# Design for Environment – Do We Get the Focus Right?

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**Abstract**
Sometimes, products resulting from design for environment (DFE) endeavours are sub-optimisations from an environmental perspective, because the tool determines the process and not vice versa. For a more systematic way of getting the focus right, a hierarchy of focusing is introduced:
1. What is the function provided and what is the optimal way of providing it while making a business out of it? Which product should the company then produce?
2. Where are the "environmental hot spots" in the life cycle of this product?
3. Which DFE tool supports optimisation of the product by reducing these hot spots?

**Key words**
Sustainable product, Design, Product life cycle

## 1 INTRODUCTION

A sustainable development was defined by the United Nations' World Commission on Environment and Development as: "... development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [1].

Today, sustainability is often considered to have three dimensions, the economic, the social and the environmental sustainability. The focus of this paper is on the environmental sustainability.

Following Graedel and Allenby ([2]), the environmental impacts from our civilisation can be seen as a product of
- the size of the global population
- the economic activity per capita
- the eco-efficiency (the environmental impact per activity)

It follows from forecasts for the first two of these parameters, that over the next 50 years, the third parameter, the eco-efficiency, must increase by a factor 10 or more to achieve sustainable development ([3]). This means that our current economic activity must be performed with less than one tenth of the negative environmental impact, it has today. Here lies a tremendous challenge to the economic sectors of our societies, not least to the industrial sector, the activities of which support our current material welfare but also give rise to some of the worst environmental impacts we experience today. Particularly, the technologies introduced in the developing countries must be environmentally friendly, since this is where the growth is going to be strongest.

To achieve sustainability, Society must expect industry to apply a product chain perspective on its environmental performance in order to avoid improvements in own activities that are obtained through changes which inadvertently cause increased impacts elsewhere (sub-optimisation), but also to spread the work for improvements along the product chain rather than have it focused on the company's own activities. A product chain focus helps make other participants in the life cycle of the product take their part of the responsibility for the overall impact of the product.

An improvement in the environmental performance of the products we consume is the goal of the emerging environmental product policies or integrated product policies that can be observed, particularly in Europe, these years ([4] [5] [6] [7]). An environmental improvement of our products is also the focus of this paper. Many companies have included environmental targets in the specification of their product development and strong efforts have been devoted to the development of environmentally benign products.

## 2 DESIGN FOR THE ENVIRONMENT

Ecodesign or Design for Environment, DFE, covers any design activity which aims at improving the environmental performance of a product. A wide range of different products have been subject to DFE, and many industries have developed their own schemes. Throughout the 1990'ies several publicly funded methodology projects had the aim of developing more generally applicable approaches to design for environment. The variety of available methods and tools ranges from general to specific tools, which focus on parts of the life cycle or on certain types of products or services. Some methods are aimed at decision support early in the design process while others are aimed at use during the detailed design phase ([8] [9] [10] [11] [12] [13] [14] [15] [16] [17]). Work under the International Organization of Standardization resulted in a guideline in ecodesign [18].

Waste handling problems are perceived as an issue by important stakeholders of the company and therefore, many DFE studies focus on the end-of-life stage of the products. For electrical and electronic products, the EU directive on WEEE, Waste Electric and Electronic Equipment [19] has been introduced because of concern about the growing volume of electronics with its spillage of valuable resources and contents of toxic substances. WEEE thus requires a 75% recovery rate for cellular telephones, and batteries, printed circuit boards and liquid

crystal displays will be required to be disassembled. On this background Seliger et al. [20] address the field of cellular phones and show that disassembly and remanufacturing of cellular phones can be a competitive business segment in the European market. The WEEE directive enhances this economic opportunity, in that it creates a large market for reuse.

An important DFE strategy aimed at minimising end-of-life impacts is remanufacturing; products need to be designed to be viable for cost effective remanufacture, reuse and to reduce the amount of waste going to landfills. With the right remanufacturing process in place, remanufacturing can be profitable for mass produced products [20] provided that sufficient quantities of mass produced products will be viable for remanufacturing. Obvious choices are automotive [16], white goods and electronics industries [20] [21]. Focusing on remanufacture of medical equipment, Feldmann and Melzer [22] demonstrate that in spite of considerable effort involved in the remanufacturing of high value products such as X-ray systems, there is a potential for environmental as well as economical benefits. Low and Williams [21], in a review of the end of life issues associated with electronic products, find that design for manufacture and assembly, DFMA methodologies generally are not compatible with design for disassembly, DFD. Boothroyd and Alting [23] give a list of DFD guidelines which include:

- product structure (organization of functional units, easily accessible and easy to assemble, and easy to separate)
- design of functional units (not yet integrated)
- material selection (few identifiable, separable materials)
- minimize waste and harmful contaminating materials
- recycling principles and requirements.

Lagerstedt [15] suggests a set of DFE rules which nicely summarize the guidance given by the various DFE tools and methods which are available:

1. do not use toxic substances, and use closed loops when possible.
2. minimize energy and material consumption in production and transportation by striving for efficiencies.
3. minimize energy and resource consumption in the use stage, especially for products with their most significant environmental aspects in the use stage.
4. promote maintenance, especially for system dependent products.
5. promote long life, especially for products with their most significant environmental impacts outside the use stage.
6. use structural features and high quality materials, to minimize weight; these should not interfere with flexibility, impact strength or functional properties.
7. use better materials, surface treatments or structural arrangements to protect products from dirt, corrosion and wear.
8. arrange in advance for upgrading, repair and recycling, through good access, labeling, modules and breakpoints, and provide good manuals.
9. promote upgrading, repair and recycle by using few, simple, recycled, unblended materials, and do not use alloys.
10. use the minimum joining elements possible, using screws, adhesives, welding, snap fits, geometric locking, etc. according to Life Cycle guidelines.

These recommendations summarize the typical focus points for the development of environmentally benign products. They are intuitively right for many product developers, especially for mass produced products.

Hence for the **focus on the disposal of the products**, media, public opinion and environmental policy of many industrialised countries have for years had a strong focus on the impacts from the treatment of the waste which is generated in huge quantities as a consequence of our consumption. The waste hierarchy adopted for reducing waste problems recommends giving the highest priority to reuse and then to recycle or recover before landfilling the waste. By closing the circle we turn the used products into new products and reduce the generation of waste.

Concern with the **focus on the use of certain materials in the product life cycle** also has its background in the waste generation, but here the concern about our exploitation of limited and non-renewable resources also plays a role. Hence the notion that biomaterials are good (they are renewable and we can harvest them without jeopardizing their availability to future generations) and that composites are bad (they cannot be separated into their original materials and the potential for recycling is hence low). By closing the circle we stop the flow of resources from raw material deposits to waste deposits and secure their availability to future generations.

The **focus on longer product life** through design for durability, maintenance or remanufacture and extension of life is also rooted in the focus on the material content of the products. The longer the life of the product, the fewer the materials used for producing a new product and the lower the environmental impact.

Sometimes the intuition behind this focus is right, and the guidelines or tools actually lead to environmentally improved products. Often, however, the improvement is small compared to what could be obtained. There is no harm in optimising the potential of a product for reuse or recycling, but if the real environmental issue of a product is the impacts from generating the electricity required to operate it, the focus on its disposal diverts the effort of the product developer from where it should be invested, namely in optimising the product's efficiency during the use stage. If the product is a vehicle for transportation, avoiding composite materials due to their poor recyclability may lead to designs with a worse environmental performance because for this type of products, the strength to weight ratio of the construction materials should be high in order to increase the fuel efficiency of the vehicle during use.

In the same way, longevity of a product often means lower environmental impact, but if the product consumes prodigious amounts of materials or energy during its use, a shorter product life may be preferable. This is the case when the development of the technology applied by the product continuously makes new generations more efficient. An example is refrigerators, where the energy consumption of models developed in the 50'ies or 60'ies lies at least an order of magnitude above what is observed for efficient refrigerators of today (not to mention the leakage of ozone-depleting CFC gases from insulation and compressor which means that they should be replaced as soon as possible and their content of CFCs collected and destroyed).

The point made in these examples is illustrated in Figure 1. An intuitive approach to design for environment sometimes improves the environmental performance of the product and sometimes not, but it often fails to address the most important environmental impacts from

the product and it generally fails to optimise the overall environmental performance of the product as viewed in a life cycle perspective.

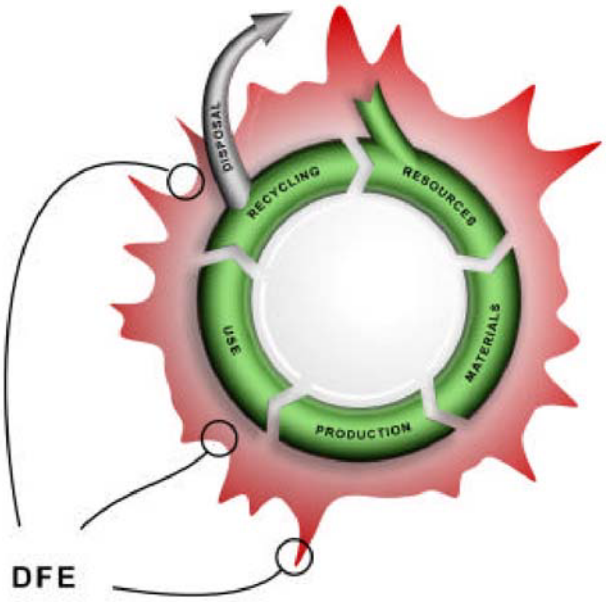


Figure 1: Focusing the effort in design for environment. The corona of the life cycle represents the magnitude of a specific environmental impact or an aggregated measure of all environmental impacts at the different points in the product's life cycle. Sometimes the DFE efforts do not address the main environmental issues for the product.

## 3 HOW DO WE GET THE FOCUS RIGHT?

In order to get the focus right for the product development, a systematic analytical approach is suggested - a **hierarchy of focusing.**

### 3.1 Step 1 – strategic considerations

The analysis starts on the strategic level with an identification of the functions provided by the product and an analysis what might be the optimal way of providing this function while at the same time making a business out of it. These considerations should include the strategic perspective that sustainability in the long run may force the company to reconsider their product strategy. Will their current type of product have a place in a sustainable economy or should they find a different way of providing the service – e.g.

- selling services instead of products (transportation rather than cars, photocopies rather than photocopiers, clean clothes rather than washing machines)
- identifying the "sustainable" way of providing the service and develop products that do it this way (oil companies broadening their scope to become energy suppliers and going for fuel cells, solar panels or wind turbines)

… or should they find a different line of business?

These are very strategic considerations. Some of them are more oriented towards long-term management but they will a very direct bearing on the strategies for product development strategies, and therefore they must be concluded before more detailed goals can be set for the new products.

### 3.2 Step 2 – focusing within the product life

Once it has been decided upon which type of product the future (near and more distant) business shall be based, a life cycle perspective should be applied to identify, where in the life cycle of the chosen product, the most important environmental impacts , the "environmental hot spots", lie. This is done by a life cycle assessment of the product. The LCA may be performed at different stages of the development process (see Figure 2).

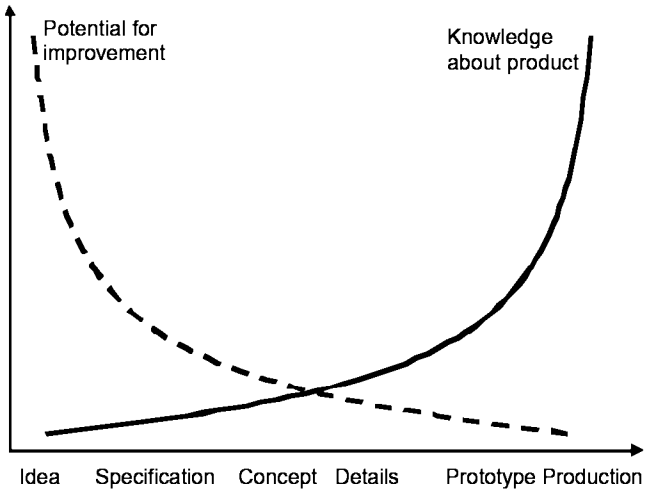


Figure 2: The environmental performance (dotted curve) can be influenced most strongly during the early stages of the product development process where the knowledge about the product (full curve) is weakest (from [24]).

At the early idea- or conceptual stage, where the product is only loosely conceptualised, the possibilities for changes and hence for improvement of the environmental characteristics are large. If the goal is factor 10 improvements, this is clearly where the attention should be focused. During the early stages, a detailed and quantitative LCA is not relevant to perform, since the product is so loosely defined. Instead, more qualitative life cycle thinking or LCA of different product concepts and life scenarios are the tools to apply for analysing environmental impacts and identifying potential environmental hot spots. Later in the product development process, it is possible to analyse consequences of small design changes. The improvement potentials are more modest here, but this is the situation for the frequent add-on oriented product development where a new version of the product largely is based on the existing version.

The environmental hot spots identified by the LCA have to be checked for improvement potentials by analysing potential changes in the product, before the improvement goals can be defined in the specification of the development process.

### 3.3 Step 3 – Implementing design for environment

After the first two steps, environmental focus points for the product development have been selected in a systematic way which assures that they represent global priorities of the product's life cycle. In addition, requirements from legislation and standards and from the most important stakeholders along the life cycle must be analysed. Only now, the proper DFE tools can be selected to optimise the product according to the priorities set (see Figure 3). The tools can be developed specifically for the identified priorities or they can be chosen among the many existing DFE tools which focus on optimisation of use stage,

selection of best raw materials, design for disassembly, remanufacture, etc.

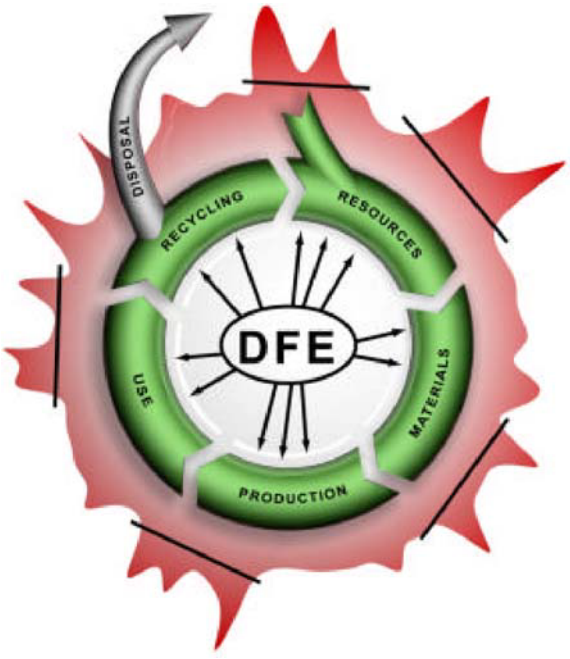


Figure 3: The systematic identification of the best type of product and of the hot spots and improvement potentials in the life cycle of this product guarantees the relevant focus of the product development process. In this way the right DFE tools can be chosen and applied to give the new product an optimal environmental performance, trimming the largest environmental impacts of the product's life cycle.

The proposed hierarchy of focusing does not require that an LCA be performed every time a product undergoes development. The main message of the hierarchy is that focus and requirements in the product development process must be based on an understanding of the life cycle impacts of the product. Once this is obtained, the recommendations can, within families of closely related products, be simplified into rules of thumb and basic principles, which in spite of their simplicity have general validity – for products within the product family.

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