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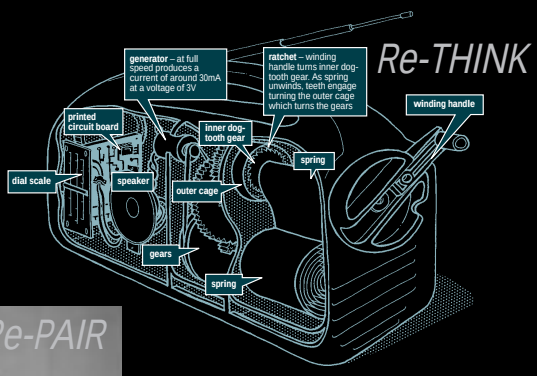

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Editorial Board

Welcome to the first issue of The Journal of Sustainable Product Design

Martin Charter and Anne Chick

Editors, The Journal of Sustainable Product Design

In order to move towards sustainability, it is predicted that we will need to achieve between 'factor 4' and 'factor 10' levels of resource and energy reduction. This will require the development of significant breakthroughs in thinking and technology. A key requirement will be for companies and other stakeholders to 'Re-think' the way they operate and the function of their products and services. In addition, businesses and consumers will need to re-evaluate the way they consume by consuming less and differently. For example, moving towards dematerialisation will require a substitution of products for services ie. from the delivery of books on paper to downloading information via the Internet. This will require a new emphasis on creativity, innovation and education in order to raise awareness, understanding and to generate new solutions. To achieve this new forms of co-operation and partnership will be required.

The key aspect of 'Sustainable Product Design' (SPD) is the addition and balancing of social and ethical issues, alongside environmental and economic issues into the product design process- to achieve 'the quadruple bottom-line'. Many of these issues have been discussed since the 70s in relation to corporate social responsibility, but have not been translated into an agenda for the design profession. For example, if suppliers of electronic components use child labour in South-East Asia what is the companies' and the designer's position?

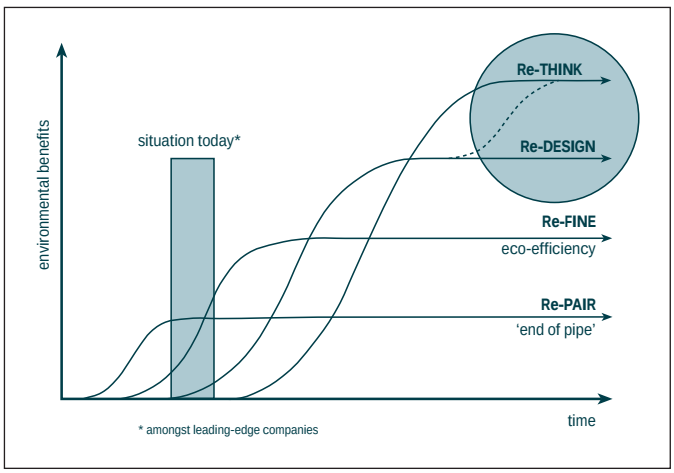

Figure 1: The 'four steps' model

There is a need to move through 'the four steps' model if we are to achieve significant resource and energy reductions and generate breakthroughs (Figure 1). At present, the majority of companies are still at the 'Re-pair' stage, dealing with 'end of pipe' solutions. However, some companies are moving towards the development of cleaner processes and the designing out of environmental problems at source, through clean design or eco-design. Leading companies are progressing to 'Re-fine' existing processes and products through the implementation of the concept of eco-efficiency (reducing resource conservation, whilst 'adding value' and reducing costs). These companies are starting to achieve incremental rather than significant stepwise improvements. However, a number of these far-sighted companies have started progressing to 'Re-design' existing products to incorporate environmental factors – although the development process is still in

its infancy. To move beyond 'Re-design' to 'Re-think' will require significant leaps in thinking, driven by an emphasis on creative problem-solving and opportunity-seeking. An essential element of this process will be the development of a more systemic infrastructure to enable the cyclical flow of resources and energy within product systems, as outlined in the emerging concept of 'industrial ecology'.

The first issue of The Journal of Sustainable Product Design focuses primarily on exploring where we are now, the 'as is' scenario. Professor John Ehrenfeld and Michael Lenox of Massachusetts Institute of Technology (MIT), US, provide a description of the formulation and implementation of eco-design strategies within companies, by drawing on three practical examples. Professor Jacqueline Cramer of Akzo Nobel, the Netherlands, illustrates major issues in developing eco-efficient product design solutions, drawing experience from the Dutch electronics company, Philips. Dr Robin Roy of the Open University, UK, illustrates how the white goods company, Hoover has gone about the 'greening' of its New Wave' washing machine. An article written by Mike Brown and Eric Wilmanns indicates how Patagonia Inc., a US based outdoor clothing and equipment designer and producer, have developed an ecologically considered design strategy for their products. A key element of Patagonia's approach has been the development of a Life Cycle Assessment (LCA) methodology utilising principles developed by Dr Michael Braungart and Professor William McDonough, of McDonough Braungart Design Chemistry. The use of these principles is further illustrated by 'Climatex Lifecycle', a textile upholstery fabric produced in Switzerland. An article on The Body Shop International shows how the 'green' cosmetics company are diffusing eco-design issues through the supply chain. There is also an account of how the 'Freeplay' radio – powered by a clockwork mechanism – was developed and operates. To conclude, there is an interview with Hans-Peter Becker, Managing director of Wilkhahn UK, a German furniture manufacturing company, which emphasises how they have integrated ecological and honest principles into the design of their products.

The Journal's first issue provides examples of products and approaches that are primarily at the 'Re-design' stage. However, there are two examples of how companies are 'Re-thinking' the role of products for a more sustainable world. The Freeplay radio demonstrates a 'low-tec' product that fulfils a human need in developing countries, and the example of Philips highlights the potential for 'hi-tec' innovative technological solutions. Some of the wider social and ethical issues surrounding product design are emphasised by Wilkhahn's and Patagonia's approach to design and doing business.

At present, there is no clear theoretical or practical framework as to what SPD means for companies or society within the industrialised world. For example, what does SPD mean for a company that manufactures and sells worldwide, who has 10,000 products, and 1000 suppliers? Is this fundamentally unsustainable? or are there strategies that can be employed to reduce the impact of products and services across the 'quadruple bottom-line'?

To progress towards sustainability does this mean that there needs to be:

- movement to an intermediate, appropriate or 'low-tec' scenario of producing and consuming locally?
- movement to 'hi-tec' scenario of information-technology products and services dominated by dematerialisation?
- or, a world dominated by lower consumption and 'more from less', with the wider implications for employment, changing work patterns and 'quality of life'?

Clearly it has to be a mix of all these strategies. However, what is needed is a pathway through these complex and evolving discussions.

The Journal of Sustainable Product Design is a platform for that debate and analysis. The aim is to publish a range of articles highlighting both 'as is' and 'blue sky' examples from around the world. Of particular interest are case studies and articles which explore new thinking and ideas.

Towards innovative, more eco-efficient product design strategies

Professor Jacqueline Cramer

Senior Consultant, Akzo Nobel and affiliated with TNO and the Tilburg University, The Netherlands

After working as an associate professor at the University of Amsterdam (1976–1989), Professor Dr Jacqueline Cramer joined the Centre for Technology and Policy Studies, part of the Netherlands Organisation for Applied Scientific Research (TNO), The Netherlands. Her research is related to the question of how government, industry and social organisations can stimulate the development of cleaner production. From April 1995–February 1997 Jacqueline Cramer worked at Philips Consumer Electronics as a senior consultant, seconded from TNO. Since then she joined Akzo Nobel in a similar position. She has also worked as part-time professor, respectively in environmental science at the University of Amsterdam (1990–1996) and from September 1996 in environmental management at the Tilburg University.

This article addresses the issue of how companies can develop innovative, more eco-efficient product design strategies. Research had indicated that there were no methodologies for investigating such innovative product changes. Philips Sound & Vision/ Business Electronics have started to develop such a methodology. The experiences gained within this company show that this methodology highlights the need to integrate environmental issues in the product planning process as early as possible. This ensures that environmental issues become an integral part of business strategy. However, the motivation towards the formulation of innovative, eco-efficient product design strategies is dependent on individual companies.

Introduction

Achieving sustainable development presents an enormous challenge to society. It means that within a few decades society will have to learn to become much more efficient in the use of energy and raw materials. According to environmental experts, within the next 50 years the burden on the environment will have to be reduced to an average of one-tenth of the current levels (Weterings and Opschoor, 1994). In other words, average eco-efficiency achievements will have to increase by a factor of ten by 2040.

Steps have already been taken within industry to increase the eco-efficiency of products. Most of these efforts focus on incremental environmental improvements of existing working methods, products and services at an operational level. Various techniques and methodologies have been developed to analyse and assess the environmental merit of such product improvements.

However, in order to reach the target of a tenfold increase in eco-efficiency, more far-reaching, innovative improvements of current production techniques are required. No methodology is available yet for developing such product changes. Some companies, such as Philips Sound & Vision/Business Electronics, have started to develop such a methodology.

When methods and instruments become available that enable the identification and selection of

Preparing for ISO 14001 is not an option – it's a matter of survival.

promising eco-efficient product design strategies, the next question is how to embed environmental issues within the organisation's culture, structure and systems.

This paper deals with this question on the basis of the experiences gained within Philips Sound & Vision. Before focusing on this particular case, there is discussion of how the efforts to integrate environmental issues into product design strategies relate to current developments in environmental management systems.

Standardisation of environmental management systems

Environmental management systems are still in the process of development. Depending on the country and the specific sector of industry, the experiences regarding the introduction of these systems may differ. Until now, however, all environmental management systems have had a common primary focus on procedures to reduce the emissions of individual plants through process improvements. The integration of environmental issues into product design strategies has received limited attention.

With the introduction of the international standard on environmental management systems ISO 14001 and related items in the ISO 14000 series, this situation may change. More than most national and regional standards on environmental management systems, the ISO 14000 series stresses the importance of product-oriented objectives and supportive tools (eg. Life Cycle Assessment (LCA) and environmental labelling). It may therefore be expected that the implementation of the ISO 14000 series provides a good framework for environmental product improvements.

A first positive aspect of the ISO 14000 series is its international character. It avoids the proliferation of conflicting and inconsistent national and regional standards on environmental management systems. Moreover, it provides a single, more cost-effective system for multinationals to implement wherever they operate (Crognale, 1995). A second advantage of the ISO 14000 series is the positive support from industry for its implementation. In fact, it was industry itself that promoted the idea of an international environmental management standard.

A third advantage is that an ISO standard on environmental management can influence the behaviour of companies with respect to the environment. It leads to a standardised method of working to which companies should conform when they export to global markets. More often, customers or clients require verification that their suppliers are taking their environmental responsibility seriously. Therefore, preparing for ISO 14001 is not an option – it's a matter of survival (Johannson, 1995/6).

This point can be illustrated by the response of various large, export-oriented South African companies. While the influence

of the national environmental legislation is still limited (except for water pollution standards), the acceptance of their products on the international market is crucial. These companies were therefore very interested in developments concerning ISO environmental management standards.

Thus, the importance of the ISO 14000 series is increasing the focus on environmental issues. However, adoption of the standard will not in itself guarantee optimal environmental outcomes. As stated in the ISO standard:

'It should be noted that this standard does not establish absolute requirements for environmental performance beyond commitment, in the policy, to compliance with applicable legislation and regulations and to continual improvement. Thus, two organisations carrying out similar activities but having different environmental performance may both comply with its requirements.'

Types of environmental strategies

Thus, the ISO 14000 series does not intend to set absolute targets for the corporate environmental performance. The company goals, will depend on its particular environmental strategy (Starik et al, 1996). Some companies, clearly profile themselves directly as ecologically sound and also as socially responsible enterprises, for example The Body Shop International and Ben & Jerry's. Such companies will continuously strive for environmental improvements to their products in order to keep or increase their market share. The incentive to improve the environmental performance is at the core of company values and has been embedded in their business strategy.

However, for the majority of companies environmental issues plays a less crucial role. This group of companies usually takes environmental elements into account, when they are forced to do so or see a direct cost or quality advantage. Within this group of companies some are gradually evolving from reactive, compliance-driven environmental management toward integrated business and environmental management focused on gaining competitive advantage. Through the adoption of this more proactive approach they aim to increase their market share and improve their public image, for example through becoming first in the consumer tests on environmental aspects and/or improving the product quality. In this way, these companies attempt to use the environmental issue as a marketing tool, albeit in a modest way.

The management of every company makes implicit or explicit strategic choices as to the way in which it wants to position itself in the market. These choices reflect the direction that the environmental policy takes with respect to its products. The ISO 14000 series provides the appropriate framework, while the environmental objectives set by the company determine the level of environmental ambition. The scope of this ambition can vary greatly.

Roughly speaking, companies can bring about three types of environmental improvements within the product chain. They can focus on:

- **incremental, step-by-step changes in existing products (time scale: 1–3 years).** The Dutch Eco-design Programme provides examples of such changes, for instance, the design of an office chair made of less material, which is recyclable and consists of fewer toxic substances; the design of reusable plant trays for Dutch flower auctions; the design of a face mask made of recyclable plastic which is qualitatively better than the original face mask. The environmental merits of incremental changes can be significant if benefits can be reaped easily. Most companies that have already made efforts to improve their environmental performance can no longer obtain high environmental benefits from incremental improvements.
- **more far-reaching changes in existing products (time scale: 2–5+ years).** In the field of packaging various examples can be given of such changes: for instance, new distribution techniques leading to less and reusable transport packaging; adaptation of packaging materials into mono-materials; new display techniques in shops using less packaging material. Through more fundamental changes in the present product, major environmental benefits can be achieved. This usually requires investment in Research & development (R&D) and initial

product costs but may lead ultimately to lower costs.

- **radical changes in the function of products (time scale: 20–50 years).** Examples of this type of product improvement are provided by the Dutch DTO Programme (Sustainable Technological Development). This R&D programme aims to set up processes to highlight innovative alternatives for present unsustainable developments. For example, the substitution of meat through biotechnological techniques (so-called novel protein foods) and the development of sustainable building methods. The DTO programme aims to achieve an increase in eco-efficiency by a factor of 10–20.

The social and organisational changes needed to realise the three types of changes vary tremendously. Incremental changes in existing products require the involvement of various actors within the company and sometimes its suppliers and customers. However, more far-reaching changes in existing products call for greater communication and cooperation between all actors in the product chain. Radical changes in the function of the product cannot be made without fundamental changes in production and consumption. Similarly, the initial cost of implementing the three types of changes increases rapidly as the changes become more radical. Existing structures (investments) have to be re-adjusted or sometimes even 'destroyed' before more radical alternatives can be implemented. Take, for example, the high financial costs of building new infrastructures or reorganising the agricultural sector in a radical way through the production of novel protein foods. However, after initial costs have been incurred, the new but radical changes may lead to substantial cost reductions and new market opportunities.

Re-designing products in a more fundamental way requires the integration of environmental issues at a very early stage of the product development process. When the first ideas about the new product concepts are developed, environmental issues should be taken into account. In later phases of the product development process the architecture of the new product has already been determined, which implies that from then on only minor changes can be made to the product.

The integration of environmental issues in the first phases of product development has to take place at a strategic level. Senior management should decide here on the strategic 'green' issues to be addressed, taking into account both environmental and market considerations. In general, proactive companies are more interested in such a strategic approach than those which make a defensive stand. Instead of waiting until environmental regulations are forced on them, proactive companies will choose to anticipate future environmental opportunities and threats. This is illustrated by the experience of implementing environmental product development within the Sound & Vision division of Philips.

The example of Philips Sound & Vision

In the 70s and 80s, the emphasis of the environmental policy at Philips Sound & Vision division was on incremental improvements, especially in its production processes. One of the major driving forces was legislation, and the associated rules concerning licensing. Since the early 90s, the focus has widened to encompass improvements in the consumer electronics products themselves.

The driving forces included:

- formulation of a corporate environmental policy by the CEO of Philips
- growing public pressure to find socially responsible ways of disposing of used consumer electronics goods
- regulations concerning the use of certain chemical substances.

In recent years, the company has initiated numerous activities to improve its products from an environmental perspective. For instance, a manual on environment-oriented product development or eco-design has been produced for designers. The manual includes compulsory environmental rules for design. These place the emphasis on avoiding banned chemical substances and instead on choosing less environmentally harmful ones for consumer electronics products. The following issues are addressed in the manual (Cramer and Stevels, 1996 A):

The Philips Eco-design manual

1 Material use

The central objective is weight reduction and a reduction in the amount of potential 'end of life' waste. Information is provided on material data and on criteria for material use in relation to the functionality required.

2 Hazardous substances/ materials

An inventory is completed of hazardous substances in components and materials according to the EACEM (European Association of Consumer Electronics Manufacturers) list of relevant substances. These substances are classified in three categories of environmental release status:

- released (according to proactive environmental standards)
- temporarily released (better alternatives are investigated)
- forbidden/blocked.

3 Industrial processes

It is recommended to eliminate and/or reduce the following auxiliary materials and chemicals used in industrial processes:

- elimination of chlorofluorcarbons (CFCs) and hydrochloro-fluorcarbons (HCFC)
- soldering
- glues
- metal coatings, chromates
- lacquers, paints.

4 'End of life'

Information is provided about the following issues:

- cost and yield table of materials and material fractions produced at 'end of life' processing
- rules for disassembly-friendly construction
- plastic compatibility rules
- packaging and packaging aspects.

5 Energy-use

Information and directives are provided about:

- energy-use in operational mode
- energy-use in stand-by mode.

6 Environmental design evaluation

Design evaluation is based on:

- environmental weight
- 'end of life' costs
- the environmental release criteria to be used.

The company is actively seeking the best ways of designing consumer electronics products so that they can be processed as environmentally soundly as possible at the waste stage.

In addition, the company is actively seeking the best ways of designing consumer electronics products so that they can be processed as environmentally soundly as possible at the waste stage. Apart from the products to be re-used, essentially four material streams will result (Cramer and Stevels, 1996 A):

Material stream I
Material which can be recycled on a commercial basis (metals, engineering plastics).

Material stream II
Material for which the price of the corresponding virgin material is lower than the cost of the secondary one (some engineering plastics, glass). Under specific conditions such materials can also be recycled.

Material stream III
Material mixtures which have a recycling potential for certain functions, but have an overall negative yield due to presence of other material types (eg. copper from printed wiring boards, copper from wires and cables).

Material stream IV
Material or mixtures of material that have to be sent directly to incineration. Waste fractions resulting from the processing of streams I, II and III will have to be added to this stream.

With better designs and 'end of life' technology, the amount of material in stream I will grow steadily in the years to come, and the amounts in stream II, III and IV will shrink correspondingly. It is expected that at the present rate of improvement a weight ratio between the four streams of approximately 1 : 1 : 1 : 1 for the total amount of consumer electronics products will be reached in ten years from now. By stepping up the R&D efforts this timespan could be reduced substantially.

Towards more far-reaching eco-optimisation of products

Initially the above product improvements were mainly incremental in nature. Gradually, the attention is turning to more complex solutions, aimed at developing more far-reaching eco-optimisation of existing products. To make recycling of consumer electronics products possible on a wider scale, for instance, Philips is now working on the next stages of eco-design. In that context, it has developed the concept of the 'green television', which incorporates all the accumulated environmental know-how. This concept will be used as a reference for future generations of the product.
The development of new eco-efficient concepts will often require changes in product planning, which will turn need key strategic decisions from senior management. Answers are needed to questions such as:

- what benefits can be expected from the 'green television'?
- how should it be promoted?
- what are the marketing implications?

To broaden the scope, the Environmental Competence Centre of Philips Sound & Vision has developed a methodology to assess which proactive environmental measures the company should now take in order to be

Philips 'green' television
a concept which incorporates Philips Sound & Vision's recent learning

prepared for the future. This has led to a list of more far-reaching environmental improvements that may be implemented in 1–5 years. The current situation is that the Business Groups have selected various items for further investigation.

These items relate, for example, to the following partly complementary, technological options:

- minimising energy consumption and the use of raw materials and toxic substances
- further increasing material recycling
- optimising the life of the product (eg. by recycling of the product or components; or by technical upgrading).

The implementation of the above options needs the commitment and support of senior management. A strategic choice should be made on how the company will deal with each particular item from an environmental and economic point of view in an early phase of product development. The marketing strategy resulting from this choice can then be translated into product requirements. Whether these requirements can be fulfilled should then be checked with R&D, and after that can be implemented in the later phases of the product development process. This whole process of integrating environmental issues into the product creation process should be well attuned to the particular product planning procedures of the company. Within Philips Sound & Vision a specific procedure (including milestones and release criteria) exists, in which the environmental issues are currently integrated from the first to the last phase of the product development process.

This strategic approach to environmental product development requires cooperation between senior management, the strategists of the Philips Sound &

Answers are needed to questions such as: what benefits can be expected from the 'green television'? how should it be promoted? and what are the marketing implications?

An intensive brainstorming session was held… to generate and select far-reaching environmental improvements in energy consumption during use and standby.

Vision division, the product developers, the marketing experts, the researchers and the environmental specialists. Integrating environmental aspects with other aspects of business is essential. Internally, Philips is currently engaged in building up this collaboration.

Three examples

By including environmental aspects at an early stage in the product development, Philips Sound & Vision can act pro-actively rather than being forced to take defensive, corrective measures. This form of integration of environmental aspects into product development can offer opportunities for far-reaching improvements to products. The potential options are currently being investigated.

To illustrate this point, below are three examples (Cramer and Stevels, 1996 B):

- the reduction in the energy intensity of Consumer Electronics products
- the reduction of the material intensity of Consumer Electronics products
- the development of potential strategies to enhance the durability of products.

With respect to the item 'reduction in the energy intensity', an intensive brainstorming session was held in the Business Groups, Television, Audio and VCR in order to generate and select more far-reaching environmental improvements in energy consumption during use and standby. As improvements could be made in various parts of the product for example, in the components or in the printed circuit board, experts from various backgrounds were invited to these workshops. The options that these experts proposed are currently being explored in a technical, economic and marketing sense.

Secondly, the 'reduction of the material intensity of Consumer Electronics products' was also developed in a specific tailor-made way. In order to generate material intensity reduction options, close cooperation was established between Philips and one of its materials suppliers. Various creative thinking sessions were also held to identify promising alternative materials that are lighter, but at the same time have the appropriate functionality for fulfilling the demands on the product. The results of these brainstorming sessions are currently being explored in R&D projects.

The project related to 'the development of potential strategies to enhance the durability of products' was developed in a slightly different way. First, a summary of the potential options for optimising the life of products was made on the basis of a literature survey. Next, the capability of Philips Sound & Vision in meeting these options as a way to achieve further optimisation of the life of its products was assessed. At this stage it was considered to be important to gauge the view of the outside world. To this end, Philips Sound & Vision's Environmental Competence Centre in the Netherlands organised a brain-

It usually takes a number of brainstorming sessions and specific R&D initiatives before a final assessment is made of the most promising environmental opportunities to be implemented.

storming session with external stakeholders which was attended by 15 representatives from environmental, consumer and women's groups, from the Ministry of Housing, Physical Planning and the Environment and the Ministry of Economic Affairs, from relevant research institutes and from Philips.

The participants at this session were asked which five (not more) activities they thought Philips Sound & Vision should give the highest priority in the context of the theme of 'optimising product life'. The reactions of the participants suggested a clear prioritisation (Cramer, 1996). Particular attention was given to the following topics:

- making more robust constructions
- designing modular constructions
- selling the use of products/ leasing.

These results were presented in other creative sessions with the Business Groups, Audio and VCR. Establishing which additional methods stand a good chance of success in the future of Philips Sound & Vision is currently part of further internal consultation and investigation. Initial results show that products usually break down due to thermal problems (too high temperature) or defective components or joints. Only after more information has been gathered on the various advantages and disadvantages of improving the durability of the products will Philips take concrete action.

The three examples clearly show that it usually takes a number of brainstorming sessions and specific R&D initiatives before a final assessment is made of the most promising environmental opportunities to be implemented. Through these sessions and specific projects, learning and experience is built up and then used to reduce the present uncertainties about environmental opportunities and market perspectives. When Philips has learned more about these far-reaching environmental improvements, it will become easier to integrate these endeavours into the regular product development process.

Conclusions

The ISO 14000 series can be a good vehicle for increasing the environmental awareness within companies. The international standard can enhance continual environmental improvements of both processes and products. The ISO standard does not intend to establish absolute environmental targets. The degree of ambition in that respect is left to individual companies. They determine the level of the playing field within the boundaries set by the government's environmental regulations. It depends largely on the strategic choices made by these companies, as to which environmental improvements will be made. Of course, these choices are not made in a vacuum. Companies choose certain environmental strategies in response to societal demands and to the business environment in which they operate.

It is understandable that most companies are reluctant to move forward from incremental to far-reaching environmental improvements of products. Uncertainties about the benefits restrain them from being too far ahead of others in terms of environmental performance. The first efforts, like those taken by Philips Sound & Vision, are still more the exception than the rule. Those companies that follow the latter approach, should integrate environmental issues in the product planning process as early as possible. This guarantees that environmental issues become an integral part of the general business strategy. Only then can product innovation and environmental improvements can go hand in hand. •

This article is a revision of a chapter first published in 'ISO 14001 and beyond', edited by Chris Sheldon, Greenleaf Publishing, Sheffield, UK, 1997.

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The development and implementation of DfE programmes

Dr John Ehrenfeld and Michael J Lenox

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'Design for Environment' (DfE) is an innovative practice by which firms may effectively manage environment impacts so as to mitigate environmental threats as well as create competitive advantages. Yet despite its promise, DfE has seen limited adoption within the business world. Drawing upon the experiences of four leaders in DfE practice, a set of factors are presented which contribute to effective environmental design. It is proposed that the execution of DfE practice is dependent on an effective implementation strategy coupled with innovative organisational structures. Effective implementation strategies are characterised by vision, support, resources, technical participation, piggy-backing, distributed responsibility, and training and education. Proven organisational structures facilitate the exchange of information from diverse organisational participants.

Dr Ehrenfeld *(left)* is Senior Research Associate in the Massachusetts Institute of Technology (MIT) Center for Technology, Policy and Industrial Development and has been at MIT since 1985. He directs the MIT Programme on Technology, Business, and Environment, a interdisciplinary educational,research, and policy programme and serves as a core faculty member in the MIT Technology and Policy Programme. He directs on-going research examining the way businesses manage environmental concerns, seeking organisational and technological changes to improve their practices. In this work, he is looking at systems for introducing 'Design for the Environment' into the product development process. He is an associate editor of the new Journal of Industrial Ecology and a member of the editorial advisory board of Environmental Science & Technology. He holds a B.S. and Sc.D. in Chemical Engineering from MIT. He is author or co-author of over 100 papers, reports, and other publications.

Mr Lenox *(right)* is pursuing a doctoral degree in the Technology Management and Policy Programme at MIT. In addition, he serves as a Graduate Research Assistant in the MIT Programme on Technology, Business, and Environment. Mr Lenox's studies link the fields of strategy and organisational theory with an applied focus on environmental management. Mr Lenox's research examines the evolution of organisational capabilities in the context of adoption of environmental management practices. Mr Lenox holds BS and MS degrees in Systems Engineering from the University of Virginia.

Introduction

Design for environment (DfE) has been hailed as an innovative practice by which firms may effectively manage environmental impacts so as to mitigate environmental threats as well as create competitive advantages (Allenby & Fullerton, 1993; Fiksel, 1993; Fava, 1993). DfE is the systematic process by which firms design products and processes in an environmentally conscious way (Lenox, Jordan, & Ehrenfeld, 1996).'First and foremost DfE is a 'technology management activity whose goal is to align product development activities in order to capture external and internal environmental considerations (Shelton, 1996).' DfE differs from traditional design activities in that environmental issues are consciously addressed during the product development process. DfE provides competitive advantages through:

- reduction of manufacturing costs
- satisfaction of consumer demands
- lightening of regulatory burdens.

Pioneering firms tout the benefits of DfE both to the 'bottom line' and to the environment (Hill, 1993; Azar et al., 1995). Consequently, interest in DfE practices has grown dramatically. A recent survey of large manufacturing firms found

that over 25% of respondents have established environmental design programmes (Lenox, Jordan, & Ehrenfeld, 1996). Furthermore, the spread of DfE interest appears to be spread over a diverse array of industries (Lenox, Jordan, & Ehrenfeld, 1996). Yet despite the push for the adoption for environmental design practices, it appears that only a handful of firms perform DfE consistently and effectively on the product development level. DfE programmes are often characterised by a disconnection between activities on the corporate level and those on the product development level (Lenox, Jordan, & Ehrenfeld, 1996; Shelton, 1996). The literature is full of examples of pilot DfE projects on the corporate level, but of few examples of the integration into product development.

Barriers

Numerous barriers to the widespread adoption of DfE practice have been identified (Fiksel, 1993, Shelton, 1994). These barriers include failures to recognise the benefits of DfE and inabilities to perform DfE consistently and effectively. These barriers derive from the complex, uncertain nature of environmental design and that the benefits of adopting DfE may have long pay-off periods. Payoffs may be based on uncertain future regulation or consumer demand. These problems are often compounded by unfamiliarity with environmental issues among product development personnel. Environmental design typically does not fit into prevailing mental models. To engineers, designers, and managers, the 'environment' falls into the domain of regulation/compliance and there is a failure to perceive the strategic benefits from the adoption of DfE practice. This failure manifests itself in the resistance to adoption by Business Unit managers. Business Unit managers may feel that environmental concerns are not applicable to their product lines. Furthermore, the uncertainty of environmental design presents challenges to performing DfE consistently and effectively.

Tools

One response to the difficulties of both diffusing DfE practice and performing DfE consistently and effectively has been a concerted effort to develop better tools. For the purpose of this paper 'tools' mean those artifacts, typically embodied in software packages or written design guidelines, which aid the detailed design of products. In this context 'tools' are narrowly defined so as to contrast with organisational issues, ie. the arrangement of individuals and groups and the interconnections, authoritative patterns, activities, and the information exchanges between them. The current collection of DfE tools are both diverse and numerous. They are applicable to a variety of product development stages and life cycle phases (Lenox & Ehrenfeld, 1995). They provide a wide range of decision support from mere inventories of environmental impacts to impact analyses and improvement opportunities. They have been developed to be broadly applicable as well as useful only in narrowly defined product clusters.

The rush for better tools is predicated on a belief that the development of better tools will lower the costs of DfE activities, thus making adoption more likely as well as making environmental design more effective. Unfortunately, many tool developers fail to consider the organisational context in which tools are to be imbedded (Lenox & Ehrenfeld, 1995). Often tools are created to be stand-alone packages that are to be merely handed to designers. All too often these tools never leave the hands of corporate level, DfE programme staff. Such tools do an injustice to the reality of product development. Many are built on a simple model of product development in which the detailed design phase is the primary activity in technology management. In many of these tools, single objectives are assumed (for example, minimise environmental impact) denying the multi-objective nature of product development. Others, while facilitating comparisons, assume that 'trade-offs' are weighed only during the detailed design phase. Most tools require worker input far exceeding that realistically available in short product development cycles.

Models of product development

In contrast, a more interpretative model of the product development process highlights the importance of product conceptu-

alisation, the establishment of requirements, and product review (Kofman et. al., 1994). An interpretative model further recognises that these activities are not disconnected but are embedded in networks of relationships. In this way, product development resembles a series of conversations among a variety of players including not only design engineers, but also Business Unit managers, corporate researchers, manufacturing engineers, and marketing personnel. It is in the conceptualisation stage of product development that recent innovations have occurred such as integrated product teams and concurrent engineering.

Based on the interpretative model of product development, previous work has proposed a more prominent role for the organisation of environmental design activities (Lenox, Jordan, & Ehrenfeld, 1996). The challenge to adoption is to overcome failures to perceive benefits while developing structures which facilitate consistent, effective environmental design. Those firms which have experienced success in environmental design have been able to do so through:

- the execution of an effective implementation strategy to overcome perception problems
- the building of inter-firm information linkages to facilitate consistent, effective environmental design.

Typically successful firms have been able to do DfE without relying heavily on tools. While standalone tools of the type discussed above may eventually play a critical function within a DfE management system, it is our contention that they are not sufficient and perhaps not even necessary for efficient environmental design.

Corporate experience from the electronics industry

Based on a series of four cases covering IBM, Xerox, AT&T and Digital, this paper presents a set of factors that contribute to effective environmental design. The four firms were selected specifically because they are recognised leaders in DfE. Each are large, multi-divisional, Fortune 500 firms from the electronics industry. Each has a long history of being an innovative market leader. Three have been selected for the Baldridge Award for quality. Two have experienced recent financial improvements after highly-publicised rough times. The other two have recently been involved in highly destabilising processes of reorganisation. Given the homogeneity of the firms studied, it is important to note that the practices discussed in this paper are at best, representative of large, multi-divisional firms which specialise in the manufacturing of high-tech, consumer products. It is possible, if not likely, that firms operating in other industries and under different circumstances may find alternative mechanisms more effective. Hopefully by drawing upon the practices of established leaders others can derive lessons that have broad applicability.

What is interesting about these cases is the way the firms have organised DfE related activities (ie. organisational structure) as

Most tools require worker input far exceeding that realistically available in short product development cycles.

well as the way the firms have approached the establishment of those activities (ie. implementation strategy). A critical factor has been the information linkages that have been established to facilitate the flow of information from those with knowledge or competencies to those who may benefit. Especially interesting is the way in which the firms studied have used design activities to coordinate a variety of environmental management functions.

Organisational structure

Research at MIT has as found that the key to effective environmental design is the exchange of information between diverse organisational groups. Of the firms studied, each adopted an 'hour-glass' structure (see Figure 1 below). In this structure an individual or team serves as a filter between support functions on the corporate level and design efforts within individual product development groups (typically at the Business Unit level). This individual or team, referred to as the DfE champion, is assigned primary responsibility for DfE efforts within individual product development groups. These champions link a number of support functions, typically housed at the corporate level, with each of the phases of product development.

Coordination with support functions

In multi-divisional firms, the coordination of organisation-wide DfE efforts is typically managed by a corporate level group, often housed in the traditional environmental, health, and safety functions. Programme coordination serves a variety of roles. Corporate level programme coordination is critical to the implementation of DfE activities on the Business Unit level. Beyond the diffusion of DfE activities, programme coordination is necessary for the dissemination of general information about DfE, the coordination of DfE activities across Business Units, as well as the review of DfE activities within individual Business Units.

At IBM, programme coordinators hold an annual conference of individuals involved with environmental design within product development and corporate research and development (R&D). This conference provides a forum for open exchange of experiences among DfE practi-

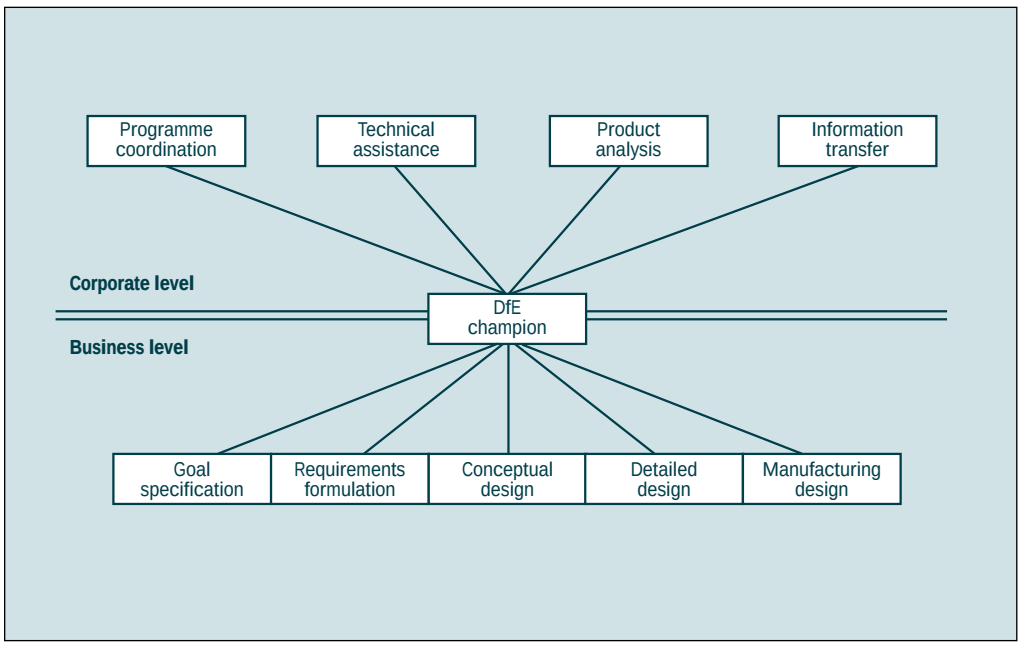

Figure 1: Organisational structure for effective environmental design

tioners in the various Business Units. Furthermore it provides an opportunity for corporate R&D to present recent innovations in practice. At Xerox, yearly reviews of DfE activities within Business Units help track progress and rank the progress of each Business Unit. Such reviews often provide incentives to Business Unit managers, who do not want to see their name at the bottom of any such list.

Technical assistance is one of the critical functions most often provided at the corporate level. Technical assistance helps product development in addressing specific design issues. For example, technical assistance may be used for assessing whether a particular cleaning approach is more environmentally benign. At AT&T, Bell Labs developed a process for eliminating lead solder from printer circuit boards. Technical assistance often resides in the corporate research centre. For example, at IBM the Engineering Center for Environmentally Conscious Products (ECECP) is dedicated to the development of product-based solutions to environmental problems. However, this is not always the case. At Xerox, technical support has been incorporated into the Product Stewardship group through the hiring of technical personnel. In this way, Xerox has combined technical assistance and programme coordination functions into one centralised, corporate unit.

Closely related to technical support functions is that of product assessment. Product assessment refers to the systematic analysis of a product's environmental impact. These assessments may be critical in the determination of future design changes. Analysis methods range from quick matrix methods (Allenby & Graedel, 1994) to full Life Cycle Assessment (LCA) (Fava, 1994). LCA and other in-depth analysis methods provide a total picture of environmental impacts. Rarely, if ever, are LCAs used to do design because of the long time and extensive resources needed to complete an assessment (Ehrenfeld, 1997). Matrix methods provide a quick, easy assessment mechanism but lack detail. At IBM, product assessment is conducted at ECECP on an ad hoc basis. At AT&T, over fifteen products have been assessed using the company's own matrix method. In general, the product assessment function is housed on the corporate level either within R&D or within the programme coordination function. In some cases, the product assessment function may be integrated into the Business Unit level. Major barriers to Business Unit integration are both the perceived and the actual cost.

Information transfer is one of the most interesting aspects of DfE. We have observed that DfE programmes have been used to coordinate between disparate environmental management systems either by exchanging information between these systems and designers, or by transferring information among systems. Information transfer is typically coordinated by a central corporate organisational body which collects and disseminates information. For example, the central information transfer unit may coordinate between numerous 'take back' facilities, manufacturing facilities, and Business Units. Again, an 'hour glass' structure appears to have been adopted (see Figure 2 below). Information may be transferred from a number of organisational sources including compliance efforts housed in corporate Environment, Health & Safety (EHS), pollution prevention efforts within manufacturing, product 'take back' efforts located in 'take back' facilities, as well as procurement issues within supply chain management. At Digital, Business Unit champions who reside in corporate EHS often visit and interact with the Digital 'take back' facility. At IBM, the ECECP will communicate with manufacturing recovery stations (MCR) to find out what their needs are and may transfer that information to Business Unit champions. At Xerox, there are elaborate feedback mechanisms between design and 'take back' efforts coordinated through their Asset Recovery Management (ARM) group.

Functions within product development

The interconnection of various support functions with a DfE champion is only helpful if further integrated with the various phases of product development. Product development involves a number of stages:

- goal specification
- requirements specification

- conceptual design
- detailed design
- manufacturing design.

While product development is often depicted as a linear process, in reality, product development is much more complex. The various stages of product development interact in a variety of ways. Consequently, the role of DfE champions is often that of a mediator. They may act as an advocate and expert for environmental design efforts. The challenge to the DfE champion is to utilise information from corporate level support functions so as to effectively participate in the product development process.

The incorporation of environmental concerns in the goal specification phase is of primary importance in the product development process. This phase is critical for the raising of environmental concerns in relation to traditional design objectives. This is also the stage when environmental concerns may be narrowed. The DfE champion(s) play a critical role in this phase. They may act as advocates and information sources on environmental design. Typically, a variety of information is needed to aid these efforts. Product assessments are a valuable tool for considering the systematic impacts of products and thus help prioritise environmental activities. Information transfers facilitate the incorporation of additional thinking. For example, the concerns of product 'take back' facilities may be incorporated.

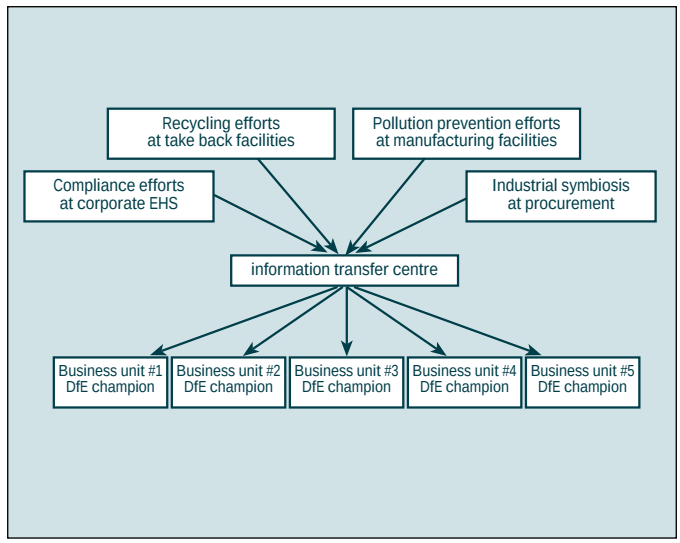

Figure 2: The information transfer function

The refinement of goals to specific constraints takes place in the requirements specification phase. As with the goal specification phase, the DfE champion should have input. The determination of specifications is what constrains, and thus influences, designers more than anything else. Here technical assistance may be necessary to help determine what is both feasible and economical. At IBM's Rochester division, the DfE champion creates extensive 'wish lists' for future product development efforts. These lists are tempered by design possibilities as expressed by designers and engineers. The actual determination of design takes place through the conceptual, detailed, and manufacturing design phases. Here the DfE champion is challenged to aid designers, if not participate with designers, in the meeting of design specifications. Often technical assistance is needed to answer certain design problems. Information transfer is critical to these efforts.

Through the various phases of design, design reviews serve an important benchmarking function. They allow the DfE group to review preliminary designs for compliance with specifications and to suggest possible courses of action. Xerox has used design reviews extensively to help influence the design process. It is within these phases that many 'green' design tools are targeted. These tools seek to facilitate design analysis so as to measure whether specifications are being met.

The implementation of DfE

DfE must take place on the product development level (Lenox & Ehrenfeld, 1995). It is only at this level that routinised design occurs. Thus the goal of implementation is the routinised

consideration of environmental issues within product development. A common characteristic of successful firms has been the ability to move DfE from a corporate level programme to product development groups typically housed in individual Business Units. Firms which have successfully implemented DfE practices appear to have followed a rather delineated implementation strategy. By delineated it does not mean that the implementation process is necessarily orderly or without conflict rather that it is involves a number of defining characteristics which contribute to success. (see Figure 3 below). These characteristics include:

- vision
- support
- resources
- technical participation
- piggy-backing
- distributed responsibility
- training and education.

These functions help facilitate the transferral of DfE practice from the corporate level to the product development level.

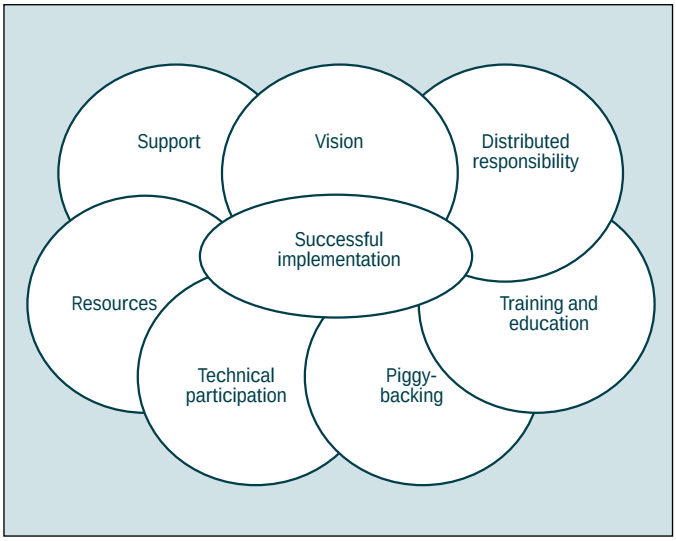

Figure 3: Devising an effective implementation strategy

Vision

Common among successful organisations has been the ability to establish a vision. By vision, it means the recognition of a need and the translation of that need into a set of broad goals. In each of the case studies, individuals, typically within EHS function were able to recognise a transition in the demands of environmental management. Towards the end of the 80s firms began to recognise the limitations of 'business as usual' – typically a reactive, 'end of pipe', compliance approach. With the advent of pollution prevention and waste reduction, firms began to pursue more proactive environmental management strategies. It was at this time that individuals in these leading firms began to recognise the role of product design in proactive environment management.

For example, in 1989 IBM convened an international task force to look for future challenges in the product environment area. In 1991, the American Electronics Association convened a special committee to develop a 'Design for Environment' conference. Among the participants, were such industry leaders as Jack Azar of Xerox, Brad Allenby of AT&T, and Barbara Hill of IBM. What is important in each of these cases is that individuals were able to recognise the importance of environmental design and to translate this understanding into vision.

Support

While vision is a first step, a vision will die without support. Support is necessary both for the dedication of resources as well as to serve as a signal to product development that DfE activities are important. Support typically derives from top management. In some cases support took the form of policy statements concerning environmental design. In others, it was the establishment of a DfE programme. At IBM, the international task force resulted in a broad corporate policy statement as well as the approval to start the Environmentally Conscious Products (ECP) initiative. At Xerox, the Vice President of EHS was able to gain support from the CEO. Such statements of support provide legitimisation for DfE programmes and can greatly increase adoption within product development units.

Support is necessary both for the dedication of resources as well as to serve as a signal to product development that DfE activities are important.

Resources

In conjunction with support is the role of resources. Resources are necessary for the establishment of a DfE programme. Typically resources take the form of staff. A dedicated management team whose primary responsibility is DfE is the most critical of resources needed. These resources may not derive directly from top management but may be secured through the shifting of personnel in existing programmes. For example, with the blessing of the CEO of Xerox, the Vice President of EHS was able to redefine the role of existing EHS employees to create the Environmental Design and Resource Conservation Team. Digital used a corporate-wide restructuring to establish its Product Stewardship programme within EHS. Note the establishment of a DfE programme and the diffusion of DfE practice to product development units does not necessarily require a large centralised staff. Often a small, focused team can be extremely effective. The primary importance of this team is to facilitate the establishment of environmental design on the product development level. It is at this lower level where additional resources may need to be secured.

Lack of understanding

One of the problems that may be encountered during implementation is a lack of understanding between the product designers, the ultimate end practitioners of DfE, and DfE programme administration, often environmental management personnel. Successful firms have mitigated this problem by incorporating technical staff in very early stages. By technical staff, we mean engineers who are familiar with product development. Technical staff can 'talk the talk' of designers. They are able to translate DfE in a way that makes sense to designers. In some cases, technical staff is given primary coordination duties for the DfE programme. At IBM, the first result of the international task force was the creation of the ECECP. It was a year later before the ECP initiative was officially started and the corporate programme established within product safety.

'Piggy-backing'

Often DfE initiative may be 'piggy-backed' from similar, established programmes. For example, DfE may be closely integrated with quality initiatives. By tying DfE adoption to the extension of current efforts, DfE is given legitimacy thus increasing the likelihood of adoption. At each of the firms studied, we found over and over again that successful quality programmes contributed to the adoption of DfE practices.

DfE champions

The key to effective implementation is the transferral of DfE practice from the corporate to product development levels, therefore formal links between these levels is critical. In each of the firms studied, transferral occurred through distributed responsibility. In other words, individuals were given responsibility for DfE activities in each

product development group, typically a Business Unit – DfE champions. The importance of champions is that they serve as advocates for environmental considerations during product development. They are critical in raising environmental considerations to the level of traditional design criteria. These champions may be established in a number of ways. At IBM, each Business Unit is required to assign a champion. This procedure has had the advantage of placing an advocate from within, thus breaking down barriers, and making DfE more accepted. At Xerox, each Business Unit is assigned a champion from an externally maintained DfE group – in this case the ARM. This champion is fully integrated into the design team. This system has the advantage of providing detailed training opportunities for the champion while still integrating them into the design team. At Digital, each Business Unit has a corresponding liaison point in the corporate DfE programme. These champions participate in the activities of the Business Unit but maintain their identity with corporate EHS. This system has the advantage of providing 'free labour' from the perspective of the Business Unit.

Training & education

A champion is often not effective if he or she is not provided with the proper training. In addition, if other members of the organisation are unaware of DfE efforts, champions are likely to meet stiffer resistance. Through training and education, organisations may raise the environmental competencies of product development staff, including champions, as well as raise awareness among other organisational participants. Xerox has pursued an aggressive multi-level training programme. At the first level, top managers go through a short explanatory training session. This session serves to merely raise corporate-wide awareness. At the second level, Business Unit managers are trained to identify the competitive opportunities through environmental design. Finally at the third level, designers are trained in detail about environmental design activities.

Incrementalism

One of the keys to effective implementation of a DfE programme is to approach things incrementally. Firms should implement slowly so as not to lose support of top management and to gain the support of individual Business Units. A rushed approach may lead to failure. Typically, we find uneven adoption among Business Units. Even among the leading practitioners of DfE, some Business Units are far more supportive than others. Pilot projects are one way in which to build both support and competency. At IBM and AT&T, initial pilot projects were used to demonstrate the potential benefits of DfE. However, failure of a pilot project may lead to a withering of support for DfE initiatives. In some cases it may be possible to dedicate resources internally, get some successes, and then gain support.

The key to effective implementation is the transferral of DfE practice from the corporate to product development levels.

Leading firms have pursued implementation incrementally, building successes in individual Business Units through the establishment of pilot projects.

Organisational characteristics

Are there certain organisational traits which may make the implementation of a strategic initiative like DfE more or less successful? Firms may possess existing capabilities which make implementation of DfE activities easier. Of the companies studied, three had been recipients of the Malcolm Baldridge Award for quality. All four are known for being innovative, forward looking companies and is recognised as environmental leaders (Fortune, 1992). Each of these attributes may make these organisations and its members much more open to both innovative programmes and environmental initiatives. Conversely, firms not possessing these attributes may face greater resistance in implementing a DfE programme. Furthermore, even innovative firms may face difficulties when faced with organisational downturns. One of the firms studied has had difficulty preserving organisational support and resources in the face of corporate restructuring. While DfE activities were eventually resumed, much of the organisational knowledge concerning environmental design was lost through attrition.

The future evolution of DfE systems and the role of tools

To summarise, the key to effective environmental design is the establishment of organisational structures which facilitate the transfer of information from various knowledge centres to the product development level. DfE champions play a critical role. Important corporate support functions include programme coordination, technical support, product assessment, and information transfer. Robust DfE practice integrates environmental concerns into the various stages of product development. Leading firms have diffused DfE practice throughout Business Units through effective implementation strategies. Attributes of these strategies include vision, support, resources, training and education, 'piggy backing', technical participation, and distributed responsibility. Furthermore, leading firms have pursued implementation incrementally, building successes in individual Business Units through the establishment of pilot projects.

As DfE practices become established, tools will become the critical component of a DfE system. Over time, interpersonal linkages may be replaced by stand alone tools or interlocking information systems. However this may not be necessarily so. Even with advanced systems, interpersonal linkages represent a robust solution to the complicated problem of information transfer and processing. The ability to develop a comprehensive database which easily interfaces with designers and is routinely updated with new information is a major undertaking. The establishment of linkages allows for knowledge to reside in multiple experts.

In the future, DfE may evolve to be more fully integrated with both environment management

systems as well as traditional design systems. In this way DfE may provide a bridge for the integration of environmental concerns into the mainstream strategic decision processes of firms. Increasingly, DfE will become a critical component of an integrated strategic environmental management system.. •

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Quick and dirty environmental analyses for garments: what do we need to know?

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Patagonia over the past seven years has pursued environmental improvements in the design and manufacture of their products. This article charts the company's progress by examining their approach to product development. They have developed a corporate environmental strategy and assessment programme, with a priority to reduce impacts and the creation of a pollution prevention policy. More radically the company wants to contribute to the formation of an economy which restores the ecological health of the planet. This has led them to adopt some fundamental ecological principles and approaches in the development of their products. This has resulted in, amongst other things, the use of only organically grown cotton in cotton garments, the development of new materials which utilise waste plastic drinks bottles, and the minimisation of packaging waste throughout the company.

Recently Patagonia has developed the 'ideal garment' Life Cycle Assessment (LCA) product rating system, as there was a need for a more rigorous process of reviewing their products. This article explains how this tool works in practice through the assessment of a hypothetical garment.

Finally the analysis of its entire product line, the common obstacles Patagonia have identified in their LCA tool and possible solutions are discussed.

Introduction

Patagonia is a designer and distributor of clothes and accessories for outdoor sports ranging from climbing to fishing to surfing. They are well-known for producing tough, durable products with high performance characteristics and bringing material innovations to the market especially in synthetic fibres. The company has over 750 employees and sales revenue for 1996 was $154m.

Increasingly, the company is becoming known for its efforts to improve the environmental performance of its products and overall operations. Patagonia for example donates 1% of all sales to grass-roots environmental groups and in 1996 this represented approximately

$1.5m in financial and inkind support. Patagonia's reputation is now such that in May 1996 Yvon Chouinard, the company's founder, was one of eight senior executives invited to a round table discussion with President Clinton and Vice President Al Gore on the topic of business and the environment.

Material assessment

Patagonia's concern about materials and processes led them in 1990 to hire several environmental consultants. They were briefed to undertake an assessment of the major materials used by the company – polyester, nylon, cotton and wool and recommend the environmentally preferable fibres for products.

Patagonia expected the consultants to report that natural fibres were environmentally superior. However, they concluded that neither polyester, nylon, cotton or wool were substantially more harmful to the environment than any other. The impacts of natural fibres were a surprise to the company. Pesticide and fertilizer used in cotton growing; sheep husbandry; fibre processing, dyeing and finishing were all processes of environmental concern in the life cycle of natural fibres. Customer care, including laundering and dry cleaning also, had significant implications (Werner International and RCG/Hagler, Bailly, 1991). So if moving to natural fibres was not the direction Patagonia should be taking – what was? The consultants' work did not address issues relating to specific products, but did give some general directions.

Early stages of eco-design

Patagonia's early attempts to identify and address the environmental impacts of its products were scattered and uncoordinated. They received diffuse information from numerous sources. For example, the company was advised that neon colours were undesirable, so it decided not to use them; Tagua nuts were tried as an environmentally and socially sound alternative to buttons, but unfortunately the nut buttons often broke when home laundered. A farm activist urged them to use organic cotton and was tried out on one specific product. This unstructured approach often lead them in confusing and contradictory directions, as the company did not fully understand what they were doing. In late 1992, Patagonia decided to develop a corporate environmental strategy to focus efforts more effectively.

Environmental assessment programme

Patagonia created an environmental assessment programme to:

- establish its environmental operating principles
- research the life cycle impacts of its products and corporate activities
- educate staff about integrating quality and environmental performance.

The priority was to reduce environmental impacts and to create a pollution prevention policy. More radically one of the aims was to contribute to the creation of an economy that helped restore the ecological health of the planet. This led Patagonia to the emerging concept of 'industrial ecology', systems thinking and the work of Hardin Tibbs, Fritjof Capra and Ernest Callenbach. This inspired them to create a set of company environmental principles which included:

- maximise system efficiency
- close the material resource/waste loop
- protect worker and public health
- use renewable resources judiciously
- conserve non-renewable resources
- educate employees and customers.

Ecological principles

These principles were adopted in mid 1993 and the hope was they would provide guidance for all employees. In practice these principles helped to identify ways for them to modify the impacts of their working practices. In the past four years there have been some notable improvements:

The use of recycled PET soda pop bottles

In late 1993 Patagonia introduced PCR Synchilla, a high performance fleece insulation product made from recycled Polyethylene Terephalate (PET) soda bottles. It was the first outdoor garment manufacturer to adopt recycled fleece into its

Over 15 tons of packaging has been eliminated with consequent reductions in waste and energy use in shipping.

product line. From Spring 1994 to Spring 1996, the company had diverted over 22 million PET bottles from landfills. Since Patagonia's recycled fleece programme began, the number of styles with recycled content has increased from 2 to 64 and has diversified to include wool/PET mix sweaters. The potential for recycling discarded fleece garments is also being explored.

Organically grown cotton

Cotton is grown as a monoculture, using synthetic pesticides and fertilisers. Concerned about the impacts of this agricultural process, Patagonia decided in 1994 to switch to organically grown cotton by the Spring 1996 collection. Although the number of products available in that season's collection dropped compared to previous years. Patagonia now has achieved record sales in cotton sportswear and technical equipment and all made from 100% organically grown cotton.

Difficulties in sourcing organic cotton fabric resulted in the forming of new relationships further 'upstream' in the textiles life cycle. Consequently, new design opportunities emerged because of this direct contact with yarn spinners and greige goods mills (Chouinard and Brown, 1997).

Packaging developments

The technical underwear products (Capilene® – clothing designed for particular sporting conditions) were previously sold in low-density polyethylene (LDPE) zip lock bags with recycled paper header cards. To reduce the amount of plastic used by the company, and packaging waste created, they switched to using just a recycled paper bag. Unfortunately this initiative failed as the bags did not perform well in the retail environment. Now the underwear is simply rolled up and a hanging tag put onto the garment (which is kept secure with a couple of rubber bands) for display in retail racks. Over 15 tons of packaging has been eliminated with consequent reductions in waste and energy use in shipping.

The need for a new tool

Patagonia became acutely aware that there was a need for a more rigorous process of reviewing its environmental operations, especially in relation to certain product lines. Since this issue was critical to their corporate persona and success in the marketplace, an immediate review of its performance with an emphasis on new product development was organised in mid 1996.

It also became recognised that there was a need for additional tools to help evaluate the environmental performance of its existing products, and to define its research and development agenda. These tools could not be developed directly out of their existing principles and Patagonia decided to contact The Natural

Step, based in Sweden and the Environmental Protection Encouragement Agency (EPEA) in Germany.

Checklists and tools

Patagonia developed The Natural Step's model for sustainability – the 'four system conditions' methodology, to be measurable and therefore applicable to building useful tools. It is summarised below as:

1 do not take anything from the Earth's crust that you cannot put back
2 maintain the integrity of the natural ecosystems
3 do not spread long-lived human-made materials around the environment
4 leave enough for others.

Patagonia's research found the EPEA's 'Intelligent Products System' a concept developed by Dr. Michael Braungart, head of the EPEA to be the most appropriate to the company's philosophy. This concept is about moving the development of products towards an environmentally sound, product life cycle oriented economy. This procedure describes products as either:

Consumable – things that can be composted at the end of their life

Service – products that are returned to the manufacturer for rebuilding or recycling

Unmarketable – things that are too hazardous to use or must be disposed of without recycling (Braungart, Engelfried and Mulhall, 1992).

The company found this concept easy to understand and used it to categorise their products. For example, natural fibre products without any hazardous materials could be composted and thus classed as a 'consumerable'; polyester garments were categorised as 'service' products as they could be shredded and recycled and multi-material coated synthetics were called 'unmarketable' as they are hard to recycle.

A rating system for evaluating Patagonia's products began to be developed. This tool had to be clear for product development staff to understand; provide sufficient information for users to incorporate in decision-making; and be useful for tracking changes in environmental performance. At the same time, the tool needed to use data that was readily available or data that did not require significant resources to obtain or analyse. The company did not have the time or funds to spend researching data relating to over 300 products which use materials and processes from approximately 200 suppliers and contractors.

The product rating system and the 'ideal garment'

They eventually settled on a modified Life Cycle Assessment (LCA) which contains six components:

Using these six categories, a rating system was developed based on a simple 1–5 scale, with 5 representing an 'ideal garment'.

Definitions of an 'ideal garment'

Product design criteria
- meets specified performance criteria
- product lifespan – minimum 10 years
- ease of repair, component reuse and composting/recycling
- product requires minimum care

Materials selection
- natural fibres produced in sustainable manner
- biopolymers
- recycled content
- all inputs to material production identified and toxicity characterised
- toxics: if used, they should be produced, consumed and detoxified on-site/the final product should not be toxic.

Production processes
- efficiency of material use analysed and optimised
- energy and water use analysed and optimised
- energy from solar-based sources
- quality standards specified and production defects meet three sigma level (97% of products defect free)
- wastes are eliminated and there is no disposal from production.

Distribution
- packaging manufactured from renewable resources and finally recycled or composted
- transportation is optimised for energy efficiency
- energy from solar-based sources.

Product maintenance
- consumer care is minimised
- product only requires cleaning with cold water and mild soap, then line dried/no ironing or dry cleaning required
- quick and cost effective repair service offered.

End of life
- consumers urged to keep and use product if it is still useful
- compostable products come with composting instructions for the consumer
- product can be returned to Patagonia if the consumer does not want to dispose of it
- where feasible, systems in place for disassembling non-compostable products for component reuse, material recycling and remanufacture.

1 **Product design**
choice of materials, features, construction, aesthetics, performance level

2 **Material selection**
origins, production and characteristics of material

3 **Production processes**
cutting, sewing and garment finishing eg. garment washing

4 **Distribution**
packaging, transportation (distance and mode from point of materials production to warehouse)

5 **Product maintenance**
consumer use and product care

6 **'End of life'**
potential recyclability, components reusability, remanufacturability and restrictions on disposal.

Using these six categories, a rating system was developed based on a simple 1–5 scale, with 5 representing an 'ideal garment'. The 'ideal garment' would be a product that could meet both The Natural Step's system conditions and was 'consumable' in the context of the EPEA scheme (Figure 1). Once the data had been gathered for a particular product it was assessed against the description of an 'ideal garment'. Although subjective, it allowed for some flexibility in lieu of defining properly what each level of the five point scale might mean for different types of products.

Figure 1: Definition of an 'ideal garment'

Hypothetical product profile: Patagonia's eco-design tool

Product
Superfleece jacket

Design
Nylon with polyurethane coating and silicone DWR, nylon, polyester, nylon snaps, polyester zip, nickel plated metal, elastic, cordlocks.
- durable in most conditions
- meets performance criteria
- multi-material
- repairable

Materials
Vendor A: material 1 / material 2
Vendor B: material 1 (recycled)/material 2
Vendor C: material 1
Vendor D: material 1/material 2 (recycled) / material 3
Vendor A: does not meet all waste water standards and has minimum air emission controls
Vendor B: state of the art
Vendor C: improved
Vendor D: pollution prevention programme
- several shades have heavy metals
- nickel is a carcinogen

Production
Cutter: company X
Sewer: company Y
Finisher: none
Efficiency: 82.7%
Company X: recycles scrap
Company Y: has an energy efficiency programme

Distribution
Fabric: US and Japan
Cutting and Sewing: Hong Kong
Finishing: none

Maintenance
Cold wash and line dry – sufficient
- requires occasional heat to reactivate DWR
- most repairs undertaken by consumer
- all components replaceable by Patagonia

End of life
. Multi-material makes recycling difficult
. base fabric not recyclable at all
. zip and fleece recyclable.

Figure 2: Hypothetical product profile

Using the tool

Implementation of the tool involved two steps. First, the Environmental Assessment staff create a descriptive database for a product and then the product is rated in each category. If there is not sufficient information to give a rating for a category, it is left blank. An arithmetic average is then given as an overall score. The overall score is not intended to be used to compare one product against another, though it is useful as an indicator for product development staff in highlighting low performing products for review. Environmental Assessment staff present products with an overall score below 3.0 for review. Product Development staff should then look at the individual components of the review to determine the significant problems. These problem areas then become the priority for development work.

To show how this tool works in practice, a hypothetical garment has been constructed for assessment. This 'Superfleece jacket' is designed for moderate protection in inclement weather, to provide an intermediate level of warmth and be able to withstand significant abuse (Figure 2). It consists of a woven shell with a durable water repellent finish (DWR) on the face, a waterproof coating barrier on the inside of the fabric, a fleece liner, snap closure pockets and a full zipper. The hood is also lined with fleece. The drawcords can be used to adjust the hood and waist and there are reinforcement patches covering the elbows. Data sources for evaluation include a bill of materials prepared by the Product Manager, fabric sources information and a customer care description from the Fabric Development Group and cutting and sewing contractor data from the Global Sourcing Manager.

Based on this description, numeric values are assigned to rate each aspect of the product and an unweighted average for the overall score is used. In this hypothetical example, they score the product as shown in the table below.

Once all the hypothetical products in the group are evaluated, the results are assessed by a team of Patagonia's Environmental Assessment staff and other employees such as the Quality and Fabric Development staff (Figure 3). First, products with a high score (over 4.0) are highlighted and then the team focuses in on any products with an overall score of 3.0. or less. A close look at the individual categories for these products will help the team identify weak points that require attention and action. Common problems among the product group are those investigated, for example, consistent use of materials without any recycled content or lack of recyclability. In conjunction with Quality and Fabric Development staff, negotiations take place on the potential 'trade-offs' between environmental performance and other product attributes, to give the Product Managers a sense of the issues which need to be addressed.

Lessons from using the tool

Patagonia is aware that its review process is highly subjective due to a dependence on qualitative assessment. In practice, the process relies on the collective expertise of employees and the use of a set template for evaluating products, creating sufficient consistency and certainty within the system. Nevertheless, judgements have to be exercised when there are competing interests, for example, an environmental improvement that would mean reducing the durability of a certain material. There is no method available which will completely absolve Patagonia from the need to wrestle with qualitative assessments. The

Figure 3: Hypothetical product evaluation results

Product	design	material	production	distribution	use/maintenance	'end of life'	overall
Superfleece	3	2	4	2	4	2	2.8

biggest problem with the tool is the lack of information available to allow certain products and materials to be compared. Patagonia is aware of this weakness and is determined to eliminate any gaps in its database.

The common obstacles encountered by Patagonia in their endeavour to produce environmentally benign products are:

- designs and/or materials that make recycling or reuse impossible.
  designs that are difficult for consumers to repair or are uneconomical for Patagonia to repair
- less than desired durability in some product categories
- the need to use materials that are toxic as no benign alternatives exist.
- grossly inefficient markers (cutting patterns)
- long distance supply chain.

None of these obstacles are easy to address in the short-term but they have given Patagonia a focus to begin to resolve them.

What to do next

Patagonia is half way through reviewing its entire product line. When complete the company will have detailed information on the environmental performance of all its products. The next step is to implement a method of evaluating new products in the development process. This needs to be done in a manner that gives appropriate feedback to designers so environmental goals can be integrated into the design process. Simultaneously, a method for examining all existing materials is required as at present insufficient information is available to Patagonia. Finally, Patagonia is developing with its environmental assessment, product and material development staff a strategy on issues that require long-term planning and development. Patagonia's goal is a substantive and measurable improvements in its environmental performance. •

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'Design for environment' in practice — development of the Hoover 'New Wave' washing machine range

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This article discusses the planning, development, manufacture and marketing of the Hoover New Wave range of washing machines, launched in 1993. The range were the first products to be awarded an European Commission (EC) eco-label for their low energy, water and detergent consumption and wash performance. Lessons about 'design for environment' (DfE) from the New Wave project include:

- **incorporating environmental objectives into product development does not require a fundamental change to the process**
- **any successful greener product must balance environmental performance against other design attributes wanted by the market**
- **for most companies, DfE involves a learning process, eg. the benefits of moving from a 'green' design approach focused on selected environmental issues to an eco-design approach aimed at balancing environmental impacts throughout the life cycle**
- **DfE is a dynamic process involving continuous technical change**
- **the environmental improvement of products cannot be fully achieved by individual companies working alone.**

Design for the environment in practice

Hoover is one of the best known manufacturers of domestic appliances in Britain and has made washing machines at its Merthyr Tydfil factory in Wales, UK, since 1948 (see Note 1). This article discusses the creation of the Hoover New Wave range of 'green' washing machines, which were launched in 1993 after a four year programme of research, design and development and investment in a new manufacturing plant costing £15 million. The New Wave range were the first products to be awarded an EC eco-label, having exceeded set criteria for energy, water and detergent consumption and wash performance. The New Wave project originated in the late 80s when Hoover found itself with a range of washing machines which were losing market share. Although the range had been updated a number of times, 'new' models relied on core designs which had not changed significantly since 1967. In 1989 Hoover felt that a completely

new design was needed. The company had already decided to buy in pre-coated steel for manufacture of washing machine cabinets, thus replacing the slow, labour-intensive and dirty process of welding and spray painting sheet steel. Developments in materials meant that the outer tub could now be moulded from reinforced plastics, rather than fabricated from steel. There was therefore an opportunity to develop a new product range and simultaneously introduce new manufacturing processes. Hoover also recognised that a growing number of consumers were demanding greener products, and that foreign competitors had already taken a lead in this market. For example in 1986, Zanussi launched its 'Jetsystem' range in which the water was pumped to the top of the machine and sprayed down on the clothes instead of wetting them in the drum, thus saving water and energy. Hoover was aware too of EC plans to label products, such as new washing machines. Environmental performance was of course only one aspect of the planned new machine's appeal. Hoover wished to move 'up-market' from its traditional position in the washing machine market with its new range, and detailed market research was commissioned to define the features wanted by purchasers in different European markets and countries.

The product development process

The development of the New Wave involved serious consideration of environmental factors for the first time. No changes to the product development process were required apart from a move from the former linear product development process to a more 'concurrent' team-based project. No environmental specialists were involved and the team 'learned as it went along'. Nevertheless, the environmental objectives added some difficult design problems, whose solution was aided by the establishment of a closely-knit product development team. At the start of the New Wave project, senior managers from Engineering, Marketing, Manufacturing and Finance met to agree the business and market specification for the new range. This formed the basis of the technical specification. Environmental impacts were a key factor in the specification. Hoover recognised that any reduction in the environmental impacts of the new machine would depend mainly on minimising water and energy consumption in use – before this had been shown by formal Life Cycle Analysis (LCA). The aim was a significant improvement over the 44% reduction in water and 38% reduction in energy consumption/kg of wash load already achieved in Hoover designs since 1967. The next step was to convert the technical specification into feasible design concepts. This involved three parallel tasks:

- Deciding how the machine was to be engineered and manufactured. For example, the best method of joining the pre-coated steel panels for the cabinet had to be decided. Replacement of the enamelled steel outer tub, previously fabricated from some 50 components, by a single-piece plastic tub contributed to a substantial reduction in the number of parts in the machine.
- Design of the visual aspects of the machine, including consideration of ergonomic principles. In particular, the Hoover industrial design team were concerned from the outset that the new machine should have a stunning visual appearance that would enable it to stand out from competing products in the market.
- Researching how to reduce water, energy and detergent consumption.

Research and development (R&D)

In order to reduce the amount of energy, water and detergent consumed by the machine Hoover asked its R&D group to conduct a feasibility study for a radically new wash process. This research produced several new concepts. These included: 'spin-wash' (slow-speed spins during the wash to wet the load with a reduction in water level in the tub from 7.5 cm to just 2 cm in the original concept design); front-fill (the idea of filling the machine from the front and using the wash load as a filter to reduce the loss of detergent flushed into

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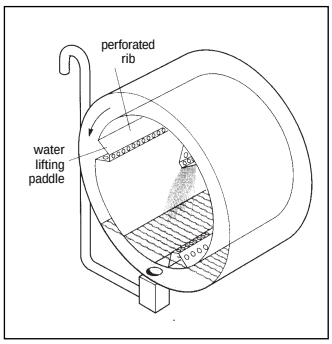

Figure 1a
Diagrammatic comparison of passive spray paddle system (similar to that used on Hoover machines).

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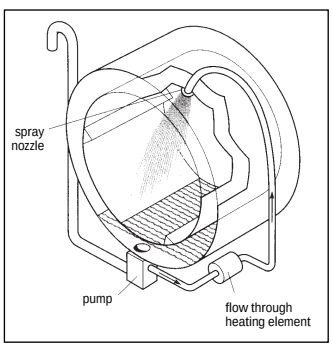

Figure 1b
Diagrammatic comparison of pumped spray system (similar to that used on Zanussi 'Jetsystem' and other washers).

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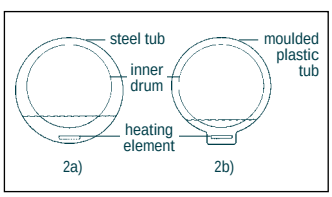

Figure 2
a) Traditional offset steel outer tub and inner drum arrangement.
b) Plastic tub with moulded in sump, shows the reduced amount of water required to cover the heating element.

the sump); 'spray paddles' (the idea of perforated agitator paddles in the drum to scoop up water from the base of the drum and shower it over the clothes – Figure 1a). The spray paddle concept would avoid infringing the patents on pumped systems used by Zanussi and other manufacturers (Figure 1b). The new wash process required parallel work to develop an electronic control system to allow more precise control of the wash cycle than was possible with the electro-mechanical timer traditionally used on Hoover machines. In addition the decision to use a plastic outer tub allowed a sump to be moulded in, thus allowing the drum and tub to fit more closely than previously and the machine to operate with less water (Figure 2b).

Design development

The research concepts then had to be developed into a practical design. This involved Hoover product engineers developing and testing key elements of the conceptual machine. They found that to get a consistently good wash performance required increasing tub water levels to 4.5 cm and reducing mechanical action, plus the development of an effective spray paddle system. Subsequently a ball valve was added to seal the base of the tub during filling, as the front fill system was insufficient to eliminate detergent lost to the sump. In parallel component designs were being finalised for manufacture, in order to reduce costs, speed assembly and improve quality. In pursuit of these aims further parts reduction was achieved by substituting snap fits for screws and other fixings on components such as the door. As a result of applying this approach throughout the design, the new machine had one third fewer parts than the previous range.

Environmental policy and eco-labelling

The original impetus for the environmental aspects of the New Wave project was the growing European market for energy and water saving washing machines. However, soon after the project had begun, Hoover senior managers began to consider broader environmental management issues. An environmental consultancy was commissioned to establish an environmental policy for Hoover. Their report resulted in the Board issuing an Environmental Mission Statement in April 1990, with an Environmental Affairs Committee responsible for implementation. The Hoover Environmental Mission stated that the company aimed:

'To adopt the best practical environmental methods in the design, production, packaging, use and disposal of its products, whilst continuing to improve their benefits to the consumer.'

Also in 1990 the EC announced its eco-labelling scheme, with washing machines among the initial categories of products to be labelled. Like the Hoover Environmental Mission, the eco-labelling scheme is based on a 'cradle to grave' approach to product environmental impacts and, in 1991, a LCA was

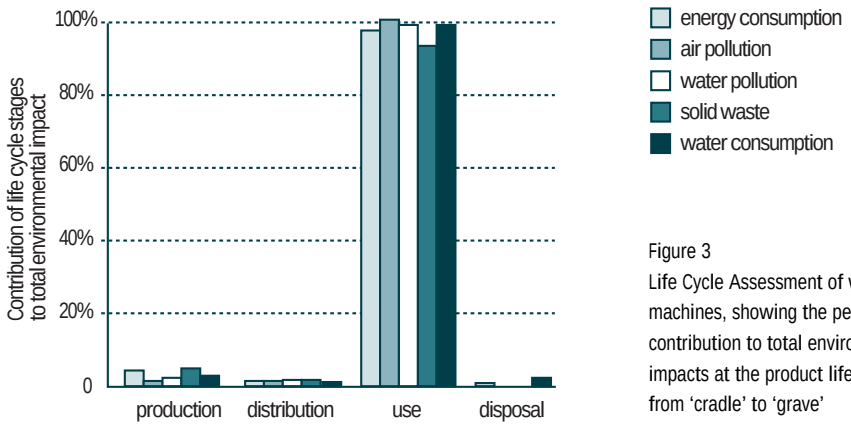

Figure 3
Life Cycle Assessment of washing machines, showing the percentage contribution to total environmental impacts at the product life stages from 'cradle' to 'grave' (After PA Consulting Group, 1991).

commissioned to establish criteria for the washing machine eco-label. The study showed that over 95% of the environmental impacts of washing machines occur during their use (Figure 3). Another LCA of washing machines, that included the impacts of detergent manufacture, concluded that some 80% of environmental impacts occur during the use phase (Deni Greene Consulting, 1992). The LCA for the eco-label confirmed Hoover's focus on reducing the water, energy and detergent consumption of New Wave, but also indicated other areas of environmental impact that should be considered before the launch of the range; if it was to meet the eco-label criteria.

Eco-design

Hoover thus began to consider the environmental impacts arising from production, distribution and disposal of the New Wave.

Production

Use of pre-coated steel for the cabinet (Figure 4) gave Hoover major savings in energy consumption (previously required for welding and drying) and eliminated toxic emissions of volatile organic compounds (VOCs) from the factory. But the company was careful not to claim environmental improvements until the 'export' of emissions to the supplier of the pre-coated steel had been evaluated. This subsequently showed that a real overall environmental benefit had been achieved – eg. pre-coated steel is roll-coated involving less energy and VOC emissions than spray painting. Environmental benefits also resulted from the elimination of welding and enamelling from tub manufacture, and from the reduction in the number of parts in terms of the amount of materials and energy needed to make the machine.

Hoover European Appliance Group

Figure 4
Pressing pre-coated steel panels for washing machine cabinets.

Hoover European Appliance Group

Figure 5
Shrink-wrapped Hoover washing machines being loaded onto specially-designed trailer. Both packaging and trailer were developed to reduce environmental impacts from distribution.

Hoover European Appliance Group

Figure 6
Part of a 1996 Hoover brochure for the New Wave Plus 5 range, showing the top-of-the-range model and the EC eco-label symbol.

Distribution

Hoover examined the advantages and disadvantages of a cardboard pack versus a polystyrene pack shrink-wrapped with polythene. Both costs were similar and could be recycled, but the company came to the conclusion that – despite controversies about its use – polystyrene performed better and had the edge on environmental grounds, being lighter to transport and using much less water and energy to manufacture. To reduce transport costs and fuel consumption, Hoover commissioned a new design of a trailer for transporting its washing machines. This enabled more machines to be carried in each load, and significantly reduced the number of vehicle movements required in bulk distribution (Figure 5).

Disposal

A reduction in the number of fixings in the machine – adopted mainly for production reasons – made the New Wave easier to take apart for recycling. Recycling was also facilitated by reducing the variety of plastics used and identifying them by type.

Marketing the New Wave

The New Wave range was first launched in February 1993. But due to a delay in introducing the Eco-labelling scheme, the award of an eco-label to the range did not occur until November 1993. By early 1997 the Hoover New Wave and its successor range were still the only appliances to have been awarded an eco-label.

Use of the eco-label is voluntary and involves payment of registration and licensing fees. Although other washing machine manufacturers have models that qualify, they have not applied for an eco-label because they do not consider the marketing advantage to be worth the cost (ENDS, 1996, a). The introduction of mandatory EC energy labelling in April 1996 gives products a ranking for energy efficiency, thus rewarding manufacturers of the most efficient machines, unlike the simple pass/fail criterion of the eco-label.

Since launch the New Wave range has sold well. Hoover believes that its environmental approach, supported by the eco-label, has been an important factor in the range's success, especially in the environmentally-aware German market in which the company doubled its market share in 1994. It also enabled the company to enter other environmentally-conscious markets such as Denmark and Austria.

In the absence of any other independent endorsement, the New Wave was initially promoted mainly on its money-saving aspects. However, in later sales material the 'environmental friendliness' of the range and the independent backing offered by the award of the eco-label were strongly featured, targeting environmentally-conscious consumers in the upper-middle segment of the UK washing machine market. In 1996 the New Wave range was replaced by an incrementally improved

range, called New Wave Plus 5, with increased capacity and lower water consumption. This range also gained an eco-label, plus the 'B' rating for energy efficiency (Figure 6).

Extending the product family

The £15m investment in the development and manufacture of the New Wave has also been employed to produce lower-priced models aimed at the volume UK and Southern European markets. By modifying the New Wave design, mainly by substituting electro-mechanical for electronic controls, Hoover developed the 'Soft Wave' and later 'Eco-Wave 5' ranges. These also save energy, water and detergent compared to previous models, but do not quite satisfy the eco-label criteria because they lack features, such as spinwash, that require electronic controls. These lower-cost ranges have the same mechanical components as New Wave and are assembled on the same lines.

Lessons

What lessons about designing for the environment can be learned from the New Wave project?

Balancing design attributes

Any successful greener product must balance environmental performance against the many other design attributes – performance, reliability, appearance, etc. – wanted by the market, and do so at a competitive price. This point was highlighted in a broader study of sixteen greener products (including the New Wave) which showed that to be commercially successful, the products had to be competitive in terms of performance, quality and value for money before environmental factors entered the list of customer requirements (Smith, Roy and Potter, 1996; ENDS, 1996 b). These various elements were included in the specification for the New Wave range from the start of its development.

Integrated product development

Incorporating environmental objectives into the product development process does not require a fundamental change to that process. What seems vital is that the 'green' product development process is carried out in a 'concurrent', integrated manner. Adopting a concurrent, team-based approach, such as that introduced by Hoover for the New Wave project, means that the marketing, engineering/industrial design, production, financial and environmental aspects of the product, can be considered by team members from the planning and specification stage onwards.

From 'green' to eco-design

Designing for the environment is a new activity, and for most companies, will involve a learning process. Hoover began the New Wave project with the aim of producing a design that would meet the growing market demand for washing machines that required less water, energy and detergent in use. The choice of materials and production processes was mainly determined by performance, cost and efficiency considerations.

During the New Wave project Hoover learned the benefits of moving from a 'green' design approach to an 'eco-design' approach.

The environmental improvement of products cannot be fully achieved by individual companies working alone.

Following the introduction of the Hoover Environmental Mission, and the company's involvement in formulating the washing machine criteria for the EC Eco-labelling scheme, environmental impacts from the production, distribution and disposal phases of the life cycle were considered. Fortunately, analysis showed that the new materials and production processes used less energy and generated fewer emissions than the previous processes. However, it is possible that had the system been designed from the start with the environment more directly in mind greater improvements might have been achieved. In other words during the New Wave project, Hoover learned the benefits of moving from a 'green' design approach focused on selected environmental issues to an eco-design approach aimed at balancing environmental impacts throughout the life cycle.

Continuous improvement

Designing for the environment is a dynamic process involving continuous technical change. Data published in Which? magazine in the UK (Consumers Association, 1995, 1996) and elsewhere (eg. GEA, 1995) indicates that the New Wave was one of the best European machines available in the mid-90s in terms of energy consumption, and among the better machines in terms of water consumption. Nevertheless, Hoover is having to continue to improve its designs to keep up with the evolving standards of environmental performance set by competitors and regulators. Further reductions in the energy, water and detergent consumption of washing machines are possible, for example by improved insulation, increased motor efficiency and controls to match water and detergent input to suit the type, amount and dirtiness of the wash load. Although some manufacturers are introducing such systems, their general use depends on cost and market advantage.

Organisational change

The environmental improvement of products cannot be fully achieved by individual companies working alone. Energy consumption, for example, depends on wash temperatures, which in turn depend on detergent formulation and consumer behaviour, given that in some countries cold water washing is common. Likewise, while the variety of plastics used in the New Wave was reduced and plastic components are marked to facilitate recycling, at present plastic components tend to be buried in landfills rather than recycled. Similarly only a small proportion of washing machine packaging is recovered for recycling. Individual manufacturers could set up their own recycling schemes, but in practice an effective and efficient system requires the involvement of other organisations such as local authorities and recycling firms and the stimulus of appropriate legislation. Apart from recycling, measures that may help conserve resources and reduce waste include increasing product life, and reusing components from repaired or discarded machines.

Although it may be argued that there are environmental advantages in designing products to last longer, the issues are complex. Hoover therefore kept to its standard design life of 10 years for the New Wave, arguing that due to improvements in technology, designing for a longer life was unlikely to be environmentally beneficial. In common with the rest of the domestic appliance industry, Hoover did not plan to 'take back' and reuse components believing that such components would be outdated and unacceptable to consumers. In any case, the UK Trade Descriptions Act requires that new products contain new components. One way by which this problem could be approached is by designing a long life basic chassis, which could be 'upgraded' with the latest control and motor technology at the end of its initial life (Goggin, 1994). However, the adoption of such radical eco-design approaches depends on market acceptability, legislative change, and perhaps on the introduction of new patterns of production and ownership, such as leasing. •

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Footnote

1. In May 1995 the Hoover European Appliance Group was sold by its US owners, Maytag, to the Italian white goods manufacturer, Candy. The policies and approaches outlined in this article may of course change under this new ownership.

Acknowledgements

This article is based on research conducted in 1995 by the author and a BBC producer, Cameron Balbirnie, during the production of a video entitled Green product development – The Hoover 'New Wave' for an OU undergraduate course Innovation: Design, Environment and Strategy. Particular thanks are due to Angus Dixcee, former Director of Engineering Development, Hoover Ltd.; Barry Mayes, Director of Engineering, Major Appliance Product Division, Hoover European Appliance Group and Caroline Knight, Manager, Media Relations, Hoover European Appliance Group, for their assistance during the production of that video and for further information.

The Greenpeace Twingo SmILE car

Introduction: Greenpeace in response to the automobile industry's failure to implement technically feasible measures which would reduce petrol consumption in new mass-produced cars, initiated the 'SmILE' (Small, Intelligent, Light, and Efficient) project, by commissioning the refit of a standard Renault 'Twingo Easy'.

What has changed compared with the original Twingo Easy?

Weight reduction: 195 kilogrammes have been slimmed off the original vehicle using conventional materials, a total weight saving of 23%.

Improved aerodynamic drag: Measured in wind tunnel tests the Twingo SmILE's body has 30% less air resistance than has the original vehicle.

Fuel consumption: Under new European Union driving cycle test conditions the Twingo SmILE achieved a fuel consumption level of 3.26 litres of gasoline per 100 kilometres, which represents a reduction of 51% compared to the original vehicle.

Smaller-displacement engine combined with a charger (loader): The Twingo SmILE features a small volume, two-opposing cylinder, four valve, four-stroke internal combustion engine, which draws its power from forcing air into the cylinder for more efficient combustion. The 'loader' is designed for optimum performance at the lower, more frequently driven speeds. With its 55 horsepower engine, the car has the same performance as the original Twingo Easy.

These design and engineering principles can also be transferred to corresponding vehicles from other vehicle categories. This element of transferability is an important factor in the SmILE project.

African wire baskets

These baskets are made from recycled wire pulled from old car tyres, as they are being cut up to make the soles of shoes. The baskets are made mainly by women in rural Zimbabwe communities in a variety of sizes and are utilised as small containers and laundry baskets. The decorative patterns are traditional designs and painted by hand using local pigments. The crafted pieces are sold by the makers in the local markets.

Hans-Peter Becker, Managing Director, Wilkhahn UK

Martin Charter

Joint Coordinator, The Centre for Sustainable Design, UK

Since 1993 Hans-Peter Becker has been Managing Director of Wilkhahn UK. His previous positions within the Wilkhahn Group have been in international marketing and sales. He has held positions in a range of consumer durable companies and his international career has included responsibilities in the Middle East and France. He studied business administration and marketing.

Could you give me some background information on Wilkhahn?

The Wilkhahn Group is a medium-sized family owned company, with its headquarters near Hanover in north Germany. The company manufactures and distributes a range of office seating and tables. We have approximately 500 employees in Germany and a worldwide turnover in the region of 120,000,000DM (approximately 62% in Germany and 38% the rest of the world). The company has its main factory in Germany and covers the European market through subsidiaries or sales office.; a second factory is located in Spain. Wilkhahn has licensed partners worldwide in the US, Australia, South Africa, Brazil and Japan.

Fritz Hahn, the founder's son, still acts as the grandfather figure monitoring and promoting the ethic of fairness and honesty throughout the business. An important component of this ethic is that ecology is an integral part of corporate policy and not a 'bolt-on'. This approach has been embedded in the firm since the 1950s, with an industrial design philosophy of simplicity, longevity and non-wastefulness.

What are the key characteristics of Wilkhahn's eco-controlling systems?

The major reason behind establishing the eco-controlling system was to integrate ecological management within the structure of the company. In effect, it has been practised in the company since the 1960s but in an un-written trial and error manner. For example, Wilkhahn stopped using tropical hardwoods over thirty years ago because we did not wish to participate in the destruction of tropical rainforests. The same results can be produced using woods from European forests, stained in a mahogany or teak colour. The company did not have a systematic approach to ecological management, however, it had fuelled its heating system using waste wood chips for many years.

The Wilkhahn Board recognised the need for a system to manage the firm's environmental concerns and impacts. So in 1992 the Eco-controlling project was launched. First, the main areas of

Wilkhahn: the implementation of the eco-controlling system

Hard factors

- product design
- the use of materials
- manufacturing processes, production
- energy
- emissions, waste
- transportation
- maintenance, re-use, repair,
- recycling, safe disposal

Soft factors

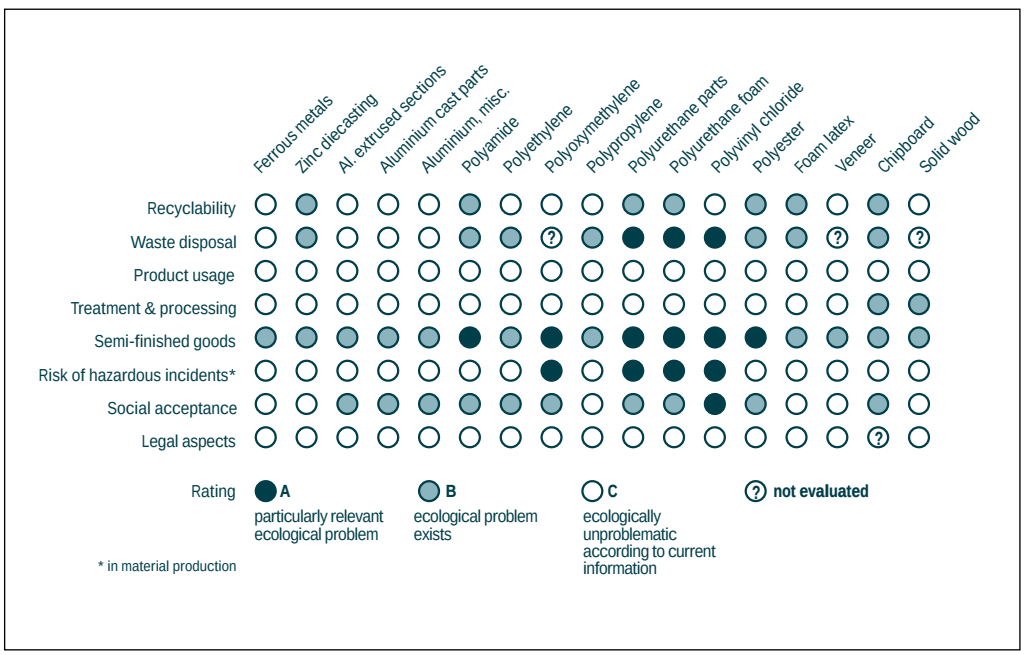
- information and documentation
- awareness and communication within Wilkhahn
- communication to the market and Wilkhahn's market partners worldwide
- impact on marketing and Wilkhahn's strategy.

responsibility were defined and an internal organisation and information network was established. Then the Ecological controlling system was developed and implemented in five phases from 1992 to the end of 1994.

We decided to look at the company as an ecological system – this basically meant examining what went into the company, what happened inside it and what went out. The company established an inventory of materials and set up a database. Then we contacted our sub-contractors to establish what materials and processes they used and which ones were environmentally benign. In parallel we developed an 'A', 'B', 'C' system – where 'A' was an ecological problem product and 'B' or 'C' products were ecologically neutral or harmless (Figure 1). As a result ecological factors have become a major criteria for the selection of core suppliers. Wilkhahn are developing relationships with suppliers who will remanufacture, recycle or dispose of our products in an ecologically benign manner.

After establishing the materials catalogue and database we begun to look at the manufacturing operations, and decided to undertake an input/output analysis. This meant examining our product, distribution systems, packaging, wastes and emissions. The aim was to highlight the ecological weaknesses within the company. For example, we focused on minimising packaging waste and introduced a reusable packaging system. All products which are not delivered in cardboard boxes

Figure 1: Materials rating according to ecological criteria



are covered in polyethylene dust sheets or wrapped in blankets. The cardboard boxes are re-used many times and then recycled. The polyethylene sheets are pressed into bales and then recycled into new film. This new system was given a special award in 1995 by the Industry Design Forum, Hanover, Germany.

An essential element of the Eco-controlling framework is to educate and involve staff. Wilkhahn believes that ecological change is not something that should be dictated from the top, but undertaken and acted upon by employees. Employees can only take environmental steps when it relates to them and their work. Employees are much more committed when they are clearer about the results of their actions, instead of hearing vague policy statements from senior management.

This is why we set-up three working groups covering:

- materials
- ways to make production cleaner
- communication and organisation – with particular focus given to how to disseminate commitment to employees.

The aim of these groups was to highlight ecological problems and to recommend action to be taken. One of the benefits of these groups is that they are interdisciplinary, with members drawn from a variety of departments. For example, employees from the design, marketing, administration and personnel departments might discuss solutions to waste problems. Another important attribute to raising the profile of ecology within the company is the 'Environmental Forum', a permanent meeting place where employees are informed about ecological matters. This service also has a telephone eco-helpline.

Wilkhahn believes that ecological change is not something that should be dictated from the top, but undertaken and acted upon by employees

As a result of our materials research we have established an ecological chart of accounts, which breaks down all the inputs (raw materials from suppliers or manufacturing materials) and outputs (products, spare parts, emissions, wastes, etc). From 1993 Wilkhahn has produced eco-balance sheets which give detailed information on the flow of materials and energy within the company. This includes the consumption of energy and water, materials, fuels and additives, the use of transport and travel as well as by-products such as materials and spent air.

To what extent does Wilkhahn market and advertise their ecological commitments and products?

Wilkhahn has a rather ambivalent attitude towards marketing its environmental credentials, as we regard ecology as an integral part of the company's culture and identity and not a means to enhance our corporate image. Whilst our brochures contain ecological descriptions of the materials used in products, we do not include ecology in our marketing and advertising strategy. Considering the public's scepticism over corporate environmentalism the inclusion of 'green' messages and images would probably have a counter-productive effect.

Could you describe the role of your 'Innovation and Ecology' department within Wilkhahn's corporate environmental strategy?

The 'Innovation and Ecology' department was set up to formulate and implement the eco-controlling system. Now the system has been established it acts primarily as an ecological 'think tank' working at a range of organisational levels, within and across all departments.

It is not just the 'Innovation and Ecology' department that is responsible for thinking 'green', it is a commitment from the whole company. Our ecological principles have the same importance as our design philosophy and runs throughout the whole

The Picto chair, developed according to an ecological design concept, using primarily environmentally-compatible materials.

company. In 1989 it was both the management and the Workers Council who issued a document that assigned ecological aspects a higher value and goal, than making a quick profit. This statement gave me as Managing Director of a subsidiary the right to say to a potential customer, who might be one of the largest polluters in a particular country – that Wilkhahn does not want to do business with them. We are very serious about our ecological commitment.

How is eco-design organised within your company?

Eco-design is a fully integrated part of our product development process. Our internal design department became so successful that it was developed into an independent design consultancy called 'Wiege', which works closely with our in-house Product management department. The procedure is that Wilkhahn invites them along with other design companies to tender for our business. This Product management department is also responsible for all ecological design activities.

Before we extended our ecological thinking, the two major criteria in designing a product were 'form' and 'function'. With our ecological responsibility came the third criterion of 'ecological accountability'. We have put a lot of effort and investment into reducing the harmful impacts of our products. In 1996 the company introduced an ecological checklist for product development to ensure that products are kept simple, that longevity is maximised, materials are reusable and the design has long-term appeal. When we say that a product should last 10–15 years, we mean this not just as an ecological or quality issue but also aesthetically. We never make fashionable products, we make modern products that should not date. Products should also produce low emissions, be low on maintenance and easy to repair.

A design brief has to be right from the beginning and include all these principles. At Wilkhahn it has lead to abandoning a product in the middle of development due to the solution being ecologically unsound. For example, if a process or material is harmful, the designers have to resolve the negative impact or rethink the design completely.

Please tell me about the development of your 95% recyclable chair – 'Picto'?

We found that if you design an eco-friendlier product and use less harmful materials, this demands a much more intelligent approach to the design of a product because the quality of the engineering may neutralise the higher costs of more expensive benign materials – 'less is more'. The lessons learnt from developing the Picto chair have given the company a stronger base for future developments. For example, we have a product called Modus – an office chair – where we have applied the 'less is more' concept – the chair no longer has a back shell, foam body and fabric, just an elastic self supporting stretch fabric.

We have always tried not to copy product trends. Fifteen years ago, the trend was to produce chairs with elaborate mechanisms which had knobs, levers and other functions. You required a driving licence to operate one. We ignored this approach and designed a chair with one lever and one tension control that adapted to the users needs – this is all the sitter really requires. We are now concerned with quantum leaps in thinking and in introducing new products and systems of mobile furniture for mobile working environments – systems for multi-purpose use.

What do consider to be the characteristics of a more sustainable enterprise?

Wilkhahn has never considered ecology to be an isolated issue. This extends from our 'less is more' design philosophy, to the choice and selection of materials, to our social commitment. The Wilkhahn triangle of design, ecology and social fairness.

Fritz Hahn, the company's founder, was not happy that as a privately owned company only the family received the profits. So, in the late 1970s he implemented a profit-sharing scheme, whereby 50% of the company's profits each year are shared between the owners and the employees. So this philosophy of fairness and co-operation is reflected throughout the organisation from the management style to product design. We have a cooperative management, and as part of this we have our own ten commandments which include principles such as 'no orders without explanations'. We did not wait for the Japanese to install quality circles!

The head of the Workers Council is also a full member of the Administrative Board. This means if Wilkhahn decides, for example, to shift parts of its manufacturing to another country the decision is taken jointly between board members and the head of the Workers Council, weighing up carefully the risk of possible redundancies at the main factory against making the company overall a stronger worldwide player. This fairness, co-operation and honesty applies to both materials and design, as well as the way we work and communicate with each other – inside and outside the company. We still think it is possible to do honourable business.

Fairness relates to the way we talk and the way we work with each other and is reflected in the design of our products and also the architecture of our buildings. we call this social architecture. Our buildings are designed not just for the managers but also for the workers. We have commissioned architecture which enables workers and management to work together. This social fairness, ecological approach and honesty philosophy is Wilkhahn's perception of a more sustainable enterprise. •

Wilkhahn has never considered ecology to be an isolated issue. This extends from our 'less is more' design philosophy to the choice and selection of materials to our social commitment… the Wilkhahn triangle of design, ecology and social fairness.

The role of supplier evaluation and product Life Cycle Assessment in product development at the Body Shop International

Kieren Mayers

Independent Researcher (in cooperation with Dr David Wheeler, General Manager, the Body Shop International)

The Body Shop International is committed to environmental responsibility driven from the top. A key element of its environmental policy has been working with suppliers on product-related issues. There are a range of departments involved in product development issues including Product marketing, Technical, Purchasing, Accessories and Research & Development. A key element of supply chain management has been the use of Life Cycle Assessment (LCA) to assess environmental and social impacts. Evaluation of suppliers has been through the use of detailed questionnaire-based evaluation. This approach has created a range of business benefits including improved efficiency and better understanding of The Body Shop's business by suppliers.

Introduction

The Body Shop International is a UK based company that produces a variety of cosmetic products for skin, hair care, and beauty. The first environmental policy was written in 1989 with commitment from Anita Roddick, founder and Chair.

Product-related objectives were established to use best practice in the use of sustainable resources, and to market products that were safe. In 1991/92, a formal environmental management system was introduced, concurrent with the proposed EC Eco-audit scheme (now EMAS). A target was set for the inclusion of significant suppliers in an environmental accreditation scheme by February 1993, and a long-term aim was to develop a product Life Cycle Assessment (LCA) scheme.

Although strategic decisions relating to environment are taken at board level. The Body Shop International has several departments involved in the product development process, that through liaison with the Board of Directors and the Ethical Audit Department, are also responsible for incorporating environmental factors and decisions into product development:

The Product Marketing Department: develops and pilots new product ideas, based on customer needs, the efficacy of ingredients, and the use of natural resources and minimal packaging which can be refilled or recycled.

The Accessories Department: maximises the opportunities for fair trade eg. the use of organic honey from Zambia in lip balms, and identifies useful products made with plastics recycled by the company.

Research and Development (R&D): works on product formulations to enhance the aesthetic properties eg. colour and smell of existing and new products. R&D also ensures formulations are environmentally and socially

acceptable ie. use minimal preservatives, and maximise the use of natural resources and biodegradability.

The Technical Department: follows legislative developments effecting packaging, labelling, and ingredient requirements.

The Purchasing Department in liaison with the Technical Department: is responsible for environmental accreditation of and data acquisition from suppliers (due largely to their close association with suppliers with respect to supply chain and demand management).

Product-related environmental initiatives were not originally co-ordinated as part of a systematic and managed life cycle approach. Since the development of the company's environmental management system in 1991/92, a Product Stewardship programme has been instigated, incorporating:

- product life cycle assessment (LCA)
- supplier accreditation
- risk assessment (of 'down-stream' product impacts such as eco-toxicity and biodegradability)
- buyer environmental guidelines.

Product Life Cycle Assessment

In 1992, the Body Shop International decided that LCA should form an integral part of its environmental management system. The product LCA was to be used as a systematic approach to the sourcing of raw materials, considering environmental and social impacts from 'cradle to grave'. This approach was to include consideration of:

- raw material extraction
- supply
- production
- process wastes
- use of products
- sewage and waste generation by consumers
- sewage treatment
- release into receiving environments
- natural environmental processes
- end products.

Having used LCA to source product ingredients, the company needed to ensure that:

- renewable resources were used for product ingredients
- raw materials were sourced from indigenous cultures practising traditional and sustainable land-use patterns
- use of non-renewable resources was minimised
- biodegradability of product ingredients was maximised
- packaging used was recyclable.

Supplier evaluation

The Body Shop International realised that product LCA was dependent on extensive data acquisition from major suppliers, and that it also effected the selection of suppliers through the sourcing of alternative materials. A detailed supplier evaluation and accreditation scheme was developed, for both manufacturers and agents, to include data collection for a formal system of LCA.

In 1992, the Body Shop International decided that LCA should form an integral part of its environmental management system.

The Technical Department is chiefly responsible for initiating evaluations, although any department with justification (based on the quantities and salience of materials supplied) may request an LCA.

The Purchasing Departments are responsible for conducting assessments, evaluations, and rating (using a five star rating scheme). Initially a questionnaire is passed on to suppliers, the completion of which enables them to achieve two star ratings. To achieve star ratings 3 to 5, suppliers must complete questionnaire 2, and participate in the companies product LCA process. They may also attend a seminar at The Body Shop International on how to complete this work, or be the subject of a site audit where relevant.

The first questionnaire is relatively concise, and asks simple yes/no questions relating to commitment to:

- environmental policy
- auditing
- statements/reports
- staffing
- environmental management systems
- accreditation
- proactive 'green' initiatives.

The second questionnaire asks similar questions, but in much more detail under the categories:

- regulatory requirements
- pollution control
- environmental management systems
- proactive initiatives.

A separate second questionnaire is given to agents covering environmental aspects of:

- transport
- storage
- warehousing.

Suppliers must provide a flow chart of the production pathway from raw materials extraction to supply of goods and materials.

Finally, as part of the product LCA evaluation, suppliers are sent a detailed data acquisition sheet. To participate, suppliers must provide a flow chart of the production pathway from raw materials extraction to supply of goods and materials (forcing total 'back-tracking' along a product's life cycle). The flowchart must specify:

- the origins of any material inputs
- who controls each process
- the country of operation.

The data acquisition sheet includes a checklist of detailed data requirements, such as:

- use of traditional farming methods
- the use of Environmental Impact Assessment (EIA)
- rates of resource utilisation
- methods of resource extraction or cultivation
- the rate of any encroachment upon lands and resources
- the use of plant and organic materials
- processing methods.

Benefits from supplier evaluation

The Body Shop International see significant business benefits to supplier evaluation as part of their overall Ethical Audit programme (which includes environmental, social, and animal protection auditing). These include:

- A positive response from stakeholders to the overall ethical audit programme
- Increased understanding of company identity amongst suppliers and stakeholders
- Improved efficiency
- Enhanced morale
- Maintenance of legitimacy in an increasing stakeholder-driven economy
- Greater understanding of stakeholder needs and aspirations
- Improved communication between business and decision-making
- Ethically desirable activity. •

This is an edited version of a case history that appears in 'Managing eco-design: a training solution', edited by Martin Charter, The Centre for Sustainable Design, 1997.

The 'Freeplay' radio

Anne Chick

Joint Coordinator, The Centre for Sustainable Design, UK

…despite being created using the most sophisticated computer design techniques, this radio is powered by one of the simplest forms of technology known – clockwork.

If we are to progress towards the goal of sustainability there is the imperative to develop products which meet the needs and circumstances of people in developing countries. These products will have to utilise cheap, efficient and easily available energy sources such as solar and human power. For example, technology using a clockwork mechanism has recently received considerable coverage due to the story of the 'Freeplay' radio invented by Trevor Baylis, a British businessman and inventor.

Innovative invention

In late 1993 Baylis was watching a television programme concerning the problems of educating people about AIDS in Africa. Radio is an effective way of disseminating information in the developing world, particularly where levels of illiteracy are high. Unfortunately, broadcasting to people in many of these countries is problematic, since radio batteries are unobtainable or expensive and electricity supplies are erratic. Baylis decided to invent an affordable radio which used an appropriate energy source for people in remote communities in the developing world (Raynor, 1996).

Baylis's original experiments with a small motor, a hand-brace and an inexpensive radio were developed at various British Universities' engineering departments and designed by freelance London-based designer Andy Davy, following a grant of £200,000 from the Overseas Development Administration (ODA).

Clockwork technology

The result was the 'Freeplay', a radio which, despite being created using the most sophisticated computer design techniques is powered by one of the simplest forms of technology known – clockwork. It has a 10 metre long, 50 millimetre wide and 0.2 millimetre thick, heavy carbon-steel spring, which is preformed and wound around a storage spool. The 'B motor configuration' or more commonly known as a 'constant force' spring is wound against it's curvature on to another spool, called the 'Talk' spool. Once fully wound and released the spring then returns itself to its original position, thereby producing a constant force on the torque spool as it unwinds (Figure 1). This torque is transmitted by a ratchet system into a transmission speeding up from 1 to 1000 in a three stage arrangement (Figure 2). The transmission drive is a small DC motor

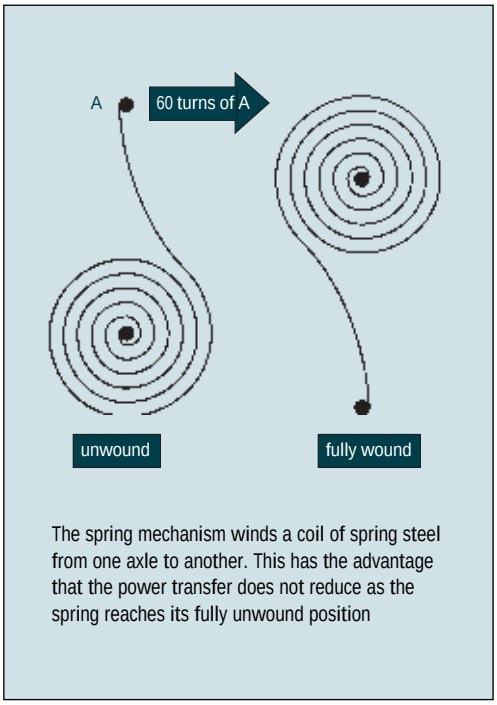


Figure 1: The 'constant force' steel spring mechanism

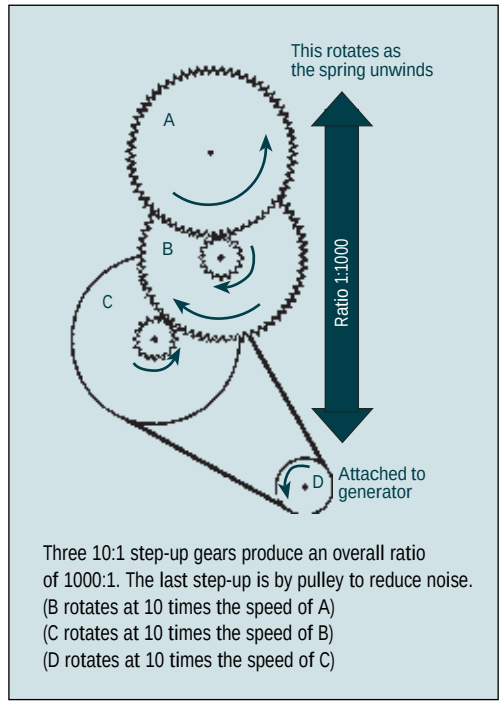


Figure 2: Step-up gears

(in reverse) providing to the radio about 100mW. The radio requires no batteries and can be either wound up with its built-in handle or plugged into mains electricity. The clockwork element takes 25 seconds to wind up and generates power for 25–30 minutes' airtime and effectively delivers FM, MW and SW. The spring has an 'end stop' for over-wind protection.

Baylis owns the rights to the radio, with 51% shares owned by his company Baylis Generators, and the remaining by the Joint Chief Chairman of BayGen Power Company. An exclusive licence has been granted to the holding company BayGen International, who manufactures, distributes and sells the radio through its commercial subsidiary,

BayGen Power Company. In keeping with Baylis's socially and environmentally responsible objectives, the radio is manufactured at a factory in Cape Town, South Africa, which is run by a consortium of associations for the physically handicapped. The plant, which has the capacity to produce one million units a year, employs 200 disabled people. President Nelson Mandela of South Africa called it 'a fantastic achievement' (Raynor, 1996). BayGen Power Industries has already sold over 150,000 units worldwide and the company has grown (excluding manufacturing staff) to over 50 employees, 10 of whom work in London at the European Headquarters.

Test-marketed in developing countries

The Freeplay has been test-marketed in several developing countries by various non-governmental organisations (NGOs) and distributors. In Russia and Ukraine the radio is being test-marketed by Stephen Hayklan, a British entrepreneur and distribution agent within those countries. The radio has also been tested in South Africa,

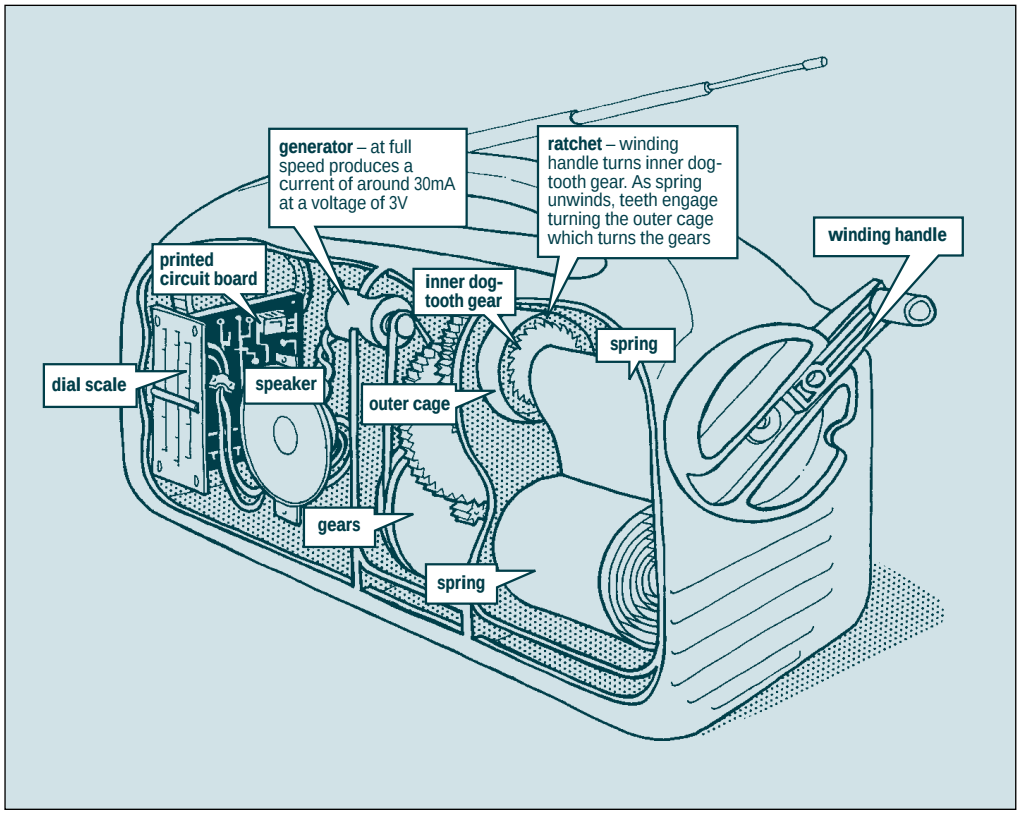


Figure 3: Cross section of the 'Freeplay' radio

Afghanistan, Bosnia-Herzegovina after the ODA brought 3000 radios and donated them to various organisations. NGOs have also been buying thousands of units and are distributing them in mass education aid projects. In Angola for example, the organisation War Child has distributed over 5000 radios to schools, healthcare programmes, and broadcasting educational programmes which cover illnesses, contraception, sanitation, nutritional advice and emergency health warnings (Appropriate Technology, 1996).

Guaranteed for 10,000 'trips'

The spring within the radio is guaranteed to deliver a consistent performance for 10,000 'spring cycles', which equates to approximately three hours play, every day, for nearly five years or 5000 hours play time. Thereafter the spring gradually decays giving diminished power output to the radio, which can still remain usable for sometime. When the quality of the sound becomes unacceptable, it is feasible for the purchaser, via the BayGen distributor network, to have the spring replaced. BayGen emphasis that the replacement of the spring should not be attempted by the purchaser as the radio is firstly, not designed for ease of access to the spring and when in the charge position the spring is extremely dangerous.

If this product could be redesigned to allow for ease of repair by the purchaser or if BayGen promoted a replacement of springs service, it would be of even greater benefit to the people of developing countries. At present, BayGen has no plans to do either.

Inventor Trevor Baylis demonstrating the 'Freeplay' radio to President Nelson Mandela, who pronounced it 'a fantastic achievement'.

This ingenious radio has been endorsed by and received many accolades from more than 20 international humanitarian organisations such as UNICEF and the Red Cross, as the ideal product for consumers in poorer and developing nations. In July 1996, it was awarded the BBC's 1996 Design Award in the 'best product' category and also won the overall award for the project which received the most votes from the general public.

BayGen is developing new applications for the clockwork mechanism – the 'BayGenerator'. In mid to late 1997 they will introduce the first of a series of 'personal power generation' products, a 'Second-Generation' AM/FM radio and the 'Freeplay Safety Light'.

Conclusion

At present, there are very few examples of 'sustainably designed' mass-produced products on the market – products which have, as well as environmental considerations at their core, progressive social and ethical aims. The Freeplay radio is a superb example of such a 'sustainably designed' product. Significantly, these BayGen clockwork products have begun to fill the huge gap for simple-to-use mainstream products that do not rely on batteries or any external electricity supply. They have highlighted the need for a different approach to product design in developing countries – an approach which considers the circumstances and needs of the people, while progressively reducing environmental impact. •

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‘Climatex Lifecycle’ textile upholstery fabric

Anne Chick

Joint Coordinator, The Centre for Sustainable Design, UK

Albin Kälin, Rohner Textil; William McDonough; Dr Michael Braungart and Dr Alain Rivière, EPEA; examining samples of Climatex®Lifecycle™

American architect and designer William McDonough was asked by DesignTex, a firm specialising in the design and manufacture of textiles for commercial interiors, to create a new line of fabrics for their Portfolio Collection, a range always designed by renowned architects. This collection was to be not just aesthetically creative but also environmentally benign in its creation.

Susan Lyons, Vice President of Design at DesignTex was instrumental in the commissioning of William McDonough. In mid 1992 she perceived that the new issue within textile design would be environmental responsibility. It was an issue in both the trade literature and the general press and she had received enquires from customers on the environmental attributes of DesignTex products. Her desire to pursue an environmental agenda was not, however simply the result of customer demand. She had a deep personal belief in environmentalism (Mehalik, 1996 (A)).

Rohner Textil textile mill

To launch her project she undertook literature research and contacted suppliers and manufacturers. In December 1992 she became interested in a fabric called Climatex, produced by a textile mill Rohner Textil AG in Heerbrugg, Switzerland. Susan Lyons became interested in the company because they had undertaken an environmental review and had begun to implement waste management practices. By early 1994 Rohner Textil’s entire product line would pass the OEKO-Tex standard 100 for textile upholstery fabrics, (a standard authorised by the International Association for Research and Testing in the Field of Textile Ecology) with a low level of harmful substances. In that year the company would also gain ISO 9001 certification and, later in 1996, receive the environmental management standard ISO 14001 and the European Eco Management and Audit Standard (EMAS) certifications (The International Journal of Life Cycle Assessment, 1996).

Mr Albin Kälin, Managing Director of Rohner Textil was prepared to collaborate with DesignTex in developing a new environmentally-considered product based on Climatex. The fabric, introduced in 1990 is a mixture of wool, ramie and poly-

Production of the William McDonough Collection at the Swiss mill, Rohner Textil AG

ester, and is designed to wick moisture away from the sitter. This product was to become the basis of the William McDonough Collection.

'Cradle to cradle' design

In mid 1993 William McDonough agreed not only to contribute to the fabric's appearance but to also be active in the manufacture of the material. McDonough's design philosophy was to have a profound influence on the direction and approach of the material's environmental characteristics. Indeed, two of McDonough's key principles became the impetus behind the project, namely the idea of 'cradle to cradle' design, rather than the 'cradle to grave' Life Cycle Assessment (LCA) approach and the concept of 'waste equals food'.

McDonough stated that in order to meet the 'cradle to cradle' design and 'waste equals food' criteria, the product had to either compost completely with no negative environmental impact, thereby becoming food for other organisms (organic nutrients) or to become raw material for another industrial product (technical nutrients). Furthermore, the organic and the technical should not be mixed as the product would be used neither as food for organisms nor raw materials for technology (Mehalik, 1996).

McDonough's design philosophy has been developed into product design protocols and three design principles through his partnership with Dr Michael Braungart, a world renowned environmental chemist and Head of the Environmental Protection Encouragement Agency (EPEA). The EPEA is the founder of the 'Intelligent Products System', a concept aimed towards an environmentally sound, product life cycle oriented economy. The EPEA is also recognised by the Society of Environmental Toxicology and Chemistry (SETAC) as a pioneer in the development of LCA methodologies (The International Journal of Life Cycle Analysis, 1996). The three design principles McDonough and Braungart developed are:

Waste equals food
Each artifact must be designed to enter either an organic metabolism, where it can decompose and become food for other living systems (organic nutrients), or a technical metabolism, a 'closed-loop' industrial cycle in which technical materials (technical nutrients) continually circulate.

Use current solar income
Solar energy, the complex and efficient system for creating and cycling nutrients should be mimicked by manufacturing processes.

Respect diversity
Respect the biodiversity of living systems and the intricate and symbiotic relationship between millions of organisms. This includes solving local social, ethical, ecological and economic problems with local solutions by emphasising the regional, cultural and historical uniqueness of a place (Rinkevich and Williams, 1997).

The textile collection also had to be aesthetically appealing, be produced on a commercial scale, conform to applicable industry standards and be competitively priced. The aesthetic concept was based on fractal relationships as a result of McDonough's interest in natural harmonic proportions throughout nature. He felt the designs should reflect this in both the protocols and the aesthetics of the material.

The Climatex Lifecycle partnership

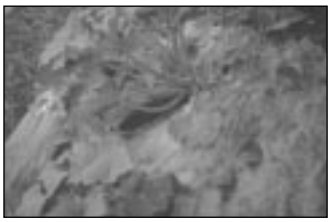
In October 1993 McDonough and DesignTex collaborated with Dr Braungart and Mr Albin Kälin of Rohner Textil to develop a fabric collection along the 'cradle-to cradle' LCA method. The challenge was to make this design philosophy a reality. The project was experimental and the approach was often 'learning by doing'. This meant having to persuade employees at all levels from senior executives down to workers on the manufacturing line to rethink the Climatex production process from scratch (Thiele Busch, 1996).

Dr Braungart examined the Rohner Textil mill's manufacturing processes in December 1993 and was impressed with the environmental attributes of Climatex and the fact it had received OKEO-Tex approval. However, a major drawback was the use of polyester in the fabric, since it comes from fossil fuels, its ability to be composted is unclear, as there was little guidance from research on the issue. William McDonough and Dr Braungart wanted Climatex to be produced without using polyester, so that only natural fibres would be used making the eventual fabric compostable (Mehalik, 1996 (B)).

Within two months Rohner Textil had eliminated polyester from Climatex and managed to maintain the high sitting comfort and all other technical qualities of the original product. This new material was called Climatex® Lifecycle™.

Rohner Textil also focused on optimising the mill's processes. For example, in order to strengthen the yarns for weaving, mills have methods like coating the yarn with potato starch (usually potatoes from conventional agriculture with fertilised and pesticide/herbicide treated fields) and wash it off after weaving using vast quantities of water. By changing some of their spinning and weaving details, then substituting starch with water recycled from the dyeing process (which also strengthens the ramie and wool yarn), and finally by not totally drying the yarns after the dyeing process, financial and environmental savings are achieved (The International Journal of Life Cycle Analysis, 1996).

A critical stage involved the development of environmentally benign dyestuffs free of mutagens, carcinogens, bioaccumulative and persistent toxins, heavy metals and endocrine disrupters for the upholstery collection, in order that it would comply with the McDonough/Braungart design protocol. This research element would dramatically increased the cost of the project. Albin Kälin agreed to pay the additional EPEA



Climatex® Lifecycle™ felt being used as a mulch for strawberry plants

The William McDonough Collection of five upholstery fabrics – Bark, Fog Lines, Golden Mean, Grass Roof and White Ash

fees, because Rohner Textil expected to acquire the patent rights to Climatex®Lifecycle™ (Mehalik, 1996 (B)).

Assessment of textile dyes

The biggest obstacle to success was persuading an international chemical supplier to subject its dye formulas to scrutiny and reformulation. EPEA contacted approximately 60 producers of textile dyes worldwide. The large Swiss chemical company Ciba-Geigy accepted the challenge and provided EPEA with the necessary information to allow the assessment of their dyes. From 1800 available dyestuffs, 16 were chosen by the EPEA. With this selection of dyestuffs it is almost possible to produce the complete colour-palette with the exception of black. (The International Journal of Life Cycle Assessment, 1996) After dye validation, Dr Braungart inspected finishing chemicals and designed tests to measure how well these products performed and composted. In all, the EPEA evaluated over 8000 chemicals in terms of the product design protocols and the final product used about 43 of them (Rinkevich and Williams, 1997).

Conclusion

Much of the credit for the development of the William McDonough collection should go to Rohner Textil. This company had to re-evaluate many of its processes to eliminate toxic products, reuse all wastes and design the final product to be totally biodegradable. The eventual fabric used a completely redesigned manufacturing process. Creating few pollutants during manufacture, it is compostable after use and leaves behind no carcinogens, persistent toxic chemicals, heavy metals or other toxic chemicals. In addition, all waste selvages from the textile production are manufactured into felt for upholstery inliners and a market-garden is testing the possibilities of the felt being used as a mulch for strawberry plants, protecting the berries from rotting and eventually decomposing into the soil. All the dyes and raw materials were also certified to be environmentally safe by the EPEA (The International Journal of Life Cycle Assessment, 1996).

The William McDonough Collection became available in late August 1995 and the fabric Climatex®Lifecycle™ has won numerous awards including the Arge Alp Environmental Award 1996 (the Arge Alp is an organisation of governmental ministers from several states around the Alps, founded to promote international collaboration in cultural, social, economic and ecological areas). DesignTex's sales staff have undertaken training on the environmental benefits behind the fabrics and with each purchase the customer receives literature on the case history of the product. Finally the William McDonough collection is successful in the marketplace with two of the styles appearing in DesignTex's top 25 selling fabrics. Furthermore, due to its success four new styles are being added to the collection in the Summer of 1997. •

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Mehalik, M. M., M. E. Gorman and P. Werhane, *DesignTex Inc. Teaching Notes*, UVA-E-0099TN Darden Case Bibliography (Charlottesville, Virginia; Darden School of Graduate Business Administration, University of Virginia, 1996).

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Thiele Busch. J., 'Imagining Perfect' in *Contract Design*, (Miller Freeman Inc., June 1996), pp 23-24.

Books

Driving Eco Innovation
Claude Fussler & Peter James
London, UK
Pitman Publishing, 1996
ISBN 0-273-62207-2
364 pages
Price: £47.50

The concept of eco-efficiency was first promoted by the then Business Council for Sustainable Development in its contribution to the Earth Summit. Since that time, Claude Fussler of Dow Europe has masterminded the interpretation of eco-efficiency in the context of business innovation. This book forms one of the major outputs from that process.

Eco-efficiency requires more than good environmental management: it involves a change in culture, questioning how the business adds value to the resources it consumes. Getting started on the path to eco-efficiency was always going to be difficult, and this book provides some valuable signposts.

This book begins by setting the scene for sustainable development and what it could mean for industry. Refreshingly, it presents a picture of challenges and opportunities rather than threats and impossible goals. But it does not pull its punches: the clear message is that far-reaching innovations will be essential.

The real meat of the book lies in its analysis of the key issues governing eco-innovation. These are presented in the form of an 'eco-compass', which a manager can plot a route towards improved eco-efficiency. The 'eco-compass' focuses attention on the key metrics of resource efficiency: material and energy intensity in products; costs of risk to health and environment; benefits of revalorising products at 'end of life' and conserving non-renewable resources; and increasing 'value-added' by offering service as well as product. Importantly, the path to eco-efficiency is presented in a way which makes sense to managers today.

Inevitably, there will be conflicting views about the evaluation of eco-innovation parameters, and it would be foolish to suggest that this book is the final word in such complex territory. The book is, however, an important stepping-stone. It will have succeeded if it helps managers to question whether there might be novel, resource-efficient and profitable ways of serving their customers. This first step is arguably the most important and the most difficult on the long road towards sustainability, and the authors of 'Driving Eco Innovation' are to be applauded for erecting the first signpost.

Dr. Jonathan Williams, Head, Group for Environmental Manufacturing, UK, which is collaborating in the development in the development of a design toolkit for eco-efficient products (paper to be published in issue 2).

Design for Environment
Joseph Fiksel (ed.)
McGraw Hill, US, 1996
ISBN 0-070-020972-3
500 pages
Price: £56.95

On the surface, a 500-pager on 'Design for environment' (DfE) must be worth reading – surely this must contain all there is to know on eco-design. However, this is a disappointing book to those who are looking for an approach based on fundamental principles. It is effectively a catalogue of current US 'best practice', and as such suffers from the usual faults of Americentric works.

Fiksel and his co-authors start with some chapters to set the scene for DfE. There is a chapter on market forces which is adequate but unexciting; one on sustainable development which has a narrow, US focus and one on DfE in corporations. A key chapter, on the conceptual principles of DfE, is missing the vital life cycle perspective which is at the core of most European work. However, he has some interesting and relevant comments on the integration of DfE with computer-aided design and on the information requirements of designers. Here, he is on the ball: the issue of information provision is sure to assume increasing importance as the DfE discipline matures.

The book then covers product and process development, making some good basic points on DfE management. Three chapters on guidelines, metrics and assessment follow but because the examples are drawn from US industrial practice, they do not carry the authority of those drawn systematically from first principles. The best chapter of the book, with some interesting examples, is that on life cycle management.

Much of the book is a selection of case studies, brought together from such fora as the annual IEEE symposiums on electronics and the environment. There are no academic contributors – though some might think this is a good thing! But the book can't see beyond the world of the big US corporation. A European or international perspective is missing, which probably explains Fiksel's scant attention to Life Cycle Assessment (LCA), which only merits a brief mention in the assessment section. The European philosophy of LCA-based analysis followed by planned design improvement has always clashed at times with the US emphasis on 'business as usual' based on the message that 'pollution prevention pays'. This book is a prime example of one side of this divide.

Fiksel is descriptive rather than prescriptive. This may be interesting but it does not show the way that DfE can progress worldwide. Use this book as a source of case studies but for the fundamentals, it is far better to consult guides such as Delft University's PROMISE manual and for a US perspective, Allenby's 'Industrial Ecology' (publ. AT&T, US, 1994) is a much better book.

Dr Matthew Simon, Leader, 'Design for Environment' research group, Manchester Metropolitan University, UK.

The Green Imperative: ecology and ethics in design and architecture

Victor Papanek
London, UK
Thames & Hudson, 1995
ISBN 0-500-27846-6
256 pages
Price: £14:95 (paperback)

When *Design for the Real World* was first published in 1969, Victor Papanek was decried by the design community who wanted to protect design from ethical scrutiny and hailed by advocates of human-scale design. Papanek has been a courageous practitioner and pioneer of 'sustainable design' throughout his illustrious career. Papanek's new book *The Green Imperative* is unlikely to have such a contentious impact as he with others have helped these issues become an accepted facet of design practice and design theory over the past three decades.

Ecological design and the concept of dwelling are the two main themes running through the book. Other themes amongst many covered are de-centralised production and ethical consumerism. The ecological content is broad and covers the ethical and political issues surrounding the role of design as well as encouraging and explaining how one can begin to design environmentally benign products through methods such as 'designing for disassembly' and the concept of rental. Papanek's fascinating conclusion is that designing products with environmental and ethical considerations will result in the development of a new aesthetic, more meaningful and satisfying than that which characterises the bulk of consumerables designed today.

The second major theme is dwelling. Papanek argues that industrialised societies have gradually eroded our senses and this has led to us living in dwellings that lack spirituality in their design. He believes that modern urban life has a dehumanising effect on us and the key to rediscovering the spiritual, sensual, social and ecological importance of space, place and dwelling is through learning from vernacular architecture. This approach displays certain qualities which Papanek thinks should inform architectural design in industrial societies. It is based on traditional knowledge and techniques, is human scale and unselfconscious. Just as ecological and ethical design can produce a more fulfilling aesthetic, vernacular architecture brings an expressive sense of dwelling.

However, *The Green Imperative* is problematic in a variety of ways. The tone of the book borders on preaching and its eclectic content will not be agreeable to some. Also, Papanek's ideological solutions to environmental, ethical and social degradation are, on occasion, over-simplistic. He over-estimates the power of design and does not elaborate enough on how the political system and economy should change to incorporate his social vision. Those wishing to read a book with a deeper analytical understanding of the role of design in advanced industrial societies should perhaps look elsewhere. Nevertheless, Papanek's grapplings with intellectual ideas, resources and his own personal experiences are often formidable. The book's empirical insights and optimism will make it an invaluable acquisition for those seeking guidance into ethically and ecologically committed design practices.

Anne Chick, Joint Coordinator, The Centre for Sustainable Design, UK.

Managing eco-design online conference
and
Textiles, design and environment online conference

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fax +44 (0)1252 732274
email: cfsd@surrart.ac.uk

23 April 1997

Life Cycle Assessment: the environmental consequences of making and using products
London, UK

✉ SCI Environmental Group
14–15 Belgrave Square
London SW1X 8PS
UK
✆ +44 (0) 171 235 3681
fax +44 (0) 171 235 7743
email:
conferences@chemind.demon.co.uk

25–30 April 1997

SOLAR '97
Washington DC, US

✉ American Solar Energy Society
2400 Central Avenue G-1
Boulder
CO 80301
US
✆ +1 303 443 3130
fax +1 303 443 3212

28 April – 2 May 1997

2nd International symposium on environmental software systems
British Columbia, Canada

✉ Prof David A Swayne Department of Computing and Information Science
University of Guelph
Guelph ON N1G 2W1
Canada
email:
dswayne@snowhite.cis.uoguelph.ca

29 April 1997

Corporate environmental reporting: guidance for environmental managers and designers workshop
London, UK

✉ Anne Chick
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5–7 May 1997

IEEE International symposium on electronics and the environment
California, US

✉ J Berry
Institute of Electrical and Electronics Engineers Inc.
445 Hoes Lane
Piscataway
New Jersey 08855
US
✆ +1 908 562 3878
fax +1 908 981 1769
email: j.berry@ieee.org

12–16 May 1997

Environmentally conscious design (training course)
Manchester, UK

✉ Dr M Simon
Design for Environment
Research Group
Department of Mechanical Engineering, Design & Manufacturing
Manchester Metropolitan University
Manchester
UK
✆ +44 (0)161 247 1626
fax +44 (0)161 247 6322
email: m.simon@mmu.ac.uk

16–18 May 1997

WREMINSECO '97 International conference on waste reduction and minimisation for a sustainable ecology
Sofia, Bulgaria

✉ PO Box 11
1231 Sofia
Bulgaria
✆ +359 2 37 23 50
fax +359 2 54 46 86

27–29 May 1997

The World sustainable energy trade fair
Amsterdam, The Netherlands

✉ Emily Osband
European Media Marketing
9th Floor
22–26 Albert Embankment
London SE1 7TJ
UK
✆ +44 (0)171 582 7278
fax +44 (0)171 793 8007
email: sustain@emml.co.uk

29–30 May 1997

Interpreting the requirements and identifying strategies for cost effective compliance with the final version of the UK packaging waste legislation
London, UK

✉ Mary O'Callaghan
IIR
6th Floor
29 Bressenden Place
London SW1E 5DR
UK
✆ +44 (0)171 915 5020
fax: +44 (0)171 915 5001

2–3 June 1997

GEMI '97 business helping business
Arlington, VA, US

✉ JT&A, Inc
4 Herbert Street
Alexandria
VA 22305
US
✆ +1 703 519 2180
fax +1 703 519 2190

2–6 June 1997

The Environmental Technology Institute conference
Arlington, VA, US

✉ Rebecca Burger
Government Institutes
4 Research Place
Rockville
MD 20850
US
✆ +1 301 921 2345
fax +1 301 921 0373

25–28 June 1997

European workshop on environmental engineering
Luneburg, Germany

✉ Prof Walter Leal Filho
University of Luneburg
Institute of Environmental Communication
Wilschenbrucher Weg 84
D-21335 Luneburg
Germany
✆ +49 4131 714373
fax +49 4131 714202
email: leal@uni-lueneburg.de

3–4 July 1997

Eco-management & auditing conference
Manchester, UK

✉ ERP Environment
PO Box 75
Shipley
West Yorkshire BD17 6EZ
UK
✆ +44 (0)1274 530408
fax +44 (0)1274 530409

17 July 1997

Towards sustainable product design 2nd international conference
London, UK
✉ Martin Charter
The Centre for Sustainable Design
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✆ +44 (0)1252 732229
fax +44 (0)1252 732274
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19–21 August 1997

11th ICED – International conference on engineering design
Tampere, Finland
✉ Tampere University of Technology
PO Box 300
FIN 3T101
Finland
✆ +358 3 365 2441
fax +358 3 65 2164
email: iced.info@ruuvi.me.tut.fi

24–27 August 1997

The Humane Village – 20th Congress of the ECSID
Toronto, Canada
✉ Design Exchange
Humane Village Congress Secretariat
PO Box 18
234 Bay Street
Toronto Dominion Centre
Toronto
Ontario M5K 1B2
Canada
✆ +1 416 216 2124
fax +1 416 368 0684

31 October 1997

Managing eco-design: 2nd International conference
London, UK

✉ Martin Charter
The Centre for Sustainable Design
The Surrey Institute of Art & Design
Falkner Road
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Surrey GU9 7DS
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✆ +44 (0)1252 732229
fax +44 (0)1252 732274
email: cfsd@surrart.ac.uk

5–8 December 1997

The Design and Environment Conference
Canberra, Australia
✉ Catalyst '97 Conference
University of Canberra
PO Box 1
Belconnen ACT
2616
Australia
✆ +61 6 201 5754/61 6+ 201 2178
fax +61 6 201 2279/61 6+ 201 5034
email: cat97@design.canberra.edu.au.

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Submissions

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Faculty of Design
The Surrey Institute of Art & Design
Falkner Road
Farnham
Surrey GU9 7DS
UK.
Email submissions should be sent to: cfsd@surrart.ac.uk.

A black and white photograph of the author(s) should be supplied.

Presentation

Articles should be 1,000–1,500 words unless to be submitted for the Analysis section (peer reviewed) and then articles should be between 2,500–5,000 words long. Manuscripts should be typed in journal style, double spaced (including footnotes and references) with wide margins, on one side only of good quality A4-size paper.

Manuscripts should be arranged in the following order of presentation.

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Second sheet: A self-contained abstract of up to 150 words summarising the paper and its conclusions.

Subsequent sheets: Main body of text, footnotes, list of references, appendices, tables (on separate sheets), and illustrations.

Authors are urged to write as concisely as possible. The main title of the article should be kept short, but may be accompanied by a subtitle. Descriptive or explanatory passages, necessary as information but which tend to break the flow of the main text, should be expressed as footnotes or appendices.

Bibliographic references: All bibliographical references should be complete and comprising of authors and initials, full title and subtitle, place of publication, publisher, date, and page references. References to journal articles must include the volume and number of the journal. The layout must adhere to the following convention:

Author, A., and B. Author, 'Title of book: Subtitle' (Place of publication: publisher, date), pp.xx–xx. or

Author, A., and B. Author, 'Title of Journal Article: Subtitle', in Journal, Vol.x No. x (January 19xx), pp. xx–xx.

These should be listed, alphabetically by author surname, at the end of the article.

If referring to works in the main body of the article, please use the 'short title' method in parentheses.

Footnotes: These should be numbered consecutively in Arabic numerals and placed before the list of bibliographical references. They should be indicated in the text by use of parentheses, eg. '(see Note 1)'.

Tables, graphs, photographs etc. All graphs, diagrams and other drawings should be referred to as Figures, which should be numbered consecutively in Arabic numerals and placed on separate sheets at the end of the manuscript. Their position should be indicated in the text. All figures must have captions. Authors should minimise the amount of descriptive matter on graphs and drawings, and should refer to curves, points, etc. by their symbols and place descriptive matter in the captions. Scale grids should not be used in graphs, unless required for actual measurement. In all figures taken or adapted from other sources, a brief note to that effect is obligatory, below the caption. Please ensure any photographs taken are of good quality. They may be supplied as prints or transparencies, in black and white or in colour.

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Proofs

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