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INDUSTRIAL INTEGRATION OF ENVIRONMENTAL ISSUES INTO THE ORGANISATION: PAST, PRESENT & FUTURE CHALLENGES

T. C. McAloone

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1 Introduction

The past two decades have seen increasing efforts to consider the potential negative effects of a product's manufacture, use and disposal on the local and global environment. Over this time two main schools of research practice have emerged: an analytical school of practice, targeted at the accounting and evaluation of environmental impacts of a given product or process; and a synthesis-oriented school of practice, targeted at the creation of environmentally improved products or processes, based upon life-cycle insight into the actual use and orientation of existing products on the market. These two schools of environmental research practice are mirrored in the way in which industry approaches environmental problems.

Since the definition in 1987 of Sustainable Development [1] efforts have been made to relate the goals and ideals of sustainability to the domain of product development, thus adding new dimensions, such as social and moral values, to the original agenda of environmental improvement. The increasing responsibility of the product developer, from environmentally conscious product developer to sustainably aware product developer has led to new insights into the way in which products are developed and used – and to where environmental effects occur in the lifetime of a product.

The role of the product developer is thus more complex in relation to sustainability, as the focus for improvement of a product may not (and very often does not) lie in the physical artefactual ingredients of the product or the processes used to create it. Rather, the focus for improvement of a product's environmental performance most often lies in the manner in which the product is *used* and *consumed*.

A product's *use* phase is often environmentally significant, as this is the largest source of environmental impact.

A product's *consumption*, or rather, a given user's *consumption behaviour* is even more important, as this dictates exactly how many use-phases, how many products and how much *product redundancy* is created, due to the user's lack of awareness, motivation or ability to consume a product in an environmentally respectful manner.

The problem with both *use* and *consumption* is that the product developer traditionally has very little power over these two elements; they occur after the product has left the factory and entered into the hands of the user (the consumer).

Until the real environmentally harmful phases of a product's life can be harnessed by the producing company, it is often* impossible to make the radical (Factor X [2]) environmental improvements to the product itself that are necessary to maintain an environmental equilibrium (*except for in the case of new technology introduction).

Over recent years, a handful of companies have begun to take control over (and accept responsibility for) a larger portion of their products' life-cycles. Where there are examples of companies taking control over larger product life areas for reasons other than environmental, there are a few examples where environmentally-based product-life 'takeovers' have been with environmentally-founded goals in mind [3]. Thus the practice of Product-Service-System (PSS) development is born.

2 Legislation's role and effect on product development

Emerging legislation and standards concerning electronic waste, automobile waste, packaging waste and other such focus areas are beginning to have a real effect in industry, forcing manufacturers to take back their products at the end of their lives. The European automobile industry, for example, must now ensure that their end-of-life vehicles are recycled to 75% (by weight), by 2006, at least 80% of the weight of discarded cars must be reused or recycled; by 2015, the percentage will rise to 85. In the electronics industry, legislation on producer responsibility and take-back laws are already in place for certain product categories, in a variety of Western European countries as well as some Asian countries, such as Japan. In the European Union, the Waste of Electrical and Electronic Equipment directive [4] is expected to come into force shortly. This leaves the original equipment manufacturer responsible for the costs associated with the collection, recycling and disposal [5]. As far as policy goes, many governments have stated that their preferred option is to let market forces encourage product take-back. However, if producer responsibility does not occur automatically, then legislation is the next logical option to choose, as now can be seen in the EU legislation for scrap automobile recycling.

Hence, as take back legislation increasingly places responsibility for product end-of-life (EOL) on the original equipment manufacturer, the loop is closed and therefore the motivation increased to design products that at least are recyclable. Product development can play a key role in reducing the costs of recycling. Interestingly some innovative companies are already taking back EOL products to their financial advantage. A decade ago, for example, computer company DEC realised the net benefit of recycling tens of thousands of computer monitors each year at a unit cost of between $3 and $6.50, because this approach was shown to be cheaper than the costs of landfill [3]. Xerox have been leader in this field in the electrical/electronics industry, redefining their own relation to the physical elements of their products and managing them as their own assets [6].

But take-back, disassembly and recycling is simply where the ecodesign story began, in the late 80's and early 90's. Since then, complex and sophisticated tools, methods and approaches have been researched and implemented in industry. We have quickly recognised the need to prioritise our ecodesign efforts, based upon a detailed understanding of the product and the life

that the product will lead, once it has left the drawing board, passed through the company manufacturing facilities and out into the real world. In the real world, there are many more pressing issues to consider than recycling.

3 Sustainable development in practice

The Bruntland Report of 1987 [1] was the major instigator of the term 'sustainable development', the way by which mankind globally should attempt to move towards the goal of sustainability.

But how can a product developing company be sure that they are on the road to sustainability? Some years after the Bruntland report we have theories such as Factor 4, Factor 10 and Factor 20 [2], all of which describe a necessary improvement in environmental performance, in order to be able to equilibrate the sustainability situation. Others have broken sustainability down into classes of 'eco-centric' and 'techno-centric', 'strong sustainability' and 'weak sustainability' [7], in order to attempt to describe the actions of individuals in their efforts towards improving the ecological profile of the products they develop and produce. But is it really possible to have these shades of green; and what does this help, when we want to carry out ecodesign?

Brezet [8] urges that we need to make leaps in order to achieve sustainability and that as we make these leaps, we move through a four-stage process:

Stage 1. Eco-redesign	Stage 3. Sustainable Product Innovation
Stage 2. Ecodesign	Stage 4. Sustainable Society

Brezet states that where the majority of the research community are presently well into stage 2 of the model – i.e. in the bridge between eco-redesign and sustainable product innovation, industry is still way behind on stage 1. There is a need to innovate in order to jump from one s-curve to the next and begin to face the challenges of the increasingly demanding environmental improvements.

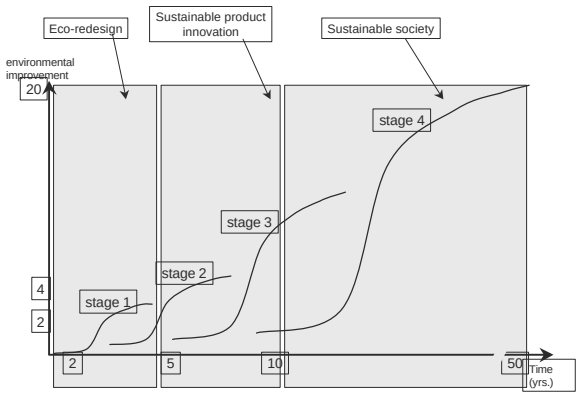

Figure 1 - Four innovative steps to sustainability [8]

4 New elements for product development

The product development process is understood to be an area of great opportunity for companies to implement new ideas and practices [9,10]. Until the mid 90's we primarily saw

environmental pressures dealt with reactively by manufacturing companies who have been forced to "clean up" their product and their manufacturing processes and attempt to recycle their products at the end of their useful lives, as mentioned above. However, ecodesign made its breakthrough in the mid 90's providing a key opportunity for companies to proactively reduce environmental impact, by thinking environmental impact into the early stages, and then building the environmentally improved principles into their products throughout the rest of the process. Industry and academia responded to this opportunity by seeking and creating tools and methods to support ecodesign [11,12].

4.1 The progression of ecodesign in companies

Good design requires both analysis *and* synthesis, thus in order to design something successfully we must be able to calculate as much about its behaviour throughout its life-cycle as is necessary to address the defined objectives [13].

Before product developers can begin to include environmental considerations as commonplace practices there are a number of issues, which must be addressed:

- information must be accessible and useable and in form which can be understood by all members of the design team;
- formal design methods, strategic frameworks and guidelines must be adapted from existing practices, in order to maximise the chances of success in implementation;
- product developers need help in identifying the environmental issues surrounding the products they are developing;
- product developers should be aware of the use and benefits of the broad range of ecodesign tools and techniques now available, and have the confidence in choosing the most relevant tools for the job;
- for ensured success of implementation of ecodesign into the organisation, an in-house 'environmental champion' should be appointed, who should act as the reference point for information and help on specific areas of environmental concern, and to ensure the provision of up-to-date information.

As product developers occupy such an essential and central position within the company the progression of ecodesign is directly affected by their willingness to take 'new' environmental ideas on board. Many problems occur, not due to lack of empowerment, but lack of overview, on the would-be ecodesigner's side.

4.2 Whole-life thinking

Those companies, which have proven to be most successful at ecodesign have long since left behind the perception that environmental improvements merely add cost to the product, in favour of the realisation that, if one can establish a link between business opportunity, cost reduction, and ecodesign the drive for implementation of ecodesign into the organisation will be at its greatest.

Taking the view that environmental improvements are opportunities to save or make money for the company, there is a challenge for product developers to begin to think differently about the product they are developing. Advanced companies (on Brezet's third curve, Figure 1) now

strive to retain ownership of their products and instead concentrate on selling a service; the product becomes an incidental part of the customer's purchase [3]. This has advantages for the manufacturer in terms of retaining their assets. It also ensures a known source of equipment for future contracts, or raw materials for replacement components.

Whole-life thinking in relation to LCA

Life Cycle Assessment (LCA) is an established science, with a strong body of centres-of-excellence worldwide, who objectively:

"evaluate the environmental burdens associated with a product, process, or activity by identifying energy and materials used and wastes released to the environment, and to evaluate and implement opportunities to affect environmental improvements". [14]

Throughout the past decade this science has grown dramatically and LCA specialists are now commonplace in almost every globally active product development-related company. The task of the LCA specialist is to *analyse* the environmental effects related to the product, process or activity, based upon a "life cycle inventory" of the product and some knowledge of the product's activities throughout its lifetime. The problems with using LCA in isolation as an ecodesign approach are documented [15,16,17].

Product life thinking, on the other hand has little to do with collecting and manipulating inventory figures; this technique rather focuses on the product itself, and in particular, the life it leads. By this it is meant that the product developer can already begin to anticipate the various life stages that the product will go through and the 'meetings' that the product will have with a product life stage and a stakeholder [18]. Product life thinking is an essential *mindset* that the product developer should adopt, to enable a *synthesis* of environmentally improved attributes to products, where they really are needed.

The analysis and synthesis activities in companies are traditionally far apart from each other. By implementing relatively simple methods this relation between analysis and synthesis has been proved to give fruitful ecodesign results [19].

4.3 Thinking in multi-products

Carrying out a detailed study on a single product may provide a sound set of recommendations for the improvement of the environmental performance of that specific product. For example some changes may include the choice of a different plastic for a specific component and standardisation of parts and materials in the product. The result will be *one* environmentally sound product. However, companies generally produce many products, and may still be using many different plastic types, may still be gluing components together, may still be using different parts where standardised ones could have been used. A multi-product approach is therefore essential, so as to be able to make company-wide improvements to the product, rather than isolating single products.

4.4 Thinking in multi-lives

Product developers have traditionally not had to think beyond one useful product life-time, when designing and developing products. But considering a second or third or fourth lifetime (take the good old British milk bottle, or the 'disposable' camera) we have a new set of rules

to consider. The product developer is now forced to think about the next generations of products, and the necessary networks that must be established in order to support a multi-product life.

Both multi-product and multi-life characteristics emphasise the need for clear strategic direction, as individual product developers cannot be expected to bear all of these considerations. By addressing environmental concerns at a high level, there lies an opportunity to discuss longer-term solutions and fix strategies into the future. This strategy determination includes the consideration of asset management, where the idea is to attempt to maintain the value-add of a product/component for as long as possible. For example if the decision were made to scrap a motor, revenue could be achieved for the aluminium, copper and steel in the motor. However, if a motor were to be refurbished for re-use the raw materials costs, manufacturing process and labour costs would be saved, with comparatively little cost to refurbish and test the motor. This asset management view then encourages the product developer to consider multi-product lives as being a sound environmental move.

4.5 Thinking of integration

The demands of taking a whole-life view and even a multi-life, multi-product view across multiple companies show that ecodesign is, in part, a problem of integration. When taking an environmental view we add to the integration problem by introducing the need to bring together knowledge from many disciplines. The typical Design for X (DFX) approach (where environment is just one of a large range of 'X' considerations) seeks to integrate one set of knowledge with design. Ecodesign adds multiple sets of knowledge then introduces entirely new dimensions of integration. This requires a balanced view of the whole product life cycle, focusing attention on the reduction of the major environmental impacts of a product or service throughout its entire life. Ecodesign is equally concerned with issues such as the 'embodied' environmental burden of the materials, the energy used by a product and its toxic emissions, and the user's use/misuse and consumption of the product.

5 Who does ecodesign?

This is a good question! The answer is that ecodesign crosses many disciplines and many levels in a typical company. Said in other words, ecodesign affects and is affected by a great deal of the business. The following is an attempt to identify roles of company-internal stakeholders of ecodesign, based upon a series of observations in industry [6].

5.1 Two essential roles for ecodesign

The expert: One argument is that an environmental 'subject-expert' is required, who should posses the knowledge of LCA, should understand the chemistry behind materials selection, should have worked for some time developing environmentally improved products, and should have expertise in environmental management. Clearly, this person would sit in a position central to the organisation, from where all environmental calculations can be demanded (to a very detailed level). The expert may indeed be manifest as many people, and may even be a dedicated department within the company.

The conduit: A counter-argument to this expert situation would see someone acting as a 'conduit' (different to an expert) with three skills as an absolute minimum:

- enthusiasm and inter-personal skills;
- ability to give guidance on ideas presented to them, by understanding the motivations of the company, by taking a life-cycle view of the product (i.e. know who becomes involved in the product, where) and not necessarily having to go too deep into environmental calculations at this point; and
- ability to act as a conduit to the deeper, more involved environmental questions (*"I know an environmentalist who can..."*).

5.2 Strategic and action-oriented decision-making

Two main types of decisions have been identified during observation: (A) the strategic decisions (which affect whole product ranges and strategies) and (B) product specific decisions (which shape each product's actual affect on the environment and hopefully influence the user to act in an environmentally responsible manner). It could be argued that the way in which to proceed would be to concentrate on the strategic decisions so that whole product ranges be altered at once. However, such an approach is extremely ambitious and often relies on very detailed company policies. Any findings could be too general, with little detail about how to improve the whole product range.

Ecodesign may be interpreted in a number of ways. Each company has specific environmental problems linked to their operations and thus will have to approach ecodesign with distinct strategies. There are a number of considerations in ecodesign and to address each of these concerns differing approaches may be adopted:

- extending the useful life of the product;
- design for remanufacture;
- use of recyclate, renewable, recyclable and biodegradable materials;
- minimising use of materials and energy;
- selection of particular materials, processes and technologies which reduce pollution and waste;
- adoption of new technologies to create areas of environmental opportunities;
- think about the product life cycle from cradle to grave;
- remove environmental problems before they occur, by designing the use-phase of the product;
- and so on…

Using all of the above may result in the *ultimate* environmentally sound product or system but the scope for application in practice will be limited. Careful consideration of the operations present within a particular product system will highlight which of the above are applicable in each case.

Each of the strategies will be of particular advantage to certain industrial practices. Extending the useful life of a product is the most general of the strategies. No matter what the product or service, by extending it's useful life the need for replacements is reduced and thus materials and energy requirements, pollution and waste production are all reduced. Allied to actively discouraging consumerism and the fashion for replacement by promoting minimalism, product

life extension may reap the greatest rewards in ecodesign. Other strategies such as minimisation of materials and energy used and use of recyclable, renewable and biodegradable materials will also be generally applicable. It must be noted, however, that these approaches to ecodesign may also be open to interpretation. For example minimisation of material may be looked upon as two completely different design decisions. It may be seen as the reduction of necessary parts to an absolute minimum along with careful mechanical design to reduce thicknesses of components etc. It may also be seen as miniaturisation, whereby the existing product, while keeping its existing configuration, is reduced to as minimal size as is acceptable. Design for remanufacture and recyclability are strategies which must also be considered very carefully within the context of the industrial operation to which they refer. Factors such as overall life-expectancy, energy requirements during use and conditions of use will all induce particular restraints on the use of these strategies.

5.3 A framework for ecodesign strategy and action

In a research project carried out in UK in the late 1990's [20] and in subsequent testing of the methodology produced in this project, it was shown that successful ecodesign requires activity at the two levels, explored above:

- *strategic*, to set the issue within the whole organisation; and
- *operational*, to put the good intentions into practice in product development.

These two levels require support, to allow a successful ecodesign result in the company. A four-stage framework was therefore established. The framework applies at both the strategic and operational levels and provides a guide for organisations to plan ecodesign:

- first to ***a****nalyse*, making an environmental assessment from a life cycle viewpoint;
- then to ***r****eport*, using new and existing communication networks to diffuse the analysis and collect feedback;
- thirdly to ***p****rioritise*, a key step given the complexity of environmental issues;
- finally to ***i****mprove*, using relevant tools and methods.

The four-stage framework, known as 'ARPI', has been developed and used with industry to aid the development and implementation of both ecodesign strategies (the way in which environmental issues are incorporated into the product development process) and action programmes (the way in which a particular design project is "greened") for specific companies, as shown in Figure 2.

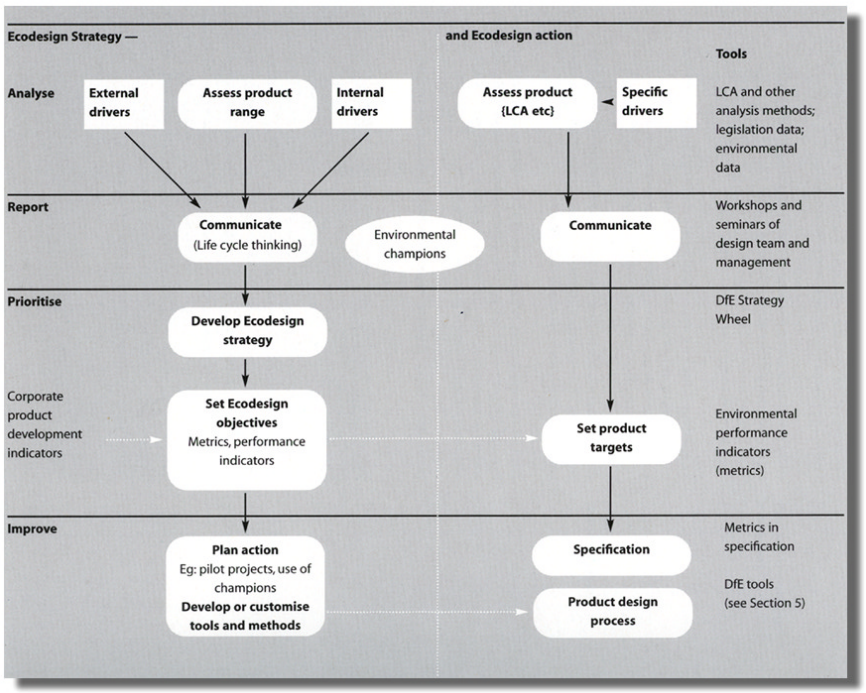

Figure 2 - The ARPI framework from the Ecodesign Navigator [20]

5.4 Testing the ARPI framework

The ARPI framework was validated by testing the approach in participating companies. The analysis stage was tested in two ways: by assessing existing products using LCA methods and feeding the results back to design teams on new projects, and by assessing products at 'post-launch' design reviews. The style of presentation of LCA and other results is important - so that environmental impact can be expressed in terms familiar to the design team (such as the relative impact of subassemblies in the product) and not in codified terms (such as categories of chemical emissions to the environment). When this was done, LCA and more specific assessments were welcomed by design teams as methods for identifying environmental issues and reinforcing life-cycle thinking [21].

6 Tooling-up

It has been experienced that one of the greatest hurdles for the majority of companies interested in beginning ecodesign is not motivation, but the knowledge of where to start looking for possibilities and making changes to the product design, and then which tools and techniques to apply to make improvements.

The past ten years in particular have seen the emergence of various approaches to address just this problem of making a start on ecodesign. The Ecodesign Pilot [22], for example, provides a guiding technique, with hints about where to start looking for ecodesign improvements, based upon the nature of the product and it's usage situation, and with a series of layers thereafter to guide the ecodesign process. The Dutch Government and Delft University of Technology produced the PROMISE-manual [23], giving detailed step-by-step coaching from design strategy to considering each phase of the product's life. The Danish book 'Miljørigtig Konstruktion' ('Environmentally Conscious Design') [24] builds a whole ecodesign mindset,

providing an approach to ecodesign that fits into the daily day of the busy product developer. Finally, the Ecodesign Navigator [20] is where the ARPI method was first developed and described. The Navigator provides a framework for classifying and identifying the relevant tools from a large database of alternatives. These four examples are just a selection of the many approaches to ecodesign existing today. However it is important to remember is, that the success of ecodesign is to be assured in the mindset of those carrying out the task. Flexibility for change, creative mind and the ability to communicate across many disciplines and time domains are three very relevant attributes of a good ecodesigner.

6.1 Ecodesign and environmental management systems

There have been evident close links between ecodesign and environmental management systems (EMS), and this is an important factor, to enable good integration of ecodesign into the company. The cycle of reviewing, planning and implementing change is an effective structure for ecodesign [25]. In a study of ecodesign implementation in SME's, van Hemel found that the existence of an EMS was a better predictor of high ecodesign performance than general environmental awareness in the company [26]. The EMS process begins with an environmental review; when considering ecodesign at the strategic level, this requires examination of product development procedures. Benchmarking is recommended here, as competitive pressure is one of the key external drivers for ecodesign. Tools and methods are needed at each stage of the cycle and at various levels in the organisation. Organisations therefore set overall objectives for ecodesign. These relate to product ranges or to product development strategy. A sample set of these is given by Eagan and Pferdehirt [27] and these objectives are sometimes incorporated into computer tools for ecodesign [28]. This method has become established in the Netherlands: an initial environmental innovation scan (or review), the identification of improvement options, a feasibility study of these and finally possible implementation in a design [29]. The prioritisation of the improvement options is implicit in the method because only a few of the possible ecodesign principles can be chosen for a project.

A more opportunist type of environmental review for ecodesign is confined to the product development and manufacturing processes. Many companies have started their ecodesign work by reviewing the environmental performance of individual products. At the simplest level, this can be to check compliance with existing or imminent legislation, using tools to check properties such as recyclability [30]. But organisations with a wider view adopt a life cycle viewpoint (implicit in the concept of ecodesign) and use some form of LCA [31].

There is still debate on the value and validity of LCA as a tool for public policy-making but the technique has become widely accepted as valuable for product design and eco-labelling [32]. Much of the argument hinges on the value judgements inherent in converting inventory data, which is objectively assessed, into assumed environmental impacts. Since LCA does not measure actual impacts, it has limited use as the sole basis for decision-making [33] but is still useful as a screening process in the early stages of product design. Accurate results cannot be expected, as differences in inventory data sets can produce results varying by up to 100% [34].

Given the limitations of LCA, there is still a strong desire in manufacturing industry for simple, easily applied measures of environmental performance and many companies have developed systems of metrics [35]. These metrics are for internal use and reflect corporate policy; there has in effect been some prioritisation of environmental issues, whether explicit or implicit, in

their development. Such metrics are widely used in design, either incorporated into computer tools [36] or set in the specification and checked during design reviews.

6.2 From small steps forward to leaps and bounds

The ecodesign community has become increasingly aware of the need to think radically in order to reach radically environmentally improved products, as Brezet challenges us to [8].

Sherwin & Bhamra [37] describe a case study where an attempt was made to go from 'normal ecodesign' (based on corrective activities, which try to engineer-out inherent environmental problems) to eco-innovation (engineering-in positive environmentally-related features). This case study was carried out with industrial designers from Electrolux on a project entitled 'Eco-Kitchen'. The exercise was to re-think the whole concept of the home kitchen, with environmental goals at the forefront of their minds. The case study was based on theoretical evidence that industry and academia are both beginning to recognise a need to be pro-active, holistic, and innovative towards a goal of sustainability – a goal which also needs to become more tangible. There were three goals for the case study:

- to balance *desire* and the *environment*;
- to *support* & not *force* the design team; and
- to look for *near-future support systems* (thus keeping the project as realistic and realisable as possible).

These goals were further supported by the aims of the case study, which were:

- to integrate ecodesign at the early stages of product development – therefore the industrial design department was selected, due to their greater influence in this company;
- to go beyond simply including environmental considerations in the same manner as cost, quality, safety etc., and instead use ecodesign as an innovation strategy in itself;
- to take a holistic view of the kitchen – so to overcome the potential problems of starting with discrete units (a fridge, a cooker, a sink etc.) in the mind, which might stifle creativity by drawing traditional solution boundaries;
- to go beyond the scientific and the technical issues that are the result of most existing ecodesign tools, to providing insight into cultural and lifestyle issues.

The results of the case study were concrete prototypes, which could be used by the team to learn about the way in which adopting a new approach to ecodesign had resulted. This case study concluded:

- There is a need to innovate. Existing tools can help to get some of the way, but a different approach is required, which will tie many of the existing methods together with new ideas to shape new products, rather than validate existing ones.
- 'The environment' needs to be considered earlier in product development. Rather than sticking to corrective action, it is indeed possible to go one step further and use environmental issues for product innovation.
- Ecodesign issues should be followed at more strategic levels of the organisation – such results as came from the project imply significant changes into the way the business is

shaped (product families, core business etc. are all re-addressed) all of which require commitment from management.

- There is a change required as an organisation matures its approach to ecodesign that takes the organisation from thinking about technical to cultural issues.

This case is an example of what can be achieved when taking an innovative stance. As a research community we need to continue to work at developing eco-innovative strategies, including steps beyond ecodesign, to eco-innovation and then sustainable design are.

7 Moving into the immaterial world

One promising attempt to rise to the challenge of enabling the formulation of eco-innovative strategies can be found in the emerging research area of Product Service System (PSS) development, where the goal is to enhance the consideration of utility, sustainability and societal values throughout the product development process. There are existing examples of the enhancement of business and market share by focusing on PSS, but these are often not a result of an upfront strategy or ambitious environmental goals.

PSS is new as an industrial practice and as a research discipline, and we still lack overview in order to be able to understand how to design a PSS. For example, who should sit in the project team for the creation of PSS concepts? No longer merely a team of engineers… A PSS requires an orchestration of a complex network of stakeholders, both in- and outside of the company, in order to deliver an *augmented product* to the customer in a satisfactory manner – and to be able to sustain this satisfaction throughout the whole company-customer relationship [38].

We can prepare ourselves for a significant change in the way that traditional product manufacturing companies deliver their product to their customers – especially in the western world, where companies no longer can expect to compete on a global market with respect to cost, quality or time. It is my hypothesis, that if carried out correctly (aided by professional methods and approaches) the shift from the development, sales and provision of discrete, physical products, to the practice of *functional sales*, provided as a product of PSS-development, will give radical environmental improvements.

For this to be possible, we need to expand both: *our mindset*, in order to be able to understand the proper nature of a PSS; and *our design degree of freedom*, in order to be able to carry out professional PSS design. We need to be able to understand how to design the life cycle first, then the product [39], in order to ensure an efficient product, durable company-customer relationship and reduced environmental effect.

8 Conclusion

This paper has taken a look at the development of ecodesign integration into industry over recent years. We can see that our understanding of environmental issues has grown and developed so that we now place our efforts in the context of sustainability. We can see evidence that companies are progressing from a practice of product planning to whole life cycle planning, and are furthermore beginning to incorporate aspects of the *augmented product*

in their business strategies. We can also see that the augmented product is gaining increasing importance for both company and customer alike, giving both opportunities for step-change environmental improvements due to the company's increased responsibility for and insight into their products, and also a challenge for companies to understand how to conceptualise, design and develop product service systems, which can both satisfy the material and immaterial needs of the customer and at the same time radically reduce the environmental effect of the product over its entire life cycle.

I believe that the shift in focus from product development to PSS development is an opportunity to create radical innovations for the organisation. I believe that PSS development is a realistic opportunity to achieve the Factor X improvements in the environmental performance of products.

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Associate Professor Tim McAloone
Technical University of Denmark
Department of Mechanical Engineering
Building 404, Niels Koppels Allé
DK-2800 Kgs. Lyngby, Denmark
T: +45 4525 6270
F: +45 4593 1577
E: tim@mcaloone.com