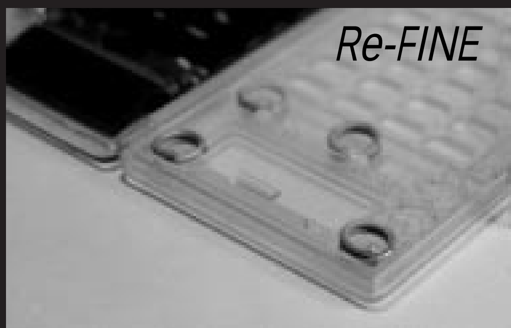
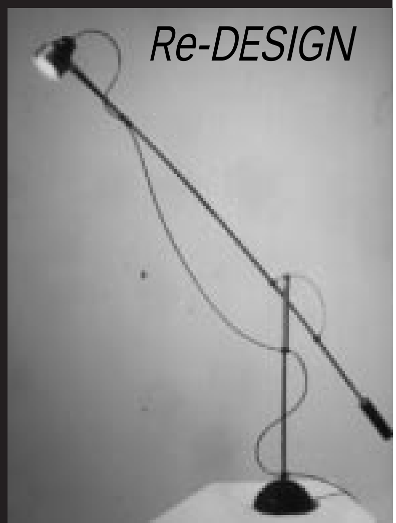
ISSUE 7 : OCTOBER 1998

The Journal of Sustainable Product Design





Re-PAIR

ISSN 1367–6679

‘Light-plant’
a functional
reminder of
resource use

Innovation,
page 52

‘Kind of Blue’ chair,
construction detail

Analysis page 41

Re-THINK

Re-FINE

Truncated two-way actuators

Analysis, page 26

Re-DESIGN

Arc lamp

Analysis page 41

Re-PAIR

Sketch of seven
part plywood jig

Gallery, page 37

ISSUE 7 : OCTOBER 1998

The Journal of Sustainable Product Design

ISSN 1367–6679

Editors

Martin Charter: Articles, Interview, O2 News and Journal marketing.

Anne Chick: Gallery, Reviews, Diary and Journal production.

The Journal of Sustainable Product Design encourages response from its readers to any of the issues raised in the journal. Entries for the Diary of events and material to be considered for review should all be sent to the Editors at the address below.

All articles published in the Analysis section are assessed by an external panel of business professionals, consultants and academics.

Subscription rates

The Journal of Sustainable Product Design is a quarterly journal appearing in the months of April, July, October and January each year. Subscription rates for one year (four issues) are £90.00 (UK) and £100 (non-UK) for the paper-based version, and £50.00 for the online version. Special subscription rates for developing countries and students are available on application. Cheques should be made payable to The Surrey Institute in £ sterling and sent to:

The Journal of Sustainable Product Design
The Centre for Sustainable Design
Faculty of Design
The Surrey Institute of Art & Design
Falkner Road
Farnham
Surrey GU9 7DS
UK
tel +44 (0)1252 892772
fax +44 (0)1252 892747
email: cfsd@surrart.ac.uk
internet: http://www.cfsd.org.uk

Editorial Board

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

Martin Charter

Joint Editor, The Journal of Sustainable Product Design

Process to product

A number of countries are starting to explore environmental policies based on products rather than processes – this was highlighted in a recent report commissioned by DGXI on Integrated Product Policy (IPP). The report defined IPP as:

'Public policy which explicitly aims to modify and improve the environmental performance of product systems.' (SPRU, Ernst and Young, 1998)

However, as yet the EU does not have a clear position on what IPP means for European business and how/if or when it will be implemented. Different European countries will have different levels of preparedness for the shift of the policy focus from process, eg.waste minimisation and cleaner production to product, eg. eco-design.

Green walls

To enable eco-design and SPDD will require solutions to 'soft' as well as 'hard' problems, eg. organisational and technological. Hitting the Green Wall' is a concept formulated by Rob Shelton of Arthur D. Little. It suggests that organisations can progress environmental projects to a certain point, eg. eco-design, but unless the benefits of the initiative are translated into business benefits to key internal and external stakeholders eg. product managers, marketing managers, customers and suppliers, then projects will go no further. For example, an excellent eco-design will fail if the designer cannot *sell* it to the product manager.

Good communications are essential. Environmental management is the driving force behind eco-(re)design (existing products) and eco-innovation (new products) with information percolating down to designers (engineers) through checklists, guidelines and software (Charter and Clark, 1996). At present, there generally appears to be little 'buy-in' to the process from other internal stakeholders. However, if there is not 'buy-in' from other key business functions eg. marketing, then eco-design is unlikely to be integrated into mainstream product development.

Innovation and creativity

A number of the issues highlighted in the IPP report relate to the sustainable consumption debate currently being progressed by the Commission on Sustainable Development (CSD) and the United Nations Environment Programme (UNEP):

- market creation
- product innovation.

To create markets for more eco-efficient products will require the development of greener markets through the increasing specification of environmental criteria in domestic, 'business to business', retailer and government procurement policies. However, there is an 'Action-Awareness' gap particularly amongst domestic customers; why? premium pricing? quality concerns? poor distribution? are all issues. In addition, under-researched products/markets are also key factors in the lack of market penetration. In domestic markets, retailers have considerable power. In 'business to business' markets the need for involvement of role players throughout the supply chain is often ignored however engagement of all internal and external stakeholders in the process will be essential for successful eco-efficient product or service development. There is a clear need for market education.

Nortel (Prentis, 1998) are approaching this issue by organising environmental presentations within customer workshops. This provides a dual purpose involving both marketing and customers in the green debate. An example, of where this approach might be useful is with purchasing managers. A study (see JSPD 6, p19) recently indicated that IT buyers saw the inclusion of recycled materials in products as lowering the products' value. There is an education job to be done of informing customers that recycled can be as good as virgin material. If these issues are addressed in the idea generation/concept development phase of product development through involvement of key stakeholders then it is more likely that greener products or services will be successful from a business perspective.

New tools

Even allowing for the economic problems in South East Asia, there appears to be growing interest in LCA as a strategic means to determine the environmental impact of products. However, a range of European companies seem to be moving towards the need for simpler tools to enable quicker decision-making. It is unlikely that designers want to be seen as specialists in environmental issues, but they need the right information. In Europe there seems to be a growing interest in the eco-design process and management system implications. Whereas South Eastern Asian companies seem to be looking at LCA and quick-fix software solutions, a mix of longer-term and immediate-term thinking. European companies may find experientally that the bias to action, may generate more appropriate systems and tools to enable progressive eco-(re)design and eco-innovation. A key common focus for the development of eco-design internationally might be an international standard, similar to ISO 14001.

And finally…

This issue of the journal draws together articles that illustrate the potential of eco-innovation from both a macro and micro perspective. The article by Johansson and Magnusson of Linköping University (Sweden) examines the relationship between innovation theory and eco-innovation using examples of shifts occurring in the car and lawn-mower sectors (p7). Frei from ABB (Switzerland) highlights that there is a need for clear goals for eco-effective product design and to be successful it should be integrated into product development (p16).

The article on 'active disassembly' (p30) by Chiodo, Billett and Harrison of Brunel University (UK) illustrates the potential for re-thinking disassembly using smart materials. Walker's article (p42) gives an illustration of a localised consumption and production view of SPDD with a range of practical industrial design cases. Sherwin, Bharma and Evans of Cranfield University (UK) give an interesting insight into the application of eco-innovation principles to kitchen design using an example of a project undertaken with Electrolux (p57). The interview with Peter James of the Sustainable Business Centre (UK) draws together some of the current thinking over the complexities surrounding the role of products and services within the sustainable consumption and production debate (p54). Finally, the O2 pages (p60) highlight a number of new developments in France and the Netherlands. •

References

SPRU at the University of Sussex and Ernst & Young Ltd, 'Integrated Product Policy', commissioned by European Commission: DGXI, March 1998

Charter, M. and Clark, T., 'Design for Environment' survey, The Centre for Sustainable Design, UK, December 1996.

Prentis, E., 'Customers – the forgotten stakeholder', Towards Sustainable Product Design, 3rd International Conference, 26–27 October 1998, London, UK, organised by The Centre for Sustainable Design, UK.

Eco-innovations – a novel phenomenon?


Glenn Johansson and Thomas Magnusson

PhD students, International Graduate School of Management and Industrial Engineering, Linköping University, Sweden

Glenn Johansson holds an MSc in Mechanical Engineering from Chalmers University of Technology, Gothenburg. He also holds a Licentiate of Engineering degree; title of the licentiate thesis: 'Design for Disassembly – A Framework'. Glenn's current research focuses on how to integrate and manage eco-design in industrial product development. Before becoming a PhD student at the International Graduate School of Management and Industrial Engineering, Linköping University, he spent a year at the Swedish Institute of Production Engineering Research. He has also two years of industrial experience designing equipment and construction parts for paper and board machines.

Thomas Magnusson holds an MSc in Industrial Management and Economics with specialisation in Innovation Management. He has two years of experience within the field of eco-design, completing applied research at the Swedish Institute of Production Engineering Research. After that he joined the International Graduate School of Management and Industrial Engineering at Linköping University. As a PhD student tied to the division of Industrial Management, he is currently focusing his research on eco-design and eco-innovation as a strategy for incremental and radical change.

It has generally been accepted that in order to reach sustainability, significant changes will have to take place. Eco-innovations ie. new products and processes providing customer value, while using less resources and resulting in reduced environmental impacts, are therefore of great importance. On the basis of selected parts of the existing innovation theory, this article explores the eco-innovation phenomenon. The theory is used to analyse two examples of eco-innovation; the struggle between steel and aluminium to the application of light weight car bodies, and the development of lawn mowers with improved environmental performance. The analysis shows that innovation theory is useful for creating a better understanding of the concept and development of eco-innovations. It is therefore concluded that the innovation theory should be part of the frame of reference when analysing and managing eco-innovations.

Introduction

In 1987, the World Commission on Environment and Development (1987) introduced the concept of sustainable development. The transformation towards sustainability requires participation of many different actors including governments and communities, consumers and individuals, corporations and enterprises; creativity and innovation is needed at every level of society (Jackson, 1996). The importance of technological innovation in this transformation process has been underlined by many authors (see eg. Stahel, 1996; Fussler and James, 1996; Jackson, 1996). Eco-innovations, ie. 'new products and processes which provide customer and business value but significantly decrease environmental impacts' (James, 1997), have attracted increased attention both in industry and academia. The purpose of this article is to explore existing innovation theory in relation to the eco-innovation phenomenon. The questions are whether existing innovation theory is applicable and if it is useful for creating a better understanding of the concept and development of eco-innovations.

The eco-innovation concept

Technological innovations can contribute to reduced environmental impact. For example, the new high voltage generator called the Powerformer developed by Asea Brown Boveri significantly reduces environmental impact compared to existing alternatives. The efficiency is improved compared to existing generators and the life cycle assessments (LCAs) conducted on it have shown clear advantages. Another example is the durable printer drums in laser printers developed by Kyocera Electronics. The durable printer drum eliminates material and energy consumption used in the production of replacement drums (Fussler and James, 1996). A third example is the Sentricon™ Colony Elimination Control System for termite control. This system uses one ten thousandth of the amount of active chemicals present in standard termite barriers (Fussler and James, 1996).

However, innovation does not always reduce the energy and material intensity or pollution. Innovation can offer profit at the expense of increased environmental burdens. Therefore, it is important to assess the environmental consequences, positive as well as negative, of every innovation. The 'Eco-compass' developed at Dow is a simple tool for assessing environmental improvements which can be used to encourage the development of eco-innovations (Fussler and James, 1996). The Eco-compass has six dimensions, all representing relevant environmental issues: health and environmental risk, resource conservation, energy intensity, materials intensity, revalorisation (remanufacturing, reuse and recycling), and service extension. These six dimensions can be used to assess innovations according to their environmental merit. For example, the development of lead-free tin solders reduces health and environmental risks by eliminating the toxic lead, the development of light and energy efficient compact cars reduces the energy intensity, and the application of 'design for recycling' guidelines improves the revalorisation dimension. Innovations should be assessed in all dimensions to ensure that the environmental merit in one dimension is not counterbalanced by increased environmental impacts in another dimension. The Eco-compass is useful to make this assessment visual and is easy to understand. It is also useful to identify possibilities for improvements and to stimulate environmental creativity. The 'Eco-design strategy wheel' (Brezet et al, 1997) and the concept of 'Material Intensity per Unit of Service' (Schmidt-Bleek, 1996) are other examples of tools which can be used in a similar way as the Eco-compass.

Innovation theory

To be able to analyse the question as to whether existing innovation theory is applicable and useful for creating a better understanding of the eco-innovations it is necessary to present a framework for the analysis. This section gives a brief introduction to selected parts of innovation theory, which will serve as a basis for the analysis in the next section. The focus is on the parts of the theory which provide managerial implications for individual companies by studying innovation and technology as phenomena in an industrial context.

The introduction begins with the 'S-curve model' (Foster, 1986) which describes the development of, and competition amongst, technologies. The model provides a picture of how technical performance is improved over time and how discontinuities arise as a result of the entrance of new technologies. Following the S-curve model, the model of Abernathy and Utterback (1978) suggests how the patterns of innovation change as an industry sector matures and how companies may change themselves to foster innovation. The 'Transilience map' (Abernathy and Clark, 1985) provides a more dynamic model which can be used to analyse the competitive implications of innovations. Finally, the concept of 'technological bandwagons' (Wade, 1995) helps to illustrate how the market success of a technology or a design arises.

Altogether the models presented in this section highlight two essential determinants of innovation, namely the technology and market aspects. As innovation, by definition, deals with both the novelty of the technology and the commercial use of it (see for example Dussauge et al, 1996), these aspects are central to innovation theory. The selected parts of the innovation theory can be used for developing an understanding of these aspects and this is vital for the ability to manage innovation.

S-curves and patterns of innovation

According to Foster (1986) technology develops over time in a pattern which can be illustrated as an S-curve. The initial phase of the development of a technology is characterised by knowledge acquisition and limited effectiveness of the new technology. As knowledge is built up, the technological performance is improved. The development is driven by numerous incremental innovations, which continuously improve the performance of the technology until its technical limit is approached. However, technical progress is not only characterised by incremental improvements, but also by discontinuous advance (Tushman and Rosenkopf, 1992). These technological discontinuities constitute rare and radical innovations which involve fundamentally different ways of doing business. A technological discontinuity can be seen as a 'jump' between two S-curves representing alternative and competing technologies. The distinction between incremental innovation (which refine and improve existing products and processes) and radical innovation (which introduce totally new concepts) is a central notion in innovation theory (Dussauge et al, 1996).

Complementary to the S-curve model, Abernathy and Utterback (1978) use a model to explain how the pattern of innovation evolves over time as an industry sector matures. Companies tend to develop and adapt to fit the different phases in the innovation pattern. In the first phase, the 'fluid pattern', the innovations are mostly radical, while the innovations become more and more incremental as the company develops from a small entrepreneurial unit to a large-scale producer. The development of a dominant product design typically relates to a shift from radical to incremental product innovation. In the fluid pattern product innovation dominates, but process innovation becomes increasingly influential as the industry sector matures. The companies are typically technology-based and flexible, working in great uncertainty with small incentives for large investments. Later on, in the second phase denoted as the 'transitional pattern', where the uncertainties about markets and targets are reduced, companies make larger investments in R&D and they can be described as science-based. In the third and last phase, the 'specific pattern', the companies become fully specialised and focused on cost reductions. As an industry sector becomes more and more specialised, the companies become tied to the technology on which their production is based. Therefore, major product changes that originate from within a specialised company tend to be rejected. Instead major product changes tend to originate from companies outside the established industry sector.

Technical progress is not only characterised by incremental improvements, but also by discontinuous advance. These technological discontinuities constitute rare and radical innovations which involve fundamentally different ways of doing business.

Impact on technology and competition

The notion about incremental versus radical innovation is taken one step further by Abernathy and Clark (1985) introducing the 'Transilience map'. Transilience means the capacity of an innovation to influence the companies existing resources, skills and knowledge. These authors challenge Shumpeter's (1942) view of innovation as the process of creative destruction and argue that although technological innovation imposes change, this change need not be disruptive for a company. They claim that innovations may either disrupt or entrench existing competencies. Whereas radical innovations disrupt and make existing competence obsolete, incremental innovations conserve and entrench the existing competence. In the 'Transilience map' these two opposites are applied on two different dimensions: the technology/production and the markets/customer linkage. Four quadrants representing different kinds of innovation are distinguished, 'Architectural', 'Revolutionary', 'Regular' and 'Niche Creation', each having different competitive impact and each requiring different organisational and managerial skills.

Regarding the development of a technology, Wade (1995) discusses the concept of 'technological bandwagons'. This concept suggests that the support a technology achieves in the technological community is decisive for its success and its diffusion. As a new technology is introduced the addition of new community members produces a bandwagon effect and thus the position of the new technology is strengthened.

The development of eco-innovations

Is the framework provided by the existing innovation theory relevant for eco-innovations? As a basis for this discussion the example of the struggle between steel and aluminium in the application to light weight car bodies is used. Additionally, examples of eco-innovation derived from an analysis of the development of lawn mowers with improved environmental performance are discussed (Bragd, 1997).

Steel technology versus aluminium technology

The emissions from cars contribute to, among other things, the 'greenhouse effect' and should therefore be minimised. Consequently, reducing a car's petrol consumption during *use* has become of great importance, and a key issue in this effort is to reduce the car's weight. Because of aluminium's low density, the use of aluminium in car body designs may provide an opportunity to reduce the emissions produced. Some car producers have shown interest in using aluminium car bodies and thus the aluminium producers see potential to reach new markets. The quality of the material needs to be further developed, but the potential seems to be substantial. Aluminium in the car body application can be seen as a new and promising technology which fulfils the requirements of a radical eco-innovation.

In response to the demand for light weight car bodies, steel producers are developing materials which are lighter than existing steel, while still having all the other properties requested. In the UltraLight Steel Auto Body (ULSAB) project, 35 companies within the steel industry have co-operated to develop high strength steel which reduces the weight of the car (Recycling, 1998). The development and use of high strength steel may be seen as an incremental eco-innovation built upon established technologies.

Today it is not possible to analyse if steel has the potential to reduce environmental impact and be competitive to aluminium. However, the struggle between steel and aluminium car bodies illustrates some interesting aspects of the development of eco-innovations.

- The aluminium technology is in its infancy in the application to car bodies but it may challenge steel technology in relation to its environmental performance. The reaction of the steel producers is to protect their position by making improvements to their technology which illustrates a common response from companies that rely on established technologies (as described by Utterback, 1996).
- If car producers decide to shift to aluminium technology it may be seen as 'jump' to a new S-curve. This jump would illustrate a radical innovation

in the car body design with the new S-curve representing the development of the aluminium technology.

- Although some attempts have been made to use aluminium instead of steel, the 'band-wagon effect' as described by Wade (1995) cannot yet be identified. Nevertheless, the concept of 'technological bandwagons' seems relevant. If the aluminium technology is accepted, a community of car producers using aluminium may be established and the 'band-wagon effect' may arise.
- The development of high strength steel entrenches existing competencies in car body design and manufacturing, but a shift to aluminium technology may destroy existing competencies. Although some car producers have shown interest in aluminium car bodies, the breakthrough for aluminium may take quite a while (if it ever happens) because it may not only destroy the competence among steel producers, but among the car producers as well.

The discussion in point 1 and 2 is illustrated in Figure 1.

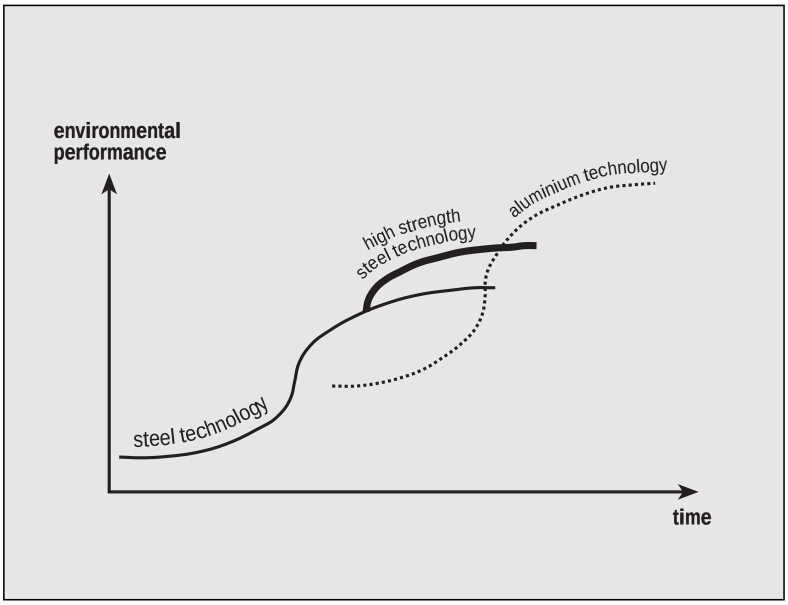


Figure 1: The aluminium technology challenging the steel technology in the application of light weight car body designs (after Utterback, 1996).

Green lawn mowers

In an analysis of the development of green lawn mowers at Husqvarna AB the importance of market differentiation and marketing strategy for green products was identified (Bragd, 1997). If Bragd's results are combined with the 'Transilience map' (Abernathy and Clark, 1985), the capacity of different kinds of eco-innovations to influence the company's resources, skills and knowledge can be understood. As discussed above, the 'Transilience map' illustrates four different kinds of innovations, each having specific competitive impact, each influencing the technology/ production and markets/ customer linkages differently, and each requiring specific organisational and managerial skills.

Through many years of experience in the engineering industry, Husqvarna AB developed competence in mechanical engineering. The company's lawn mowers had traditionally been based on the combustion engine technology, which is regarded as a dominant design in the gardening industry. Husqvarna AB developed several applications of the catalyst technology for small engines. The application of the catalytic converter improved the combustion technology by reducing the odour and the amount of harmful substances emitted into the air. In addition the general environmental profile of the products has been improved. Because the environmental performance of the combustion engine has been improved the applicability of the company's existing knowledge has been reinforced. However, the catalytic converter has not affected the way the lawn mowers are used and thus the customers have not needed to re-learn how to use the lawn mowers. The improved environmental performance combined with no changes in customer use has resulted in strengthened ties with established customers and improved service in the established application. Because the catalytic converter has strengthened the existing technological competencies and customer linkages it can be classified as a regular innovation in the 'Transilience map'.

Husqvarna AB has also developed a new battery-powered lawn mower with positive environmental features such as no exhaust fumes and low noise levels. The battery-powered mower represented a completely new technology for the company and demanded new technological skills. This was recognised by the management and the required competence was acquired externally. However, the dimension of the 'Transilience map' focusing on the influence on markets and customer linkages was not recognised. Existing distribution networks and traditional marketing strategies were used and the product's potential to attract environmentally conscious customer groups was not identified. The analysis by Bragd (1997) shows that the new product required new knowledge of the customers and thus re-education of the customers was needed. Furthermore, the distribution network had to learn new practices and the demands of the service and the after market support changed substantially. Applying the 'Transilience map' on this example, it is clear that the battery-powered lawn mower was treated as a revolutionary innovation which disrupted existing technological competencies, but maintained the existing market and customer linkages. However, the product had the characteristics of an 'architectural innovation', with the ability to disrupt the existing customer linkages and attract new markets.

In addition to the battery-powered lawn mower, Husqvarna AB developed a solar lawn mower, which is a robot that mows at random without human intervention (Bragd, 1997). The product originated from a prototype presented by an inventor at a trade fair in 1991. The technology of using daylight as fuel totally eliminates the emissions produced during *use* and can therefore be characterised as a radical step towards environmentally sound products. To Husqvarna AB the solar technology was an entirely new technology outside of existing competencies and this required new expertise. As a result of the innovativeness of the project, several external consultants and distributors wanted to participate in the generation of the technology. Offering a completely different way of mowing grass the solar mower required customers to change their perceptions of how to cut grass. The analysis performed by Bragd (1997) shows that the marketing had to be based on symbolic aspects, which had to be visible to the customer ie. modern and futuristic. Another lesson learned from the introduction of the solar mower was that the marketing department tried to cover too many markets at the same time. Market research should have been conducted before the launch, to identify market segments to focus on, and the product should have been tested on a reference market. Another finding by Bragd (1997) is the importance of finding suitable forms of distribution that fit the requirements of the product's characteristics. From a marketing perspective the solar mower should not have been treated as a mainstream product, but as a special product in communication and selling tactics. Relating the solar mower to the 'Transilience map' it is clear that the product was seen as a 'revolutionary innovation', ie. the solar technology was new to the company, but the product was not treated differently in relation to market linkage. However, like the battery-powered lawn mower the solar mower had the characteristics of an 'architectural innovation' and should clearly have been treated differently from a marketing perspective.

In Figure 2, the examples of the lawn mower with catalytic converter, the battery-powered lawn mower, and the solar mower are illustrated in the 'Transilience map'. The solar mower and the battery-powered lawn mowers represent the same kind of innovation (architectural innovation) but the solar mower has more radical impacts on the technology dimension as well as the market/customer dimension.

Discussion and conclusions

It seems that eco-innovations follow the same pattern as illustrated in Abernathy and Utterback's model (1978) which states that major product changes rarely originate within mature industry sectors. The solar mower is an example of this phenomenon, because the

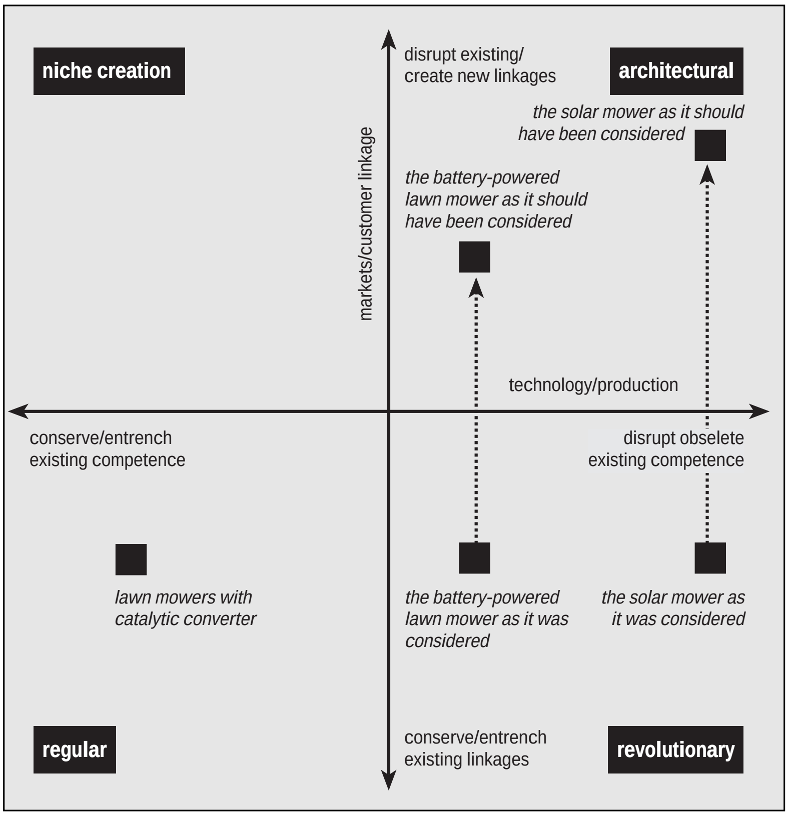


Figure 2: The lawn mower with catalytic converter, the battery-powered lawn mower, and the solar mower placed in the 'Transilience map' (after Abernathy and Clark, 1985).

product originated from an inventor outside the mature gardening industry. The solar mower also illustrates the resistance among companies based on established technologies to adopt new technologies, because when the product's inventor presented the prototype at a trade fair, the whole industry laughed and argued that there was no market for such a thing (Bragd, 1997).

However, Abernathy and Clark (1985) argue that companies and industry sectors can de-mature as a result of changes such as new technological options, changes in customer demands, and government policy. Although rejected when first presented, the solar mower illustrates that a radical eco-innovation can be exploited by a company within a mature industry sector. Husqvarna saw the new solar technology as an opportunity to create an image of the company as being innovative (Bragd, 1997). The solar mower, being slightly less radical than the battery-powered lawn mower, illustrates that a company in an established industry sector can benefit from new technological options to develop radical eco-innovations. The aluminium car body is another example, where the aluminium industry, due to environmental demands from the car producers, has seen the opportunity to move to more radical modes of innovation.

The battery-powered lawn mower illustrates that a company in an established industry sector can benefit from new technical options to develop radical eco-innovations.

New technological options, environmental customer demands and government policies result in changed conditions for the companies. Those who learn to anticipate, interpret and correspond to these changes will be able to create competitive advantage. A company can either adopt a re-active position and just achieve minimum demands, or choose a pro-active position in order to exceed or push demands. An empirical study by Bianchi et al (1997) revealed that companies adopting a re-active position usually develop incremental eco-innovations in order to comply with specific external demands, whereas pro-active companies accomplish incremental as well as radical eco-innovations. Adopting a pro-active position seems to be a key factor for companies in established industry sectors if they are to accomplish radical eco-innovations. In order to achieve competitive advantage managers in pro-active companies committed to environmental issues should support the development of eco-innovations, for example, by implementing environmental policies, promoting environmental sound ethics, and shaping reward systems which support environmental creativity.

The successful pursuit of different kinds of innovation require different kinds of organisational and managerial skills. Classifying the eco-innovations according to the 'Transilience map' may provide insight into different aspects of eco-innovation and help to better understand the capacity of eco-innovations to influence the company's existing resources, skills and knowledge. The battery-driven lawn mower and the solar mower exemplifies that classifying eco-innovations according to the 'Transilience map' may be useful when planning for the launch of the products. These products were viewed by the management as 'revolutionary innovations', but should have been seen as 'architectural innovations' emphasising the need for new market linkages. The market dimension of new eco-innovations is very important as discussed by Bragd (1997). Bragd's analysis of the two lawn mower examples shows that understanding the market dimension and the buying behaviour of the existing and potential customers is very important when introducing environmentally sound products. This is congruent with Abernathy and Clark's (1985) statement that 'architectural innovation' demands unique insight about user needs combined with the ability to see the application of the technology in a new way. Thus, it is clear that the awareness of the kinds of innovation the company is managing is critical, as this awareness is a prerequisite for being able to adjust the organisation and the management practises accordingly.

This article also has shown that radical eco-innovation may disrupt existing competence and make it obsolete. The need for products with significantly improved environmental performance may provide major opportunities for pro-active companies (as discussed by Hart, 1997), but it may also result in major threats for established industry sectors. The struggle between the steel and the aluminium technologies illustrates this, as the need for lighter car bodies and the introduction of new light-weight materials threatens to disrupt the competence of the established steel industry.

The concepts of 'organisational communities' and 'technological bandwagons' (Wade, 1995) deepen the understanding of the diffusion patterns for new technologies. The lesson to be learned is that organisational support is just as important as technological superiority. So, even though environmentally sound products and services may be desperately needed, superior environmental performance is not enough. Organisational support is necessary to gain market acceptance. Awareness of this should mean that pro-active companies can create bandwagons of environmentally sound technologies.

This article has shown that the existing innovation theory provides a useful framework for creating a better understanding of the concept and the development of eco-innovations. For example, the theory provides insight into the competition between technologies, factors affecting market diffusion and market success and the impacts of different innovations on a company's skills, and knowledge. Hence, it can be concluded that innovation theory can and should be part of the frame of reference when analysing and managing eco-innovations. The models and tools provided by the innovation literature can serve as support for the companies when managing eco-innovations.

This paper has only 'scratched the surface' of the eco-innovation concept. Consequently, it is not possible to state that the framework represented by existing innovation theory helps to fully understand all aspects of eco-innovation. On the contrary, the discussion in this article reveals many interesting questions that need to be further elaborated. One such question is how to relate the environmental dimension of innovations, ie. the environmental performance, to traditional performance measures such as price, functionality, and technical performance. •

References

Abernathy, W. J, Clark K. B. 'Innovation: Mapping the winds of Creative Destruction', in Research Policy, Number 14, (1985), pp 3-22

Abernathy, W. J, Utterback, J. M. 'Patterns of Industrial Innovation', in Technology Review, (June/July 1978), pp. 41-47

Bianchi, R., Noci, G., Pozzi, C., Priano, A. 'Analysing basic patterns of environmental innovation within value chains', Proceedings of the 4th International Product Development Management Conference, (Stockholm, 1997)

Bragd, A. 'Learning from the introduction of green products: two case studies from the gardening industry' in The Journal of Sustainable Product Design, Issue 3, (July 1997), pp 7-17

Brezet, H et al 'ECODESIGN – a promising approach to sustainable production and consumption', (United Nations Publication ,UNEP, 1997)

Dussauge, P., Hart, S., Ramanantsoa, B. 'Strategic Technology Management', (Chichester, John Wiley & Sons, 1996)

Foster, N. 'Timing Technological Transitions', in Horwitch, M. (ed.) 'Technology in the Modern Corporation: A Strategic Perspective', (Pergamon Press, Inc., 1986)

Fussler, C., James, P. 'Driving eco-innovation -A breakthrough discipline for innovation and sustainability' (London, Pitman Publishing, 1996)

Hart, S. L. 'Strategies for a sustainable world', in Harvard Business Review, (January-February 1997), pp 66-76

Jackson, T. 'Material concerns - Pollution, profit and quality of life', (London/New York, Routledge, 1996)

James, P. 'The Sustainability Circle: a new tool for product development and design', in The Journal of Sustainable Product Design, Issue 2, (July 1997), pp 52-57

Recycling, Nummer 3, (Helsingborg, Indufa Förlag AB, 1998)

Schmidt-Bleek, F. 'Dematerialisation -From Concept to Practise', in AFR-report 136, (Stockholm, 1996)

Schumpeter, J. A. 'Capitalism, Socialism and Democracy', (Cambridge, Harvard University Press, 1942)

Stahel, W. R. 'Conditions of demand and supply with dematerialisation as a key strategy', in AFR-report 136, (Stockholm, 1996)

Tushman, M. L., Rosenkopf, L. 'Organisational Determinants of Technology Change: Towards a Sociology of Technology Evolution', in Research in Organisational Behaviour, Vol. 14, (JAI Press, 1992), pp. 311-347

Utterback, J. M. 'Mastering the Dynamics of Innovation', (Boston, Massachusetts, Harvard Business School Press, 1996)

Wade, J. 'Dynamics of Organisational Communities and Technological Bandwagons: an Empirical Investigation of Community Evolution in the Microprocessor Market', in Strategic Management Journal, Vol. 16, (1995), pp. 111-133

World Commission on Environment and Development, 'Our Common Future', (Oxford University Press, UK, 1987)

Eco-effective product design: the contribution of environmental management in designing sustainable products

Dr Michael Frei

Environmental Manager, ABB Power Generation Ltd, Switzerland

Dr Michael Frei worked as a research fellow in the Eco-Performance group at the Institute for Industrial Engineering and Management (BWI) of the Swiss Federal Institute of Technology (ETH) in Zurich, Switzerland. His main research field was environmental management and sustainable product design (SPD), resulting in a PhD on eco-effective product design.

Since July 1998 he has been the Environmental Manager at ABB Power Generation Ltd. (Switzerland).

In research, as in practice, there is often a weak link between environmental management and product design. To solve this problem, environmental aspects should be integrated into the earliest design phases. Eco-effective product design aims to systematically establish and implement goals in product design with the aim of improving environmental performance. These goals should be based on significant environmental aspects of the products and take into account environmental requirements. The paper includes a case study as an example of eco-effective product design.

Introduction

Companies increasingly have to consider the environmental aspects of their activities in order to improve their environmental performance. For a company which designs products, design activity plays an important part in this task. Design defines the product's environmental impact over its total life cycle and any improvement in the product design process will mean that environmental performance can be improved. Many companies are starting to recognise this, but there are few examples of the systematic integration of environmental aspects in product design.

The goal of eco-effective product design is to close the gap between environmental management and product design (Frei 1998). To enable this various goals should be set eg. the avoidance of hazardous materials, reduction of emissions during manufacture or increased eco-efficiency. Eco-effective product design focuses on the systematic development and usage of these goals in sustainable product design (SPD) (Figure 1).

In environmental management and SPD the term 'eco-efficiency' is often used. However, it is important to make a distinction between effectiveness and efficiency. Effectiveness can be defined as a measure of goal achievement and efficiency as the amount of resources used to reach the goal. Therefore 'eco-effectiveness' can be defined as the systematic derivation and usage of goals to

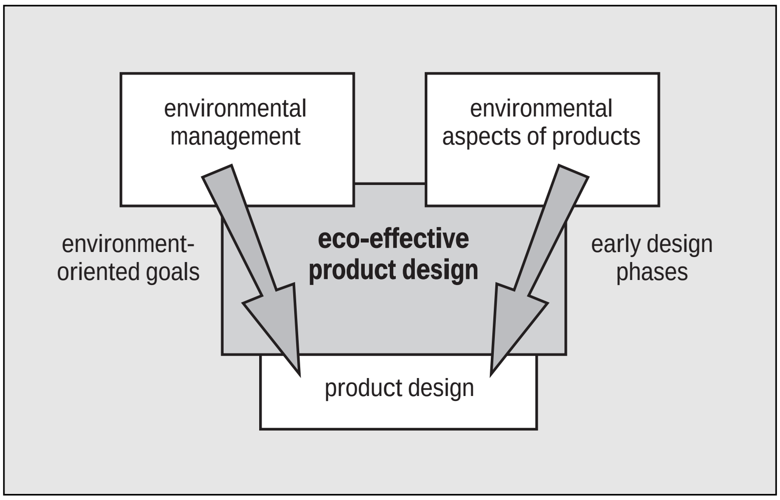


Figure 1: The goal of eco-effective product design is to integrate environmental management and the environmental aspects of products in the design process

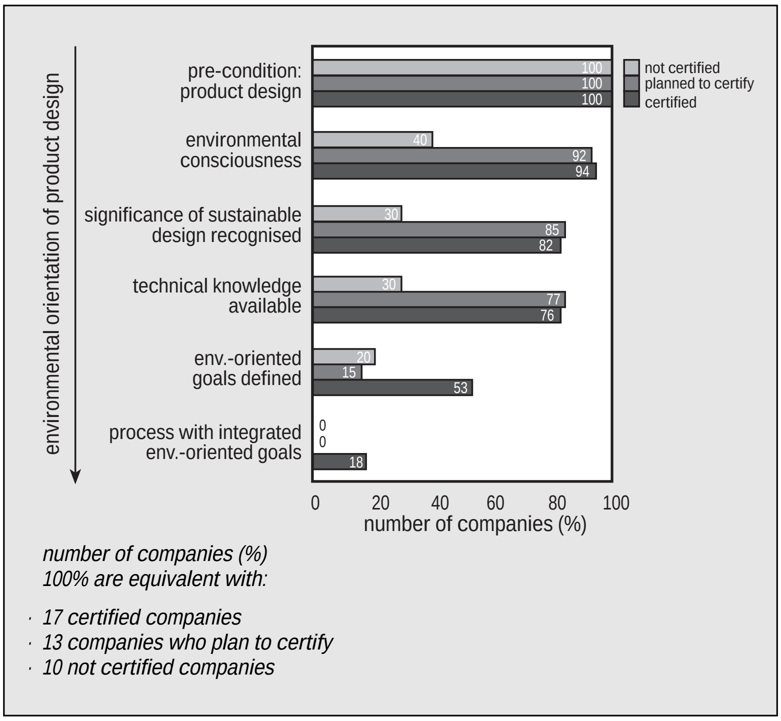


Figure 2: Missing environmental orientation of product design in practice (Frei and Waser 1998)

improve environmental performance (Frei 1998).

The missing environmental orientation of product design

Increasingly, companies are improving the environmental performance of processes, however products are not being improved. A study was carried out in the Autumn of 1997 amongst 42 Swiss companies, producing electrical and mechanical products (Frei and Waser 1998). The results reinforce the problem of translating environmental aspects into product design. Most of the companies studied had a significant level of environmental consciousness and the relevant technical knowledge to design more sustainable products. However, only a few companies have defined environmental goals for product design and have a process in place which integrates such goals.

The research indicated that there are significant differences between those companies which have achieved ISO 14001, those applying for the certificate and those which have not achieved it (Figure 2). The latter has a low environmental consciousness and SPD is accordingly less important. Companies which intend to apply for a certificate show about the same level of environmental consciousness and knowledge as certified companies. The weak point is the development and usage of environmental goals in product design, even amongst ISO 14001 certified companies. Only about 50% of the certified companies define such goals, and less than 20% show a product design process which systematically integrates these goals. This result is somewhat of a surprise, because ISO 14001 requires that goals be defined based on the significant environmental aspects of the products (ISO 14001, chapter 4.3.3; cf. Frei et al. 1998).

Basics of sustainable product design

Sustainable product design (SPD): a systemic approach

SPD is part of a socio-technical

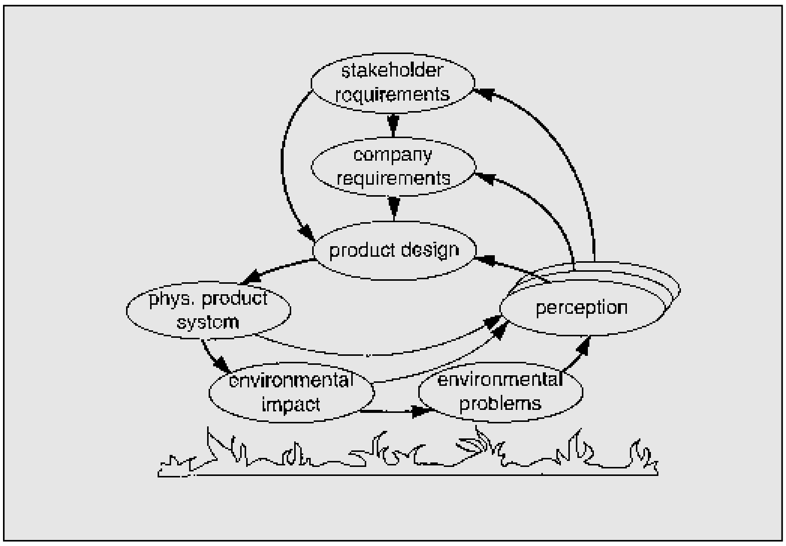


Figure 3: SPD in an organisational context

system (Figure 3). It is important to remember that product design defines the physical product system which causes environmental impacts and which may contribute to environmental problems. These results are perceived by internal and external stakeholders, which results in requirements for product design. Only sustainable products which have a high customer acceptance can replace less sustainable products.

Product design also defines the product system covering the whole product life cycle. For example, material and energy inputs and outputs in the product system cause key environmental impacts. These impacts contribute to environmental problems like global warming, which are perceived and assessed by different stakeholders. The designer has to make the 'right' green decisions during the design process – and therefore should be aware of the significant environmental aspects of any new product.

It is also important to be aware of the role that 'the environment' plays within the company. For eco-effective product design to progress it is crucial that the company sees environmental aspects of products as an important means for cost savings or marketing.

Five principles of sustainable product design

For SPD to be successful, the above mentioned systemic considerations have to be taken into account. The main conclusions can be summarised in five principles (Frei 1998):

- *Concentration on the product function:* the task of product design is to develop functions eg. the car's function is to provide a transport solution. Therefore, environmental impact always has to be related to the product's function (cf. functional unit in ISO 14040). On the other hand, the function often already defines the most significant environmental impact of a product eg. the emissions of a car because of its petrol consumption.
- *Consideration of the whole product system:* the product system describes the product life cycle (cf. ISO 14040). The basis of SPD is life cycle engineering – limitation on only one or a few phases, like recycling – is not acceptable.
- *Consider environmental impacts:* SPD has to consider the potential environmental impact of any new product – based on the product function and the whole product system. The necessary knowledge can be gained by analysing existing products. General checklists are of no help in this situation.
- *Considering environmental requirements from stakeholders and the company:* sustainable products have to be credible to stakeholders, eg. customers. Therefore, environmental requirements of internal and external stakeholders must be considered.
- *Integration into the design process:* SPD can only be successful if environmental aspects are systematically integrated into the regular design process (cf. Lenox and Ehrenfeld 1997). For this integration, environmental goals are crucial.

The previously mentioned research study highlighted that the problem lies in the application of these principles within organisations.

The concept of eco-effective product design

The integration of environmental aspects at the very beginning of the design process is essential. Environmental aspects – like the petrol consumption of a car – should be taken into account in the list of requirements. In these early phases the main decisions are made, which also define potential environmental impacts (Frei 1998).

Eco-effective product design focuses on the systematic development and usage of environmental goals in product design. These goals should be based on the significant environmental aspects of the product. The procedure can be structured in four main steps (Figure 4):

- *Derivation of environmentally-oriented requirements from internal and external stakeholders.*
- *Evaluation of the significant environmental aspects of the new product:* a reference product – an existing product similar to the one being planned – should be selected and its environmental impact analysed.
- *Product planning:* the environmentally-oriented requirements and the significant environmental aspects of the new product must be integrated with all other requirements and product ideas. The result is recorded in the list of requirements.
- *Design:* the list of requirements is the basis for the design. The requirements are applied and the greeness of the product should be reviewed.

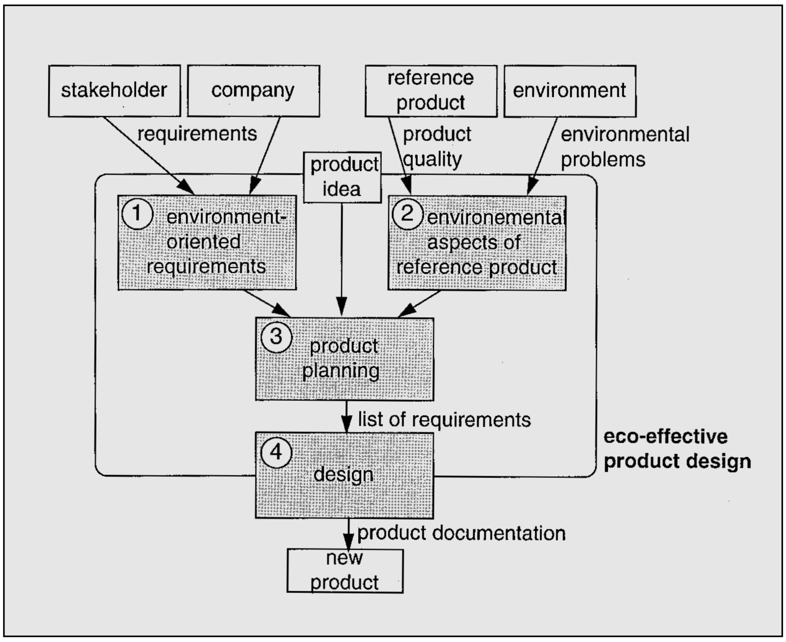


Figure 4: The concept of eco-effective product design (Frei 1998).

Derivation of environmental requirements

Stakeholders have diverse requirements concerning products. The question is, how does the company perceive its environmental situation and how does it deal with the stakeholders' environmental requirements? The answer lies in the firm's environmental strategy which, for products might be based on:

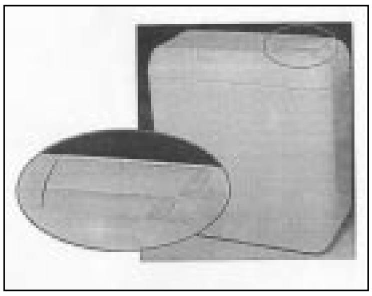
- reactive problem-solving
- reacting to immediate pressures
- legal compliance
- risk avoidance
- cost reduction
- environment as a marketing consideration
- systematic improvement of the environmental performance of products.

The environmental strategy gives the framework for eco-effective product design by defining environmentally-oriented stakeholder requirements. Quite often this strategy is not formulated explicitly. Environmental policy, environmental reports, environmental programmes as well as the general strategy – especially the product-market-strategy – can give some input.

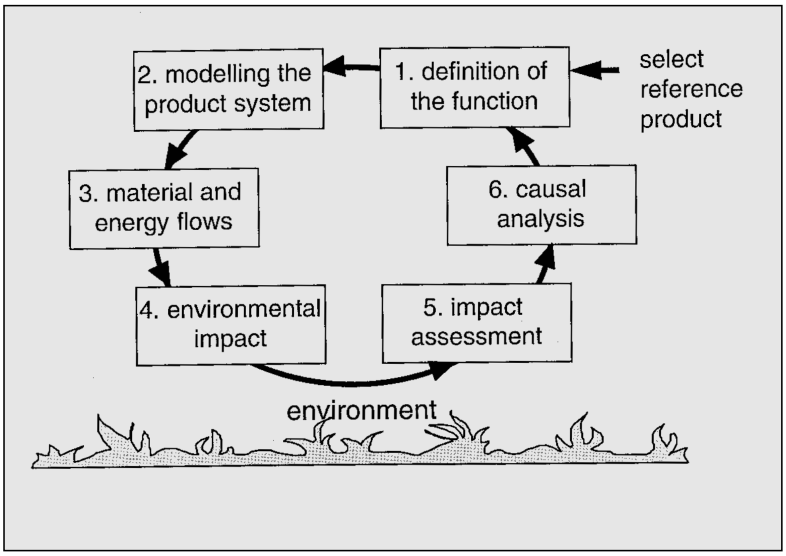
Evaluation of the significant environmental aspects of the reference product

Apart from the environmental requirements, it is important to know the significant environmental aspects of the product itself. These are two different viewpoints, with two different results.

In order to evaluate the significant environmental aspects of a product it is not enough to consider only materials. In addition, the product function and the whole product system have to be taken into account. A lot



above Figure 5: Flushing system (Source: Geberit Ltd.)



right Figure 6: The 'environmental learning cycle' to determine the significant environmental aspects of products (Frei and Zust 1997)

The environmental strategy gives the framework for eco-effective product design by defining environmentally-oriented stakeholder requirements.

of products cause their main environmental impact during their usage (so-called 'active' products) because, eg. of their energy consumption.

The integration of environmental aspects into the design process. poses a problem. In the early phases – where the most important decisions are made – only little knowledge is available about the potential environmental impact of the product. To solve this problem, the environmental aspects of a reference product should be evaluated against various technical, environmental and economic criteria. The reference product must be essentially similar to the new product with regard to its function and attributes.

To evaluate the significant environmental aspect of a product the 'environmental learning cycle' can be used (Frei and Zust 1997), which is based on the principles of Life Cycle Assessment (LCA) (cf. ISO 14040). The 'environmental learning cycle' represents a cycle of six steps (Figure 6).

- *Definition of the function*: the cycle starts by defining functions of the reference product. The function has to be seen from the customer's point of view. Therefore, a functional unit, which is a measure of the performance of the functional output of the product system, must be defined (ISO 14040).
- *Modelling the product system*: based on its function, the product system has to be modelled. For related products, all product life phases must be considered.
- *Material and energy flows*: every product system generates material and energy flows and the inputs and outputs of the system have to be evaluated.
- *Environmental impact*: the material and energy flows have an impact on the environment. These flows must be described in terms of elementary flows into the environment (ISO 14040).
- *Impact assessment*: the environmental impact must be assessed against its influence on environmental problems. The

definition of environmental problems is not only influenced by the environment but also by society, customers and the company. In addition, environmental problems can change over time and according to location – a fact which has to be taken into account in impact assessment.

- *Causal analysis:* the connection between environmental impact and the function or composition of a product must be investigated. The result of the causal analysis are the significant environmental aspects of the product.

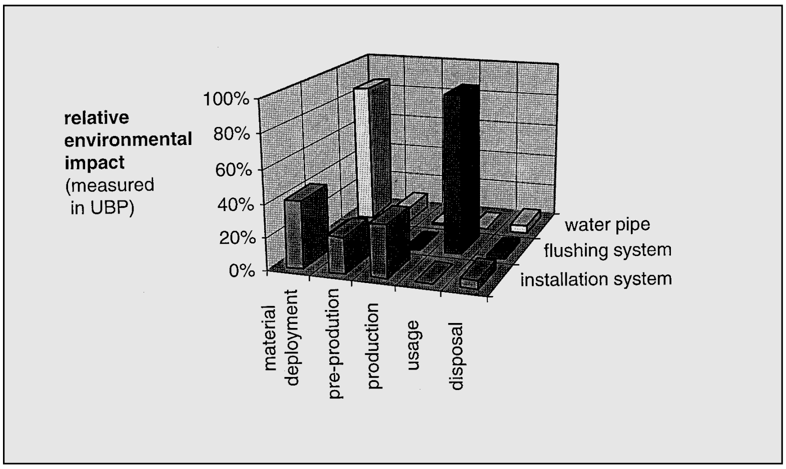


Figure 7: The relative environmental impacts of three representative products of a sanitary company over their product life cycle (Frei 1998, data from Gerber 1997).

Example: flushing system

The concept of the eco-effective product design is illustrated using the design of a new flushing system (Figure 5). Key internal and external requirements that have to be taken into account include:

- the reduction of the water used for flushing
- the usage of Polyvinyl Chloride (PVC) – due to pressure group concerns
- environmental considerations being a central marketing feature for the new flushing system.

Evaluation of the significant environmental aspects

The 'environmental learning circle' was applied to evaluate the significant environmental aspects of a flushing system (Gerber 1997, Frei 1998). The function of the product was defined as the flushing of a toilet over 50 years. Therefore, not only the physical product was considered, but also the water consumption during the usage phase. Based on this function, the product system was modelled with around 45 processes over material deployment, production, usage and disposal. To evaluate and assess the environmental impact, the BUWAL method with ecopoints (BUWAL 1990) and Eco-Indicator '95 (Goedkoop 1995) was used. The result of the assessment shows that 95% of all environmental impact resulted from water consumption during the usage of the flushing system (cf. Figure 7). A second environmental aspect – although less important – is the general supply of materials and their disposal. An additional factor results from the use of brass when assessed with Eco-Indicator '95. To summarise, there are three significant environmental aspects of the flushing system:

- water consumption in the use phase
- material intensity (weight)
- use of brass.

Product planning

The main internal and external environmental requirement of the flushing system is to minimise water consumption during the use phase. To minimise the water consumption, a technique which allows the user to select two different flushing quantities was added to the list of requirements. This resulted in about a 40% reduction in water use.

Design

Design can be structured into task clarification, conceptual design, embodiment design and detail design. In task clarification, the requirement was to reduce water consumption during its use phase. During the conceptual design the significant environmental aspect was addressed, eg. the function of 'flushing'. The embodiment and detail design dealt with, among others things, the mechanism for the two flushing quantities; and the detail design of the flushing mechanism included material selection.

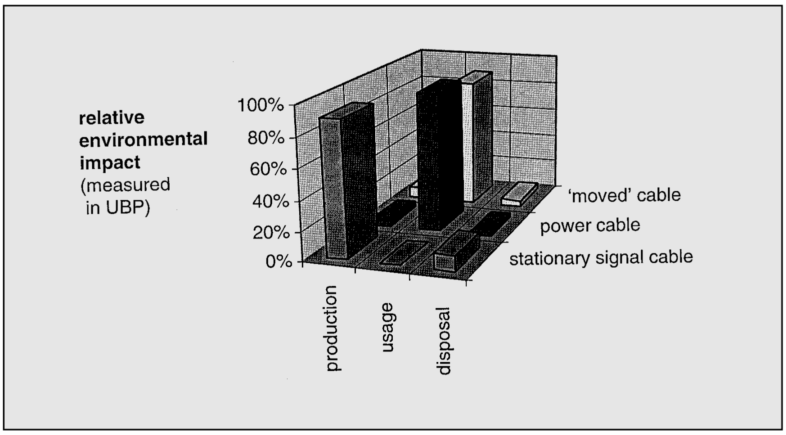


Figure 8: The relative environmental impacts of cables over their product life cycle (Frei 1998, data from Seipelt 1998).

In a case study, the 'environmental learning cycle' was applied to analyse the significant environmental aspects of the whole product spectrum of a sanitary company (Gerber 1997, Frei 1998; Figure 7). Twelve reference products were defined. The figure shows the relative environmental impacts for three representative reference products over their life phases. The result shows the biggest environmental impact was during material deployment for the water pipe, during the usage phase for the flushing system (because of the water consumption) and over the whole production chain for the installation system (mainly because of transportation). Overall, the impacts from the production phase were small compared to the product's whole life cycle. The case clearly shows how concentrating on the production would have been the wrong strategy for improving the environmental performance of this company.

In a second case study, the environmental impacts of signal and power cables were analysed (Seipelt 1998, Frei 1998). The results could be clustered in three groups (Figure 8):

· 'signal cables' for data transmission (with the significant environmental impact in material deployment)
· 'power cables' (with the biggest impact through energy loss in the usage of the cable)
· 'moved cables', eg. built into cars, trains or aircraft (which increase the energy consumption of the vehicle because of their weight).

This example illustrates that certain measures, eg. dematerialisation, can be appropriate in some cases ('signal cables') and inappropriate in others ('power cables') eg. dematerialisation would increase power losses. It is especially important to distinguish between 'active' products, ie. products which cause environmental impacts during their usage (like 'power cables' and 'moved cables'), and 'passive' products, which have no impact in the usage phase.

Product planning: definition of the eco-effectiveness

During product planning, eco-effectiveness is defined by drawing up a list of requirements. This list defines how the internal and external environmental requirements and the significant environmental aspects of the reference products should be taken into account. In a first step, the requirements are collected, in the second, the product life cycle is briefly modelled and in the third, the result is fixed in the list of requirements (Figure 9).

· *Collecting environmental requirements*: internal and external stakeholders and the idea of the product itself define environmental requirements.
· *Modelling the product life cycle*: the goal of the second step is a systematic check of requirements. To achieve this, the product life cycle is briefly modelled and the consequences of different variations assessed against technical, environmental and economic criteria. Using this process, the environmental impacts of all requirements are considered – not only the environmental elements. The basis for the modelling of the product life cycle is the 'environmental learning cycle'.
· *Drawing up the list of requirements*: the results of the previous step are recorded in the list of requirements. The significant environmental aspects of the product therefore build an integral part of the list of requirements and should be

automatically taken into account in the design process.

Design: translating eco-effectiveness

To achieve eco-effectiveness various design strategies, such as prolonging product life, dematerialisation or recycling can be used. It is, however, essential that these design strategies are not an end in themselves but conceived to fulfil the above-defined goals (cf. Alting and Legarth 1995). The aim of design should be to translate eco-effectiveness efficiently.

Applying eco-effective product design

To apply eco-effective product design, a process of change within the company is necessary. 'The environment' has to be recognised as strategically important. SPD is not primarily a technical task, but a new capability which concerns the organisation as a whole (cf. Lenox and Ehrenfeld 1997).

The organisation's ability to learn is essential for the application of eco-effective product design. Therefore, value systems, so called 'local theories' – the way people involved in the process think about environmental topics – plays a crucial role. Organisational learning is the result of changes of 'local theory' that result from the interplay between the individual and organisation on one hand, and action and learning on the other (Baitsch et al. 1996; Muller-Stewens and Pautzke 1994);

· designers learn about SPD through their actions

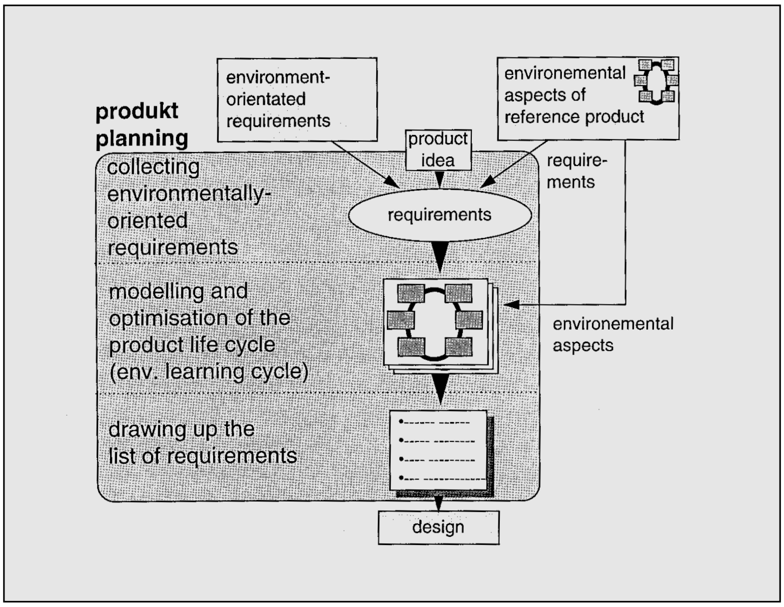


Figure 9: Product planning with the steps 'Collecting environmentally-oriented requirements', 'Modelling and optimisation of the product life cycle' and 'Drawing up the list of requirements' (Frei 1998)

· individual experiences are brought into the organisation and are discussed; the 'local theory' on SPD changes
· knowledge gained is used to design new structures, tools etc. in order to improve the design of sustainable products,
· the institutional knowledge (corporate culture) of the organisation influences, in its turn, individual action and experience.

Based on these reflections on organisational learning (especially on Baitsch et al. 1996) and 'systems engineering' (Zust 1997) a procedure to apply eco-effective product design has been developed (Frei 1998; Figure 10).

· Complete an analysis of the design process, internal and external stakeholders, environmental requirements, environmental problems resulting in the significant environmental aspects of the products.
· The goal should be to integrate environmental aspects into the product design process – eg. defining environmentally-orientated goals for every product in all relevant design phases. The goal definition process has to include all stakeholders involved in the process. By confronting these people with different views, the change process related to the 'local theory' can be stimulated. The new, common 'local theory' should build the basis for the goal definition.
· The organisation, tools and the deployment of the employees involved in an eco-effective product design should be planned. The initial planning steps can be repeated several times.
· In the final stages of eco-effective product design, special attention has to be paid

to the training of employees.

· The implementation of a eco-effective product design process, should already include recommendations about the further development of the design process.

Conclusion

There appears to be a gap between environmental management and product design. The empirical study shows that this is true even amongst environmental leaders. The goal of the concept of eco-effective product design is to close this gap and should be based on a systemic approach to SPD and its five principles.

Eco-effective product design takes environmental aspects into account in the early phases of design. Its focus is on the systematic development and usage of goals in product design. The aim is to improve the environmental performance of products. These goals are based on the environmental requirements of all stakeholders and on the significant environmental aspects of the products.

The environmental impact of the product, as well as the perception of its impact by stakeholders should always be considered. Increasingly, technological, environmental, economic and social aspects have to be integrated in SPD. Therefore, it is important to develop integrated organisational systems to manage this process. •

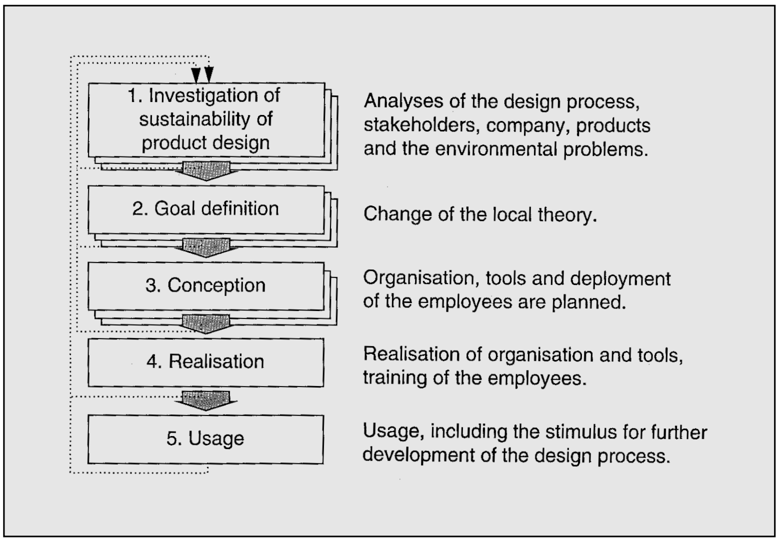


Figure 10: Procedure to apply the eco-effective product design (Frei 1998).

References

Alting, L. and Legarth, J. (1995). Life Cycle Engineering and Design. In: CIRP Annals – Manufacturing Technology. Vol. 44/2/1995. Hallwag, Bern, 569-580.

Baitsch, C., Knoepfel, P. und Eberle, A. (1996). Prinzipien und Instrumente organisationalen Lernens. In: Organisationsentwick-lung, 3, 4-21.

BUWAL (1990). Methodik fur Oekobilanzen auf der Basis ökologischer Optimierung. Ein Bericht der Arbeitsgruppe Oeko-Bilanz. Schriftenreihe Umwelt, Abfälle Nr. 133, Bern.

Frei, M. (1998). Die öko-effektive Produktentwicklung – Der Beitrag des Umweltmanagements zur Entwicklung umweltgerechter Produkte. Dissertation Nr. 12593 der ETH Zürich, Zürich.

Frei, M., Dannheim, F. and Schott, H. (1998). Neuer Fokus des Umweltmanagements – Die zentrale Rolle der Produktentwicklung in der Umsetzung des Umweltmanagementsystems nach ISO 14001. In: QZ, 7.

Frei, M. and Waser, M. (1998). Umweltmanagement und umweltgerechte Produktentwicklung in der Praxis – Resultate einer Umfrage unter okologisch fuhrenden Unternehmen der Schweizer Maschinen-, Elektro- und Metallindustrie. Betriebswissenschaftliches Institut (BWI) der ETH Zürich, Zürich.

Frei, M. and Züst, R. (1997). The Eco-effective Product Design – The Systematic Inclusion of Environmental Aspects in Defining Requirements. In: Krause, F.-L. and Seliger, G. (Eds.) Life Cycle Networks, 4th CIRP Seminar on Life Cycle Engineering. Chapman & Hall, London, 163-173.

Gerber, R. (1997). Bestimmen der bedeutenden Umweltaspekte der Produkte der Firma Geberit. Unveröffentlichte Diplomarbeit. Betriebswissenschaftliches Institut (BWI) der ETH Zürich, Zürich.

Goedkoop, M. (1995). The Eco-Indicator 95. Weighting method for environmental effects that damage ecosystems or human health on a European scale. Pre consultants, Amersfoort, Netherlands.

ISO 14001 (1996). Umweltmanagementsysteme – Spezifikation mit Anleitung zur Anwendung. EN. ISO 14040 (1998). Umweltmanagement – Produktökobilanz – Prinzipien und allgemeine Anforderungen. EN.

Lenox, M., and Ehrenfeld, J. R. (1997). 'Organizing for Effective Environmental Design', Business Strategy and the Environment, 6, (4), 1-10.

Müller-Stewens, G. and Pautzke, G. (1994). Fuhrungskräfteentwicklung und organisatorisches Lernen. In: Die lernende Organisation: Konzepte fur eine neue Qualität der Unternehmensentwicklung. Sattelberger, T. Gabler, Wiesbaden, 183-205.

Seipelt, D. (1998). Bestimmen der bedeutenden Umweltaspekte von Energie- und Signalkabel der Firma Huber+Suhner. Unveröffentlichte Diplomarbeit. Betriebswissenschaftliches Institut (BWI) der ETH Zürich, Zürich.

Züst, R. (1997). Einstieg ins Systems Engineering – Systematisch denken, handeln und umsetzen. Verlag Industrielle Organisation, Zürich.



Active disassembly

Joseph Chiodo, Professor Eric Billett and Dr David Harrison

Research Scientist, Cleaner Electronics Research, Brunel University, UK; Chair in Design, Brunel University, UK; and Lecturer in the Department of Design, Brunel University, UK

Joseph Chiodo is a Research Scientist at Cleaner Electronics Research, Brunel University, UK, and doing a PhD in 'Design for Environment with Active Disassembly'. He graduated in 1994 from Manchester Metropolitan University with an Industrial Design Masters degree in 'Environmental Optimization through Industrial Design'. Since 1988 Joseph has worked intermittently as a freelance product designer in the UK and Canada and he teaches under-graduate, MA and MBA modules in environmentally sensitive design.

Professor Eric Billett holds the Chair in Design at Brunel University, UK. From his appointment in 1989 through to 1997 he was Head of the Department of Design, and under his leadership the Department developed into the leading design department in the UK, rated 5 in 1992 and 5* in 1996. Prior to his appointment at Brunel University, Professor Billett was head of Chemistry at St Mary's College, Strawberry Hill, Twickenham.

David Harrison is a Lecturer in the Department of Design, Brunel University, UK. He holds a BSc in Engineering Science from Exeter University and a PhD in Robotics from Portsmouth Polytechnic. He has held a Westminster Fellowship in the Parliamentary Office of Science and Technology.

Industrial recycling is a practice of growing importance and impending European 'take-back' legislation and economic pressures are increasing this. In addition, landfill sites have become problematic and therefore industry needs novel approaches to recycling pre and post consumer waste. As a result, recyclers are working on broadening the range of reusable components from the waste stream. However, cost constraints limit the number of different products that can be recycled. Future trends in product design engineering point towards recycling as an integral part of the life cycle of electronic consumer products. As the amount and diversity of electronic products increases dramatically, current models of production and dismantling seem outdated.

A unique project entitled 'Active disassembly using smart materials' was funded by a 'Blue Skies' Engineering Physical Sciences Research Council (EPSRC, UK) grant at the Faculty of Technology, Department of Design at Brunel University in the UK. The first phase of the project was completed in 1997 and further funding has been granted for the second phase. This new two year EPSRC project started in late spring 1998 and is investigating 'Design principles for active disassembly'. This research is observing a hierarchical/variable temperature triggering regime and its product design implications (Chiodo, Billet, Harrison and Harvey, 1998).

The aim of this initital project was to test a novel form of disassembly on the casings of consumer electronic products. This form of disassembly is called 'active disassembly'. Ideally, products designed with 'active disassembly' in mind have their internal designs altered minimally so releasable fasteners and actuators made from 'smart materials' can be incorporated into their assembly. These smart materials consist of shape memory metals or 'shape memory alloy' (SMA) and shape memory plastic or polymer (SMP). These smart material releasable fasteners and actuator devices have the ability to dynamically change shape at specific temperatures and thereby 'split' their host candidate products' macro assemblies.

Throughout the paper the releasable fasteners and actuators made from smart materials shall be refered to as 'devices'. When these devices are inside candidate products and enter the dismantling line at the recycler's facility, the product's 'active' or self-disassembly can be triggered by appropriate temperatures.

Introduction

This paper reports initial results in the application of SMA and SMP smart material devices to the active disassembly of assembled consumer electronic products. The smart materials considered in this study are alloys of Nickel-Titanium (NiTi), Copper-Zinc-Aluminium (CuZnAl) and SMP made from polyurethane. In this novel form of disassembly, two distinct approaches can be taken when planning the eventual dismantling of a product. The devices can either be incorporated into existing product designs (retrofitted) or incorporated in the product during the design phase (design for active disassembly). Since this was an initial investigation, the feasibility of retrofitting the devices to assembled products has been explored. The design of the devices, cost effectiveness, range of permissible ambient temperatures and triggering temperatures are each considered key parameters to be improved in future research. In this work, general heat sources (vector air and steam jet) between 60–100°C (140–212°F) were employed to raise the devices above their triggering temperatures. After the full run of experiments, observations were made detailing outline design guidelines as a starting point to the current work. The entire process is best labelled as 'active disassembly using smart materials' (ADSM).

Background – the sustainable society

In order to move towards a sustainable society which is within the carrying capacity of the planet, a drastic revaluation of the throw away 'consumer society' is required (Henderson, 1996). Crucial to this move towards sustainability is the reduction of extraction and processing of resources, particularly raw materials and energy derived from fossil fuels. Predictions of the necessary factors of improvement vary extensively from four to twenty (Chiodo, Ramsey, Simpson, 1997). Achieving these large factors will require a combination of lifestyle changes, significant breakthroughs in technology and different design processes for problem solving. Designers have a key role to play in Factor 'X' reductions in material and energy use.

A typical design process ranges from the early stages of concept generation to the later stages of refinement. In the early stages there are opportunities for significant improvements, whereas the later stages can focus on incremental improvement. This later stage is typically accomplished by engineers.

The importance of recycling

Life Cycle Analysis (LCA) has demonstrated that in many products, the disposal phase contributes significantly to the overall environmental impact

Figure 1: Candidate product fitted with a triggered 1-way actuator

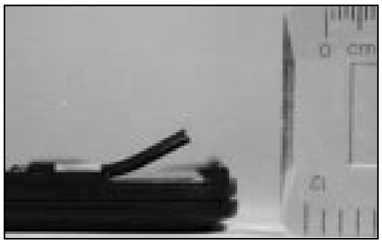


Figure 2: Triggered NiTi actuator displacement for product separation

Figure 3: After successful disassembly experiments

Figure 4: Before experiment, actuators inside semi-transparent product

The EU draft 'take back' directive states that 70–90% by weight of 'end of life' electrical and electronic equipment will have to be recycled.

Figure 5: Truncated two-way actuators placed in calculator before experiment

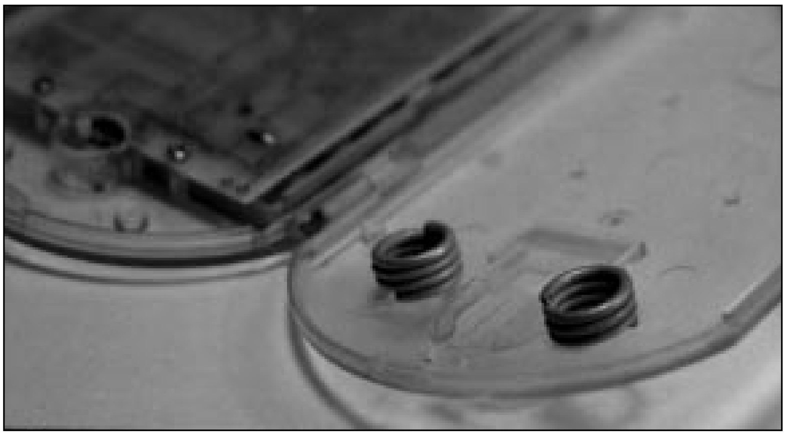


Figure 6: Full two-way actuators placed in second calculator before experiment

of the product (Hawken, 1993). This is particularly the case where a product contains toxic materials (ECTEL, 1997), scarce or valuable materials, or materials with a high energy content. 'Waste from Electrical and Electronic Equipment' (WEEE) often combines all three of these situations; for example, toxic lead solder, cadmium batteries, precious metals and quality plastics. Furthermore, the quantity of this waste is rapidly increasing as the number of electronic products in our lives grows dramatically. In 1998 the EU was expected to produce 6.5 to 7.5 million tonnes per year of WEEE (AEA Technology, 1997), which represents approximately 1% of the total EU solid waste stream (ECTEL, 1997).

This problem is common in the G7 countries and is leading to various 'take back' laws such as obligatory return for large and small appliances in the Netherlands in 1999 and 2000 respectively (Boks, Nilsson, Keijiro, Suzuki, Rose, Burton, 1998). The draft EU 'take back' directive states that 70–90% by weight (depending on the type of waste) of 'End of Life' electrical and electronic equipment will have to be recycled (EU, 1998). In Japan, the 'Appliance

Recycling Law' is to be ratified in 1998 with 'take back' to be implemented on TVs, refrigerators, washing machines and air-conditioning systems in 2001 and computers in 5–10 years (Boks et al, 1998).

These changes will oblige manufacturers to dispose of their products at 'end of life' (EOL), and therefore, create an incentive to manage this as efficiently as possible.

Design for disassembly

Serious research into disassembly began in the early 1990s. Currently, the only options are hand disassembly and robotic disassembly or the combination of the two. Both approaches have had only limited success. There are profitable and versatile dismantling facilities using hand disassembly with simple mechanical aids such as hammers and drills. However, the proportion of each product recycled is rarely very high and there are technical and physical limitations on the size, speed and safety of the process (Boks, Templeman, 1997). Robotic solutions have proven to be costly and inflexible, requiring product specific programming, object orientation and vision recognition systems. Moreover, the speed of disassembly is not significantly improved from manual disassembly. However, robotic disassembly is still under serious investigation, particularly in Japan.

Consequential advantages would be realised if a rapid and simple generic process for product disassembly was developed that was not product specific. Ideally such a process would be initiated by a simple triggering incident which would lead to an orderly sequence of disassembly events. Ultimately, this would result in the separation of the product into its separate components grouped by material type. This paper considers smart materials as the basis for the implementation for this strategy.

Smart materials

The family of smart materials which lend themselves to 'active disassembly' include shape memory metals or alloys (SMA) and shape memory plastics or polymers (SMP). Below a certain 'transformation temperature' (Tx) (Gilbertson, 1994) they behave as relatively standard engineering materials and can be used in all normal ways; above this critical temperature however, they undergo a very specific shape change that can (if required) be reversible if the temperature is lowered again. It is this change of shape above a critical temperature which can form the basis of active disassembly.

The major difference between the metals and plastics in this context is that the metals can generate a significant force as they change shape whereas the plastics do not. On the other hand the metals are more expensive at present. Both materials are described below.

By incorporating smart materials early in the design process, the designer can ensure that at the EOL (perhaps 15 years later) the product contains all the necessary information and mechanisms to disassemble itself following a single generic triggering event such as heat. It will not be necessary for the dismantler to have a record, nor plans of the design for the EOL disassembly.

Shape Memory Alloy or Metal (SMA)

SMA is a small group of metals made up of two or more metallic elements with particularly remarkable shape change and force provision properties. As the temperature crosses or changes across a critical value, known as a transformation temperature (Tx) they undergo a large and predictable shape change or so called 'Shape Memory Effect' (SME).

SMAs were invented by the American military and are now used in a variety of applications such as spectacle wire frames, submarine and fighter jet couplings, military circuit board connector sockets, space station connector components, cell phone antennas, teeth braces and some medical applications. Because of an increasing envelope of uses, prices have and are continuing to drop and therefore, exciting new opportunities exist for inexpensive actuators and fasteners in a range of electronic consumer products.

The important qualities of SMA from a design perspective is that they are corrosion resistant and in many ways resemble stainless steel. They have the mechanical

DESCRIPTION

Actuator characteristics:		Shape memory alloy actuator types:				
Composition		NiTi-1	NiTi-2	CuZnAl-1	CuZnAl-2	
Tg in °C		95-100	52-60	+70 to +100		
Actuator forms:		1 Ribbon	1 Rod	1 Helical	3 Helicals*	
Dimensions (mm):		2.5	2.2 dia.	1.5 dia.	1.5 dia.	*1/3 = 2 high
		x0.375	x31.0	x8.0 I.D.	x8.0 I.D.	*1/2 = 3 high
		x31.0		x6.0 high	x h'ghts	*2/3 = 4 high
Forces (N)	1	XXX	62-64	12-13.5	*1/3 = 4	
provided	2	--	--	--	*1/2 = 6	
by actuators	3	--	--	--	*2/3 = 8	
Mass (g)	1	0.11	0.45	whole=2.8	*1/3 = 0.5	
of actuators	2	--	--	--	*1/2 = 1.5	
	3	--	--	--	*2/3 = 1.0	

* = Truncated designs (in fractions) from the original (CuZnAl-1) 'whole' size design type

RESULTS

	Drop test	Total F provided by actuators: NiTi-1	NiTi-2	CuZnAl-1	CuZnAl-2	Separt'n force / product **	#Of snap fits	Trial result
Sub assembly trials:								
IC 1	--	< F	--	--	--	X	--	failure
IC 2	--	< F	--	--	--	X	--	failure
PCB 1	ok	< F	--	--	--	X	--	failure
TI30X (calclt'r)	ok	< F	124-128	< F	< F	X	--	failure
Product housing trials (small electronic products):								
Royal DM75	ok	--	124-128	no trial	no trial	XXX	11	success
Canon LS--37H	ok	--	124-128	no trial	no trial	30	6	success
Canon LS--37H	ok	--	> F	48-54	--	30	6	success
Brats 1	ok	--	> F	48-54	--	12	6	success
Sharp EL--240L	ok	--	> F	48-54	--	64	6	success
Brats 2	X	--	> F	--	24	26	6	failure†
Total F/device:		--	(62-64)x2	(12-13.5)x4	(6x2)+4+8			
Employable experiments		X	yes	yes	X			
Future development?		no	yes	yes	yes			

Legend

Tg = Transformation temperature
X = Not tested
-- = not applicable
XXX = Altered in earlier disassembly
sub = sub assembly
F = Force
< F = Insufficient force as this SMA was altered, force tests were incomplete.
section, forces were too low in comparison with the larger actuators providing 62-64 N
which also failed. However, it was clear that due to the cross
> F = Excessive force as lesser force providing actuators worked in this particular application.
** = Max. (of 20 tensometer tests / product) force required to separate housing assembly.
† = Successful disassembly but, inspection revealed excessive wear on snap fits.

Figure 7: SMA descriptions and results of preliminary disassembly experiments. These tables describe the characteristics of the SMA devices and the candidate products used in the experiments. Additionally, the results of these experiments are described in terms of the forces provided from the SMA devices as well as the success of the same trials.

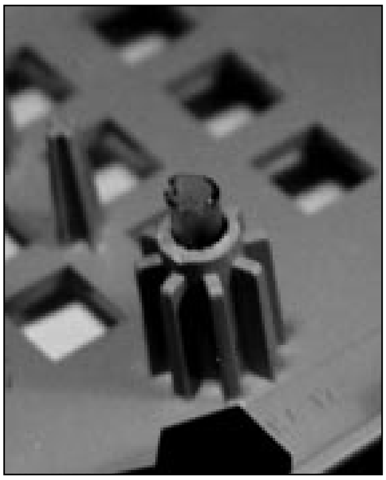


Figure 8: SMP compression sleeve inserted inside injection moulded form bolt acceptor inside the BT telephone

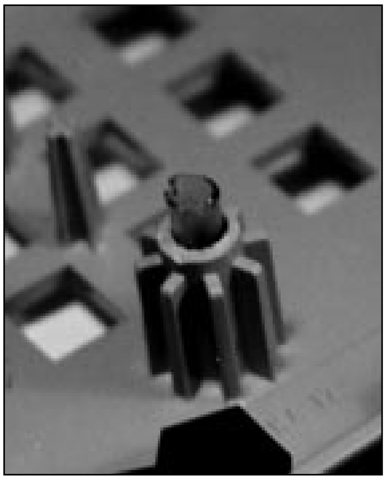


Figure 9: Slightly undersized bolt inserted inside SMP compression sleeve within injection mould assembly bolt acceptor inside the BT telephone

strength to form reliable fasteners yet upon exposure to a high transformation temperature, they will change form. The critical temperature can be placed according to the designer's choice somewhere between −190 to +190°C (-310 to +374°F). These limits are due to the current state of development of SMA.

Shape memory polymer or plastic (SMP)

SMP is a very small group of plastics that can be formed by the normal processes including injection moulding and with properties similar to those found in Polyurethane, Polypropylene and ABS (Acrylonitrile-Butadiene-Styrene).

SMP was invented in Japan and has become commercially available in the last couple of years. Currently SMP is used in the design of automatic carburettor chokes and utensils handles. Medical and many other applications are becoming recognised as SMP becomes more fully commercially exploited.

'Shape Memory Effect' (SME) in SMP is different from in SMA. Plastics above their transformation temperature or glass transition temperature (Tg) loose their mechanical strength and return to their originally formed shape. Unlike the metals, the plastics do not provide significant force accompanying this triggering procedure.

Shape Memory Effect (SME)

SME can be categorised three ways; one, two and multi-way SME. The 'effect' happens in many different ways and by varying degrees. As described in the SMA and SMP sections above, their SMEs are quite unique. SMP is generally a multi-way effect and SMA is generally a one and two-way effect. These unique characteristics offer designers new solutions to products previously requiring dynamics such as movement and force provisions. By using smart materials, part reduction is plausible as these materials provide movement, shape change and force with one material. Previously, more parts would have been required for the same function. It must be noted that SME is impossible without the temperature exposure, therefore the product will not experience SME if the smart material specified has a Tx above normal operating temperatures.

One-way SME
Materials that recover to the original form one or more times after exposure to heat. In one-way effects, the material would have to be forcibly re-shaped in order to recover again.

Two-way SME
Materials that can recover many times to the original form and deform again to a secondary form after exposure to a specific temperature or stimulus repeatedly. The amount of successful times the material can recover and reform again depends primarily on the material, extent of deformation and the extent of heat. The designer has many options with two-way devices since the devices can take the place of switches or more complex mechanisms requiring more than one moving part. The

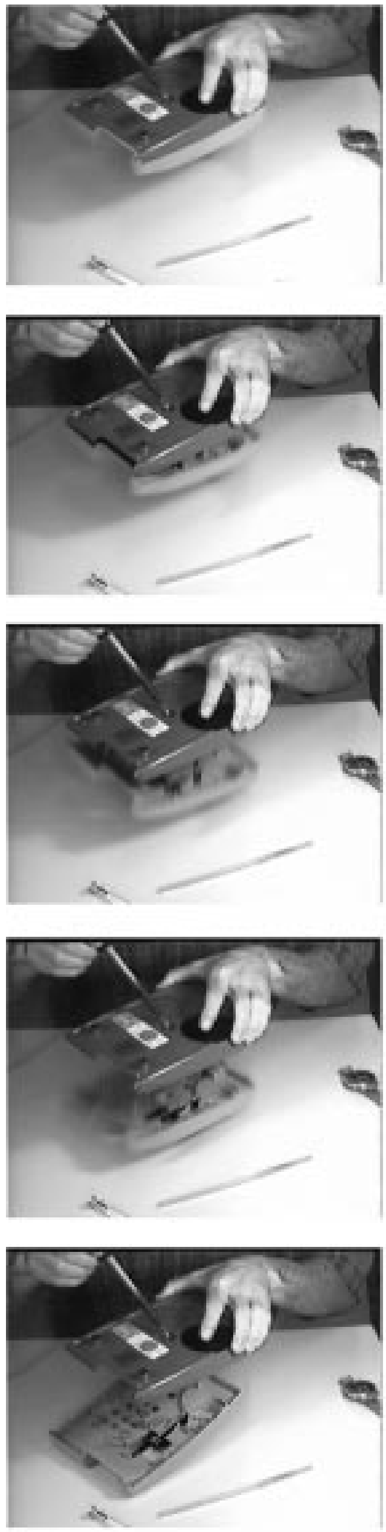


Figure 10: Showing various stages of the SMP disassembly experiment with a standard BT telephone

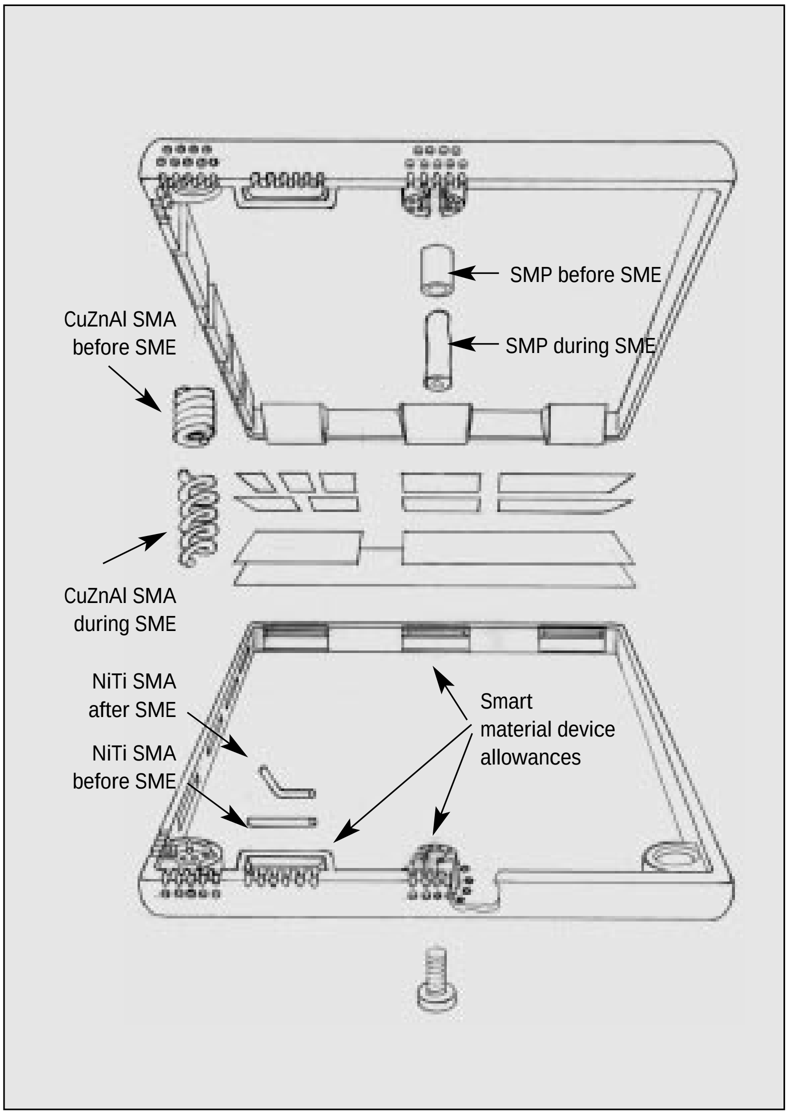


Figure 11: General outline guidelines for design for active disassembly

external stimulus for the transformation is temperature change (heat).

Multi-way SME

Here the material acts the same as in the two-way states except the material may be formable to more shapes depending on the extent of the external stimuli (heat and force). Sometimes in this case the material may be altered infinitely into different shapes such as is the case for SMPs. One could view the variable nature of SME in SMP as metamorphic (Spillman, Sirkis, Gardiner, 1996). This characteristic provides the most exciting possibility for designers as SMP could be considered a 'live' material. A smart material with the ability to take on different forms on demand.

Experiments with Shape Memory Alloy (SMA) Actuators

A number of experiments were conducted with SMA devices, applying them to the active disassembly of electronic products. The initial experiments investigated releasing socketed Integrated Circuits (ICs) from Printed Circuit Boards (PCBs) and a PCB sub-assembly. A further series of experiments attempted the disassembly of product housings. Both 1- and 2-way SME SMAs were used, alloys of Nickel-Titanium (NiTi) and Copper-Zinc-Aluminium (CuZnAl) respectively.

SMA results

Figures 1, 2 and 3 indicate the NiTi 1-way SMA actuators whilst Figures 4, 5 and 6 indicate the CuZnAl 2-way actuators. The results are summarised in Figure 7 (Chiodo, Anson, Billett, Harrison, Perkins, 1997).

In initial experiments to eject chips from PCBs, it proved impossible to develop sufficient forces with the actuators to overcome the frictional forces. This was primarily because of the limited size of actuator which could be positioned below the chips. NiTi rod actuators worked successfully to disassemble small electronic products including a personal organiser and calculators. These 0.5 gram actuators provided very high forces (62– 64 N) over a displacement of 5mm. Therefore for further trial purposes, it was decided to

After manually disassembling and incorporating devices into the test products, examinations were made for an outline of general methodology for design modifications. It was found that the test products would best incorporate 'active disassembly using smart materials' (ADSM) when designing with the general considerations below:

- avoid alloys / combination materials
- controlled break points
- over-specification reduction
- hierarchy of subassemblies
- vinculum strength reduction
- isolation of costly materials
- component/material type reductions
- standard grab points
- compression hinges
- general simplification
- reusable components
- toxic material elimination
- undamaged component disassembly
- moulding material fasteners
- accessibility
- modularity
- miniaturisation
- separate materials
- eliminate adhesives
- reversible fasteners

Although the above considerations are useful for active and other disassembly methods, there are a number of specific factors relating to ADSM. These include:

- actuators should be placed in and around the fastening element
- actuators should be placed such that the actuator temperatures correspond to hierarchy of sub-assemblies
- location specific force provision
- force provision must surpass tensile force in fastening elements of the constituent assemblies
- vectorial passage for ambient temperatures are necessary to induce SME
- average to tight tolerancing for memory devices
- locators and seats for memory devices
- passage for clean separation
- temperature/time balance affects the structural integrity of the product and the disassembly procedure
- trigger temperatures must be specified for a timely active disassembly
- use of a non-specific disassembly line would optimise the potential of ADSM
- design of memory devices depend on product applications for best disassembly results; some standardisation can be investigated however
- generally, SMA actuators and SMP releasable fasteners would be in the low temperature state in a product in use at a typical ambient temperature range of -50 to approx. +90˚C.

Figure 12: Outline design guidelines checklist for design for active disassembly

employ lower cost, lower force-actuators. Cu-based helical (spring shape) actuators also provide sufficient force to actively disassemble calculator cases.

Experiments with Shape Memory Polymer Releasable Fasteners

Numerous experiments were conducted with SMP releasable fasteners applying them to the active disassembly of various products. The initial experiments investigated the releasing of PCBs and housing assemblies of product housings.

SMP results

Initial experiments to release PCBs from opened product housing assemblies proved successful. The SMP holding brackets replaced the screw assemblies used in current production methods. All experiments proved disassembly within seconds of being exposed to Tg (SMP transformation temperature) or higher +55˚C (+131˚F) . It is envisaged that higher temperatures outside of normal operating temperatures would need to be used for many applications.

SMP experiments shown in Figures 8, 9 and 10 are those employed in the second set of experiments. These SMP sleeves

With future development, the average product disassembly times could be reduced to less than one second.

were placed inside the bolt assembly with the bolt slightly undersized. This was an application to trial smart material usage with absolutely minimum changes to current manufacturing methods.

SMP releasable fasteners in the form of compression sleeves worked successfully to disassemble large product housings such as the BT telephone (see Figures 8 and 9). This disassembly application provided releases between 15 and 135 seconds (see Figure 10). All experiments were performed at room temperature; +22 to +23.5°C (+72 to +74°F). A heating probe, +100°C (+212°F), was applied to the single bolt assembly. The assembly bolt temperature was between 43°C (+109°F) and 45°C (+113°F) after disassembly. The 15–135 second disassembly time range is attributed to the reforming of the SMP compression sleeve used. More accurate reforming would significantly reduce this range in time.

With future development, the average product disassembly times could be reduced to less than one second!

Design implication

The experiments showed that, in principle, smart materials could be used to actively disassemble small electronic products. Working prototypes of a variety of component ejectors and releasable fasteners were produced, and used successfully in disassembly trials.

In all cases, optimised designs would use less material and permit a cheaper fastening mechanism (see Figures 11 and 12). Design for conventional and active disassembly use similar design outline guidelines and require only minimal changes to existing designs. SMA and/or SMP devices or actuators could be implemented surrounding a snap-fastened assembly. The bottom mould would have incorporated air allowances near the actuator/snap fastener assembly. This would ideally encourage actuation of the devices on a dismantling line upon the EOL. The product could travel in one direction through a 'heat' chamber being exposed to increased actuation or transformation temperature. This type of disassembly leaves undamaged components. The whole process encourages the separation of dissimilar materials. For 'Outline Design Guidelines', see Figures 11 and 12.

Costs

Current SMA prices are a relevant issue for cost effective disassembly. The high volume prices per gram for the SMAs used here were for NiTi approximately 20¢ US (£0.15 UK), for CuZnAl 4¢ US (£0.03 UK). Each gram of CuZnAl provided up to 5 Newtons (N) with a reasonably optimised actuator design. The NiTi provided slightly over 142 N per gram at five times the cost without optimising the design. Here, Cu-based devices cost 0.8¢ per N whilst NiTi costed 0.1408¢ per N at the time of testing.

Small order SMP prices are at about $60 US (£37.50) a kilo but, volume purchasing would lower this price to the same as typical engineering polymers. Furthermore, prices of smart materials are coming down as production and applications increase. Future work will explore the optimisation of the design of actuators in active disassembly observing cost and a more detailed application on a range of consumer electronic products including communication products.

This investigation produced a novel and fundamentally different product disassembly technique which provided a new means of dismantling a variety of constituent product assemblies. Current disassembly practice is largely by hand. Usually about 80% of the cost of such disassembly is attributed to labour. Robotic disassembly research is currently under development, but has so far been shown to be very expensive as it requires dedicated dismantling facilities. This condition makes recycling prohibitive and difficult in a low profit margin industry.

Role of recyclers

Recyclers currently recycle a range of consumer products salvaging precious metals from PCBs and ICs. Some further dismantling is done on larger material/value intensive products such as large appliances, computers and their cathode ray tubes (CRT). However, cost constraints still limit the number of different products that can be recycled profitably. Broadening this range would significantly increase profit for recyclers and consequently would create a larger role for them in the life cycle of consumer electronics. As 'take back' legislation becomes EU law (within the next one to five years time depending on the member state), a wider reaching recycling technology makes more sense. As recycling becomes an integral part of the product life cycle, a generic recycling process is most likely to be the most profitable way forward. With the amount and diversity of electronic products increasing dramatically, current models of production and dismantling are cost heavy. The changes to the product that will allow active disassembly create either little or no cost increases. This provides an excellent driver for manufacturers and recyclers. As product design engineering points towards recycling as an integral part of the life cycle, active disassembly provides a considerable cost advantage over current dismantling schemes.

Active disassembly addresses all of these issues and has revealed the potential for non-specific dismantling. Therefore, there is potential for the associated lower costs of a generic disassembly facility such as that used in ADSM. A third-party dismantler could recycle a variety of companies' consumer products at the end of their useful life cycle. Products could then be economically recycled as their dissimilar and contaminated materials are separated. The success of this project has led to a patent (UK 2,320,277). A small group of electronic consumer product manufacturers have expressed interest in testing potential applications; work is now under way.

Conclusions

Active disassembly would widen the range of recyclable electronic consumer products, it would significantly increase the volume of recycled material used in manufacturing new products and potentially reduce recycling cost and cost per new product.

Most of the 'active disassembly' devices are cheap and could prove to be a very valuable investment. Additionally, the smart material actuators and devices are highly re-usable, costs too would divide every time the devices are re-used.

In 'active disassembly' the cost added to some products may be a few cents/pence but, most products' costs would not change significantly in volume manufacturing.

The generic nature of the process would mean that a single dismantling centre could accept products from a variety of manufactures in a single disassembly line. This would mean that the transportation costs of returning the products to the manufacturers could be minimised. This last aspect is very important as a journey of more than a few miles can consume more resources than are saved by recovering the materials embodied in the product.

'Environmental Impact Reduction' (EIR) and cost reduction/efficiency are obviously the key issues in LCA. As legislation points towards producer responsibility, recycling as an integral part of the life cycle of electronic consumer products becomes a more attractive possibility.

For a successful reverse logistics infrastructure to be developed it is important that a manufacturer in say, Japan, should be able to discard the responsibility of discharging the product in say, Europe or North America. For example, it would not be environmentally beneficial to discard an automobile or computer by bringing them back to Japan after a 15 year life in Europe or US.

Recycling resources from electrical and electronic equipment locally would significantly reduce the environmental impact and cost. Active disassembly could provide this and become an important driver to a more environmentally responsible form of product stewardship. •

References

Chiodo, J. D., Billett, E. H., Harrison, D. J., and Harrey, P. M., 'Investigations of Generic Self Disassembly Using Shape Memory Alloys: 1998 IEEE Int'l Symposium on Electronics and the Environment – ISEE – 1998' (Oak Brook, Chicago, Il, USA., 4–6 May 1998), pp. 82–87.

Henderson, H., 'Building a Win-Win World: Perfecting Democracy's Tools' (San Fransisco: Berrett-Koehler, 1996), p. 247.

Chiodo, J.D., Ramsey, B.J. and Simpson, P., 'The Development of a Step Change Design Approach to Reduce Environmental Impact through Provision of Alternative Processes and Scenarios for Industrial Designers: ICSID'97 The Humane Village Congress' (Toronto, ON, Canada, 23–27 August, 1997), in press.

Hawken, P., 'The Ecology of Commerce – A Declaration of Sustainability' (New York: Harper Collins,1993), pp. 45–46.

The European Trade Organisation for the Telecommunications and Professional Electronics Industry (ECTEL) 'End-of-Life Management of Cellular Phones – an industry perspective and response' (England: industry publication, 1997), p.25.

AEA Technology, 'Recovery of WEEE: Economic and Environmental Impacts. Final Report A report produced for the European Commission DG XI', (EU, June, 1997).

The European Trade Organisation for the Telecommunications and Professional Electronics Industry (ECTEL) 'End-of-Life Management of Cellular Phones – an industry perspective and response' (England: industry publication, 1997), p. 23, 39.

Boks, C.B., Nilsson, J., Keijiro, M., Suzuki, K., Rose, C. and Burton, H. L., 'An International Comparison of Product End-of-Life Scenarios and Legislation for Consumer Electronics: 1998 IEEE Int'l Symposium on Electronics and the Environment – ISEE – 1998' (Oak Brook, Chicago, Il, USA., 4–6 May 1998), p. 20.

WEEE-7/8/98, EU: Second Draft, Proposal for a Directive on Waste from Electrical and Electronic Equipment Council Directive of 7 August 1998.

Boks, C.B., Nilsson, J., Keijiro, M., Suzuki, K., Rose, C. and Burton, H. L., 'An International Comparison of Product End-of-Life Scenarios and Legislation for Consumer Electronics: 1998 IEEE Int'l Symposium on Electronics and the Environment – ISEE – 1998' (Oak Brook, Chicago, Il, USA., 4–6 May 1998), p. 20.

Boks, C.B., & Tempelman, E., 'Future Disassembly and Recycling Technology for the Electronics and Automotive Industry', (The Netherlands: Internal document code K370, Faculty of Industrial Design Engineering, Delft University of Technology, April 1997), pp. 9–16.

R.G. Gilbertson, 'Muscle Wires Project Book' (Mondo-tronics, Inc.: San Anselmo, CA., 1994), pp. 2–7.

Chiodo, J. D., Anson, A.W., Billett, E. H., Harrison, D. J., and Perkins. M., 'Eco-Design for Active Disassembly Using Smart Materials: Int'l Conference on Shape Memory and Superelastic Technologies' (Pacific Grove, CA, USA., 2–6 March 1997), p. 272.

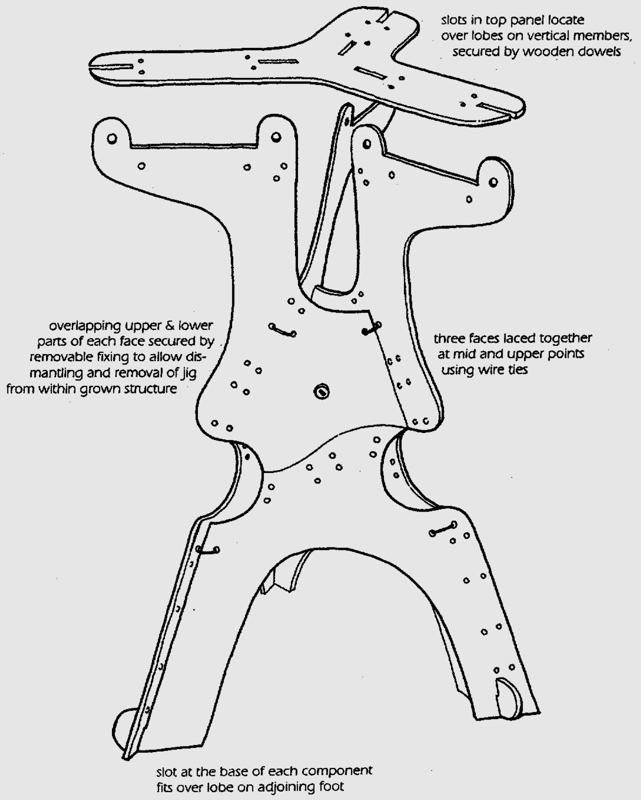
Spillman Jr. W. B., Sirkis, J. S. and Gardiner, P. T., 'Smart materials and structures: what are they: Smart Materials & Structures, V. 5, no. 3, (Istitute of Physics Publishing, June 1996) p. 248.

Top: Borderline chairs
Below: River tables

Sustainable furniture

Woodschool timber utilisation project

The Woodschool project is an example of a sustainable design service where the products are locally and sustainably grown, designed and manufactured using low grade and waste hardwoods. The project is a reflection of the need to optimise the use of woodland resources from sustainably managed forests. Oak, ash, elm and beech are made into innovative high 'value added' quality furniture. The Woodschool project was established under the umbrella of the Borders Forest Trust (BFT) initiative. BFT was formed in 1996 in response to sustained public commitment to native woodland restoration in the Scottish Borders. The diverse range of BFT projects reflects the growing recognition that native woodland is a land use, bringing tangible social, economic and environmental benefits to local communities in rural Scotland. Profits from Woodschool are covenanted to the Trust for the creation of new community woodlands and the development of other environmental projects across the region.



Sketch showing general arrangement of seven part plywood jig used to control growth of seat 2 experimental structures

Sustainable grown furniture

Christopher Cattle, furniture designer

Furniture designer, Christopher Cattle has been 'growing' wooden furniture for small scale production. He does this by using jigs to control the forms into which the young tree grows, and by grafting joints. Two experimental schemes are currently running in Britain, with the aim of investigating the viability of such a system. The scheme is examining such aspects as the suitability of various tree species and the structural integrity of the grafted joints. The key aim of the project is to find a commercially viable sustainable production method which will be of benefit to rural communities in the Developed and Third Worlds. The 'start up' benefits of such a scheme are that it requires mechanisation of limited scale with the greatest investment required being land, time and manpower.

Peter James, Director, Sustainable Business Centre, UK

Martin Charter

Joint Coordinator, The Centre for Sustainable Design, UK

Peter James describes himself as a 'virtual person', an independent who regularly works with the universities of Bradford and Wolverhampton (where he holds visiting professorships in environmental management), Ashridge Management Research and the UK Centre for Environment and Economic Development (UKCEED). He previously worked in business schools in Britain and Ireland and as a science journalist, initially with BBC Television and subsequently as a freelancer. His co-authored publications include 'The Green Bottom Line: Environmental Accounting in Business' and 'Environment under the Spotlight: Current Practice and Future Trends in Environment-related Performance Measurement' (ACCA) as well as many articles and papers on environmental performance evaluation, accounting, product development and sustainable business. His current research includes a European project on the development of eco-services and work with BT on telecommunications and Agenda 21.

Eco-efficiency is becoming a very popular idea with business – what's your view on this?

It's fine as far it goes – which tends to be a focus on getting better resource productivity in existing processes and products. But we should interpret it more broadly. As Claude Fussler of Dow argues, the real long-term opportunities lie in eco-innovation – designing new products and processes that meet consumer needs in different, smarter ways and produce orders of magnitude improvement in eco-efficiency. Most companies also divorce eco-efficiency from the social dimensions of sustainability. And, as road transport shows, you can become ever more efficient but still increase overall impacts because consumption continues to soar.

How do you think we can achieve sustainable consumption?

With difficulty – few companies are ever going to voluntarily restrict demand! So it has to be a combination of carrots and sticks – and the fields they grow in. Carrots include support or protected space for innovations which can help achieve it – such as 'Local Exchange Trading Systems' (LETS) schemes or sustainability-shaped car hire or leasing initiatives. Sticks means internalising environmental costs, creating 'economic subsidiarity' – a presumption by governments, takeover authorities and others that economic activity should be conducted at the lowest possible level – and also creating demand 'ceilings' for some products. The US experience of demand side management in electricity, especially in California, has been interesting in showing how this could work – although its now breaking down as a result of deregulation.

But perhaps most important is changes in the big 'field', ie. the values which drive our consumption. And the big target here is mobility – as societies and individuals (including me!) we have to put less emphasis on travel. Unfortunately, the problem is created just as much by the apparently anti-establishment 'Lonely Planets' and 'Rough Guides' as by multinationals or the airline industry. I suspect that the solution will be more virtual travel and that middle class values may need to become less rather than more cosmopolitan. A slightly unpleasant kind of 'green regionalism' may be necessary – our place is best and we don't want to know too much about yours because if we do we'll want to travel.

What about social sustainability?

It's difficult enough to get a consensus about environment between different countries, cultures and religions and this is even more pronounced on social issues. I think the debate about sustainability and how we assess it has been dominated to date by western and western-influenced groups. A 'world ethic' of sustainability will need to be constructed from Asian and Latin American, Islamic and Confucian roots as well as from a European/North American and Christian, Jewish or other secular positions. The implication is that designers and others need flexible rather than rigid criteria that can accommodate these differences. I suggested five of these – life chances, basic needs, social norms, human capital and autonomy and community – in a recent article for the Journal (JSPD 2, July 1997) but there's much scope for refinement and of course other good evaluation schemes around.

How can we measure sustainability issues in eco-design?

On the environmental side, there's an emerging consensus on what should be measured. Most of the schemes which are around focus on the same areas – mainly energy, materials, hazardous substances and sustainable resources. The difficulties come when you consider how to measure, what kind of detail is required, the weightings you put on different kinds of impact and extending it into the social dimensions of sustainability. And the answers depend upon your objectives. Sometimes you want precise 'dial' measures so that you can control and fine tune. But in other cases we may want 'can opener' measures that get us into a problem and help us to prioritise and see the main issues but don't always need a lot of precision. One problem with LCA is that it often gives us a dial when we need a can opener to reveal the broad pattern of impacts and help to prioritise action.

The various LCA-based eco-points packages can also be valuable for some specific purposes but are often dangerous because of their hidden assumptions. How do you rate Polyvinyl Chloride (PVC) for example? Fairly benign according to one popular package I've used – but of course very bad in the eyes of many environmentalists, because of the health concerns. The outcome is what I call 'spurious precision' – apparent precision that underlies basic gaps in knowledge and/or disagreement about what is known. So we need ways of measuring that, to highlight rather than suppress uncertainty and disagreement. Qualitative rather than quantititative approaches can often be best for this. The 'Sustainability Wheel' which I wrote about in Issue 2 (JSPD 2, July 1997) is one attempt to create such an approach.

You're now working on eco-services – is a move to services the essence of sustainable business?

Yes – and there is great potential – but we need to be careful. Some services can be eco-efficient but drive higher consumption. If you take telecommunications-based services such as videoconferencing or e-mail, for example, they seem eco-efficient because their direct effect is to substitute information flows for physical resources. But their indirect effects can be problematic – because you need to see people less often you might relocate to a nice but remote area and make fewer but longer trips so that distance remains the same. And, just as we now know that new road construction ultimately fuels demand for road transport, so the building of information 'superhighways' might generate more rather than less travel. It's nice – and profitable – to meet the new contacts around the world made possible by e-mail and lower phone costs. The same trends can also make it as easy to trade with – and transport goods to and from – another continent as the next county.

So unless framework conditions are right – such as, in the case of transport, adequate public transport, internalising the full costs of pollution and some degree of road pricing – I'd assume that any service, however eco-efficient, will tend to increase consumption in the longer term. Many eco-efficient services are also dependent upon intensive deployment of information and communication technologies. Hence they increase society's electronic dependence – which may be OK but is certainly worth thinking about.

The move to leasing or hiring instead of buying which much of the eco-services literature has focused on is also interesting but potentially problematic. There's a lot of consumer resistance – producer goods may be a better bet for real change – and it's not always environmentally beneficial. Hiring or leasing cars, for example, can lead them to being driven more and harder than when people own them. We hope to get a better understanding of all these issues in the European project we're just beginning.

You've stressed the need for a more international and diverse approach to sustainable business. What are the implications of this for eco-design?

As I've said, more flexible criteria – and also building the cultural issues into evaluation processes. In the 'Sustainability Wheel', for example, there's a category of social norms to highlight this issue. More broadly, I think that Asia and Japan in particular will become much bigger influences on eco-design and eco-services. Not because of overt environmental action or awareness – although, even with the current economic crisis, I think overall Japan is no worse and possibly 'better off' than other developed countries. And other Asian countries are no different than European ones in similar stages of development. But because of 'uninentional sustainability' – environmental and social improvements which occur as by-products of other changes. In environment, for example, Japanese society and business (as with German society and business) still tends to have longer-term perspectives – which is vital for environmental improvement – compared to say Britain or America. I'd also say that the historical values in Japanese society are far more compatible with sustainability than the west's generally nature-hostile Judaeo-Christian heritage. After all Tokugawa Japan – which prospered while turning its back on foreign trade and subsisting on the country's own carrying capacity – is arguably the only example we've ever seen of a large-scale sustainable society. And the design context in Japan – crowded cities, small homes, an aesthetic appreciation of fragility and the miniature, a high awareness of dependence on imported materials – is perhaps more intrinsically supportive of dematerialised and smart products and services than say America or Sweden. Because, let's face it, the future of the planet isn't going to be determined by what people value and buy in countries such as Canada or Italy but in those such as Brazil, China and India which have high populations and legitimate expectations of a better life.

Are you optimistic or pessimistic about achieving sustainable development?

Both! Optimistic because one has to be and also because it's becoming clear that clever policies and new technologies and products can drastically reduce environmental impacts. Pessimistic – or at least concerned – because their dependence on high technology, particularly on information and communications technologies, may create fairly atomised, stunted and unfair societies. We'll need good social design as well as eco-design to prevent them. •

Experiments in sustainable product design

Stuart Walker

Associate Professor, Faculty of Environmental Design, The University of Calgary, Canada

Stuart Walker is Associate Professor of Industrial Design in the Faculty of Environmental Design at The University of Calgary where he teaches industrial design technologies, drawing and presentation techniques, sustainable product design and design studio at the graduate level. He is a member of the publications committee of the Industrial Designers Society of America, guest editor of the Innovation journal and adviser to Alberta Education in design studies. His work on sustainable product design has been presented and published in North America, Europe and China. He holds an MDes (RCA), the Diploma of Imperial College and a PhD from the University of Leeds.

Sustainable product design (SPD) is being approached in many ways but often, it seems, there is more attention given to related but peripheral aspects, such as technological innovations or analysis methodologies, rather than to 'designing' itself. This lack of emphasis on designing as a process of exploration and discovery, and its relationship to sustainability does a disservice to this vital, creative activity in which diverse and often disparate ideas find synthesis in material form.

The artefacts presented here address various aspects of SPD and form the basis of the discussion. They demonstrate that products suited to local production (an important facet of sustainability) are both feasible and can add a richness to our material culture that is lacking in much contemporary product design. These explorations start to show that environmental and social concerns can be responsibly addressed through design and that product aesthetics can begin to reflect the ethical core of sustainability.

'… design holds the potential to create, not new objects, but a newly responsible social order.'
Alexander Manu, Designer, Canada

It is a fruitless task to try to define SPD – there is no common essence and it is inappropriate to try to find one. Sustainability, and hence SPD, encompasses a great diversity of approaches which will vary with place, time, environment, culture and knowledge. No one knows what a sustainable society will look like – we can only speculate on possibilities from our present standpoint. As we work towards achieving a sustainable society our knowledge and understandings will increase, and so our vision of sustainability will evolve – the goal posts will keep moving, as it were. Sustainability is thus a fluid, dynamic, unfocussed goal – and this is the way it has to be – any attempt to define a vision of a sustainable society will always fall short.

Similarly, any one approach to SPD will be incomplete. Some current approaches focus on

The following examples are designs for everyday functional products. They utilise commonly available materials, off-the-shelf parts, simple tools and the notion of local labour rather than highly mechanised production.

product life cycle assessment (LCA), others on product longevity or 'design for disassembly' or the use of recycled materials. All these are important and can make a contribution but all are inadequate. The author has attempted to translate ideas about sustainability into product prototypes and to interpret the abstract, theoretical ideas in the creation of tangible, material objects which is the important aspect of investigative design work.

The designs presented here are centred on the notion of local production. Local production for local markets has many environmental and social benefits and has been identified by various authors as one of the main features of a sustainable society (eg. Van Der Ryn and Cowan, 1996 and Hawken, 1993). Three crucially important guiding principles of sustainability are:

- environmental stewardship
- social equity
- development – rather than growth (Roseland, 1992).

These principles have been used by the author, together with work done by Urban Planners in the development of 'Sustainable Community Scenarios' to explore what sustainability means in terms of product design. The following examples are designs for everyday functional products. They utilise commonly available materials, 'off the shelf' parts, simple tools and the notion of local labour rather than highly mechanised production. They are not conceived as commercially viable designs which can compete in today's market place. Rather, they are academic explorations which, through the activity of designing, examine possibilities for creating products for local use, repair and recycling within a general notion of a sustainable community scenario.

'Exploratory practical work (as design research) is a good alternative to conventional practice. I do not go along with a view often promoted in higher education that teachers of design have to be practitioners.'
Professor Nigel Cross, Open University, UK

The resulting designs are not readily classified. They are not typical product designs for mechanised production – that is, industrial design. Nor are they craft designs – little or no traditional craft skills are required to produce them. These artefacts represent a kind of hybrid category which draws on elements of mass-production, semi-mechanised production and hand-fabrication. Mass-produced parts are combined with locally produced components, re-used items and/or recycled materials. Again, this seems appropriate when we talk about SPD. In working towards sustainability we should be drawing on many existing procedures and techniques and modifying them and adapting them, but not necessarily rejecting them. Many of the negative consequences of our current, evidently unsustainable, approaches are not necessarily due to inherently harmful methods but due to a lack of balance or moderation in their use.

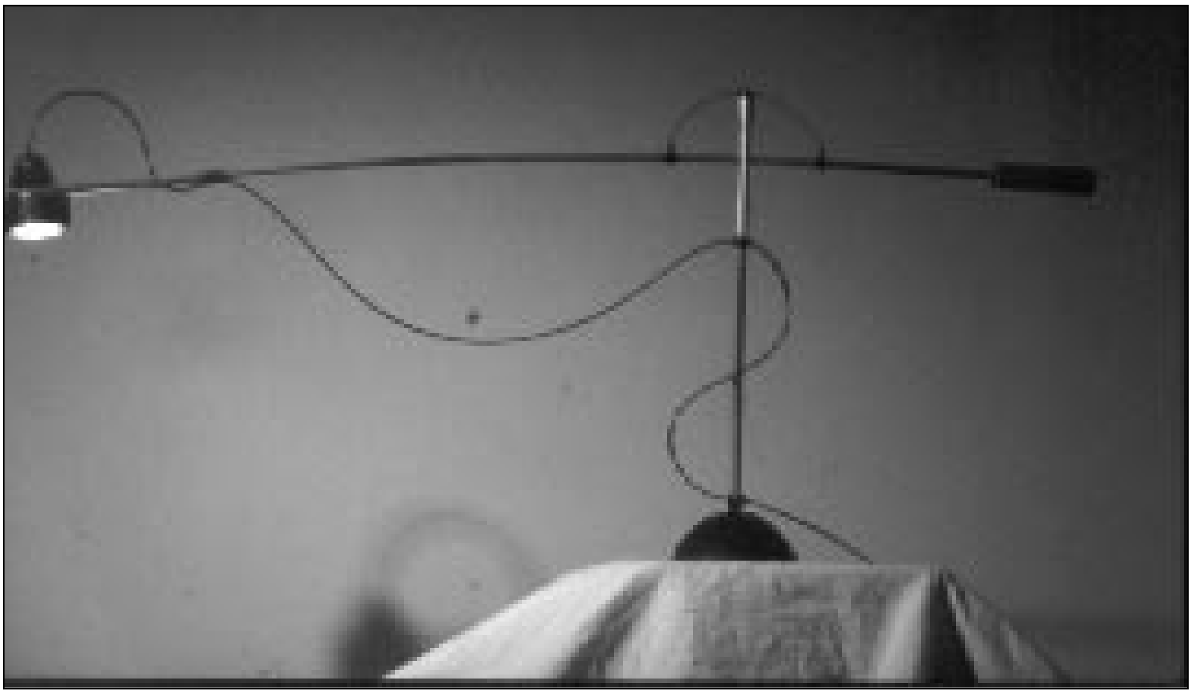


Figure 1: Arc Lamp – a task lamp from bamboo canes and reused components

The thesis of sustainability recognises that labour is relatively expensive but it also points out that current automated production methods fail to include the so-called 'externalities' in the economics (pollution, social consequences of unemployment, etc.). Thus, the costs of current mass-produced products are kept artificially low because aspects important to achieving sustainability are not taken into account. Local production (using local materials, producing products for local use) allows reductions in transportation and packaging, facilitates recycling, inverse manufacture and cyclic use of materials and parts, local maintenance and repair. It also allows products to be adapted to local needs and to reflect local or regional aesthetic preferences. This, in turn, contributes to cultural and community identity – 'community' being an important aspect of sustainability (Nozick, 1992).

These designs therefore represent a shift in the way we think about product manufacturing in terms of our scales of production, the provision of fulfilling employment, social responsibilities and use of materials. The resulting products also tend to challenge our preconceptions of aesthetics – which, in contemporary product design, are closely linked to the notion of 'newness'. SPD explores reuse of materials, re-manufacturing and product longevity. If we begin to create long lasting products made from re-used materials and parts, then we will have to reassess our ideas of products and the value and place of the 'new', the glossy and the 'perfect'. A product which bears the marks of time and use and its own history could, potentially, have a richness lacking in squeaky clean products. However, in order to appreciate this richness we will have to readjust our value system and our expectations of product aesthetics.

In these 'experiments' various aspects of SPD have been explored:

Inventiveness of necessity

Sustainability demands resourcefulness and restraint. New solutions have to be found which require less. In the Arc Lamp (Figures 1–3) the flexibility of movement was attained using a simple arc of wire over a fulcrum. The arc shifts the balance point as the lamp-head is raised or lowered. The arc replaces the relatively complex

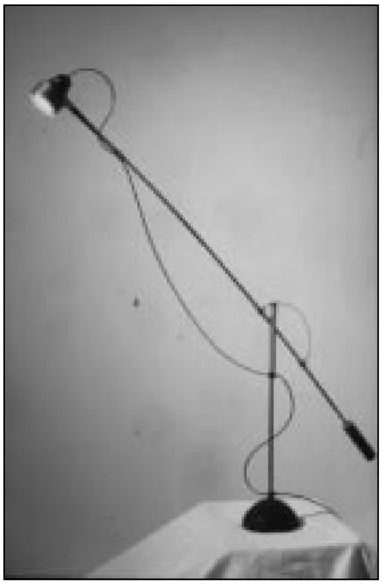


Figure 2: Arc Lamp – raised position

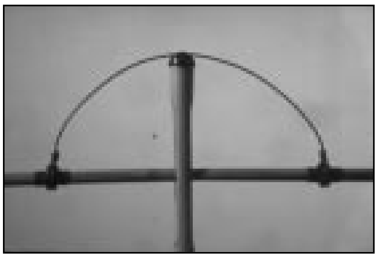


Figure 3: Arc Lamp – adjustment detail

friction or spring mechanisms frequently used in task lamps. The motion is wide ranging and flowing – the action is delicate, poised, bird-like. Construction is from bamboo garden canes, a food tin (lamp shade), a water-pipe and two corks (counter-weight) and a cast concrete base. Electrical parts are standard, 'off the shelf' components.

Improvisation and spontaneity

The constraints of limited resources – materials, processes and tools – combined with a realisation that most contemporary products are actually a physical manifestation of unsustainable practices – can create a liberating environment in which to reconsider the nature of objects. The 'Kind of Blue' chair (Figures. 4–6) is an exercise in improvisation, spontaneity, 'making-do' and the inclusion of 'chance'.

'There is a Japanese visual art in which the artist is forced to be spontaneous... The resulting pictures lack the complex composition and textures of ordinary painting, but it is said that those who see will find something captured that escapes explanation... direct deed is the most meaningful reflection.'

Bill Evans, jazz pianist, UK

There is a strong relationship between intuitive, extemporised, 'rough' design work and sustainability. Minutely considered, meticulously justified, 'honed' design may have a certain kind of beauty but in many respects it a sterile, lifeless beauty which represents only one side of our humanity. We can appreciate the precision but there is often little or no sense of empathy or 'resonance'. The intuitive gesture, the spontaneous, the improvised – all are driven by an energy, vigour, momentum and enthusiasm which are unavoidably lacking in fastidious, highly considered work. And of course when a product is being put into production in the tens or hundreds of thousands using expensive tooling and aimed at worldwide markets, everything has to be carefully planned and controlled.

Here, then, is another reason for reconsidering our scales of production. Smaller scale production for local markets allows us to adopt approaches to design and manufacturing which permit these aspects of design, and ourselves, to be re-introduced. This helps ensure a 'wholeness' in the creation of our material environment – it enables products to be a more complete expression of our material needs – needs which extend far beyond the utilitarian.

'[Ruskin] thought that liveliness and vigour and the positive mark of humanity were manifested in rough work.'

Martina Margetts, writer, US

In the case of the 'Kind of Blue' chair, the individual pieces of wood, comprising off-cuts or found pieces, were used as they came to hand, in the form and size they happened to occur. Fastenings are nails, glue or screws; and the geometry of construction ensures stability.

Figure 5: 'Kind of Blue' chair – construction detail

Figure 6: 'Kind of Blue' chair – rear view

Aesthetic longevity and 'surface'

Many contemporary products rely on shiny, highly polished, 'new' surfaces for their visual appeal. Automobiles, audio equipment, kitchen appliances and furniture are common examples. However, monochromatic, glossy surfaces, on painted metals and moulded plastics, are delicate and highly susceptible to marring. Any bumps, scratches or dents are immediately obvious and the accumulation of tiny surface scratches, caused when using or cleaning the object, will eventually dull the surface. And it is usually a difficult task to maintain or repair such a surface once it is marked. This deterioration of surface quality can cause a sense of dissatisfaction in the owner or user. Even though the product might still be functioning well, the appearance can seem scruffy and drab. The lack of opportunity afforded by the material to maintain or repair the surface can compound this sense of discontent. Thus, the product will often be replaced because of its appearance – it has become prematurely 'aesthetically obsolete' due to its surface qualities.

There are various ways to address this issue, which is another important facet of SPD. Above, is discussed 'rough' work from the point of view of spontaneity and improvisation, however, 'rough' surfaces can also contribute to aesthetic longevity. Surfaces which are 'unfinished' or created from reused parts or recovered materials – as in the 'Kind of Blue' chair – are often able to absorb wear and tear in ways which do not detract from the overall appearance of the object. One more scratch on a variegated, irregular surface that is an integral part of the object's design, will be unlikely to cause

Smaller scale production for local markets… enables products to be a more complete expression of our material needs – needs which extend far beyond the utilitarian.

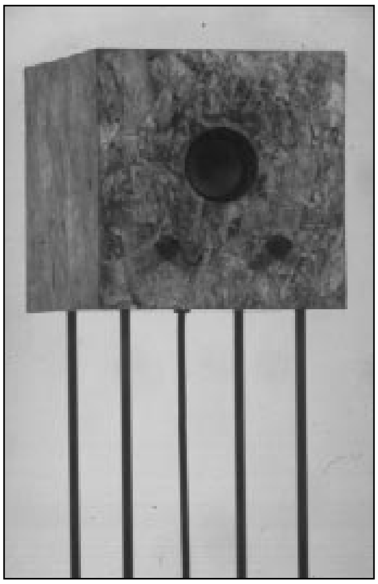


Figure 7: Cable Radio – three-quarter view

aesthetic dissatisfaction. Hence, reused materials can be employed in aesthetically sensitive ways to create objects whose surfaces are able to absorb abuse. But it should be noted that the aesthetic qualities of such surfaces will be quite different from those of the artificially 'distressed' surface, which is often applied to create the impression that the object is older than it really is. The spurious or bogus quality of such surfaces suggests an affectation or pretentiousness – the resulting objects lack authenticity and could be seen as a form of kitsch.

Another, related way of addressing the issue of aesthetic durability is to provide a complex surface that is easily maintained. In the 'Cable Radio', (Figures 7) the casing is constructed from a coarse particle-board which yields an irregularly, randomly patterned surface when polished. This surface can withstand minor scratches and knocks without detracting from the appearance of the object. Furthermore, the surface can be easily maintained by the owner and 'revamped' with a cloth and polish.

Energy use

Miniaturisation of electronic components over the years means that we now live with a profusion of small, portable, battery driven products. The widespread use of portable radios, music systems, personal stereos, calculators and so on means that vast quantities of batteries are being discarded, often after only a few hours of use. Even if rechargeable batteries are substituted for disposables, the losses incurred in recharging represents an imprudent use of energy. These inefficient, wasteful and harmful practices are a common feature of non-sustainable product design.

The 'Cable Radio', (Figures 7), is a design for a 'mains-powered' radio. Part of the design challenge was to resolve two seemingly contradictory elements. On the one hand, the small size of contemporary components and circuitry allows the product envelope to be quite small. On the other hand, a 'mains-powered', and only 'mains-powered', product is not a portable object. It is therefore important to convey this idea – that the object has a 'place'. The inclusion of the long legs and the use of the power cable as a visual element articulates the non-portability of the product. The housing for the electronics and speaker is relatively small and is positioned at an appropriate height for ease of operation and for listening.

Local manufacture – forms and fastenings suited to basic tools

All the designs presented here are capable of being manufactured at locally based 'generalised' production facilities capable of producing diverse products, in relatively low quantities (batch production) for local or regional markets.

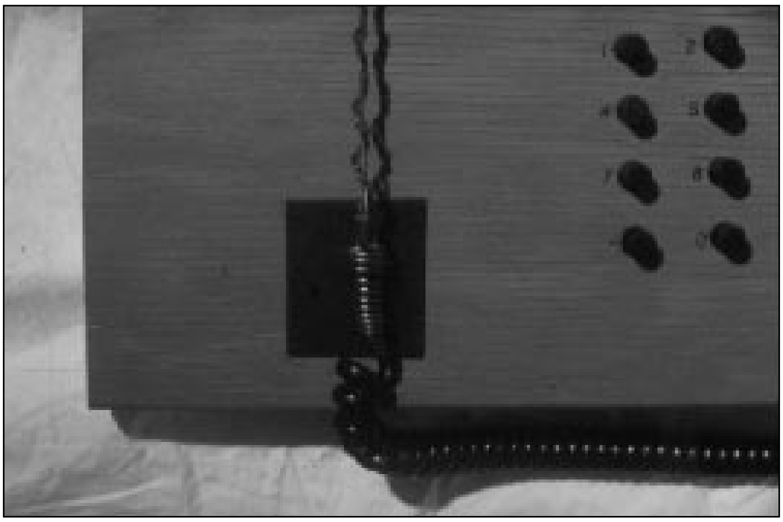


Figure 8: Plaine Telephone – detail of keys

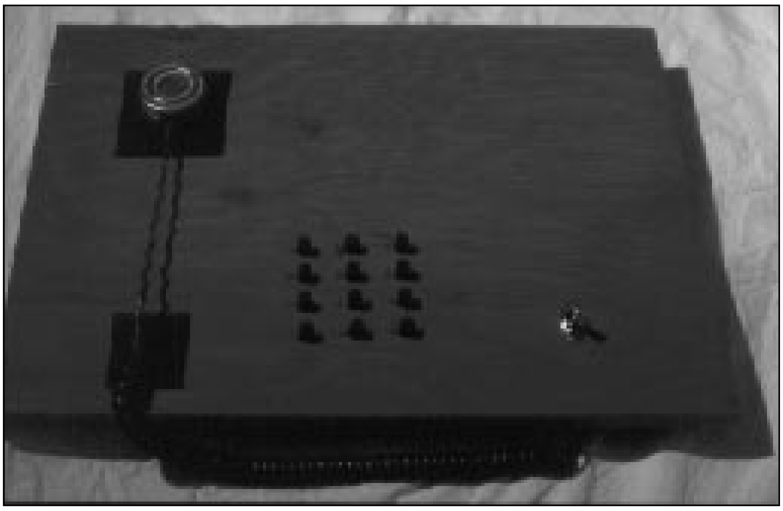


Figure 9: Plaine Telephone – simple construction for local production

The design of such products is, of course, influenced and constrained by the economic, environmental and social considerations of this type of production.

Currently, capital and energy intensive techniques are widely used to produce intricately moulded components and casings, often with integral fittings. However, these high quantity processes, used for producing products for international distribution, are not appropriate, desirable or economically viable at the local level. The 'local approach' requires the development and evolution of alternative techniques which employ skills and materials in new ways and in unconventional applications. For example, almost all the design precedents for many electrical and electronic products rely on high quantity techniques such as injection moulding. Most historical and contemporary telephone designs, for instance, feature moulded casings. An important area of exploration for SPD, therefore, is to consider alternative approaches, that do not utilise high quantity techniques and which can be readily and economically manufactured at the local level.

The 'Plaine Telephone', (Figures 8–9), is made from a piece of plywood. All cuts and drilled holes are at right-angles for ease of manufacture with basic equipment. Keys are simple cylindrical pegs, the 'handset' utilises a re-used bottle cap and some wire and is set on location pads fashioned from a rubber inner-tube, an 'off the shelf' toggle switch replaces the switch that is normally activated when the handset is replaced, and the circuitry is simply screwed to the underside of the board. The intent here was to create a usable telephone by employing the simplest of 'local' techniques – it represents an exercise in looking for alternatives to precedents, rather than any suggestion of a definitive 'local' design.

Integration of scales – mass-produced plus locally made components

As discussed, sustainability is strongly linked to the idea of the 'locale'. An important but seemingly little explored aspect of SPD is, therefore, a reassessment of our scales of production so that products can be made, repaired and re-used within a local or regional 'industrial ecology' of cyclic resource use. Such a shift would mean that where appropriate, products and parts

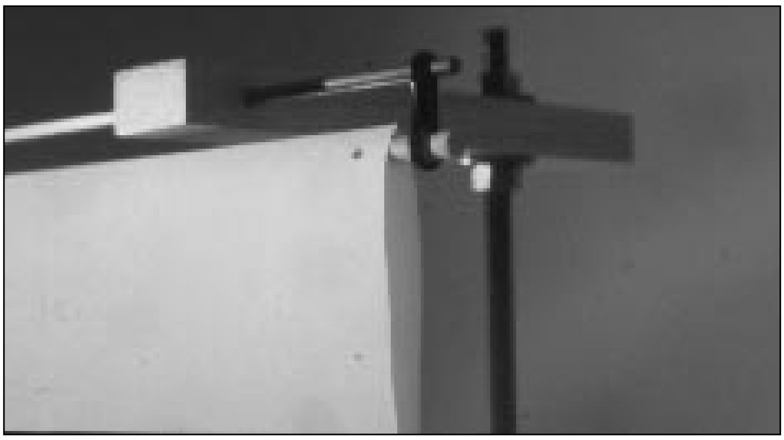


Figure 10: *(top)* Lumière Floor Lamp – off-the-shelf components and a pebble

Figure 11 Lumière Floor Lamp – detail of construction

would be made using locally available resources. However, there would remain many components that would be more appropriately manufactured in high quantities – light sockets, switches, light bulbs and electronic parts would be difficult to manufacture at the local level and it would be inappropriate to do so. It is often important, for instance, to retain standardisation of these types of components for safety reasons and to ensure compatibility. Hence, SPD must combine and integrate scales – using locally produced parts made from local materials in combination with mass-produced parts where appropriate and necessary. If the mass-produced parts are minimised and non-specific to a particular product design, then they can be recovered and more easily re-used in other applications. A standard, mass-produced lamp socket can be used in a variety of lighting designs, similarly a length of threaded rod or electrical cable has many possible design applications. On the other hand, a specialised moulding produced for one particular product application might be difficult to re-use.

The Lumière floor-lamp (Figures 10–11) illustrates this integration of scales. It utilises a number of 'off the shelf', mass-produced components (lamp socket, bulb, cable, floor switch, threaded rod and fasteners), together with locally produced and found components (reused hardwood components for the cross-arms and base, a locally-made sheet of paper as the shade and a pebble for the base weight). Packaging and shipping of components is reduced to a minimum. Fabrication of a number of parts and assembly is done locally and the basic design can be modified and adapted to utilise locally available resources and to suit local requirements. In addition, the design is such that its construction is explicit and easily comprehended – this facilitates repair and disassembly for replacement or recovery of parts. Reuse is encouraged by the fact that all mass-produced components are standard, 'off the shelf' parts which can be incorporated into a wide variety of designs.

Elegance and empathy through design

When developing products within the limitations imposed by the 'locale', then the processes, the techniques and human skills must be used imaginatively to convert often uninspiring or 'non-ideal' materials into elegant forms which contribute in a positive way to our material culture.

The 'Remora Box', (Figures 12–13) is a legged, leaning chest constructed from recovered planks with screw fastenings and threaded-rod legs. Here the attempt was made, through 'design', to bring an element of style and finesse to an otherwise prosaic item constructed in an expeditious and rudimentary fashion from commonplace materials. An additional feature of this approach is that the simplicity and evidently basic means of construction allows a certain empathy with the object that is based on an understanding of what the object is made from and how it is constructed. Many contemporary products lack this sense of 'connection' because they are made using processes, materials and fastenings that are foreign to the user or owner. This lack of understanding of one's material environment not only hinders product repair and maintenance, it also creates a certain distance or lack of association with the objects that we use. Without a greater sense of rapport with our material surroundings we tend to value products only for their functional convenience but not as material things. Consequently, when products fail to perform their intended task they are often discarded and replaced rather than maintained, repaired or upgraded.

The examples presented here represent an approach whereby the environmental and social issues inherent to the notion of sustainability can be addressed by and made relevant to the discipline of product design. This exploration has been conducted through direct engagement in the creative activity of designing itself rather than through investigation of technical addenda which can inform, but are not central to, the design process. It suggests that a reassessment of our approaches to product manufacturing is both necessary and feasible. Design aimed at local scale manufacturing has the

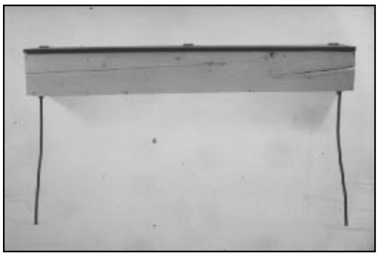


Figure 12: Remora Box – legged, leaning chest

Figure 13: Remora Box – corner detail

potential to provide fulfilling employment while enhancing the possibilities for product repair, maintenance and the cyclic use of materials. But it is the designer who must put the flesh on the bones of this potential. It is through design that we can demonstrate how 'things' could be, how products can be redefined for local and regional conditions, how a diverse and thoughtful variety of routes could bring a richness and depth to the creation of our material culture so that it is not only environmentally and socially responsible but also aesthetically expressive of the ethical core at the heart of sustainability. •

Sustainable product design (SPD) in action

Economics: Simplicity of design, use of inexpensive, locally available materials, ease of production, incorporation of 'off the shelf' parts, provision of local employment opportunities, low capital production equipment.

Environment: Use of natural materials which can be maintained and repaired, use of water-based paints and re-used parts, use of fasteners that allow disassembly and re-assembly. Finishes and other aesthetic considerations contribute to product longevity. Low energy production methods.

Ethics: Responsible use of human and material resources. Designs incorporate considerations significant to both environmental stewardship and social equity. These sustainable principles are expressed in the aesthetic resolution of the products - the designs begin to 'add value' to the product beyond merely utilitarian. This encourages care and maintenance of our material environment and contributes to product longevity. In turn, this starts to address the problems of excessive consumption with all its 'unethical' implications of selfishness, greed, vanity, immoderate attitudes, etc.

Social: Provision of local employment through local production, repair and maintenance. The evolution of local designs, expressing a local aesthetic helps create a sense of cultural identity. Local scale production fits well into scenarios of more sustainable ways of living that have been developed by urban planners. These scenarios emphasise the importance of 'community' and include mixed use developments incorporating reidence, production, retail, recreation, etc.

References

Cross, N., 'The Refereed Journal', in proceedings of Designing Design Research 2, (26 February 1998), at: http://www.dmu.ac.uk/ln/4dd/drs2.html

Evans, B., 'Improvisation in Jazz', liner notes from the 'Kind of Blue' album by Miles Davis, (New York: Columbia Records, [1959] 1997).

Hawken, P., 'The Ecology of Commerce: A Declaration of Sustainability', (New York: HarperCollins, 1993), p. 144.

Manu, A., 'The Humane Village Explained', The Humane Village Journal, Vol.1, Issue 1, (1994) p.11.

Margetts, M., 'International Crafts', (London: Thames & Hudson, 1991), p.13.

Nozick, M., 'No Place Like Home: Building Sustainable Communities', (Ottawa: Canadian Council on Social Development, 1992), pp. 14–15.

Roseland, M., 'Towards Sustainable Communities: A Resource Book for Municipal and Local Governments', (Ottawa: National Round Table on the Environment and the Economy, 1992), pp.7–9.

Van Der Ryn, S., and S. Cowan, 'Ecological Design', (Washington D.C.: Island Press, 1996), pp. 57–81 and pp.147–159.

The 'eco-kitchen' project – using eco-design to innovate

Chris Sherwin, Dr Tracy Bhamra and Professor Stephen Evans

Researcher, Research Officer and Lifecycle Engineer, Cranfield University, UK

Chris Sherwin is a researcher in eco-design at the CIM Institute, Cranfield University. He is currently undertaking his PhD looking into how companies and designers can use eco-design to innovate. A particular interest is how to integrate behavioural and lifestyle factors into eco-design practices and processes, and in shifting the focus from supply to demand side issues. He has an MA in Furniture Design & Technology, which focused on design for sustainability.

Dr Tracy Bhamra has been a researcher in the area of Environmentally Conscious Design and Concurrent Product Development for six years. Firstly at the Manchester Metropolitan University where she completed her PhD in Design for Disassembly and now at Cranfield University where she is a Research Officer.

Professor Stephen Evans has spent over 12 years working in the defence/aerospace industry. His research interests are in the implementation of improved product development processes and in bringing environmental concerns into the product development process. Dr Evans is a graduate of the University of Bath and has a doctorate in Manufacturing Systems Engineering. He is a Chartered Engineer and a Member of the Institute of Electrical Engineers.

The agenda is now being set for eco-innovations in sustainable products, services and lifestyles. This requires a new and more radical approach to eco-design, beyond the small step improvements that are the focus of many present developments. This article focuses on the 'eco-kitchen' project, a collaboration between Electrolux Industrial Design and Cranfield University, which aimed to develop new ideas and concepts for future products or services. A key intention was to highlight how eco-design can be used to innovate and and that such new developments must engage new forms of environmentally sensitive behaviour as well as cleaner technologies. Using examples from the project to illustrate, the paper demonstrates one future direction for using environment as innovation strategy.

Introduction

Many stakeholders are now recognising the need for innovation that goes beyond merely incremental improvements to existing products or situations. It is being acknowledged that companies need to innovate in order to keep up with increasing environmental pressures from legislation, consumers and competitors. The best and most advanced companies have recognised that it is necessary to improve both existing products but also to re-think future products and business strategies. Fussler has discussed the need for eco-innovations noting that 'environment' is a useful way to be proactive and create new markets for more sustainable products and services and that move society towards sustainability (Fussler, 1996). Also within the bigger picture of sustainable development, Agenda 21 and the Rio Declaration have highlighted the need for new systems of production and consumption (UNEP, 1992).

In its recent publication 'Design for Environmental Sustainability, the Royal Society of Arts (RSA) in the UK suggests that 'accessing the societal' brief is the next great challenge for environmentally conscious design (RSA, 1997). It is also suggested that the scale of environmental improvement necessary is somewhere between Factor 4, 10 or even 20. In short, the re-design of what exists is, in many cases, unlikely to deliver such improvements, so eco-innovations are needed in both technologies and lifestyles –

In short, the re-design of what exists is, in many cases, unlikely to deliver such improvements, so eco-innovations are needed in both technologies and lifestyles

Figure 1: 'Smart sink' – controls, calibrates and purifies water and gives feedback on rates and levels of consumption.

supply and demand side (Beard and Hartmann, 1997). The above drivers highlight the need for innovation and suggest that there is a new and innovative role for design emerging. This duality could see design representing opportunities to communicate 'visions' of more sustainable lifestyles, which engage consumers and users (Charter and Chick, 1997).

'Eco-kitchen' project

The 'eco-kitchen' project is a collaboration between Electrolux Industrial Design Department and Cranfield University with the intention of developing innovative new products and solutions that acknowledge the need to move from 'refine and repair', towards 'redesign and rethink' (see JSPD 1, April 1997). One of the key interests for both parties was for environmental considerations to be integrated into the design process at the earliest stage, written into the brief and included at concept generation, to give a greater level of innovation.

Process

An initial LCA of the kitchen indicated that the greatest impact of the kitchen (over 80%) took place during its *use*. In the *use* phase, consumer behaviour brings into play a whole series of issues dealing with lifestyles and behaviour which means that design developments will have to engage not only technological and material, but also cultural issues. The 'eco-kitchen' project was viewed holistically as a domestic 'scenario or need' (rather than a series of products) which means that the boundaries became issues surrounding 'food culture'. This approach allowed design developments to look beyond specific artefacts, to product systems, relationships or to services. It was also recognised that these 'domestic needs' are not simply the physical or

Environmental impact of household activities (Denmark)

Activities	Resources (%)	Discharges (%)
Eating	38	36
Clothes & Laundry	7	8
Personal hygiene/health	10	4
Leisure (at home)	15	12
Cleaning	2	1
Heating	14	12
Transport (car)	14	27

biological needs of nutrition or sustenance, but are culturally defined – the need for dining as social status or for eating as a courtship ritual (Tansey, 1995). This meant that cultural factors had to be integrated and considered in design developments. The kitchen was also recognised as a domestic setting and social centre of great significance. As Pearson notes:

'The kitchen is the heart of the house, the centre of consumption, the hub of daily life. It is the place where family and friends gather to eat, drink, and chat, share their joys, or solve their problems... What we need now is a new type of kitchen, a new focus for our daily life that is not intended for surface show but stands for the sounder principles of personal health and universal ecology. A kitchen where we can enjoy the pleasures of healthy food without it costing, literally, the earth.'

(Pearson 1989)

Even in terms of environmental impact, the kitchen needs special attention. A study of the environmental impact of domestic needs in Denmark (Figure 1) shows that food and eating represents the greatest household impact in terms of both inputs and outputs (WRF, 1996).

Approach – a 'partnership of awareness'

Some industrial designers are now recognising that they operate in a gap between production and consumption, as the link between 'products and people' and that they can have influence over how people treat objects and artefacts, and promote less materialistic lifestyles (Dewberry and Goggin, 1996). In view of this potential, the design project had both a supply and demand side orientation with the design team stating that the aim should be to design products for responsible

The 'eco-kitchen' project is a collaboration… with the intention of developing innovative new products and solutions that acknowledge the need to move from 'refine and repair', towards 'redesign and rethink'.

Figure 2: 'Chest freezer' – an efficient cold storage unit with an integrated household recycling facility

…industrial designers are recognising that they operate in this gap between production and consumption, as the link between 'products and people'.

manufacturers to produce, that encourage and enhance behavioural change by ethical and aware consumers. This was defined as a 'partnership of awareness.'

Project brief and design criteria

Although this was viewed as a concept and visionary project, the designers were keen to use real constraints and approach the task as a 'live' project. Electrolux chose to follow their usual design process, by defining market constraints and user group profile. The two key groups being:

- innovative – value quality, novelty and speed and convenience;
- responsible – a strong sense of ethics, family-orientated, buy quality and durability.

The brief also defined five key criteria for consideration in their design developments, which were:

- balance desire and environment
- work with current consumer clusters and market segments
- use real (rather than ideal) behaviour
- support and encourage (not force) consumers
- near future support systems – such as internet shopping, household waste collection, etc.

Results

Seven new product concepts were the outcomes. Some of the proposals were outside of traditional product categories or were a new generation of kitchen products. In short, they moved beyond eco-design. Some of these are illustrated below:

- The 'Smart Sink' is the centre of household water management. A membrane sink expands to minimise water use and a smart tap switches from jet to spray to mist to suit customer needs. A consumption meter and a water-level indicator in the main basin gives feedback on rates and level of water usage. Household grey water is

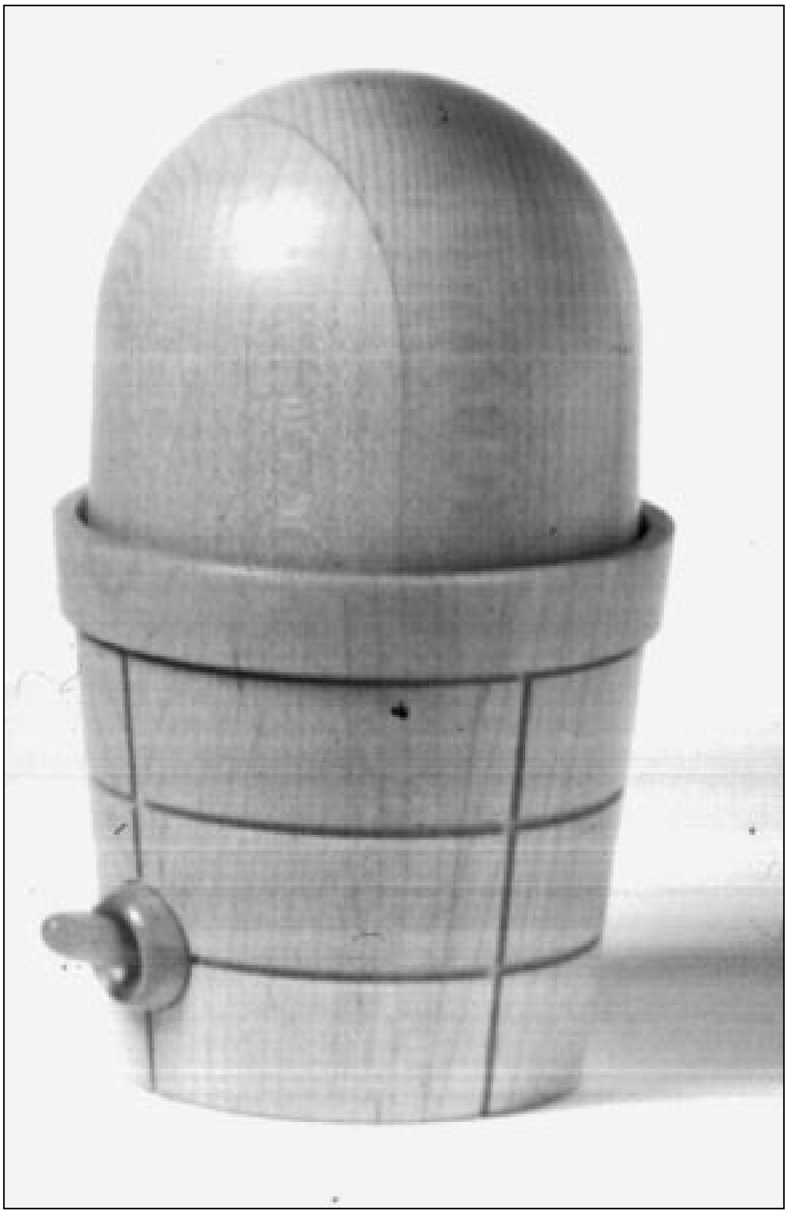


Figure 3: 'Light-plant' – a functional reminder of resource use

managed visibly by an osmosis purifier and a cyclone filter located in the pedestal, and linked to the household grey-water storage.

- The 'Data-wall' is the brain of the kitchen. It is an 'information product' that helps manage and communicate domestic resource use. It is connected to most kitchen products for feedback on levels of *use*. Along with this it also holds an inventory of food stock, communicating quantities, freshness and use-by dates. It is a link to the supermarket for home-shopping and delivery service and contains the 'menu-master' – advice on recipes, cooking techniques and health and dietary issues. Behind this information interface is the kitchen storage – refillable and reusable containers that have a jewellery like, cherishable quality.
- The 'Light-plants' are communicator's of environmental principles, a functional reminder of resource use. Left on a windowsill they collect and store solar energy, and when placed on the table they emit stored energy as light. This approach – defined as

Figure 4: 'Data Wall' – an information product that acts as the kitchen 'brain'

eco-erotica – represents the 'greening of desire' in which designers can surely have a central role.

- The strength of some products is their simplicity and elegance. As cold air falls, it is not efficient to have a front door access on freezers because cold air 'falls out'. The 'chest freezer' works on the principle that it is more efficient to have access to cold storage from above. The body is ceramic to increase thermal mass and has been raised so the top is a work-surface. In doing this, the space underneath is utilised as a domestic recycling centre.

Conclusions

A key strength of the project is that it has tangible and visible products as outcomes, which helps make sustainability more understandable. But the process itself is illustrative of the issues in implementing sustainable product design, for a number of reasons:

- The project represents an attempt at not just designing new business opportunities but in 'accessing the societal brief'. It looks at sustainability in terms of the domestic situation, shifting the focus from strictly supply-side towards demand-side, therefore offering visions of a more sustainable lifestyle.
- The approach was holistic, in that it looked at a domestic scenario or need – the kitchen – rather than using existing products as starting points. Some of the products also look beyond the boundaries of the

kitchen, ie. to provide resource management for the whole domestic setting. For instance the 'Smart Sink' illustrated how all household water could be purified including grey water storage that also collects rain-water. Information also flows through the kitchen, from product to product and is managed and communicated by a central kitchen 'brain' – the 'Data-wall.'

· Because the key impacts of the kitchen are in the *use* phase of consumer behaviour the project included a series of cultural and lifestyle considerations. This illustrates the type of issues eco-desgn must tackle if it is to grow and mature as a working concept. •

References

Beard, C. and Hartmann, R. (1997). 'Sustainable Design: rethinking future business products'. The Journal of Sustainable Product Design 1(3): 18-27.

Charter, M. and Chick, A. (1997). 'Editorial Notes'. Journal of Sustainable Product Design 1(3): 5-6.

Dewberry, E. and Goggin, P. (1996). 'Spaceship Ecodesign'. Co-design 05 06 (01 02 03): 12-17.

Fussler, C. and James, P. (1996). Driving Eco Innovations: A break-through discipline for Innovation and Sustainability. London, Pitman Publishing.

Pearson, D. (1989). The Natural House Book: Creating a healthy, harmonious and ecologically sound home. London, Gaia Books Ltd.

RSA (1997). Design for Environmental Sustainability: The Research Agenda for Sustainable Product Design. T. F. Committee. RSA.

Tansey, G. (1995). Food, Culture and Human Needs: Part 1; Chapter 4. The Food System: A Guide. London, Earthscan Publications Ltd.: 47 – 84.

UNEP (1992). Agenda 21. The Earth Summit. London, United Nations Environment Programme. Section 1: 57-61.

UNEP (1992). The Rio Declaration on Environment and Development. The Earth Summit. London, United Nations Environment Programme: 11-13.

World Resource Foundation (WRF) (1996). 'Environmental Impact in the Home'. Warmer Bulletin August (50): 22.

Sustainable design website: linking people, ideas and tools

Martin Charter

Joint Coordinator, The Centre for Sustainable Design, UK

The Journal of Sustainable Product Design has developed a partnership with the O2 Global Network to further disseminate information and ideas on eco-design and sustainable product design. O2 Global Network is an international network of ecological designers. The O2 Global Network is organised into national O2 groups which work together to provide various services such as: O2 Broadcasts, which report live from O2 events using email and the Worldwide Web (WWW); O2 Text meetings, a meeting place on the Web; the O2 WWW pages, which provides an overview of activities; O2 Gallery, an exhibition of eco-products on the Web; and, an O2 mailing list.

For further information on the above activities and the O2 Global Network contact: O2 Global Network
Tourslaan 39
5627 KW Eindhoven
The Netherlands
tel/fax: +31 40 2428 483

O2 Global Network new homepage: http://www.hrc.wmin.ac.uk/o2/
e-mail: o2global@knoware.nl
mailinglist: http://ma.hrc.wmin.ac.uk/lists.o2global.db

'O2 News' will update readers of the Journal on the latest eco-design issues from around the world and on O2's national activities.

O2 website

The O2 website for sustainable design supports information and knowledge exchange among designers and entrepreneurs engaged in the development of environmentally sustainable products and services. Its aim is to fill a gap in the information needs of designers and companies.

People

- Interesting 'green minds' worldwide
- The eco-design experts guide for the Netherlands.

Ideas

- Web report of the Factor 4 conference, February 1998, Amsterdam
- Columns by the Foundation for Smart Architecture
- The o2 Challenge, workshop on Sustainable Business Concepts, November 5, 6, 7 1998, Rotterdam, the Netherlands

Tools

- The latest and most interesting books, sites and reports on eco-design
- The calendar covers eco-design events, tradefairs and contests worldwide
- Case studies and updates on the latest eco-design materials.

The O2 website www.o2.org is a collaborative project between O2 Nederlands.

With questions and feedback about this site: Go to an index page and click on the FEEDBACK button. Or contact the webmasters at the Netherlands Design Institute: Conny Bakker (conny@design-inst.nl) or Mariette Overschie (mariette@design-inst.nl).

O2 France: new developments

- Launch of new library services covering eco-design issues:
  - durability
  - lightweighting
  - renewability
  - recyclability
  - energy efficiency
- Recently designed a lamp for Habitat using eco-design principles
- Organising recycling exhibition for the city of Cliche – a suburb of Paris
- Completed a study on greenhouse gas emissions covering thirty multinationals for 'Found for Nature and the Environment' (France).

Sustainable Business Concepts (SBC)

Definition

SBC are product-related business solutions integrating ecological, economic and social goals. 'Sustainable', because SBC strive for higher ambition levels than current practice, increasing eco-efficiency with a 'factor 4' or more. 'Business', as SBC comprise economically realistic innovations of both product-, service- and technology-combinations, as well as organisational change. 'Concepts' as SBC will form conceptualisations of ideas and visions rather than detailed blue-prints of sustainable business solutions. SBC will arise from changing contexts in the business environment. The identification and design of SBC is envisioned to inspire, cathalyse and mobilise businesses, government and entrepreneurs to take up the sustainability challenge.

Source: O2 Magazine year 6 issue 2 (August 1998)

Sustainable Business Concepts (SBC)

Statements

- SBC is about combining economy with ecology
- SBC is about major innovations of new activities, instead of minor improvements of existing activities
- SBC require strategic decisions within companies
- SBC is about fulfilling the essential needs of consumers and knowing future markets
- SBC focuses on the total range of innovation/organisation of products, services, technologies and systems
- SBC will not only be developed by bigger companies: smaller companies with their innovative and dynamic character will be a major source of new SBC as well
- Designers can play a crucial role creating new solutions which integrate consumer needs with business capabilities.

Source: O2 Magazine year 6 issue 2 (August 1998)

Kathalys open

Minister Wijers of the Netherlands Ministry of Economic Affairs opened the Center for Sustainable Product Innovation, Kathalys, on 15 June 1998. Kathalys is a partnership between TNO Institute of Industrial Technology and the Faculty of Industrial Design of Delft University of Technology. Its mission is to initiate and introduce R&D projects which could lead to innovations amongst manufacturers of industrial products. To this end two services are offered: concept and project development and eco-design implementation. The first relates to the accomplishment of sustainable product innovation projects; the second relates to the integration of environmental aspects in industrial product innovation processes. Kathalys has in-house expertise in Life Cycle Analysis (LCA) and Life Cycle Costing (LCC) methods, energy efficiency of products and product systems, optimisation of the eco-efficiency of products and product systems, and new product service combinations, eco-design implementation methods and future-oriented environmental, technological and social foresight activities.

For more information: Kathalys, PO Box 5073, 2600 GB Delft, telephone +31 (0)15 260 87 45.

(im)Material: explorations toward sustainability, 2–3 October 1998

The Design Academy, in collaboration with O2 Netherlands and the Eindhoven Technical University's Centre for Sustainable Technology Development, offers designers an opportunity to add their voices to the sustainability agenda, through the '(im)Material' symposium in De Witte Dame, Eindhoven's new centre for art, design and information technology.

Presentations are clustered around four seminars dealing with Life Cycle Assessment ('Assessing Life Cycles'), the design of systems ('The Dividing Line'), trend manipulation ('Trend-benders') and the roles of information and education ('Only Human'). The '(im)Material' symposium is configured as a preliminary event for O2's 'Sustainable Business Concepts' workshop in November. •

For more information: '(im)Material' Symposium, The DEsign Academy, Emmasingel 14, PO Box 2125, 5600 CC Eindhoven. Telephone +31 40 239 39 39. Fax +31 40 239 39 40.

Books

Green marketing: opportunity for innovation
Jacquelyn A. Ottman
Lincolnwood (Chicago), USA, NTC Business Books
ISBN 0-8442-3239-4
270 pages
Price: US $ 24.95

When I reviewed the first edition of this book in 1994 I compared it to one of the self-help books that are so popular in America. It was snappy, informative, clearly focused and tends to make you enthusiastic about wanting to get out there and do things differently and better. However, it also shared the typical weaknesses of such books of tending to reduce the greening challenge into relatively simple checklists of things you can do to create a greener company around yourself.

The second edition is a larger, glossier and more substantial affair, and it has begun to get to grips with some of the difficulties involved in the greening of companies rather than just focusing on the necessities and the opportunities. So new chapters covering 'The Secret to Avoiding Backlash' and how to 'Work from the Inside Out' deal with some of the implementational issues that those who rushed off enthusiastically clutching the first edition may have encountered. There are other changes too. The book's emphasis has changed to reflect the evolution of the green agenda. It deals with the change in environmental concern to become less explicitly 'top of mind' among many consumers and managers, instead becoming more of a central core value influencing consumption and marketing decisions. The chapter on dealing with different stakeholders is now entitled 'Teaming Up for Success' reflecting the trend towards collaborative solutions for environmental problems. It is a pity that these developments in the book have not really been matched by a more sophisticated approach to the characterisation of green consumers. The book has a very useful discussion of green consumer psychology, but it still classifies consumers according to the Roper Organisation's 'True Blues' to 'Basic Browns' framework which is very simplistic and perhaps too American to be very useful elsewhere.

The very American focus of this book, and the way that this limits its usefulness outside of America, is the major weakness in an otherwise very valuable contribution. This is reflected in the case study choice and the handling of many specific issues. The vignette case studies are interesting and are helpful in keeping the discussion lively and closely tied to the realities of business. The companies used however are all American (or in a couple of cases represent European companies' experience in America) and are often relatively obscure, which will limit the book's appeal outside of the US. The issue of accuracy and honesty in environmental marketing claims is a very important issue, but the book deals with it almost entirely within the framework of adhering to Federal Trade Commission Guidelines. At a more fundamental level, America, as the most extreme example of a consumer-orientated society, is the place in which the difficulties of dealing with the environment within the existing marketing paradigm become most apparent. Although the book calls for a new marketing paradigm, most of what it proposes looks very like the old one, in which it is assumed that consumer sovereignty operating within free markets will drive companies to improve their products in search of opportunity and profit. The marketing focus of the book is also a very narrow one, dominated by issues relating to end consumers, product development and product-based communication. To make a profound difference to the greening of industry, a broader focus and a more radical approach to the greening of marketing will be needed.

This book is very useful in providing a 'pep talk' for managers who may need to be convinced about the need to make their company and their marketing more environmentally orientated. It is lively, interesting, full of relevant practical examples, and very non-threatening. In the wake of the recent experience of many companies of hitting 'The Green Wall' (to use Arthur D. Little's terminology) in trying to implement corporate environmental programmes, its reassuring tone perhaps makes it a very timely contribution. Since the UK tends to often follow US management trends, the very American focus of the book will hopefully not grate too much on British readers.

Ken Peattie, Senior Lecturer in Strategic Management, Cardiff Business School UK

Cannibals with forks
the triple bottom line of 21st century business
John Elkington
Capstone Publ.
UK, 1997
ISBN 1-900961-27-X
403 pp; £18.99

Despite the consistent rumblings inside firms that environmental management is not being implemented fast enough, one should remember the spectacular speed with which environmental issues have been taken up by industry in virtually all of the developed world. Within only five years, virtually all firms that claim to be amongst the 'great and the good', have begun to publish an account of their environmental effects – although environmental accounting is (still) in its infancy. A new challenge for firms is that they are now increasingly being asked about their sustainability impacts as well.

But against all this flurry of activity, the question remains, is it enough? Enough in terms of the firms' ability to maintain (or gain) competitiveness, enough to satisfy public concern about the organisation's impact on ecology and society, enough to reduce the environmental impacts to be within acceptable levels. Elkington argues probably not, but that businesses are to be judged against each of these three criteria – his 'Triple Bottom Line'.

In fact, Elkington argues, in a book that remains on the passionate side of a very cogently argued line, that firms will have little choice but to revolutionise traditional business practice, and that the smart firms have begun to do so already. In this, the book's tenor is not new. For many years, authors have, with varying degrees of conviction and success, argued that firms all over the world are taking up environmental issues, and that those who don't soon will fall behind. The hard evidence for this is still not as forthcoming as proponents of this view (the reviewer included) would like to have it.

However, what is remarkable about this book is its unashamedly environmental stance, arguing that, environmentally and socially, we have little choice but to see firms adopting a much more radical perspective than environmental management has so far proposed. The book cogently argues that the core of this revolution is nothing less than a redirection of fundamental business philosophy: a departure from the monotheistic profit-motive as the one and only goal for firms and to move towards the inclusion of social, ethical, environmental and economic rationale as the key determinant of business success.

What will ease this necessary transition are what Elkington calls seven Revolutions. Using his highly visual, imaginative and visionary language with lateral illustrations and a wealth of business experience, he argues that seven long-term trends will start to affect firms. They are:

- Markets: the increasing number and immediacy of customers has reduced the viability of compliance to external or market standards as success determinants. Instead, competitors and market drivers determine product design and quality. It remains to be seen how this trend is to affect basic research or fundamental product design as more and more market strategies are aimed at outmanoeuvring competitors. A glimpse of this future may be seen in the creativity (or lack thereof) of recent car design.
- Values: Elkington predicts a continued rise of ethical values as factors in corporate strategy, covering recruitment, consumer choice, geographical dispersal of production and ethical staff policies. This adds a social dimension into corporate policy and strategy that will make many managers uncomfortable as it means the very inclusion of many factors that so far were seen as being 'not the business of business'. Nike and child labour or Shell's Nigeria come to mind.
- Transparency: firms have become much more transparent over recent years. Revolutions in IT and globalisation of communications mean that geographically dispersed 'skeletons in the cupboard' can now be disclosed and transmitted globally without firms having a realistic chance to prevent it effectively. In fact, the amount and the level of detail of disclosed information – voluntary or not – has dramatically increased. This calls for far more consistency and far fewer skeletons. In fact, as Elkington argues, environmental

management systems have not been able to keep up with the increased demand for environmental reporting. However, it should also be noted that these environmental reports are poor tools for dialogue and are read by very few (so far).

- Life-Cycle Technology: rightly or wrongly, firms are increasingly held accountable for the environmental impact of their products and its ingredients across the whole life-cycle. For highly vertically integrated firms, this makes sense as they control much of the value chain. For others, this means more effective management of the life-cycle up- as well as downstream. Witness the growing use of supplier surveys and the complex debate on Extended Producer Responsibility and Product Stewardship.
- Partnerships: the development of collaborative and dialogue-inducing relationships between pressure groups and producers, or between governmental agencies and corporations, means, again, an opening of the firm towards outside groups as well as a re-definition of firms' perceptions of these groups. This 'dabbling with the enemy' means also that pressure groups can behave schizophrenically or at least inconsistently.
- Time: Elkington outlines the contemporary dichotomy between faster and faster response times required and the requirements on firms to develop the very long-term perspectives that sustainable development demands which is precluded by short-termism.
- Corporate Governance: Elkington argues that, far from being outdated, the debate about the role of corporations in (post-) modern societies is alive and demanding. The Corporate Social Responsibility debate has resurfaced and questions the purpose, meaning and contribution of organisations. If organisations are assumed to have a purpose beyond making money through material transformations, using part of this to pay taxes and to recompense a shrinking workforce, then firms have, at least to some extent, justify their existence and their role in the societies they operate in. This may turn out to become the most basic and most fundamental revolution.

In laying out this premise for change, Elkington argues for radical alterations not only in the way business goes along its unsteady and complex path, but in our perceptions of what firms are there for. By expressly addressing the capitalist modes of production and its unacceptable environmental impacts, Elkington, laudably, evaluates the very system of production that – since the spectacular demise of the former Soviet – is seen as 'the best possible', rather than as 'the one that has survived but which is in dire need of radical change'. It is his background as a Consultant that makes the power of his argument and the radical approach taken so refreshingly positive, optimistic and, yes, readable and applicable.

Dr. Walter Wehrmeyer is the BG Surrey Scholar on Contaminated Land at the Centre for Environmental Strategy of the University of Surrey, UK

26–27 October 1998

Towards Sustainable Product Design 3 conference incorporating Managing eco-design 3 conference
London, UK

✉ Martin Charter
The Centre for Sustainable Design
The Surrey Institute of Art & Design
Falkner Road
Farnham
Surrey GU9 7DS
UK
+ 44 1252 892772
+ 44 1252 892747
cfsd@surrat.ac.uk

28-30 October 1998

The Demanufacturing of Electronic Equipment: Second Annual Seminar and Exhibit
Florida, USA

✉ Florida Educational Seminars, Inc
2300 Glades Road, Suite 307E
Boca Raton
FL 33431 Florida
USA
+ 1 561 367 0193
+ 1 561 367 8429

29 October 1998

Electronics R&D needs in the UK electronics sector: driving eco-design
London, UK

✉ Martin Charter
The Centre for Sustainable Design
The Surrey Institute of Art & Design
Falkner Road
Farnham
Surrey GU9 7DS
UK
+ 44 1252 892772
+ 44 1252 892747
cfsd@surrat.ac.uk

4–6 November 1998

ENTREE '98 Innovation Strategies for Economy and Environment
Deventer, The Netherlands
Sirkka Poyry

✉ UETP-EEE
Av. de L'Oree 19
1050 Bruxelles
Belgium
+ 32 2 6390 391
+ 32 2 6390 399
sirkka.poyry@feani.com

✉ Kjell Erik Bugge
Hogeschool Ijselland
Faculty of Chemistry, Environment & Technology
PO Box 657
7400 AJ Deventer
The Netherlands
+ 31 570 663 106
+ 31 570 663 667
kjellerik.bugge@hsij.nl

5–7 November 1998

O2 Sustainable Business Concepts challenge international design workshop
Rotterdam, The Netherlands

✉ The Conference Manager
O2 Netherlands
P.P. Box 519
3000 AM Rotterdam
The Netherlands
+ 31 10 411 8102
+ 31 10 404 9395

15–18 November 1998

Partnership & leadership: 7th international conference
'Building Alliances for a Sustainable Future'
Rome, Italy

✉ Kurt Fischer
USA Co-ordinator
Greening of Industry Network
The George Perkins Marsh Institute
Clark University
950 Mani Street
Worcester
Massachusetts
+ 1 508 751 4607
+ 1 508 751 4600
kfischer@clarku.edu

16–18 November 1998

Care Innovation '98 eco-efficient concepts for the electronics industry towards sustainability
Vienna, Austria

✉ Mr Bernd Kopacek
International CARE 'Vision 2000' Office
c/o SAT, Aldergasse 3/1
A-2700 Wiener Neustadt
Austria
+ 43 2622 27367
+ 43 2622 2736722
care_vision_2000@magnet.at

19–20 November 1998

International NWO Conference 'Beyond Sustainability'
Amsterdam, The Netherlands

✉ Gerard Barendse/
Helais Udo de Haes
CML
Leiden University
P.O. Box 9518
NL 2300 RA Leiden
The Netherlands
+ 31 71 5277 489/461
+ 31 71 5275 587
barendse@rulcml.leidenuniv.nl

20-21 November 1998

Ecologizing societal metabolism: designing scenarios for sustainable materials management
Amsterdam, The Netherlands

✉ Rene Kleijn/Ester van der Vet
CML
Leiden University
PO Box 9518
2300 R A Leiden
The Netherlands
+ 31 71 5277 480
+ 31 71 5277 434
kleijn@rulcml.leidenuniv.nl

25–26 November 1998

Values, ethics and sustainability
Guildford, Surrey

✉ Penny Savill
Course Secretary
Centre for Environmental Strategy
University of Surrey
Guildford GU2 5XH
UK
+44 1483 259047
+44 1483 259521 / 259394
p.savill@surrey.ac.uk.

25–27 November 1998

Third international conference on ecobalance
Tsukuba, Japan

✉ Ms Shoko Tsuda
Ecomaterials Forum
The Society of Non-Traditional Technology
Kotoharia Kalkan Building 3F
1-2-8 Toranomon
Minato-ku
Tokyo 105
Japan
+81 3 3503 4681
+81 3 3597 0535
mitoh@snet.sntt.or.jp

26–28 November 1998

Doors of Perception 5 - PLAY
Amsterdam, The Netherlands

✉ Ideel Organiseren
Weteringschans 269
NL 1017 XJ
Amsterdam
The Netherlands
+ 31 20 420 1711
+ 31 20 626 5845
registration@doorsofperception.com

2–5 February 1999

'R'99 – recovery, recycling, re-integration' – 4th world congress with company displays
Geneva, Switzerland

✉ Ms Maria Buhler
PEAK Ltd
R'99 Project Manager
Seefeldstrasse 224
CH-8008 Zurich
Switzerland
+ 41 1 386 44 44
+ 41 1 385 44 45
buehler@peak.ch

1–3 March 1999

Second international working seminar on re-use
Eindhoven, The Netherlands

✉ Simme Douwe P Flapper
Eindhoven University of Technology
Faculty of Technology Management
Pav.C01, PO Box 513
NL-5600 MB Eindhoven
The Nethrelands
+ 31 40 247 2322
+ 31 40 243 6492
l.j.a.hendriks@tm.tue.nl

25–26 March 1999

Fifth annual international sustainable development research conference
Leeds, UK

✉ ERP Environment
PO Box 75
Shipley
West Yorkshire BD17 6EZ
UK
+44 1274 530408
+44 1274 530409
elaine@erpenv.demon.co.uk

15–17 April 1999

Case studies in environmental education and research
Zurich, Switzerland

✉ Umweltnatur- und Umweltsozialwissenschaften ETH Zentrum
HAD CH – 8092
Zurich
Switzerland
+41 1 6325892
+41 1 6321285
auDes.conference@uns.umnw.ethz.ch

7–9 June 1999

Eco 1999

✉ ACE
2, Avenue de la Republique
92340 Bourg-la-Reine
France
Penny Allen
+33 145 42 89 64
+33 145 43 11 87
Christophe Bonazzi
+33 146 65 91 10
+33 146 65 91 10
Convergences Eco 1999
120 Avenue Gambetta 75020
Paris
France
+33 143 64 77 77
+33 140 31 01 65

22–24 September 1999

Sustainable consumption in the 21st century
Southampton, UK

✉ Conference Administrator
Index Communications Meeting Services
Crown House
28 Winchester Road
Romsey
Hampshire SO51 8AA
UK
+44 01794 511331/2
+4401794 511455
icms@dial.pipex.com

Contributor guidelines

The Journal of Sustainable Product Design is targeted at Environmental directors, managers, Design managers, Product designers, Academics and Environmental coordinators in local and central government worldwide.

Submissions

Three copies and a $3^1/_2$" Macintosh – or IBM compatible disk should be sent to:
Martin Charter
The Journal of Sustainable Product Design
The Centre for Sustainable Design
Faculty of Design
The Surrey Institute of Art & Design
Falkner Road
Farnham
Surrey GU9 7DS
UK.
Email submissions should be sent to: mcharter@surrart.ac.uk.

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

Presentation

Articles submitted to the Analysis section (peer reviewed) should be between 2,500–5,000 words. Shorter articles of 1,000–1,500 words are also requested for the Case Study and Innovation sections. 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.

First sheet: Title, subtitle (if any), author's name, affiliation, full postal address and telephone, fax number and email. Respective affiliations and addresses of co-authors should be clearly indicated. Please also include approximately 100 words of biographical information on all authors.

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.

Copyright

Before publication, authors are requested to assign copyright to The Centre for Sustainable Design. This allows The Centre for Sustainable Design to sanction reprints and photocopies and to authorise the reprint of complete issues or volumes according to demand. Authors traditional rights will not be jeopardised by assigning copyright in the manner, as they will retain the right to re-use.

Proofs

Authors are responsible for ensuring that all manuscripts (whether original or revised) are accurately typed before final submission. One set of proofs will be sent to authors before publication, which should be returned promptly (by Express Air Mail if outside UK).

Copy deadlines

Issue 8: 11 December 1998
Issue 9: 19 March 1999
Issue 10: 18 June 1999

Typography: design@emspace.co.uk

Environmentally printed by The Beacon Press
(BS7750, ISO 9002 and EMAS accredited).

Text pages printed on Sherwood Offset, a paper made from
100% genuine waste with no chlorine bleaching, carrying
both the NAPM and Blue Angel environmental awards.

Covers printed on Conservation Bright White, a NAPM
and EUGROPA approved board which is 100% recycled.

Printed with vegetable based inks.

ISSUE 7 : OCTOBER 1998

The Journal of Sustainable Product Design

The Centre for Sustainable Design

an initiative of

The Surrey Institute of Art & Design