product specific and are therefore to be specified and/or adapted accordingly in each case. Such a simple benchmark permits the representation of the improvements transparently compared with established ecological evaluation models.

The comparatively simple system of evaluation permits the application in the early concept phases, where a life-cycle-assessment is not meaningfully applicable due to the lack of available information. Further on, with this approach we obtain a benchmark which declares the degrees of the improvement to the final customer in an understandable form.

Transferred to the redesigned BEnefiT vacuum cleaner prototype, a set of advantages can be shown. Compared with reference, the prototype thus reaches an improvement from 1.6 to 2. It consumes only half of the electricity during the use phase like conventional devices while delivering the same suction power. With a total weight of only little more than 4 kilograms, it is over 1 kilogram more lightweight than comparable devices, which means an improvement factor of approx. 1.25.

Through the reduced material usage and the extremely reduced and co-ordinated material variety - 13 instead of 26 different materials - an improvement of about 50% is reached. The simple construction structure of the device, which gets by with only one connecting element, makes a disassembly time of 13 seconds possible for the achievement of sort-pure material fractions. The reference device, which was the best one available on the market, needs a disassembly expenditure of 182 seconds - an improvement around 14. Therefore a clear proceed can be gained within the recycling in place of costs. The vacuum cleaner housing consists of only two construction materials, polypropylene and polycarbonate. That is, in contrast to approximately nine different materials in comparison devices, an improvement around the factor 4.5. The polycarbonate portion is, in fact, so small that the complete housing can be regarded with the recycling as a high-quality PP material fraction [5].

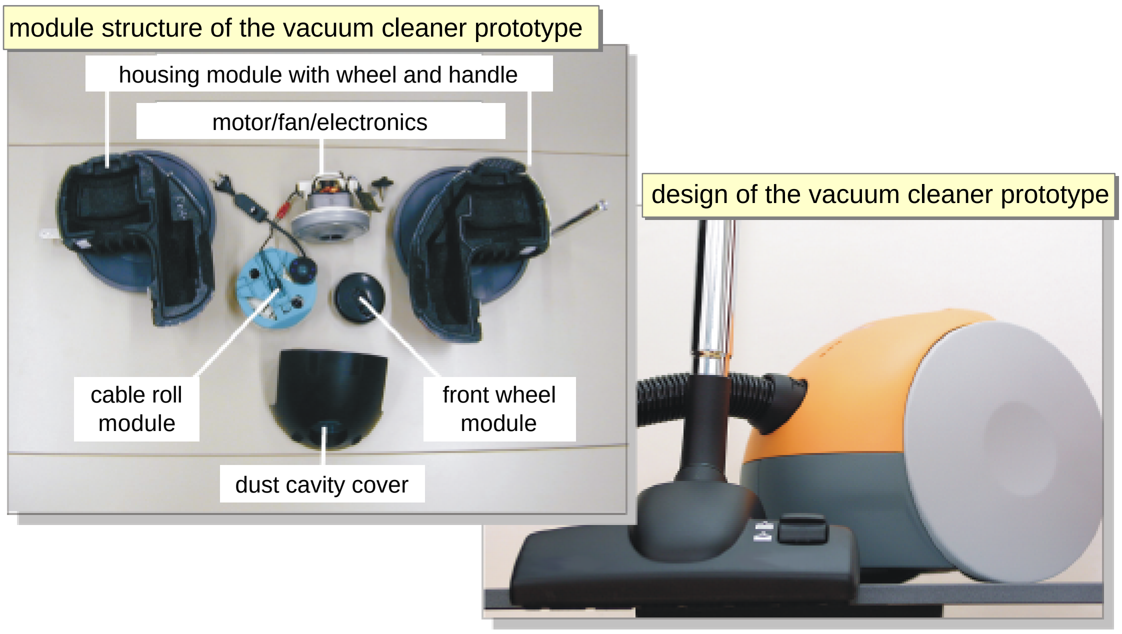

Figure 5. Design and simplified structure of the consequent environmental aware redesigned vacuum cleaner.

The environmental referred progress mentioned, which is verified /substantiated / confirmed by a life cycle assessment accomplished during the later development phases (Figure 7, Figure 6), yields further advantages, like that the product is substantially simpler to assemble, to handle, to stow away and altogether also lower-priced for the customer.

Impact Category	Device	Value	Improvement [%]
CO2-Äquivalent [kg]	Reference	718,25	42
	Prototype	413,95	
Energy consumption [kWh]	Reference	845,00	42
	Prototype	487,00	

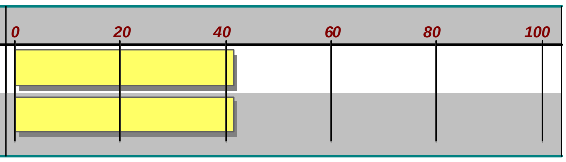

Figure 6. Improvements in the use phase of an environmental oriented redesigned vacuum cleaner exemplified pictured in essential impact categories.

Impact Category	Device	Value	Improvement [%]
Renewable energy sources	Reference	0,0357	97
	Prototype	0,0010	
Energy Sources (non renewable)	Reference	19,3155	75
	Prototype	4,8360	
Eutrophication (NO3)	Reference	0,0000	0
	Prototype	0,0000	
Eutrophication(PO4)	Reference	0,0165	45
	Prototype	0,0090	
Human toxicity	Reference	1,19E-04	100
	Prototyp	0,0000	
Ozone depletion (CFC11)	Reference	9,79E-06	100
	Prototype	0,0000	
Resources	Reference	368,3840	7
	Prototype	56,2920	
Oxygen	Reference	32,0116	82
	Prototype	5,8670	
Heavy metal to air	Reference	0,0008	100
	Prototype	0,0000	
Heavy metal to water	Reference	0,0002	100
	Prototype	0,0000	
Summer smog (C2H4)	Reference	0,0215	-20
	Prototype	0,0270	
Greenhouse effect (CO2)	Reference	58,9813	74
	Prototype	15,3880	
Acidification (SO2)	Reference	0,2780	2
	Prototype	0,1370	

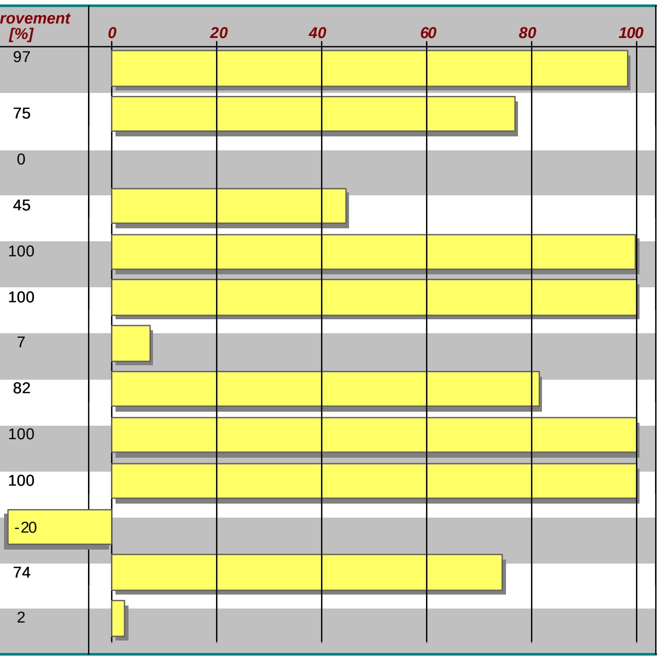

Figure 7. Improvements in the production phase of an environmental oriented redesigned vacuum cleaner exe mplified pictured in different impact categories.

5 Key Conclusions

A successful environmental innovative product development concentrates in contrast to the conventional proceeding, which derives improvement approaches on the basis of an ecological evaluation and/or weak point analysis - usually a life cycle assessment -, on the attention of substantial development targets.

Contrary to the conventional proceeding, which derives improvement approaches on the basis of an ecological evaluation and/or weak point analysis – usually a life cycle assessment-, a successful environmental innovative product development concentrates on substantial development targets.

Such development targets, like little weight and size, high energetic efficiency in the chain of acting elements realized by the product, etc., are general requirements to break through development barriers in a generic development process, which is oriented at the design methodology [4].

These development targets are reached with consistent improvement at the energetic effect chain realized by the product on the one hand and at the material- and product-structure of the product on the other. This leads to an implicit improvement of environmental product properties by achieving product requirements in an accustomed way, even though no environmental evaluation like a life cycle assessment has to be performed. Therefore, there is no additional burden to the developer to use complex evaluation tools. This could be demonstrated impressively in the Bavarian BEnefiT project by the example of a vacuum cleaner, which was completely redesigned with consideration of the factors mentioned. The vacuum cleaner, existing as functional prototype, proves the obtained progress.

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