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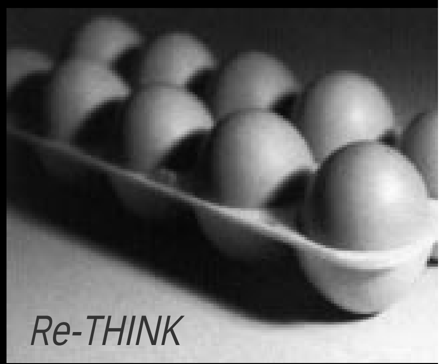
The Journal of Sustainable Product Design



ISSN 1367–6679

Re-THINK

Battery-powered lawn mower by Husqvarna

Analysis, page 7

Increased creativity and innovation are critical to sustainable solutions

Analysis, page 18 and Interview, page 38

Re-FINE

Sketch for a table with a glass top using Metzzo legs

Gallery, page 41

Detail of carpet sweeper, designed by Agim Meta

Analysis, page 28

Re-DESIGN

Table made from Metzzo

Gallery, page 40

Re-PAIR

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Editors

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Editorial Board

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

Martin Charter

Joint Editor, The Journal of Sustainable Product Design

It is essential that business starts to incorporate environmental and broader sustainability thinking at the start of the product development process, if we are to move towards increased 'quality of life' worldwide. If this does not happen opportunities will be missed. To enable this will mean developing mechanisms to raise awareness and understanding of issues amongst all internal and external stakeholders involved in the process. Part of this will mean increasing education and training, but may also mean re-education, dispelling popular misconceptions. In addition, thinking broader than environmental sustainability will mean considering social and ethical impacts of the product development process. The Brent Spar issue clearly illustrated that society does not necessarily belief the 'hard' science. Therefore, ignoring the 'softer' issues maybe costly from a stakeholder acceptance viewpoint.

Many of these issues are being highlighted in the electronics sector, which faces increasing pressures under producer responsibility, with most activity focusing on 'end of life' management (EOLM) rather than eco-design. In October 1997 a draft discussion document on the management of 'end of life' electrical and electronic waste was circulated by the European Commission for comment amongst the European electronics industry. The paper has considerable implications for the development and design of products, particularly the need to:

- eliminate toxic materials
- increase recyclability
- increase dismantlability
- improve reverse logistics.

Companies in the electronics sector have highly complex supply and 'value chains'. Implementing eco-design will mean increasing information requirements from raw material, component and sub-assembly suppliers, many of whom are likely to be poorly prepared for the situation. In addition, the electronics sector is leading the way in the implementation of the international environmental management standard ISO14001, which will also push companies to greater understanding of the direct and indirect environmental effects of products throughout the life cycle.

For eco-design to progress in the electronics sector it must be integrated into existing businesses through re-engineering existing business processes. There will need to be a 'learning company' approach. Companies are likely to make mistakes and will need to avoid falling into the pitfall of the 'not invented here' syndrome, where new ideas from outside the company are not recognised or nor absorbed as quickly as they should be. Another key lesson will be a need to adapt the eco-design process to company culture taking account business function 'power' structures eg. is the firm financially or marketing-driven?

It is essential to try and involve other business functions in the eco-design process. For example marketing and sales should participate to ensure that there is dialogue and sensitivity to customers needs, so opportunities are not missed. As previously mentioned suppliers are a key stakeholder in the success of any eco-design initiative. Each element of the 'value chain' will need to understand eco-goals for the end product to enable them to take action. Education and re-education, training and re-training and clear communications will be essential elements to increasing stakeholders environmental awareness eg. Electrolux have launched an eco-literacy programme through its Intranet aimed initially at employees.

There is a need for a overall target for the eco-design programme and eco-performance objectives and metrics for specific products or services. A key need is to broaden the discussion into eco-product development and design, getting eco-stimulus and creativity into the idea generation phase. This can produce breakthroughs eg. the solar powered lawnmower and on-going innovation eg. dematerialisation (less energy, less resources, more functionality) – moving from books on paper, to downloadable information from Internet.

There is also a need for new tools in the eco-product development and design process. For example, Nortel recently organised customer eco-focus sessions and Trucost in New Zealand have launched software that examines ecological costs of products. In addition, to enable improved and more time-efficient decision-making companies such as BT, SC Johnson Wax and Philips are exploring 'cut-down' life cycle assessment (LCAs) tools.

The fourth issue of the Journal of Sustainable Design focuses on papers related to electronic products. Dr Stuart Walker, Associate Professor at the University of Calgary and Ralf Nielsen, Assistant Professor at the University of Louisiana explore the need for a systemic shift to move towards sustainability, with an emphasis on a movement towards local scale production and consumption. The article illustrates the product design implications of 'product sharing' ie. viewing the portable personal computer as part of a community-based service rather than a series of single products. H. Scott Matthews, a doctoral student at Carnegie Mellon and Gregory Chambers, Corporate Manager of Worldwide Environmental, Health and Safety for Quantum Corporation, explore the eco-design implications of various 'end of life' management (EOLM) options, using the example of disc drives. The paper suggests that companies are not fully realising the cost:benefits of designing for improved EOLM. Anna Kärnä, a doctoral student at the Helsinki School of Economics and Eva Heiskanen, a Researcher at the University of Tampere explore different stakeholders attitudes to the greening of 'product chain' management, particularly illustrating the importance of the retailers and the need for reliable information. Niall Murtagh, Senior Research Scientist at Mitsubishi Electric Corporation examines the technical issues surrounding the dismantling of televisions, providing implications for product development and design. An interview with Ralph Earle III, Director of the Alliance for Environmental Innovation focuses on the need to consider the 'decision-making fabric' of the company when launching eco-design, with examples of projects being undertaken with Johnson Wax and Starbucks, a coffee retailer. The Innovation section provides a comparison of the environmental impacts of four radios, with the conclusion that 'human powered' products are not necessarily greener than 'battery powered' products, with much depending on the EOLM disposal option chosen. The O2 pages focus on the activities of the New York City chapter, and highlight an interesting process that has been developed to educate designers about sustainable product design.

The Journal looks forward to comments and responses to articles, and encourages the submission of papers particularly on eco-innovation and broader perspectives of sustainable product development and design (SPDD). •

Systemic shift: sustainable development and industrial design pedagogy

Stuart Walker & Ralf Nielsen

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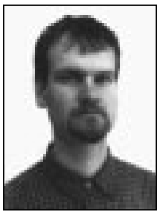

Dr Stuart Walker is an associate professor and former director of the Industrial Design Programme, in the Faculty of Environmental Design at The University of Calgary. In his research and design activities he is examining the issues surrounding sustainable product design, with particular emphasis on product aesthetics.

Ralf Nielsen is an assistant professor at The University of Southern Louisiana where he teaches sustainable product design as part of the Industrial Design Programme.

The precepts of sustainability have significant implications for the future of product design and production, and the meanings of material culture. Considerable work is currently being done in the development of methodologies, such as life cycle assessment (LCA), in order to evolve conserving and regenerative systems of production and consumption. However, it is also being widely recognised that a more fundamental, systemic shift in our approaches to product design, manufacturing and our material expectations will be required if sustainability is to be fully embraced.

In this discussion, the nature of this systemic shift, and its meaning in terms of product design, are considered with particular reference to a Master's degree project which addresses product design within the context of a 'sustainable community'. This project not only illustrates an approach to sustainable product design, and the range of factors which have to be considered, it also suggests an innovative pedagogical model for learning.

The project was placed within a sustainable community scenario, developed by urban planners. An outline of this contextual setting is included in order to demonstrate how a 'product' – in terms of its design, its use and its overall impacts, has to be considered within a broader system which includes ways of living and working, and notions of independence and inter-dependence. An account of the approach adopted during the product design phase is given together with an analysis of the project, and the questions it raises. This is followed by a discussion of the potential of this example as a pedagogical model which synthesises 'sustainable development' with industrial design. Finally, the implications of such an approach to product design are discussed with reference to the broader proposition of a systemic change to production and consumption, a proposition which, increasingly, is being acknowledged as a contingent factor for achieving sustainability.

Introduction

This paper describes an approach to sustainable product design developed to address the negative environmental and social effects associated with products which are in a rapid state of technological advancement. The personal computer (PC) was chosen as the vehicle for this conceptual exploration because it represents a particularly problematic area for the application of sustainable principles.

An introduction to sustainable development, and the shift needed to align our ways of designing, producing, using and disposing of products with sustainable principles, is followed by an overview of the project and a discussion of the main findings. The approach adopted during this Master's Degree project suggests an innovative pedagogical model for addressing sustainable product design. Suggestions for developing this model to address other, related areas of design are included.

Sustainable development

Over the last ten years, since the 1987 report 'Our Common Future' (Brundtland et al, 1987), the terms 'sustainability' and 'sustainable development' have been used extensively to describe many different, and often contradictory, approaches to environmental and economic issues, and business planning. Despite their common usage, often the core meaning of these terms, and the magnitude of the changes they imply, are not well understood. These terms encompass such considerations as environmental stewardship, reductions in the use of natural resources, and conservation of habitats. In addition to these terms, 'sustainability' and 'sustainable development' require a commitment to social issues – to social equity within and between countries. Furthermore, the terms challenge our ideas of 'growth'; 'development' and 'growth' are frequently seen as synonymous – but development does not equate with growth (Hawken, 1993). 'Growth', a word frequently used in today's business environment, is a *quantitative* term, it means increasing in size; it seems that whatever the current size of a business, there is always a perceived need to become bigger; whatever the profits, there is always a perceived need to have more. Obviously, 'growth' cannot be sustained. On the other hand, 'development' is a *qualitative* term, it suggests improvement in social, environmental and economic conditions. When linked to 'sustainable' it suggests that such advancements be achieved in ways which are consistent with continuous improvement.

The systemic shift

In order to align our ways of living and our current working practices with the principles of sustainability many authors (eg. Fioruzzi, 1995 and Manzini, 1996) are suggesting that a fundamental, systemic shift is needed. The magnitude of change implied by 'sustainability' is so significant that it cannot be achieved by small, incremental improvements to our current approaches. It is the 'current approaches' themselves which, in many respects, are the primary obstacle, therefore small improvements to those approaches are unlikely to achieve the changes necessary for sustainability.

A number of writers in the field (such as Van der Ryn and Cowan, 1996, and Orr, 1992) have suggested that one of the key ways to move in a sustainable direction is to shift our activities towards human scale and local scale endeavours. Such a shift could have major environmental and social benefits and advantages but it would also mean significant changes in the ways we live and work, the nature of our material culture and the ways we manufacture and use products.

In the field of urban planning designs have been developed for 'sustainable urban communities' (Perks, Kirby and Wilton-Clark, 1996). These community designs incorporate residences, businesses, and retail and recreational facilities within a compact community form. They are designed to be sensitive to environmental and ecological issues and to provide employment opportunities and facilities for other human activities – all within easy reach of residences: by walking, cycling or by use of public transport. These community designs have higher population densities than those of conventional suburbs in North American cities, and provide a variety of housing types. Higher population densities not only require less land use, they also help to ensure that businesses, public transport and other facilities can be economically viable. These explorations, which attempt to align our forms of living with principles of sustainability, have considerable implications for the role of the industrial designer.

Implications of sustainable development for product design

Sustainable community design, and investigations into ways of living which could provide both environmental and social benefits, have a number of implications for the design, manufacture and use of products – implications which can contribute to our understanding of the term sustainable product design.

Local scale design and production

Product design and production within and for sustainable communities will require a reorientation and restructuring of our ways of manufacturing. Sustainable development points towards smaller scale, flexible manufacturing facilities which allow for a variety of products to be produced for local or regional markets. This, in turn, will require innovative design services which allow products, through their design specifications, to be manufactured, and re-manufactured economically in smaller quantities.

Local resources

Use of local energy and materials, and local knowledge and skills would enable products to be designed and produced in ways which are suited to the utilitarian and cultural needs of the area, and which are sensitive to local environmental conditions. Such production would also create local employment opportunities and permit product repair, maintenance, upgrading, re-production and recycling at the local level. It would also reduce packaging and the need for long distance shipping.

Dematerialisation, shared products and a service based economy

Another aspect of product design and sustainability is dematerialisation. The concept of dematerialisation relates to the replacement of products with services. Technological advances could, conceivably, allow a transformation to a more service-based economy, where many current products are no longer required. On-line services such as telephone directories, newspapers, videos and music, could, potentially, obviate the need for many individual, autonomous products – which all require materials, manufacturing, packaging and shipping. It is not yet clear if such services would indeed reduce material consumption. For example, at one time it was widely expected that office computers would reduce paper usage, whereas now it has become apparent that paper use has significantly increased with the introduction of computers. However, there are other potential advantages of dematerialisation within the sustainable community model. Services within such a community could allow the use of many shared products and facilities – such as laundry facilities, lawnmowers, public transport, etc. While such services still require products, their shared use means that the overall number of products is reduced.

Case study

Technology and sustainability – a conceptual exploration through design

This Master's degree project was conducted to explore the potential of designing products in ways which adhere to the principles of sustainable development. The focus of the project was the portable PC. This was chosen because it seemed to be a particularly problematic area for the adoption of sustainable principles.

The technology of PCs has been advancing at a rapid rate for a number of years. This has meant that PCs have been becoming 'technologically obsolete' within a short time of their purchase. The product might continue to fulfil its intended function, but advances have meant that new, more powerful machines offer a greater number of desired functions and faster operating speeds. As a result the machines are replaced within a relatively short period. The pace of development in PCs has been impressive – current models are able to operate in the order of three thousand times faster than the original IBM PC introduced in 1982 (Young 1993). However, this rate of advancement has also meant that PCs are being discarded at equally impressive rates – it was predicted that between 1992–96, 50–70 million computers would be disposed of (Aeppel, 1994).

The project set out to examine if and how the industrial designer could make a contribution to sustainability by addressing this problem of technological obsolescence through a re-design of the PC.

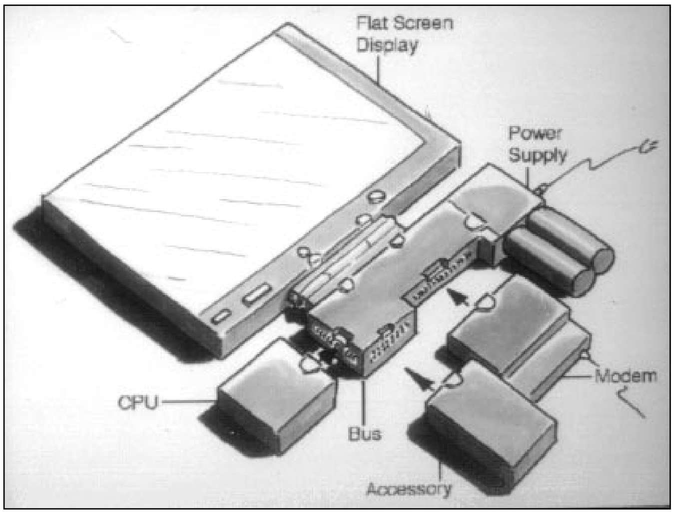

Figure 1: A 'snap-together' systems concept

The initial approach – modularity

The initial approach was to explore the potential of a modular computer which could be readily upgraded by the user. It was recognised that the rate of 'technological obsolescence' of the different components within a PC varies considerably, but the whole computer is replaced when the 'weakest link' needs to be upgraded. For example, a computer might be replaced in order to take advantage of the latest developments in Central Processing Unit (CPU) speed or memory capacity, but the screen, keyboard, disc drive and casing might still be functioning in a satisfactory and acceptable manner. A modular design would, potentially, allow only those components to be replaced which have become 'technologically obsolete'. This would reduce the number of components being discarded, and also allow the user to customise the product according to their particular needs and economic means.

As an analogy, the 35mm single lens reflex (SLR) camera is an example of a product family where different components can be purchased and assembled by the user. A basic camera body and standard lens can be supplemented with telephoto and wide-angle lenses, tripods, flash-units, motor-drives and so on. The backwards compatibility of this family of products allows the camera to be adapted and upgraded, and the life of the product is extended. Over time, all of the 'original' components may have been replaced and the product will have evolved into something new.

Using the SLR camera as a model, the PC was divided up into its various component parts – comprising display devices, input devices, CPUs, power supplies, data storage devices and buses. Conceptually, these various components might be separate items which could be easily assembled by the user and exchanged as required.

Incidentally, some computer manufacturers are now exploring this type of modular concept.

A series of design explorations were conducted using the modular concept:

A systems approach

Stacking and snap-together components with standard electro-mechanical connections were explored to develop a folding notebook type product (Figure 1). However, it was realised that the spatial and volumetric compatibility of components was a significant constraint in this concept. Future components would have to conform to the established geometry of the system, and as the spatial and volumetric requirements of new technologies was unpredictable, this concept did not provide the necessary flexibility for an adaptable, and durable system.

A non-systems approach

The constraints discovered in the systems approach led to the examination of ways which were conceptually more flexible and adaptable to new technologies. As an example of the potential flexibility required, the idea of upgrading display devices from a flat screen to a virtual reality headset was used. Similarly, a data-glove could, conceivably, replace a keyboard. Designing a product family which could adapt to such changes was not possible within the 'systems' approach discussed above. In the 'non-systems' approach, the various components were physically separated in order to facilitate spatial and volumetric flexibility (Figure 2). One concept utilised a folding folio, made from a fabric, used to house the components. Another idea was a belt or strap with pockets for the components. A further possibility used the metaphor of a student's book-strap to bundle components.

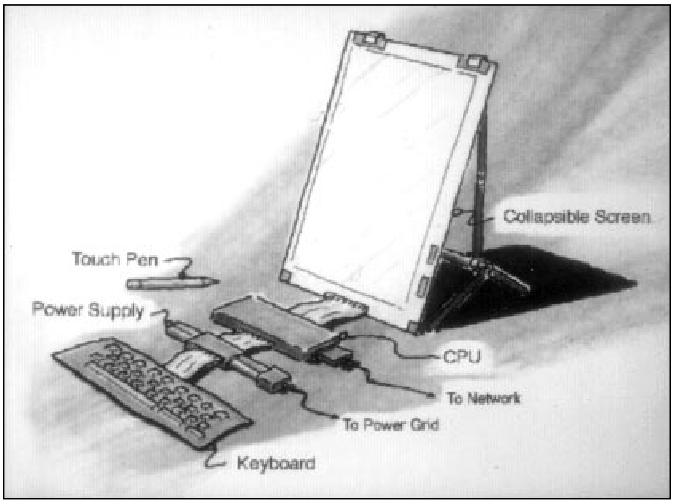

Figure 2: A non-systems approach offered greater spatial flexibility for upgrading

These ideas would allow for the necessary volumetric flexibility – for upgrading, adaption and customisation – and would contribute to environmental stewardship by reducing the amount of materials and products entering the waste stream. However, despite these potential advantages, these concepts also had a number of significant disadvantages. The relatively large number of separate components linked by electro-mechanical connectors, and bundled in a particular configuration, would mean that the computer would have to be unpacked and set-up for use – a potentially time consuming and awkward task, which could also create wear problems and damage. These factors seemed to outweigh the potential advantages of flexibility, upgradability, etc.

A change of approach – delivery of computer services in a sustainable community

Having explored the potential of modular concepts – both in a rigid 'systems' format and in a more flexible, 'non-systems' format, it became clear that the design of such a computer was problematic, for both technological and usability reasons. While the basic criteria of upgradability, flexibility and user customisation appeared to fulfil many of the environmental considerations by reducing materials throughput, the design of a modular concept seemed to create as many problems as it solved. Furthermore, familiarisation with the issues during these early stages of the project revealed that, although the modular system would allow some savings in terms of resource use and waste production, there would still be a requirement for packaging and shipping a large number of individual components needed for regular upgrades.

At this point it was decided to explore a different strategy. The concept of 'product sharing', emanating from the work in 'sustainable community design' mentioned above, suggested a new 'service-oriented' direction. A network system would allow much of the computer hardware and software to be removed from the PC unit and would allow upgrades to be carried out once for a large number of users. Such a system would require a personal interface to be linked to a central server system, rather than remaining an independent, autonomous unit. However, the recent rapid development and use of on-line services suggested that this lack of autonomy would not be a significant problem.

The project at this point became not 'how to design a portable computer in a way which was compatible with the principles

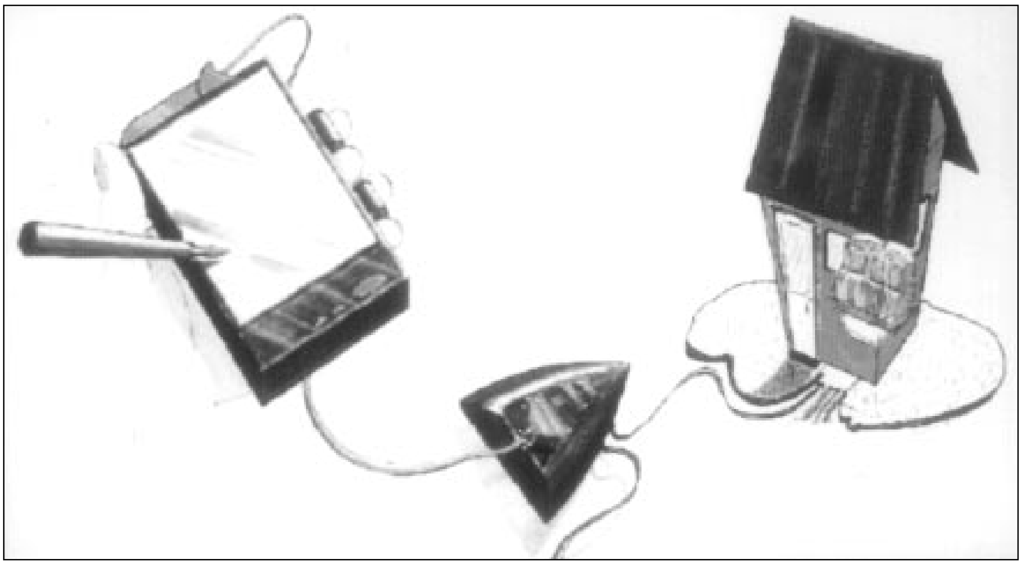

Figure 3: The Personal Net: minimal interface connected to a community computer facility

of sustainability?' but 'how to deliver the services offered by the portable PC in a way which was compatible with the principles of sustainability?' There is a subtle but important difference in the phrasing of these two questions. The first question constrains the designer to think in terms of an autonomous unit similar to existing portable computers. The second has no such constraints, and allows fresh ways of tackling the problem.

The context of the project remained the sustainable community scenario developed by urban planners. The community network approach was initially conceived in a way where file storage and software would be located at a local, community-run computer facility. Later it became apparent that it was possible to extend the number of shared components to include CPUs, buses, power supplies etc. which would, in turn, significantly reduce the number of components held by the individual users. This concept resulted in a significantly different computer architecture. The 'personal product' was reduced to a minimal 'dumb' interface unit, with some form of display and an input device such as a keyboard or pen. All other components were located at the community computer facility. The Personal Interface can be seen as a window to these shared facilities. This concept is not unlike that of mainframe computers, X-Windows architecture, or some of the low cost computers designed for accessing the world wide web (WWW).

The 'community net' appeared to satisfy, to a much greater degree than the previous ideas, many of the energy and materials issues related to environmental stewardship, while also allowing users to access a variety of hardware and software which might be beyond the economic means of many computer users – if they had to purchase equivalent products on an individual basis. Thus the concept also appeared to contribute to social equity, which is one of the key elements of sustainable development.

The personal net

This conceptual design reconfigures the architecture of the PC so that the majority of hardware and software components are shared from a community facility, with minimal interface hardware held by the individual user (Figure 3). The context for use of this design is the sustainable community scenario. The product concept is, in many respects, compatible with sustainable principles. It substantially reduces energy and materials requirements for manufacturing because of the

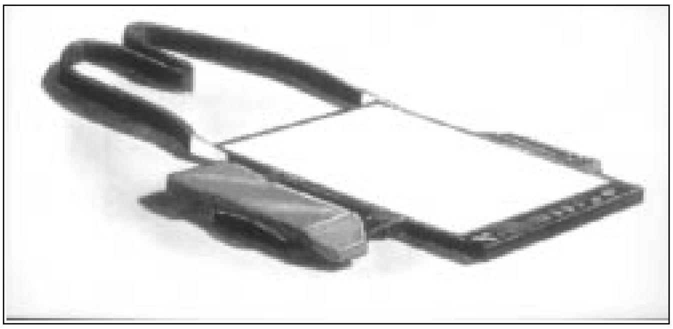

Figure 4: Personal interface: Phonepad concept

shared nature of the majority of components, and it facilitates a degree of social equity in its accessibility. Furthermore, technological advancements in CPU, computer memory and storage, peripheral hardware, and software can be upgraded at the central facility, thus all users benefit from these upgrades and premature obsolescence of many individual, autonomous products is avoided.

The viability of such an approach was investigated once the conceptual design was found to be technically feasible. It was estimated that each community facility, or 'node', could serve approximately 800 users. Links between different community nodes would facilitate communications and allow users access to different resources. The community facility (node) would be located in a convenient location within easy access for the users. It was estimated that the higher population densities envisioned for the 'sustainable community' designs would allow a centrally located node to be within 4 minutes walk (approximately 400m) of 800 users.

It was also estimated that a monthly service fee in the order of $50 to $80 per month would cover costs of: start-up equipment, a building to house the community computer facilities, the salaries of technical support staff and an administrator, hardware and software upgrades, and energy consumption of the facility. While such a service fee might appear to be unattractive to potential users it is cost competitive with the alternative of purchasing a new PC every 2 to 3 years, while offering added benefits of technical support, and a broader range of up-to-date hardware and software. Added to this are the environmental benefits of the concept and the social and community aspects of the central facility.

For those in the community requiring only occasional use of a computer, the community computer facility could provide a number of terminals on a pay-per-use basis. An additional advantage of the concept is that individual users can choose their own personal interface equipment – the development of a product family comprising a variety of input, output and network connection devices would allow

The product concept is, in many respects, compatible with sustainable principles. It substantially reduces materials and energy requirements for manufacturing because of the shared nature of the majority of components, and it facilitates a degree of social equity in its accessibility.

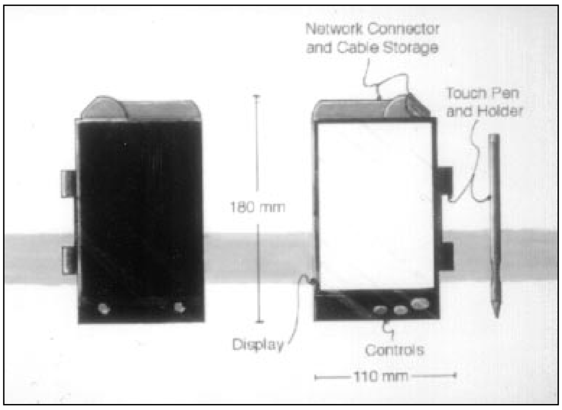

Figure 5: Personal interface: notepad concept

Figure 6: Personal interface: laptop concept

users to select equipment appropriate to their needs (Figures 4–6). The minimal nature of the personal interface also lends itself to portability – a criterion of the design exercise.

This conceptual design fulfils many of the requirements set out in the initial project brief, which sought to explore the potential of redesigning a portable PC in a way which would be aligned with the principles of sustainability, and which would overcome, as far as possible, the negative aspects of technological obsolescence. The benefits include:

- resource use reduction: energy and materials usage are significantly reduced because fewer products are manufactured. Use of paper products is also reduced because fewer manuals and handbooks and less packaging are required.
- extended product care: recycling, repair and reuse of components is facilitated because the majority of hardware is moved one step closer to the manufacturer. This allows manufacturers to track and take increased responsibility for their products, thus encouraging and supporting ideas of extended producer responsibility and the requirements of product take-back legislation.
- reduced impacts of technological obsolescence: the sharing of major hardware and software components begins to reduce the negative environmental effects of rapid technological obsolescence. Designers and manufacturers would be able to place increased emphasis on reliability, quality, and

maintenance of components. These factors could save significant amounts of energy and materials, not only during the manufacturing stages, but also during the operational life of the products.

- flexibility in upgrading and extended product life: the problems encountered in the earlier 'modular' concepts, related to the spatial and volumetric constraints of new components, are overcome by housing most of the hardware in a community facility. This allows relative freedom from spatial constraints and facilitates component upgrading by trained technical support staff, which in turn contributes to extending the useful life of products.
- product leasing and software protection: local management of the community facility could also allow more closely controlled leasing agreements with hardware providers and software developers, which could result in consistent, predictable sources of revenue and reduced losses due to software piracy.

This conceptual design appears to resolve many of the conflicting priorities which often seem to exist between sustainable development and product design. By taking into consideration the work of other disciplines (in this case urban planners), it illustrates a process of design which broadens the more traditional, product focused approach. This 'broader perspective' resulted in a design concept which was contextually based within a 'sustainable community scenario'. As a result, the insights of those working in other disciplines, at larger scales of intervention, and the priorities incorporated into the community design, were able to inform the product design process. This resulted in a conceptual design capable of delivering PC services in a way which is compatible with the overall community design principles and infrastructure.

Potential for further work

This project prepares the groundwork for market and economic feasibility studies which would be necessary prior to the detailed design of a family of products capable of delivering computer services via a community net approach. In furthering this work, a number of issues not touched on during the project, could be considered. For example, the manufacturing of the computer products at the local level could be investigated. This would create local employment, allow products to be tailored to local needs, allow the use of locally available materials and so on. In considering these aspects, the relationship between mass-produced parts and locally produced parts and assembly could be examined. In addition, the conceptual ideas for the interface-hardware designs, developed during the project, adhere to our traditional notions of product aesthetics – which have evolved from a modernistic, industrial culture. The introduction of locally appropriate designs which could be, at least partially, manufactured at the

By taking into consideration the work of other disciplines… [this conceptual design] … illustrates a process of design which broadens the more traditional, product focused approach.

local level, suggests that product aesthetics could also evolve in ways which start to reflect and embody the sustainable ethos which underpins the product. Such an evolution would start to reflect both sustainable values and particular cultural preferences.

The economic feasibility of these ideas would also have to be closely examined. But this would have to be done in a way which recognises the environmental and social costs of our current ways of manufacturing, distributing and using products – the so called 'externalities' which are generally not included in our present economic models. Changes at the government (policy) level would be required to enable and encourage such a shift.

A pedagogical model for sustainable product development

As a pedagogical model for addressing product design in the context of sustainability, this project raises a number of significant points and avenues for further exploration.

Issues-oriented design and interdisciplinarity

It becomes evident that in order to incorporate the principles of sustainability, the focus has to change from being 'product oriented' to being 'issues oriented'. The conceptual basis of the approach had to embrace the broader issues which tend to create conflicts between our ways of living and working, and the priorities of sustainable development. This raised deeper questions related to environmental, social and economic conditions. In order to explore these issues, work from other disciplines was found to be important, particularly the sustainable community scenarios developed by urban planners, which provided a contextual anchor for the consideration of products and product design. The sustainable community scenario was, in effect, a mechanism for focussing the project.

The project suggests that designers can use 'scenarios' of a 'preferred future' as a tool to understand the steps which need to be taken in order to redirect our approaches to design. A wide range of studies can inform the designer when progressing these concepts, including anthropology, sociology, economics and engineering. It is only by beginning to understand these broader issues, and their relationships, that significant progress towards sustainability, and sustainable product design, can be effected.

Technological evolution and sustainable development

The project illustrates an approach to design by which technological obsolescence can be both acknowledged and incorporated into the process of product design, production, use and disposal. The project demonstrates that a harmony can be achieved between two seemingly opposed sets of priorities ie. technological evolution and sustainable development. Further work in this area could explore the feasibility of local scale manufacturing and the development of product aesthetics. Such investigations could enhance opportunities for local employment, use of local materials, and for creating products attuned to cultural values and identity.

Dematerialisation

The project also addresses the concept of dematerialisation. The PC was reduced to a minimum by allowing users to share community facilities. This creates a 'service-oriented', rather than a 'product-oriented', focus. As technologies converge, the potential of this concept becomes even more significant. In principle, many currently autonomous products – all with their own manufacturing facilities, materials requirements, packaging and shipping, and disposal problems etc. – could converge into minimal interface products. Televisions, radios, music equipment, newspapers, telephones, videos etc. could be addressed in similar ways to the PC. With on-line services, many of these products could, conceivably, be eliminated. Thus, the project suggests that service- or systems-oriented design approaches can be a valid area for inclusion in industrial design education, especially if sustainable product development is to become incorporated into design curricula.

'Independence' and 'inter-dependence'

Finally, the project raises issues about 'independence' and 'inter-dependence', and about the nature of community based enterprises. Examination of the logistics of running a a community based facility is required. The community 'server' could be an entirely commercial enterprise, or it could be run as a community cooperative – where the users own the facility and participate in its operation. A cooperative approach may also be appropriate for the actual manufacturing of the products. The industrial cooperatives of Mondragon, in the Basque country of northern Spain, have demonstrated the economic feasibility and social benefits of such an approach (Morrison, 1991).

Conclusion

The challenge of aligning the design, manufacturing, use and disposal of products with principles of sustainability is both formidable and complex. When products which are in a rapid state of technological development are considered, this challenge becomes even more difficult. The case study illustrates a possible approach which has the potential of overcoming many of the apparent conflicts between sustainable development and our material needs and desires. The adoption of such an approach in the commercial sector will require a number of changes, including government policy, so that manufacturing corporations are encouraged to consider alternative ways of delivering services, while ensuring economic viability. Furthermore, our predominant notions of 'growth', which are still prevalent in the commercial sector, have to be challenged if the 'systemic shift' is to be effected in a timely manner. The exploration of these potentialities, through academic design projects can illustrate and give form to the opportunities which exist for rethinking our ways of living and working. A shift in design curricula, to recognise and encompass ideas such as interdisciplinary studies, scenario building, economics (particularly local scale economics), sociology, and sustainable development will help to provide the foundations for addressing new approaches to product design. This is, perhaps, the necessary first step in the process of change. •

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Unraveling the environmental product design paradox

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As global mandates on 'end of life' product disposal finally go in to effect, companies must begin to define appropriate 'end of life' strategies. Business decision-makers need to be more aware of the opportunities, issues, and liabilities which will face the company in the near future, and will need to be able to sufficiently address them. Environmental Product Design (EPD) suggests the need to consider the life cycle environmental, health, and safety impacts of a product early in development. EPD increases the 'end of life' value of products, but seems to decrease the benefit to the company. This paradox served as the launching point for a study in how to find benefits from EPD.

This paper presents a case study of Quantum, a manufacturer of electronic commodities and defines the frameworks for analysing product disposal alternatives. Alternatives studied include contractual agreements, total destruction, total disassembly, and reuse. One of the primary sources of data used is a composition analysis from an external recycler. The analysis shows the optimal strategies for each disposal option. Further illustrations show the implementation of a management information system to link disposal with design.

Introduction

Product-environmental concerns in the electronic commodities supply chain are being driven by Original Equipment Manufacturer (OEM) customer environmental management system requirements. They are viewed increasingly as business competitiveness decisions for both the OEM and the supplier.

Decisions on the materials composition, fabrication, assembly, and ultimate disposal of a product should be made based on 'end of (useful) life' disposal alternatives [Fiksel 1994, Graedel 1995, OTA 1992]. Emerging international regulations require take-back and proper disposal of products by commodity manufacturers at the end of their useful life [ASTM 1996, EU 1993]. Appropriate flexibility exists as to where in the commodity manufacturers supply chain this occurs.

At this time, European countries are leading regulatory efforts, but it is only a matter of time until most industrialised nations have some form of mandatory take-back. Even individual states (eg. Minnesota and New Jersey) in the US have begun to consider take-back. This trend in regulations is a direct result of the technology advances and shorter life cycles of electronics commodities, the decreasing amount of available worldwide landfill space, and the increasing level of worldwide environmental awareness. The economic bottom line of this trend is that all products used in locales subject to environmental restrictions or take-back legislation will need to be reclaimed by the manufacturer (or an agent thereof), regardless of either their original point of sale, or the intermediary distributor of the product.

In this paper, we describe the environmental performance issues facing Quantum, an American manufacturer of computer storage products. For Quantum, environmental performance means considering the environmental health and safety (EHS) impacts of products during the product development life cycle and developing specific programmes that will result in measurable reductions in those impacts over time. To put perspective on the magnitude of impacts, Quantum shipped over 6.5 million drives to Europe and over 11 million in the US in 1996.

Because of Quantum's position near the top of the supply chain (both buying parts and sub-assemblies for products and manufacturing components for use in customers' products), the company receives many questions from business partners and customers about the use of restricted substances in products and processes. As part of this effort, Quantum has organised a list of environmentally relevant substances and monitors their use across the supply chain. Quantum provides customers with data about product component materials that helps them determine issues of recyclability, reuse, and restricted substance percentage. Quantum's Environmental Product Design (EPD) programme is designed to reduce the negative impact on environmental and human health and safety of all Quantum products, processes, operations, and facilities.

The essence of the EPD programme is in preventing negative impacts before they start – by considering these issues in product design and materials selection, as an integral part of the product development cycle. EPD is thus positioned as a business issue.

Take-back issues

Electronic products are ultimately used in every part of the world. Although warranties provide an indirect contract between the end user and the manufacturer, with the only direct contracts being between producer and customer. This indirect relationship will become increasingly important in the future when legal obligations require knowledge of a firm's businesses and products, and, more specifically, their environmental burden.

In short, manufacturers of electronic goods are already incurring potential future liability for every product which may reach the end of its useful life in environmentally sensitive areas. A straightforward mechanism for measuring the actual liability would be to create a comprehensive real-time product location tracking system to monitor the number of products in each legislative region subject to environmental restrictions, and the cost of reclaiming such affected components or products. Of course, this system is infeasible. In its absence, firms must resort to a 'least uncommon denominator' approach of environmental management – where the mere existence of a material or process restriction somewhere on the planet leads to the elimination of that material or process in all products produced for any region.

Similarly, all firms need to monitor the environmental performance of their suppliers. By necessity, product take-back and materials specification comes from the top of the supply chain [Stock 1992]. Even though in some instances products will be contained inside another supply chain as a sub-assembly (eg. internal hard disk drives within computers), it can be assumed that if a product is returned to an OEM, they could return the sub-assembly to its manufacturer. Ultimately, suppliers should be prepared to take back all necessary products on their own. The smart supplier makes the issue of adapting to its reverse logistics requirements a 'non-issue' for its customers.

Take-back relevant to Quantum at this time happens via the OEMs. However, recent discussions with key customers have shown that their 'end of life' reverse logistics or product reclamation facilities currently find it profitable to process Quantum products due to the high content of metals. For this reason, no Quantum product is returned via such networks.

In determining take-back networks, firms must be able to physically take back products before they can realise any subsequent benefit from extracting value. A logical starting point is to begin by analysing current repair or return networks. The existing volume of returned units is the most important factor in determining whether the repair and return mechanisms already in place can effectively serve as a larger take-back network. In the case of Quantum, the volume of returns is so small that attempting to include 'end of life' products in the same logistics stream would currently be infeasible. However, the inherent network could support take-back by adding capacity.

Despite a current lack of Quantum products being returned via take-back or other 'end of life' agreements, it is prudent at this time to consider the business decision of implementing a product take-back programme in Europe. Since customers are implementing such measures, suppliers need to consider the parameters of the system. There is a need to investigate how Quantum's design choices will impact on take-back programme strategies, in order to both reduce environmental impact and improve take-back program economics. We need to ensure that our *drives* can be easily managed at 'end of life'.

EPD does more than just benefit the environment. The bottom-line benefits of EPD can be seen in an increased ability to manage total cost through each product's life cycle by considering issues such as product 'end of life' costs during the design phase. Quantum sees this activity not as an additional cost of operation, but as an 'end of life' investment in the product.

The EPD paradox

On the surface, implementing a product take-back system is not an exercise in maximising benefit, but rather, in minimising cost. However, this statement is short-sighted and serves to illustrate the Environmental Product Design (EPD) paradox:

EPD increases product 'end of life' value, but decreases the benefit to the company.

One of the reasons firms decide to implement EPD is to increase the 'end of life' value of their products. However, this 'end of life' value determination should necessarily also include the benefits and costs of taking back obsolete products. As noted above, this is generally speaking a net loss to the company. One of the by-products of 'building in' additional 'end of life' value at the design stage is that it makes the product more valuable to non-users when it becomes obsolete. Thus secondary markets are created which seek to extract that value from the products outside of any reverse logistic or take-back network. The existence of these secondary markets reduces the number of products which are actually taken back by the OEM. Finally, the manufacturer receives less of a return from the added 'end of life' value than it would have without implementing EPD. Thus the benefit to the company is decreased.

Linkage to Full Cost Accounting

The 'pay off' from such an analysis comes from incorporating 'end of life' information into the data used by managers to make product engineering and economic decisions such as design or pricing. One application of such information is in Full Cost Accounting (FCA). FCA seeks to identify and quantify all costs related to the manufacture of a product [US EPA 1995, Epstein 1996]. All information on lifecycle costs greatly enhances the accuracy of this type of system. With information on the ultimate disposal of the product, and access to the related management information, it becomes possible for designers to easily see the effects of their materials and process decisions on the ultimate fate of the product (including take-back).

Product disposal options are a function of the design of the product. Designers are not generally knowledgeable about environmental or 'end of (useful) life' issues, and the goal of a management system should not be to make them experts in such areas. However, by expressing the 'end of life' parameters as costs we show the inherent costs of making bad decisions, an area where designers can be made experts. Few firms currently give such information to designers. However, adoption of a methodology as described in this paper provides the necessary tools to link business environmental strategy with product design.

'End of (useful) life' technology

Quantum is working to implement FCA to address the need to link design stage decisions and 'end of life' issues. This requires a significant amount of knowledge about the 'end of (useful) life' features of the product. The increase of detailed analyses is highlighting technologies and processes which allow for various take-back options. For example, a hard disk drive can be completely destroyed, disassembled, or reduced to its elemental components with available technologies. However, the optimal corporate strategy for product disposal depends not only on the bottom line, but also on the firm's level of commitment to the environment and the proprietary nature of its products. In the absence of proprietary concerns, cost-benefit analysis would suffice in the determination of corporate strategy. The existence of private information in the form of 'trade secrets' complicates the optimisation process.

Technologies which accept old products as input and then destroy, disassemble, or break them down into their raw materials are becoming increasingly efficient and cost-effective. Interviews and discussion with major firms in this industry suggest that total destruction is a growing international industry response to product reclamation. Most major computer OEMs are opting for this strategy. In total destruction, an external contractor promises to completely destroy a product, and also certifies zero discharges to the environment from disposal (excluding energy needed for destruction). This method is popular amongst companies since it guarantees that no subsequent brand recognition is possible. Brand recognition is important in this sense because costs related to such things as Superfund liability come as a direct result of agencies finding toxic waste sites and noting which firms are the primary users of the sites, and then charging them for the 'clean up'. This is an attractive option for Quantum, which stands out as one of a handful of electronic companies with zero liability under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).

'End of life' analysis

Quantum investigated the costs of dealing with 'end of life' products. The research involved only the costs incurred by Quantum once the products were back in their control; it did not include the costs associated with the logistics of transferring the product from the end user to Quantum.

With this in mind, four hard disk drive products manufactured in 1996 were disassembled and subject to materials analysis. To

The optimal corporate strategy for product disposition depends not only on the bottom line, but also on the firm's level of commitment to the environment and the proprietary nature of its products.

add a level of insight, products A and B had the same capacity (2 Gigabytes) but different design. Products C and D are separate 1.2 Gigabyte models. Using an independent laboratory, the product was broken down into its major sub-assemblies, and then its materials.

The scenarios were considered for analysis based on the assumption that products were subject to environmental restrictions and thus could not be disposed of locally by the user. It should be noted that this does not mandate actual take-back – just a responsibility on the part of the producer to reclaim the product at the end of its useful life to prevent disposal. The four options available to the manufacturer were considered to be:

- contractual reclamation and total destruction
- materials reclamation
- sub-assembly reuse
- product reuse.

A: Contractual reclamation and total destruction

As noted above, total destruction is done to certify that the product has not been landfilled (and thus meets regulatory requirements) and also serves as a means of removing any linkage between the firm and any residual materials. The form of the contractual arrangement is similar to cardboard and mixed office paper recycling, where the recycler agrees to take away the residual materials and is allowed to process it in any way with no added benefit to the manufacturer. Implementation of this option would entail negotiating many localised contracts to meet a firm's worldwide disposal requirements.

At estimated 'end of life' return volumes, the option of contractual destruction was quoted as a cost of $5 per unit by recyclers. All in all, the recycler would benefit even more than by the $5 contract fee by being able to reclaim the metals content of all drives and keeping those profits as well. In return, the manufacturer receives a clear conscience. Using EPD, the recycler could have less materials to process, making recycling easier and more profitable.

B: Materials reclamation

Companies typically only monitor 'component level' data for their products. For example, the cost and weight of the major sub-assemblies. Typically, these sub-assemblies are purchased from a contractor for manufacture. However, necessary and relevant information such as raw materials content and usage is not monitored. Without this knowledge, supplier questionnaire responsiveness and regulatory tracking are cumbersome.

Materials reclamation involves taking components and performing various 'reverse engineering' technologies to return them to their raw materials composition. The only sub-assemblies not completely broken down in our analysis were memory and controller chips, since they had potential reclamation value. Chips were left in consideration as a sub-assembly.

This information has subsequently been placed in a proprietary database tracking the usage of materials. Although specific actual data cannot be provided, relevant ratios can be expressed to show the magnitude of the results. Table I shows the total weight, number of chips and materials used, and current materials value expressed as a percentage of original production cost for the four products. Again, the materials values shown do not include any costs related to take-back logistics, just the benefits of raw materials extraction.

Considered as a sub-assembly, chips were priced for their open market commodity value. A surprising fact was that the chips already had a zero value in the recycled chips market after only one year. The firm providing that quote noted that demand for such chips was zero for two

Product	total weight	chips used	materials used	materials value
A	850g/1.9lbs	7	20	1%
B	510g/1.1lbs	5	22	1%
C	794g/1.8lbs	8	27	1%
D	482g/1.1lbs	6	25	1%

Table I: Materials specification for case study products reasons. First, most of the chips were proprietary and the manufacturer was the only potential user. Second, the chips were already outdated and demand had shifted to faster, larger capacity devices. Due to the nature of demand in this market, it was safely assumed that there would be no value by end-of-life.

EPD could potentially be used in this scenario to reduce the number of chips used in the design of the product, since it is reasonable to guess that they will be worthless at end-of-life. Similarly, material substitutions could be made to lower the metals count and to increase end-of-life value.

C: Sub-assembly reuse

The option of reusing sub-assemblies must be considered given the materials composition results above. Since raw materials extraction yields such minimal benefit, it is clear that there is considerable 'value added' in production. Thus if the high-value pieces could somehow be reused, additional benefit could be realised.

Chips are one of the primary 'value added' components in electronics today. However, as seen above, chips from recently produced drives already had no demand in the market. One of the reasons noted for this was the 'technology push' to more complex components. However the more important issue is the proprietary nature of the chips. Most of the chips reclaimed were Quantum-manufactured controller chips, which are worthless to all other manufacturers. Only Quantum could create demand for this residual product. Due to quality concerns and future technology shifts, there is no plan to reuse these chips.

Subassembly	% Product Weight	% Product Value
Housing	64.5	70.0
Magnet Plates	12.2	5.4
Disks	8.4	10.0
PCB	5.1	5.0
Motor	4.4	3.8
Head/Track Assembly	2.8	4.1
Other	2.6	1.7

Table 2: Percentage composition of weights and raw materials for subassemblies in case study

Similar arguments were advanced about reusing other high-tech sub-assemblies such as heads, disks, and motors. To determine the feasibility of reusing sub-assemblies, the materials extraction data was generalised back up to the sub-assembly level. Table 2 summarises average percentage weight and raw materials values (as a function of total residual materials value) for the main sub-assemblies across the four products.

The only sub-assembly which seems to pass quality and technology reuse concerns is the housing. Interestingly, the housing accounts for 65% of the product's weight and 70% of the potential extracted materials value. A real opportunity may exist to maximise the 'end of life' investment by further studying the potential for reuse of housings. Reuse would decrease the amount of metals discarded at 'end of life', decrease use of raw materials, and would utilise one of the components which represents a considerable share of value. However, successful adoption of such a programme must fit with all internal quality assurance, production efficiency, and 'time to market' values.

The only feasible scenario for reusing housings would be if the net cost of reclaiming and preparing old housings is less than the cost of simply buying new housings. [Note again that the tables do not adjust for reclamation fees, thus even the benefits from reusing housing will cost money.] Since the raw materials value of housings is only in the $1 range, the reclamation costs could prove prohibitive. This option is being studied at this time.

Interestingly, working with OEMs to promote EPD gives them greater insight into which subassemblies are the high value parts. If at 'end of life' the OEM selects just the high value pieces and returns the rest, the component manufacturer stands to lose a large percentage of its 'end of life' investment.

D: Product reuse

Although not specifically studied, this option merits explanation. Similar to the problem with reusing component technologies at the 'end of life', cumulative problems exist with attempting to reuse total drive products. The only way to effectively reuse products is to identify the components which are obsolete and replace them. The key point, however, is in how 'obsolete' drives are defined. Typically drives are completely obsolete in all areas of interest: capacity, speed, etc.

However, if the manufacturer were to take-back products prior to 'end of life' (eg. exchange or upgrade programmes), this could be an attractive and profitable business. Clearly 1–3 year old products still have a resale value much higher than simply the raw materials value. Again, reclamation costs could be prohibitive.

The EPD paradox revisited

All four options involve the tradeoff of processing costs and extracted end-of-life value. Implementing any of the four options using EPD would cost more. We repeat the EPD Paradox:

EPD increases product 'end of life' value, but decreases the benefit to the company.

The caveat to the paradox is that short-sighted firms fail to recognise the benefits of EPD, which are realised outside of traditional accounting methods. Currently, firms are unable to account for most of the costs and benefits which are accrued by EPD. Many firms do not recognise the current liabilities of their products, and few recognise any potential liabilities, due to financial reporting guidelines. Likewise, corporate accounting and finance systems fail to see the benefits.

The true benefit of EPD can be seen in one of two ways. First, since each of the options above have a cost to the manufacturer, it seems that take-back is an exercise in loss minimisation. Finding ways to lower costs improves the attractiveness of an option, eg. avoiding reclamation fees. Second, all else being equal, a product with an additional 'end of life' value designed into it is superior to a product not designed for 'end of life' investment. Seemingly, this difference can and should be seen as a competitive distinction against other products. If marketed correctly to customers (specifically OEM customers), this could be a valid reason to command a price premium over other products, generating additional benefit to the company. Maximising the 'end of life' values of products is something all firms will need to be concerned about in the future, and if a component manufacturer is able to help in such overall efforts, they should be rewarded.

Information system and results

The European Union eco-management and audit scheme (EMAS) and ISO 14000, require companies to act as a good global citizen in the procurement, specification and usage of materials which may cause environmental damage. In some cases, firms will require other firms to be certified to these standards as a requirement for doing business. In most cases, though, firms will only require companies to show that they have considered the environmental impacts of its products and have an environmental management system in place to monitor these effects.

In preparation for such environmental management systems, Quantum has created a product database for designers which records data from the materials usage level, through to the sub-assembly level and overall product composition level. The full value of this additional information about products is best realised when made available to designers and other decision-makers within the firm.

Designers will be able to see the materials mix present in current drive sub-assemblies, and with the addition of information on environmental restrictions, the net impacts of these materials selection decisions. As time goes on and additional products and regulations are added to the system, designers should gain substantial insight into how materials and component decisions change the 'end of life' value of the product. This information is invaluable in maximising 'end of life' value.

The information system allows for the generalisation and comparison of various material, sub-assembly, and overall product options relevant to their environmental attributes. It is via this system that some interesting specific product conditions were discovered. First of all, as seen in Table I, the products analysed had similar features but different designs. Although A and B were virtually the same capacity drives, drive B was roughly half the weight as A but added two materials to the composition. One of the materials added now appears on restricted substance listings provided by our customers. Thus, one of the presumed reasons for being able to reduce the environmental impact of the drive (its weight) actually introduced a substance which may in the future prevent its disposal in certain areas. It is the identification of these instances which promotes usage of such a system.

Conclusion

It appears that companies expending resources on EPD seem not to directly realise return on their investment. However, on closer examination, under the revealing light of innovative valuation methods, it becomes clear that the value of EPD flows directly to the investing organisation through reduced risk, increased customer satisfaction and improved efficiency of operation. The increasingly tight-knit value chain of international manufacturing and consumption reveals these benefits. For this reason, manufacturing organisations should embrace EPD as vital to business performance. •

Footnote

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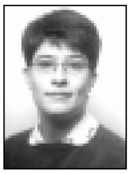
The challenge of 'product chain' thinking for product development and design – the example of electrical and electronic products

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Product development decisions have a considerable impact on the life cycle wide environmental performance of a product. However, many stakeholders bring different and sometimes conflicting requirements into the design process. One way to understand the life cycle of products is to gain a better understanding of the roles, perceptions and positions of different stakeholders in the 'product chain', such as raw materials producers, manufacturers, the trade and consumers. This article presents findings from a 'product chain' study concerning electrical and electronic appliances. It also discusses the implications of 'product chain' thinking for product development and design.

Introduction

Product development and design have an increasingly important role in environmental improvement. The shift from 'end of pipe' solutions to cleaner production has now moved to the even more fundamental level of 'cleaner products'. Product development is increasingly challenged to address the impact of design decisions on environmental burdens across the full life cycle of a product. Product development is well equipped to address this task: it has been estimated that up to 90% of the whole life cycle costs of a product are determined at the design stage (Keoleian & Menerey 1994). On the other hand, product development does not operate in a void. Many stakeholders bring different and sometimes conflicting requirements into the design process.

Life cycle design is becoming relatively well-instituted. Information and models for evaluating the life cycle wide consequences of design alternatives have become available. In many of these models, the product life cycle is conceptualised solely as a system of physical flows. In this article another approach is introduced, which recognises that the product life cycle also consists of stakeholders, who may either obstruct or facilitate the integration of environmental aspects in the product life cycle. Thus life cycle design (LCD) is discussed within the broader context of life cycle management (LCM).

LCM requires concerted action by a number of different stakeholders. These stakeholders include raw materials producers, manufacturers of finished goods, the wholesale and retail trade, the maintenance and service industries, as well as consumers and public authorities. The chain of actors involved in the environmental life cycle of the product is often nowadays called the product chain. The integration of environmental aspects requires a flow of environmental information, corresponding to the flow of materials, products and money within this chain of stakeholders.

In the following section, an overview of the concept of 'product chain' thinking is presented. Next, findings from the study concerning 'product chain' stakeholders' perspectives on electrical and electronic products in Finland are highlighted. Finally, there is a discussion over the usefulness of 'product chain' thinking for product developers and designers.

What is 'product chain' thinking?

The focus on 'product chains' in the environmental context has a number of different origins. Concepts such as 'integrated chain management', 'environmental co-makership' (Cramer & Schot 1993), 'product stewardship' (eg. Boons & de Groene 1996), and 'value chain management' (Linnanen & Halme 1996) are closely related. A rather similar, although somewhat broader, concept used in the US is 'industrial ecology' (eg. Allenby 1994).

The idea of 'product chain' management (PCM) originates from environmental life cycle assessment (LCA). LCA has highlighted the fact that many actors along the product life cycle influence the environmental impact of a product. For example, there are many groups that may influence the environmental burdens of construction materials: starting from product developers from the firms producing construction materials, through to construction firms, their various sub-contractors, to residents and municipal waste authorities (Essunger & Tell 1991).

Life cycle thinking links product issues to the environmental management strategy of a firm. Often, significant environmental threats and opportunities are related to a firm's suppliers or customers. The first product stewardship programmes were established in the chemicals industry, where the installation of the product is often the most problematic stage in the life cycle. In recent years, the environmental evaluation of suppliers has also become increasingly widespread. Environmental PCM includes 'downstream steering' (ie. product stewardship), 'upstream steering' (placing demands on suppliers) and finally, 'co-operation' with relevant stakeholders such as competitors or local authorities (Linnanen & Halme 1996).

Linkages between actors in the 'product chain' may help to spread environmental improvements from one organisation to another (eg. Hass & Groenewegen 1996). Often, processes that lead to environmental improvement may originate in one organisation or stakeholder that has specific power or motivation to enable environmental improvement. Concepts such as 'key actors', 'ecological gatekeepers' and 'environmental catalysts' have been used to describe this type of stakeholder. Conversely, industrial networks and buyer-supplier relationships in the product chain may obstruct the diffusion of environmental improvement. Individual organisations may find it difficult to change their activities due to resistance by customers or suppliers, or due to missing links in the chain of demand for environmentally improved products (Boons & deGroene 1996).

In order to succeed in the market, environmentally improved products have to be credible. Some minimum level of consensus on the goals and means of environmental improvement is also needed for concerted action in the product chain (e.g de Man 1996). These are major challenges, because there is still considerable scientific and political uncertainty over environmental priorities. Customers frequently distrust manufacturers'

Customers frequently distrust manufacturers' environmental claims, because they are perceived to be used to gain competitive advantage, but cannot be tested by the customer. Credibility, trust and a systematic flow of environmental information are thus major issues in product chain management.

environmental claims, because they are perceived to be used to gain competitive advantage, but cannot be tested by the customer himself. Therefore, credibility, trust and a systematic flow of environmental information are major issues in PCM.

Consumers are often mentioned as the driving force of 'industrial greening'. However, product chain studies have, until now, usually not included consumers as stakeholders in the product chain. This focus is, however, changing. New initiatives are focusing on demand management and consumer involvement in the development of radically new product concepts (Jansen 1996). Other growing issues that have been highlighted in recent studies are the roles of retailers and organisational buyers.

Conditions for environmental improvement in the product chain of electrical and electronic appliances in Finland

A study was undertaken with the aim of clarifying the informational, organisational and economic issues involved in PCM from the point of view of key stakeholders. The groups selected as the most important and influential stakeholders in the product chain of the consumer products were consumers, trade and producers.

One of the four product groups studied was electrical and electronic appliances (see Note 1). Product chains of appliances are often long and consist of many stakeholders: raw materials and component suppliers, end-product manufacturers, the wholesale and retail trade, consumers and business customers, product maintenance and repair services as well as waste handlers. Manufacturing of appliances is generally considered to be a relatively 'clean' industry, but most environmental problems relate to component, especially PCB (printed circuit boards) manufacturing. However, in recent years, awareness of environmental impacts caused by the products along their life-cycle has increased, eg. energy consumption of appliances, as well as increasing waste problems created by 'end of life' equipment. Bans on some environmentally hazardous substances in products, such as heavy metals and chlorofluorocarbons (CFCs), have also been introduced. Legislation has been proposed in the European Union (EU) and in many member countries to extend producers' responsibility for collecting and recycling 'end of life' equipment.

Electrical and electronic appliances are a large product group – with products varying from large household appliances to consumer electronics, computers and small household appliances. The aim of the research was to clarify the perceptions of product manufacturers, trade representatives and consumers roles and responsibilities in the 'product chain'.

Core questions asked were:

- How do different stakeholders see the opportunities and obstacles of improving the environmental quality of products?

- What kind of environmental information is used and needed by different stakeholders?
- How do they see that responsibility should be shared between different stakeholders in order to improve the environmental quality of products?

Focus group interviews enabled members of each group to discuss issues with other members of the stakeholder group (see Note 2). The discussion was followed by a questionnaire. The data and methods used are described and evaluated in more detail in Timonen et al. (1997).

The following interpretation is based on respondents' views expressed in the focus group discussions. References to the extent of agreement within and between groups are based on data from the questionnaire, which explored the level of agreement on views brought up in the different groups.

Opportunities and obstacles to environmental product improvement

Environmental awareness in the market

Consumer respondents considered electrical and electronic appliances to be environmentally-sensitive products, because they are durable goods that impact on the environment both during production and use, as well as on disposal. However, consumers did not bring up green issues as an aspect of relevance when selecting and purchasing appliances: 'it's the price and quality that count the most'. They stressed the following factors in choosing electrical and electronic appliances:

- technical characteristics
- price
- popular and familiar brands
- easy maintenance and repairability
- energy consumption
- durability.

Energy consumption and product durability were also seen as environmental aspects. There appears to be increasing awareness of energy saving features of large household appliances (refrigerators, freezers, stoves). Durability and expected product life were also discussed among consumers, since they felt that many appliances are increasingly short-lived and not repairable.

The retailers described consumers as being 'pocket-book greens', meaning that they were not prepared to pay extra for environmental characteristics. Only a very small segment of consumers were considered environmentally progressive:

'You can almost see it when a customer comes in, what it's worth telling them. It's such a small group of our customers that appreciate those environmental things, there are really very few of them. The others, they listen to their pocket-books.' (Retailer).

The producers saw clear differences between 'business to business' customers and ordinary consumers, and also pointed to national differences in environmental awareness. Organisational buyers are already starting to express clear environmental requirements, with environmental awareness increasing in procurement policies during the 1990s. In general, environmental consciousness in Finland was viewed as being somewhat lagging in relation to, for example, Germany or Sweden. It was, however, recognised that the role of environmental concerns had grown in Finland, too. But this increase in awareness is not yet discernible in consumer choice for household appliances and consumer electronics.

There were different views of the future environmental development of products. Producers mentioned that they had started to pay attention mainly to packaging re-design, energy saving features of products, and material selection (eg. recyclability of plastic parts). Energy saving improvements have followed mainly from component development, and have been fairly easy to implement. In material selection, producers have started to pay increased attention to decreasing the amount of different materials used in products. This has been due to cost reduction pressures, and not only because of environmental reasons. As concern over the improved recyclability of products has grown, producers said that changing material contents of products occurred incrementally. Progress is slow due to cost considerations and the fact that many of the parts and components are standardised and are not made according to each company's own specifications.

Producers, however, believed that many environmental product improvements could still be achieved:

- energy efficiency of products would still improve
- materials would be substituted for more environmentally compatible ones
- lightweighting and recyclability would increase
- the number of components in products would decrease.

They also hoped that product expandability and multifunctionality would increase. Consumers were not optimistic in their expectations. Pessimists mentioned that due to the growing volume of appliances as a result of the increasing number of product variations, products will become increasingly short-lived and 'disposable,' meaning less repairable or durable. Many consumers were also sceptical about producers' environmental claims.

Current information flows in the 'product chain'

All stakeholders seemed to have a need for more precise product-related environmental information and it is evident that information exchange could be intensified in the 'product chain'. Producers emphasised the difficulty of obtaining information on the material contents of components and parts from their suppliers. This information is being increasingly required due to a growth in enquiries from customers and also to provide data for product LCAs. It is often very time consuming to collect the information needed, because supply chains are long and international.

The role of retailers as information providers was intensively discussed, as the 'point of sale' situation is often important in the purchase of household appliances. Consumers saw that finding out about environmental aspects requires considerable initiative from consumers, as salespeople are not usually able to tell customers about environmental aspects, and this information is not necessarily easy to find in product brochures. The retailers did not want to adopt the role of a general educator, they stated that they would inform those customers who asked specifically about environmental issues. At the 'point of sale' the customer's willingness to buy and ability to pay influence how much time the salesperson normally devotes to presenting the characteristics of products:

'Well, its not really our job (to provide guidance)... in our outlet, for example, salespeople understand that if a consumer comes in to buy a washing-machine costing FIM 1500,- or one costing FIM 4000,- ... one doesn't wait long if someone starts really pondering about that 1500 marks' machine and there are other customers in there... he then starts serving other customers in the hope of actually managing to sell something. You could say that this kind of guiding thing, in a way, it's a risk for the shopkeeper, because you have to remember, we have to do business every day. If we start guiding and advising consumers, then it's the end of our business rather quickly.' (Retailer)

Both retailers and producers highlighted the importance of training salespeople, telling them about new product features. For example, according to retailers, some environmentally sound television sets had failed in the market due to ineffective communication. Although the television sets were energy efficient and recyclable, their sales were low because customers believed that 'eco-TVs' were questionable or of lower quality. This was maybe due to lack of clear messages from the producers to salespeople about environmental product characteristics. Salespeople hesitated to introduce environmentally improved products because it was believed that environmental values were 'soft' values which do not sell products.

Consumers saw a lack of opportunities to choose environmentally sound appliances and to make choices on the basis of environmental criteria . This was mainly attributed to a lack of information, although as expected, consumers admitted that other criteria are more important than environmental product attributes when buying a new appliance. Producers have been quite careful and maintained a low profile when marketing products with environmental claims. Only one of the interviewed companies, a computer manufacturer, had carried out a green marketing campaign. Generally, environmental aspects (such as information about energy saving features of products and packaging recycling) have been emphasised in product brochures only during the very last few years. Producers seem to have chosen a careful approach to ensure that they don't distribute information, which might be misleading or lead to negative publicity later. Consumers, on their part, had not yet noticed many environmental marketing claims concerning appliances.

Problems in using information

Another reason why consumers may lack motivation to address environmental concerns is that it is difficult to understand and compare the various environmental issues in the product life cycle. Is, for example, the composition of the plastic casing of a computer more important than the recyclability of the packaging? Or should one focus on the maintainability or on the energy efficiency of a refrigerator? In addition, electrical and electronic appliances are such technically complex products that it may be difficult for a buyer to assimilate all the necessary information in a buying situation.

All stakeholder groups mentioned that the lack of concrete information was a real problem. Consumers claimed they would be better motivated towards 'green' concerns if clear calculations could be presented, for example, about energy saving. Retailers saw the EU's energy label-type of communication as a good starting point, although also these labels were seen to have problems. Producers stressed the need for more standardised data exchange forms, which would help both producers and suppliers to give and acquire information concerning, for example, product material composition and hazardous substances.

Environmental labelling

Third party labelling schemes have been developed related to various electrical and electronic appliances including: the EU energy label (currently compulsory for refrigerators, freezers, dishwashers and washing machines); the Nordic environmental label (criteria for over 10 products exist); and the EU Ecolabel (criteria for 4 appliances exist).

The role of environmental labelling is clearly still vague in the electrical and electronic appliance market in Finland. The Nordic environmental label includes the largest number of criteria for different kinds of appliances, however almost half of the respondents thought that the Nordic label will not be influential in the future, and that the EU eco-label may be more significant. The producers and trade thought that various environmental labels (including producers' own labels) are currently so diverse that it would be better if an internationally recognised label, such as the EU eco-label, should gain a prominence. The unwillingness of producers to apply for the Nordic label was partly explained by the

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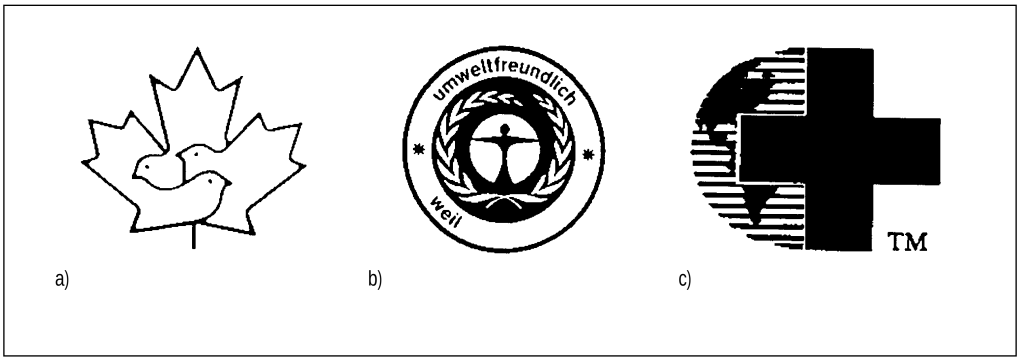

Figure 1: Some third party environmental labels which include criteria for electrical and electronic appliances: a) Canadian Environmental Choice, b) the German Blue Angel label , c) the US EPA Energy Star label.

fact that most appliances manufactured in Finland are sold outside Nordic countries. Producers have applied for the labels which key customers require, such as TCO'95 or the German Blue Angel label.

Shared responsibility and whose responsibility for environmental improvement?

How should responsibility be shared?

Different stakeholders generally agreed that producers should be responsible for environmental issues related to appliances because they have most information and product-related knowledge and because they develop and manufacture the products. After producers, local authorities and consumers were considered equally important as the stakeholders who should bear the most responsibility. Less responsibility was assigned to the trade or to the media.

Power to influence products

There were some differing views on what responsibility actually entails. Consumers saw their own ability to influence the market as small, and thought that the responsibility should be with the trade, ie. retailers should screen products and select the most environmentally benign ones into their product range, thus making the consumers' decision-making easier. Producers, too, considered the retail trade as having an influential role in environmental issues. However, retailers voiced some reservations about changing their product range by including environmentally improved products. They did not believe that their clientele would include enough 'green consumers' to make such business profitable, and existing price margins do not allow any extra 'eco-initiatives' without a much clearer demand from customers. Rather than increasing the sales of 'green' products, retailers seemed to prefer to gain environmental merit through initiatives for recycling products or taking care of packaging waste.

The producers, on their part, emphasised their own responsibility to continually search for new product improvements. Environmental aspects were – notwithstanding the stated consumer indifference – seen as issues that could provide competitive advantage in the future. And if not a competitive advantage, at least disadvantage for those companies that do manage environmental issues. Producers seemed to be confused by the lack of interest in the consumer market and were faced with a dilemma: they saw a diffuse and unspecified growing demand for environmental solutions, but little actual current rewards for their efforts in environmental product improvement.

The lack of economic incentives for environmental product improvement was also highlighted both by producers and retailers. They complained that, under current conditions, the costs of environmental improvements are borne by those taking the initiative, while laggards manage to free-ride. The license fees for environmental labels were mentioned as an example of this situation. Possibilities of capitalising on improvements were seen as small, and local authorities were considered to be somewhat unappreciative of business efforts. More co-operation between 'product chain' actors and authorities was called for.

Extended producer responsibility

One practical example of the increasing need for 'product chain' co-operation is the EU's and some of its member countries' planned legislation on producer responsibility for 'end of life' equipment. The issue of organising collection and recycling of 'end of life' appliances, was met with confusion amongst respondents. No clear ideas on how responsibility for this specific issue should be shared were presented. However, respondents understood that every stakeholder will have to take their responsibility for the take-back and treatment of 'end of life' equipment. Some fears of free-riding were presented, but respondents also believed that voluntary measures could be successful, e.g company-specific recycling systems. At the time the group discussions were held (1996 and early spring 1997), there was no signs of impending legislation from Finnish authorities or the EU. Some working groups and pilot projects had been established, but the work was proceeding slowly as the product group is so large and the problems complex.

Summary of the 'product chain' developments in electrical and electronic products

Public awareness of environmental issues has only recently arisen in relation to electrical and electronic products. Customers consider the product group environmentally sensitive, but lack knowledge on what aspects to look at. Generally accepted environmental criteria for electrical and electronic products are still lacking. As the products are complex, it will probably take some time for these to emerge, and it is still difficult to articulate these criteria in a simple way.

The driving forces in environmental product development are indirect and include the general public opinion, subtle pressure from the authorities, and expectations of future customer demand. Producers consider environmental issues to be of growing competitive importance. The small segment of customers (mostly 'business to business' customers and the very small segment of environmentally aware consumers) who do express a demand for environmental information and improvements are seen as the fore-runners of the environmentally conscious generation of customers of the future.

Trade and organisational buyers have an increasingly important role in formulating the product range available to the consumer, as well as in supplying information about products and their characteristics to the consumers. The integration of environmental aspects into these roles and responsibilities is only just starting. Mostly, environmental activities amongst retailers are currently limited to store level activities, such as packaging reduction or 'end of life' equipment take-back services. Using environmental criteria in product range decisions is still a new idea for the trade.

There is a lack of both supply and demand of environmental product information. Very little quantitative environmental information is collected in the life cycle of electrical and electronic products, and supply chains are long and complex. Manufacturers often find it difficult to obtain information on the material contents of components from their suppliers. Standardised environmental data forms could help both manufacturers and suppliers to give and acquire information. But even if very detailed information were available to product manufacturers, the real challenge is to forward it from manufacturers to customers in a understandable way. If the information is too detailed or technical, it is difficult for customers to interpret and integrate it with their other product selection criteria.

- Environmental product improvements driven by 'business to business' customer requirements, expectations of future customer demand and subtle pressure from authorities
- No clear consensus on environmental priorities in the product group
- Environmental awareness of ordinary consumers (households) still weak in product purchasing decisions
- Trade has an important role in formulating the product range and supplying information
- More specific and standardised environmental product information needed (eg. material contents)
- Environmental information is difficult to assimilate in relation to technically complex products: there is a challenge of communicating environmental improvements effectively to customers
- Role of environmental labelling is still vague in the market
- Draft legislation on extended producer waste responsibility will increase co-operation in the product chain: producer responsibility → shared responsibility.

Figure 2: Summary of product chain developments in electrical and electronic appliances.

Environmental labelling might be one solution to this problem, but very few appliance manufacturers have applied for the EU or Nordic Swan environmental label, although criteria for many products have existed for quite a few years. Instead, some other labels, such as the US EPA Energy Star and TCO '95 labels are widely in use. One reason for this may be that manufacturers only use the labels that important customers require.

Organising take-back and recycling of 'end of life' equipment will be a real future challenge for this 'product chain' given a potential EU Directive. The aim of EU draft legislation is to extend producers' responsibility for 'end of life' products, but practical solutions will probably be based on shared responsibility, with consumers, trade, manufacturers, communities and waste processors each having their own responsibilities. However it is likely that the costs will be borne by the producer and passed onto the customer through higher prices. But it is still very unclear how this co-operation will be organised in Finland.

The following list summarises the main developments in the 'product chain' of electrical and electronic appliances.

Implications of 'product chain' thinking for product development and design

Concrete environmental information is needed

Customers lack real facts or issues such as energy consumption, product composition or waste management instructions. This makes it very difficult for them to select environmentally sound products. Consumers should be more effectively informed on why it is worth buying environmentally sound products. Product development should establish systems to gather information on the environmental loadings of materials and components used in products (together with purchasing) and communicate it in an understandable format to customers and other 'downstream' stakeholders (together with marketing).

Other stakeholders in the 'product chain' (for example, repair service providers and recyclers) also need environmental product information. One way of spreading information in the 'product chain' is to attach an 'environmental specification' to the product (Kärnä 1997). The specification should answer questions that are frequently asked from manufacturers (see Figure 3).

Co-operation is needed

However good the eco-improvements that designers make to products, their potential to reduce environmental impacts is usually contingent on the behaviour of others. For example, marking plastics parts by type to facilitate recycling is useless if 'end of life' appliances are not collected and dismantled for recycling. Energy-saving features do not save energy if they are not used correctly. Worst of all, an environmentally improved product may fail in the

- Material contents of the product:
  - amounts of different materials
  - environmentally hazardous substances
  - reusable and recyclable parts and materials
  - are recycled materials or reused components/parts used in the product?
- Products' energy consumption
- Instructions for repair and maintenance
- Instructions for 'end of life' product take-back

Figure 3: Information for 'product environmental specifications'

market, making the whole effort useless.

Selecting key issues for environmental improvement still requires value choices, although there are many LCA and other tools for product development. Furthermore, 'trade offs' have to be made between environmental and other product requirements. To increase the credibility of the solutions chosen, the valuations made in product development should be opened up for a wider stakeholder debate. This is in line with recommendations to engage stakeholders in companies' environmental management systems (eg. Welford & Jones 1995).

PCM may help product developers to understand the needs of important stakeholders and secure success for the measures taken. There are,of course, different ways of being involved in the 'product chain' and gathering and spreading information. This information allows product developers to compare their own views with those of other actors, and gives direct feedback from product users and other stakeholders.

Product chain management is a stepping stone toward sustainability

Some day, maybe rather soon, we have to go beyond incremental product improvement and radically rethink the way clients' needs are provided for. Such innovative leaps cannot usually be achieved within the constraints of a single business firm (or a single function within that firm). Truly sustainable solutions will require large adaptations from all sectors in society (Jansen 1996). Sustainable technology development is an even broader concept than PCM, involving the scientific community, policy makers and other stakeholders in society. PCM provides firms with a stepping stone towards sustainability. •

Design for environment (DFE) or eco-design →

Product chain management →

Sustainable technology development

Figure 4: PCM as a stepping stone to sustainable technology development.

Footnotes

1. The study included four different product groups: detergents, clothing and textiles, electrical and electronic appliances as well as paper products.

2. Twenty two respondents participated in four focus group discussions on electrical and electronic products (10 consumers, 5 trade representatives and seven producers' representatives). Consumers were chosen from the Consumer panel maintained by the Finnish National Consumer Research Centre. The retailers' group included owner-retailers, buyers for retail chains and one import agent. Manufacturer respondents were product designers and marketing managers in companies which produced eg. personal computers, television sets and monitors, mobile phones and large household appliances.

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Automated disassembly support tool – a knowledge-based support system for disassembly of television sets

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One of the keys to improving the recycling process for electrical products lies in the ability to achieve semi-automated disassembly. However, for most existing products this is difficult because exact product data is not available. Mitsubishi Electric is building a trial plant for the disassembly of domestic electrical appliances, and this paper describes a knowledge-based disassembly support tool which attempts to overcome problems due to the lack of product data. A database built up by analysing previously disassembled television sets is accessed in real-time by the support tool; statistical analyses of the data are carried out to infer unknown dimensions and other values for the products to be disassembled; these parameter values are then used to guide the disassembly process. It is expected that the results of the trial plant will provide valuable information for designers and developers so that the 'end of life' stage of next generation of electrical products can be optimally designed.

Introduction

Problems related to the disposal of discarded consumer electrical products are becoming significant for all sections of society. For manufacturers, there are several reasons for becoming involved in product recycling and, or disposal: legislation is being introduced requiring manufacturers to shoulder greater responsibility for used products; as consumers become more environmentally aware, ecological or 'green' products are becoming necessary in order to stay competitive; and in some cases simple economic advantages, such as the reuse of materials or parts, can be realised by efficiently recycling old products.

Recently, environment-related legislation has been introduced in Japan requiring electrical appliance manufacturers to co-operate with local authorities in finding solutions to disposal

Compared to Europe where most disassembly is carried out manually, the projects currently being undertaken in Japan are attempting to automate the disassembly process as much as possible and to investigate whether such an approach is economical.

problems. In 1992, four home appliances (television sets, refrigerators, washing machines and air-conditioners) were designated as 'special items' due to the quantity discarded every year and also due to the environmental hazard they pose, and in 1994 a law was enacted placing responsibility for disposal of large television sets (25 inches screens or larger) and refrigerators (250 litres or larger) with the manufacturer. This law will be extended to cover all sizes of the four home appliances listed above and will be implemented in the year 2000. Japanese electrical manufacturers are now investigating how best to prepare for this scenario.

Over the last few years, Mitsubishi Electric has become involved in various projects dealing with the disposal of electrical products, and is working with other companies to develop recycling strategies within the Government-sponsored Association for Electric Home Appliances. Results of existing trial disassembly plants are being studied and plans are underway for another plant. Compared to Europe where most disassembly is carried out manually, the projects currently being undertaken in Japan are attempting to automate the disassembly process as much as possible and to investigate whether such an approach is economical. The reasons for this include an awareness that disassembly is an unattractive task for human workers due to dirt, dust, odours and dangers posed by broken items, in addition to the high cost of human labour.

As part of the research into automated disassembly, the application of data and knowledge bases is being considered. Knowledge-based techniques are used to facilitate the application of information collected concerning items to be recycled. One trial project was undertaken in 1996 to build a support tool for the semi-automated disassembly of discarded television sets. Using data collected over a 6 month period, a Computer Aided Disassembly software tool (CADIS) was developed and tested. Although the tool is presently only being applied to the disassembly process, plans include its application for gathering feedback information to aid designers in the design of new products.

This paper firstly describes some issues in the overall disassembly task, pointing out the merits of, and the difficulties associated with automated disassembly. The type of knowledge needed for disassembly, whether manual or semi-automated, is outlined, as is the manner in which disassembly differs from conventional assembly. The knowledge required for disassembly of television sets is then discussed, before detailing the strategy used in the prototype tool, CADIS. This strategy shows how a limited amount of data collected from old television sets can assist in certain disassembly tasks. The results of tests used to evaluate the tool are outlined, and the contribution of this work to design for 'end-of life' is discussed. While this project was not carried out in a design context, the strategy used

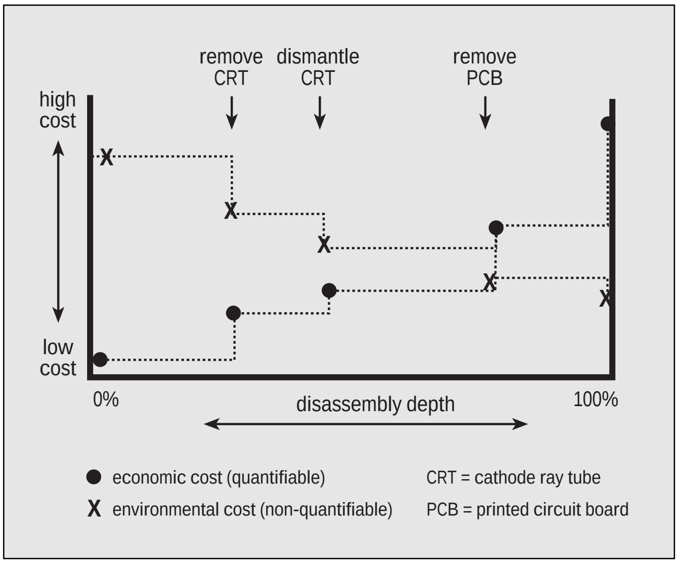


Figure 1: Disassembly depth versus economic and environmental cost

to solve the disassembly problem and the results of the disassembly process can provide impetus and direction for designers.

Disassembly issues

In contrast to much of the published work on disassembly (Jovane et al, 1993, Zussman et al, 1994), the work described here is a hands-on attempt to solve problems as they exist today. Though the 'end of pipe' approach described here is ultimately less desirable than a comprehensive 'Design for environment' (DfE) strategy, for the foreseeable future various 'end of pipe', ad hoc methods will be necessary to cope with existing products.

Disassembly depth

A major issue is to what extent should disassembly be carried out, ie. should the aim be to disassemble all parts of the appliance, only large parts, easily removable parts, valuable parts, hazardous parts, etc. or some combination of these? The extent to which disassembly is carried out is referred to as the disassembly depth. Figure 1 illustrates general cost trends for the disassembly of a television set, simplified to show how costs vary with three disassembly steps – removal of the cathode ray tube (CRT), dismantling of the components of the CRT, and removal of the printed circuit boards (PCB). Comparing or attempting to balance environmental and economic costs is difficult and decisions will often depend on national or regional constraints, but the generic nature of the graph will usually be the same.

In considering the optimal depth of disassembly, dismantling steps which dramatically decrease the environmental cost are given priority, eg. toxic materials should be separated even if the economic cost is high, because if they are not separated, the environmental cost will be unacceptable. Similarly, if the dismantling of certain parts is very difficult, the economic cost may not justify their separation for medium environmental cost. Referring to Figure 1, normally the selected disassembly depth would be represented by a point on the horizontal axis far enough from the zero disassembly point to include disassembly or separation of major hazardous parts (eg. CRT), but not so far as to include disassembly or separation of parts which are difficult and therefore expensive to remove, eg. all cables or screws.

Generally, disassembly will proceed while the economic cost steps are not too large and the environmental cost steps are significant. While some recent DfE tools (Boothroyd and Dewhurst, 1996; Navin-Chandra, 1994) enable detailed analyses of economic and environmental costs, in the case of existing appliances such precise analyses are usually not required for making disassembly decisions, since the important costs and physical parts are obvious, and decisions can be taken using this information.

Manual versus automated disassembly

At present most dismantling is carried out manually, which tends to result in high economic costs. As a consequence of this, only minimal disassembly is carried out. The key to improving the disassembly process lies in automation. Where machines can carry out disassembly, expensive manual labour can be reduced, and dangerous and monotonous work by human workers can be avoided.

A human will normally use two sources of information in carrying out a disassembly task:

· Real-time, ad-hoc information obtained from the senses, permitting reactive planning. With machines, this is equivalent to information obtained by sensors.
· Knowledge or expertise about the product, permitting predictive planning. With machines, this is equivalent to information contained in data or knowledge bases.

Work on the CADIS system considered only the second of the two information sources, ie. how to effectively utilise knowledge or stored information about a product. The objective was to reduce the need for expensive sensors as much as possible by providing back-up support information.

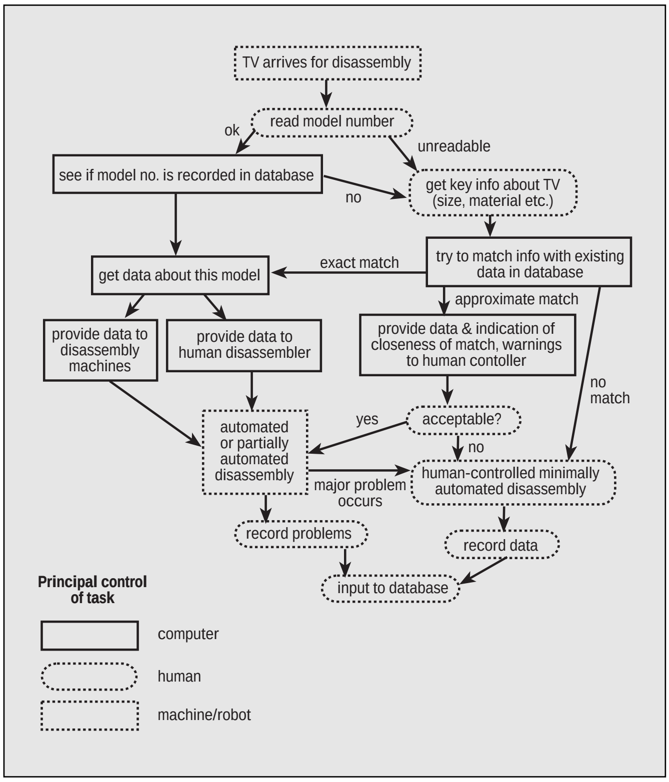


Figure 2: TV disassembly flow diagram and task distribution

Disassembly versus assembly

The disassembly process is not simply the reverse of assembly for the following reasons:

· The detail and precision of automated assembly machines cannot be justified for disassembly because the price of a dismantled product is usually only a small fraction of a newly assembled product.
· In any case, expensive automated assembly machines are not required, since the required specifications for the disassembly of old products are not strict compared to those of new products, eg. it may be possible to break off certain parts rather than unscrew them.
· The detailed design information available for the assembly of new products usually cannot be easily obtained for old products which are about to be disposed of.
· Due to the economic restrictions referred to above, many different models and variations of a product must be disassembled in the one location using the same automated disassembly tools or machines, ie. a high level of flexibility is required.

With these considerations in mind, research into the automation of the disassembly of domestic electric products was undertaken. This paper describes how databases of product data and an associated knowledge-based support system can assist in the realisation of semi-automated disassembly of old television sets.

Research strategy

Appliance manufacturers have not systematised or maintained data on electrical products over the last 20 years. While the model numbers given to each product type may have been systematically selected to some extent in particular companies, in general the methods of selecting model numbers have changed over the years and often they were selected arbitrarily, eg. the 'inch size' often appears in TV model numbers, but the other letters and figures are not consistently selected. Thus very little or no product data exists for most current electrical appliances.

The initial work carried out in this project involved organising product data which had been laboriously collected from about 150 dismantled television sets. Analyses were then carried out to determine which data were useful in guiding disassembly. Software was written to extract information on trends and relationships among the data, and the results were utilised to estimate unknown parameters to enable semi-automated disassembly to be achieved.

The following specific issues were considered:

- *What data or information is useful?* The data or information considered useful for disassembly of television sets includes dimensions and locations of all major parts, types of connections holding the parts together, and types of part materials. For the initial prototype of the tool, the following specific parts and part-groupings were dealt with:
  - rear cover (or casing)
  - cathode ray tube (CRT)
  - electron gun
  - remaining parts (printed circuit board, cables, front cover, etc.)

  Thus, the disassembly depth was determined beforehand by human decision. Since the economic value of the main parts and their impact on the environment is known, a detailed analysis to determine the disassembly depth was not considered necessary.
- *How should data be represented and stored?* Data and information are stored in relational databases which were built up by analysing and measuring old TV sets. For the present prototype this level of data and knowledge representation was sufficient, but for further development of the system, more powerful representation formalisms will be necessary, eg. object-oriented databases, representation of rules, etc.
- *Which type of algorithms and reasoning should be used in the software programmes?* The programs are used to detect patterns in the collected data. Approximate reasoning strategies are then applied to infer values for unknown TV dimensions. These points are outlined in more detail in the next sections.

Disassembly support software tool

This section describes the Computer Aided Disassembly software tool (CADIS) developed to provide assistance in the disassembly process. Figure 2 shows the disassembly flow diagram for old TV sets and indicates the tasks to be undertaken by computer, machine and human. CADIS carries out the computer-controlled tasks. As shown in the flow diagram, two scenarios are possible:

- The TV model number is readable and is already recorded in the CADIS database. In this case, CADIS simply accesses the data corresponding to the model number and reads the data relevant for disassembly. Information to assist removing the casing (the best location for cutting open the casing), the dimensions of the CRT, the type and location of CRT screws, etc. is provided automatically to guide the disassembly process. In the current prototype, the information is displayed graphically with pull-down menus available to view the information numerically.
- When the model number of a TV is unreadable or is not found in the database, more detailed information describing the TV must be input to CADIS using an interface as shown in Figure 3 (ie. the overall dimensions of the casing, the dimensions and position of the CRT screen, the name of the manufacturer, the year of manufacture and the casing material type). An algorithm searches the database and carries out a statistical analysis to provide estimated information to assist in the disassembly. This information is then output in graphical and numerical form.

Figure 4 summarises how CADIS assists the disassembly process. At present CADIS is not connected directly to the disassembly line and requires human input and transfer of data, which is output through the user interface.

Estimation of unknown product data using database statistics

A model-based matching approach was initially tried – each TV recorded in the database is regarded as an individual model, and the strategy entails searching the database for the TV model judged to be closest to the current TV to be disassembled. However, this approach has the major problem of deciding which criteria should be used to judge closeness, eg. TV sets may resemble one another in external size but not in CRT dimensions, or in year of manufacture and manufacturer but not in material or style.

Rather than employing such a model-based strategy, a more detailed parameter-based approach is used. Parameter values, such as dimensions, material types, manufacturer name, etc. of a TV to be disassembled are compared to database values of corresponding parameters, and the closest match is found.

The CADIS prototype estimates where the TV casing should be cut (in semi-automated disassembly, cutting the casing open is more feasible than unscrewing), the position and type of the screws which fix the CRT to the casing, and the size and position of the electronic gun.

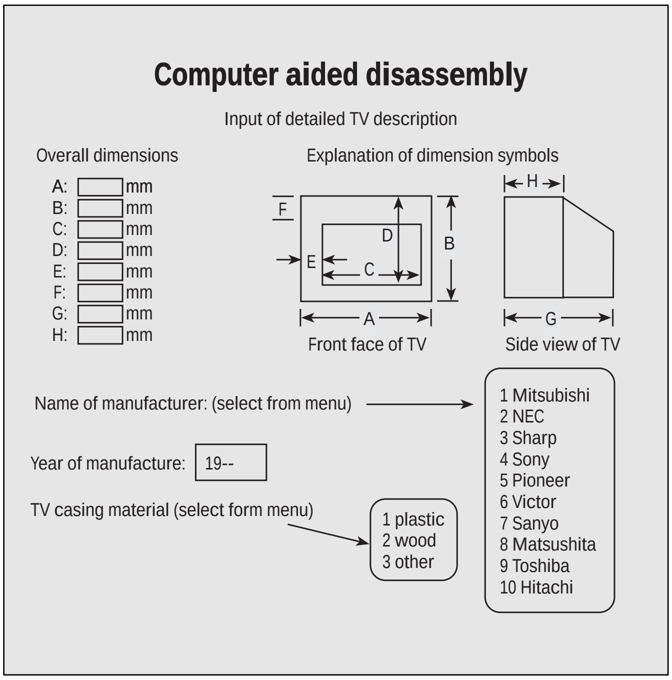


Figure 3: Detailed input window

Although this data is only approximate, exact accuracy is not required, since sensors are used to hone in on the exact positions.

Destination of recovered materials

The goal of the disassembly is to separate the CRT and the PCBs before treating them and the remaining parts according to whether they will be recycled or disposed of. The CRT is built up of panel glass on front and funnel glass behind. These are separated before detoxification of the lead-containing funnel glass takes place. After cleaning and crushing, the glass can be returned to the manufacturere for recycling.

The PCBs are crushed after being removed. They undergo dry distillation through fuel extraction and treatment of the metal-plastic mixture. Between 10 and 20 grams of solder, an alloy of tin and lead, is used in each PCB in a television sets. These two metals are valuable materials with a usable life of 22 to 23 years. Moreover, lead is designated as a toxic industrial waste with strict treatment control. The solder recovered from the PCBs is refined and re-used.

The TV casing and remaining items are crushed before metal and plastic material recovery takes place using various separation techniques.

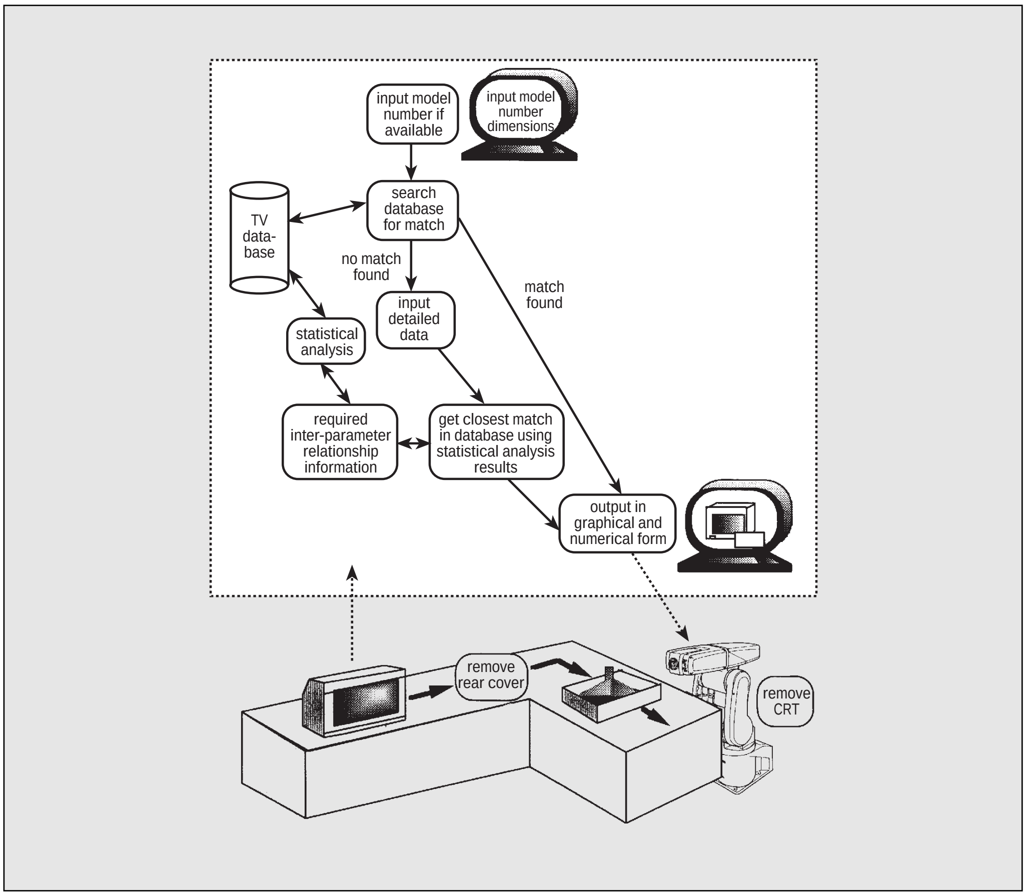


Figure 4: Schematic of Computer Aided Disassembly guidance system

Testing and implementation

Since the trial disassembly line is not yet built, tests have been confined to using the data collected from old TV sets. Where a tolerance of +/- 15 mm is acceptable for initial positioning of the sensor in determining CRT screw positions, CADIS accurately predicts values for 90% of a sample of 145 TV sets. Using this initial position information, detail-level sensors can hone in on the exact screw centre to enable automated removal of the screws.

In general, however, it should be pointed out that even with good approximations or in the rare case of an exact match between the current TV model number and one in the database, problems may occur due the condition of TV, mistakes in database, etc. These are recorded by the human controller for entry into database, to help prevent similar situations re-occurring.

The output from CADIS includes a graphical 3D representation of the TV casing as a wire-frame and a solid CRT which can be viewed from any angle and can be magnified when required. The graphical user interface is built using the I-DEAS Master Modeller of SDRC Corporation. Figure 6 shows typical graphic output. The CADIS prototype runs on a Sun SparcStation 20.

Implications for product design and development

The disassembly support tool described here has been built to facilitate the recycling of products which were initially designed with no consideration for ‘end of life’. Thus, the approach is ad-hoc and only the automation of certain parts of the disassembly process is being attempted. However, other benefits can be obtained to assist designers and developers. It is expected that the implementation of the trial disassembly plants and the application of tools such as CADIS will provide valuable feedback for designers of new products. Such feedback will include information on the following:

- areas where standardisation of product parts and sections is most desirable, such as screw types and locations, connections, and materials
- desirable types of connections and fastenings – which connection types are amenable to automated dismantling
- how product data should be stored – whether bar-coding or chip implant, etc.
- which product data should be stored to facilitate ‘end of life’ treatment, dimensions, materials, etc.

An important issue not yet tackled is how to gather this feedback information. Future work on CADIS will consider how to automate the acquisition of information and data obtained during the disassembly process. This knowledge acquisition process is not only aimed at gathering feedback information for design, but also at updating the database in order to improve the disassembly process. Ultimately, it is hoped to develop a general knowledge repository for information and data about electrical products. A store of knowledge is necessary because the size of a dismantling project will be beyond a single human expert or group of experts.

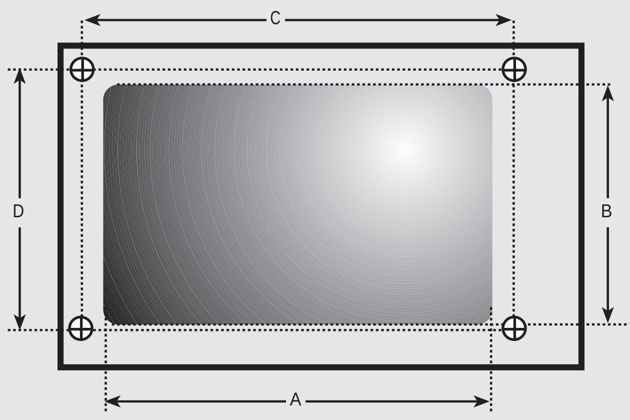


Figure 5: Estimation of coordinates of CRT screws from external screen dimensions

Conclusions

The computer aided disassembly support system, CADIS, described here is primarily intended to permit partial automation of the dismantling of old television sets. Secondary aims include the application of the methods to other electrical products and the gathering of knowledge to aid the design of new products.

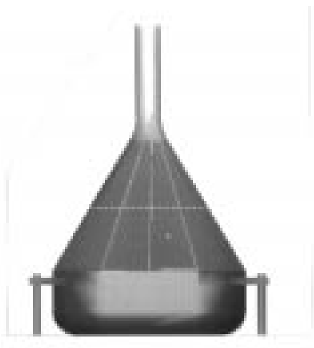
In the disassembly process, CADIS is intended to complement, not replace sensors, since the information it provides is only approximate. However, such estimates can obviate the need for large scale sensors, by giving initial position information for detail-level sensors. And in situations where approximate information is sufficient, such as a desirable location for cutting open the TV casing, the output from CADIS can replace sensors and human control.

The intention in this work was also to utilise as effectively as possible the limited amount of data collected from old TVs. Although collecting such data is time-consuming and laborious, and only a relatively small number of items can be analysed, it proved a valuable source of information about products for which no data were available. The project enabled approximate but nevertheless useful information to be obtained from the small data set, which could be applied to any TV that arrives for disassembly.

Figure 6: Graphical output from CADIS showing views of cathode ray tube inside TV casing

a) 3D view

b) Rear view



b) Side view

On a larger scale, problems still exist regarding the logistics of electrical appliance disposal – how to collect and transport old TVs, and how to achieve a practical balance between automated and manual tasks. Furthermore, while the automation of disassembly is aimed at reducing overall costs, it is difficult to determine precise cost data without actually carrying out trials with the system. The trial plants in operation and being planned in Japan at present depend on state or industrial funding, and their economic viability without such funding is doubtful. Thus the role of these trial plants and proposed disassembly support tools such as CADIS is one of pointing out directions in which to proceed, proving (or disproving) cost estimates, and providing data for design of future products. •

Acknowledgements

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‘Greenfreeze’ – the CFC and HFC free refrigeration technology

Greenpeace, Germany

Greenfreeze production line in Kelon factory, China
© Greenpeace/Hindle

Greenfreeze is a chlorofluorocarbon (CFC) and hydrofluorocarbon (HFC) free refrigeration technology in which propane and butane are used as coolants and cyclopentane is used for insulating foam. The environmental organisation Greenpeace has promoted and pioneered the use of Greenfreeze refrigeration, which was first developed by the Foron company in Germany. The technology is now being used by a growing number of large manufacturers of refrigerators such as Bosch Siemens. The primary market is Europe. Factories using Greenfreeze are opened or scheduled to open in Many European countries, Australia, Argentina, Turkey and Russia. The largest manufacturer is in Kelon, China and produces 1,000,000 Greenfreeze fridges per year and plans to convert more to this technology.

During the tenth anniversary meeting of the Montreal Protocol in September 1997, Greenpeace received a prestigious award from the United Nations Environment Programme (UNEP) for its work in promoting ozone and climate-friendly refrigeration.

For further information contact Doug Parr, Greenpeace UK on +44 171 865 8240.

Dr Freisendanz, developer of the cooling method, with a prototype of the Foron fridge
© Greenpeace/Scharnberg

Ozone-safe fridge produced by ddk Scharfensteln GmBH, Saxony, Germany
© Greenpeace/Scharnberg

Kelon factory, China
© Greenpeace/Hindle

'Biopac' – starch based packaging

Franz Haas Waffelmaschinenfabrik, Austria

The starch packaging 'Biopac' is manufactured by Franz Haas Waffelmaschinenfabrik. This company usually produces wafers but, following a lengthy research project, applied its experience in heat technology to finding an alternative biodegradable and edible material to plastic packaging. The ingredients of this starch based packaging is potato starch (80%), water (11%), modified cellulose (4%), oils (3%) and thickening agent (2%).

The basis for the successful use of starch based packaging is found in a variety of applications such as cups and saucers. These have been made to be water resistant and heat retaining by coating them with a soya and egg white mixture. The Biopac material is being used by companies such as the large furniture chain IKEA in their restaurants, the fast food chain McDonalds (Austria) and the Swedish national airlines, as well as at major international events where disposable cups, saucers, cutlery and crockery are used in huge quantities. The benefit of this packaging is that it can be mixed and dried with the food leftovers and subsequently sold as cattle food. This way, the use of edible packaging material is made financially feasible.

Biopac has been used in a variety of packaging applications including trays for the transporting of chemicals and pharmaceuticals, creating a biodegradable alternative to the PET trays normally used for such applications.

The Biopac information was compiled by Frank Wuggenig and adapted for publication from his Design Management degree thesis entitled 'Good Enough to Eat? The Scope and Possibilities of Edible Packaging' (The Surrey Institute of Art & Design, UK, July 1997). For further information contact Frank Wuggenig on +44 181 390 7682.

Ralph Earle III, Director, Alliance for Environmental Innovation, US

Martin Charter

Joint coordinator, The Centre for Sustainable Design, UK

Prior to joining the Alliance for Environmental Innovation, Ralph Earle spearheaded Arthur D Little's development of its consulting methodology on Competetive Environmental Strategy. An associate director in the firm, he received Arthur D Little awards for Innovation, Staff Development, and Marketing. He has also served as Assisstant Secretary of Environmental Affairs for the Commonwealth of Massachusettes. Mr Earle serves on the Advisory Board for the University of Michigan Corporate Environmental Management Programme, the Board of Directors of the Environmental League of Massachusettes, and the Board of Directors of the Dimock Community Health Centre. He hold a Master's Degree in Public and Private Management from the Yale School of Management and a BA, cum laude, from Harvard College.

What do you think will be the key drivers for sustainability within business over the next five to ten years?

The first will be a resource scarcity. It has been talked about for sometime but really has not come to pass yet. I think the fact that the world got together at Kyoto and developed an agreement to reduce emissions means that there is some broad based international recognition that resource scarcity will be a reality. I think that it will probably effect the developing world more than it will effect the developed world since their need for resources in the short-term will be greater as they are trying to transform their economies. In the North, we are now well down the eco-efficiency learning curve.

Number two is customers. Greener customer demands, especially in Northern Europe, are already a fairly well developed phenomenon and this is forcing companies to develop environmentally friendlier products. Competition will drive companies to pursue 'green' issues as fundamental to their business strategies. However, thinking more broadly the greening of 'business to business' markets in North America is extremely vibrant. This is primarily because, unlike most individuals, business's pay for the cost of their pollution whereas individuals have not been asked to pay that bill yet. So I think that the 'business to business' market is more dynamic, in terms of recognising the fundamental economic possibilities of offering sustainable solutions.

Third is government intervention which is a somewhat awkward way of driving towards these goals.

Do you see sustainability as still being defined in environmental terms or as including a wider social or ethical agenda?

I think that this is an important and complicated set of issues. In North America, many companies tend to lump these issues together and typically handle them outside core business functions. Environmental issues tend to be easier to quantify, so there is a greater willingness to tackle some of these compared to the much thornier details of what wages should we pay in South East Asia. When you are dealing with the global economy, there are some highly diverse cultures and different economies, so considering social and ethical issues is very, very tricky.

In the next five to ten years, I think that the economic and environmental aspects of the debate will be greatly advanced, but social issues will be at a similar stage to where the environment debate is today. The Montreal Protocol was a precedent in the environmental field and that is really one of the more transformational agreements that the world has achieved to date. However, there is yet to be a Montreal Protocol covering social issues, I think the debate needs that kind of push. What is clear is the difficulty of quantifying and recognising different social aspects. It is now fairly easy to objectify environmental performance ie. either you have emissions or you don't. The basic conclusion is that the softer issues are much more subjective but we need some simple tools just to enable us to perceive what cultural, social and ethical issues. The investment community, in particular, is extremely uncomfortable with issues that are difficult to quantify.

This is not my expertise but my sense is that there is a mix of different concepts in companies, environmental health and safety, corporate social responsibility, ethics, and corporate governance and, if you start to link all of these concepts together you are moving forward on the business sustainability agenda. However, we are now expecting businesses to play a different game. Companies exist in a capitalist economy with the primary objective being to provide a return to its shareholders. We are now asking business to get involved in social policy formulation which is not something that they were originally set up to do. To broaden the sustainability agenda we need a wider consensus on these issues that translates to public and private policies.

In terms of environmental sustainability, how do you see the issues being operationalised in product development and design?

First of all I think that the people who are effectively implementing change are articulating the benefits of sustainable products and services to their stakeholders, not in sustainability terms but in business terms. This may include the words sustainability but it may not. What we are trying to do is to push the concepts of sustainability by effectively thinking through what it means for a particular organisation and then focusing on where the greatest demand for environmental effort within the company should be. The issue is how do we then articulate the sustainability question in terms that business will understand and act upon. The broad task is that if we don't believe that there is a good business argument there, we are unlikely to be able to convince the company.

The second is understanding the 'decision-making fabric' of companies, as every company has a particular decision-making culture. In some companies it is finance, others it is marketing, product development or distribution or logistics. We need to understand what the real drivers for decision-making are within the company? How did the CEO get his or her job? What are the values that underlie the way you get ahead in that company. So you need to answer the business argument, and then you must articulate the answer in the terms that the 'business user' makes his or her decisions. So you don't try and redirect the company in a kind of a pioneering way, it is more of a flanking strategy.

There are companies in the consumer products world that are product 'leaders', they are the ones first to market with the new floor cleaner or the new pesticide. Secondly, there are companies that are 'followers' who are good at reverse engineering products. You are going to make a very, very different argument for sustainability in a 'product leader' company versus a 'product follower'– as the way that they are likely to contribute to sustainability will be fundamentally different. The 'leader' would develop an eco-efficient product and the 'follower' would take an existing eco-product and then make it more eco-efficient.

Could you explain some of the projects you are involved in, and some of the key lessons learnt in eco-efficient product development?

We use the words 'environmentally preferred' because we are really talking narrowly about the

Most companies don't like to change the way they make decisions overnight. So learn hard, think hard and work hard to understand how the company makes decisions.

environment, we are not addressing the broader social question. Our first project is with Johnson Wax who are trying to integrate environmental considerations into the very fabric of their product policy. We are taking their existing product development approach and injecting eco-thinking into their process through individual participation and persuasiveness. We are also working on the development of strategies and metrics to make the system replicable throughout Johnson Wax's other product development processes.

The second project is with Starbucks Coffee which is roughly a billion dollar company that has focused on the provision of European coffee. They are opening roughly a store a day, and are growing at about 40% a year. Historically they have used two cups because their coffee is served quite hot. We are working with them to achieve two objectives: use more reusable cups as opposed to disposable ones; and to re-design the disposable cup. It is quite a specific example of 'environmentally preferred' product design. An interesting dilemma for the company and designers is how to integrate 'form and function' and reduce environmental impact at the same time.

The first major lesson learned from these projects is the need to articulate the decisions in the way the company already makes decisions. Problems occur when you try to get them to adopt a new decision-making framework, especially if you are an external environmental organisation. Most companies don't like to change the way they make decisions overnight. So learn hard, think hard and work hard to understand how the company makes decisions.

Secondly, it is essential to understand the 'bottom line' impacts from day one. Doing 'environmentally preferred' product development may be a philanthropic social exercise within the company but your ability to succeed both with instant 'wins' and in the longer-term will depend on the project's ability to generate 'value' for the company. So observe, understand and be creative in articulating the business management benefits very early on.

Thirdly, we have learned a lot of lessons about our whole operations in particular, how to manage 'NGO: business partnerships'. •

Ab Stevels studied Chemistry at the Eindhoven University of Technology and, after being employed at Philips Electronics Eindhoven in 1966, he received his PhD in Physics and Chemistry at the Groningen University, the Netherlands. In 1969 he joined the Philips Research Laboratories and worked on various subjects in solid state chemistry and materials science, then as a glass technologist, laboratory manager, head of development and general manager of the Optics business. In 1989 he was transferred to the Consumer Electronics division and since 1993 he has been senior advisor on environmental engineering of Philips Consumer Electronics. In 1995 he was appointed part-time professor in Environmental Design at the Faculty of Industrial Design Engineering, the Delft University of Technology, the Netherlands

Arjen Jansen is Assistant Professor at the Faculty of Industrial Design Engineering at Delft University of Technology since 1994. His research subject is Human Powered Energy Systems in Consumer Products. In addition to his teaching activities in Engineering and Design, he is responsible for the popular IDEContest. Arjen Jansen graduated in 1988 at the Faculty of Industrial Design Engineering and has working experience both as freelance industrial designer and design consultant and as project engineer in various international companies.

Renewable energy in portable radios: an environmental benchmarking study

Professor Ab Stevels and Arjen J. Jansen

Professor and Assistant Professor at the Faculty of Industrial Design Engineering, Delft University of Technology, the Netherlands

This paper presents the results of an environmental benchmarking study of four portable radios, two of which are powered by an alternative system, and the others are powered by batteries. The study shows that there is considerable room for the improvement of both electronics and (human powered) alternative energy systems. It also indicates an interesting environmental 'trade off' between the use of batteries and alternative energy sources. The analysis is the initial result of a research project at Delft University of Technology (DUT) on the subject of 'human powered energy systems in consumer products'. Ongoing research on this subject will focus on the analysis of physical constraints of the human body, new systems for converting human power into electricity, possibilities for the application of these systems in consumer products and assessment of the environmental consequences.

Introduction

At the Department of Engineering Design of the Faculty of Industrial Design Engineering, research within the Technical Product Analysis group (TPA) concentrates on the technical analysis of products, particularly addressing the environmental aspects of product design.

Methods

Four radios were 'environmentally benchmarked' using a methodology developed by the TPA, and utilising the EcoIndicator 95 value [Goedkoop 95], and classification factors [Goedkoop 95]. SIMAPRO software version 3.1 [Pré consultants 95] was used for calculating life cycle analyses (LCA). The TPA method is a practical approach to gathering and analysing data on products with a similar or comparable functionality. A draft version of a manual, in which the TPA methodology is described, will be available from the authors at the end of 1997.

Ben Wessling

Figure 1 The analysed radios

Description of the analysed radios

The **BayGen Freeplay** radio is produced in South Africa and has been designed to be used in remote areas where batteries are hard to get or very expensive. The BayGen received worldwide attention because of its alternative energy system, invented by Trevor Baylis. Although the radio was not primarily designed as such, it is seen as a 'green' alternative by West-European consumers and specific environmental organisations [Benjamin 96], [Belgiovane 95]. In the analysis we focused on the 'green' perception of this radio. The BayGen Freeplay is charged manually by winding a constant-torque spring. The spring can be wound up to a maximum of 60 revolutions, average charging/winding time is 40 seconds. The required input torque is 1.66 Nm, with the total required labour input being 628 Joule. The output drum of the spring delivers a constant torque to a gearwheel transmission, which is coupled by a small driving belt to a dynamo (Mabuchi RF 500TB). Total gearing ratio is 1:904 (dynamo speed is approx. 1800 rev/min). A fully wound-up spring allows the radio to play for 30 minutes. By dividing the output at the dynamo of 162 Joule (90 mW x 1800 sec) with the input of 628 Joule, an efficiency of 26% for the total energy system is highlighted.

The **Dynamo & Solar** (D&S) radio is produced in China. It has a versatile energy system and can be powered by batteries (two penlights) or by a built-in nickel cadmium (NiCd) battery (two Varta V280R cells, capacity 280 mAh). The built-in NiCd battery can be charged by a solar panel (amorphous Si, 25 cm^2), by net-current or by a hand-powered dynamo. When winding the handle at maximum speed, the NiCd batteries are charged with 100 mA. Winding the handle at a sustainable speed, it takes about 11 hours (at 25 mA) to charge the built-in battery. The solar panel is able to charge the batteries with 0–5 mA (cloudy day) to a maximum of 48 mA (bright sunshine).

Both the **Grundig Boy 55** and the **Philips AE 1595** are small portable radios powered by batteries only (two penlights, AA/R6). These radios served as the benchmark for the analysis because they have a functionality similar to the BayGen and the D&S radio (AM/FM, portable, no use of net-current). The Grundig and Philips radios are produced in China.

	power consumption at 70 dB(A) [mW]	weight of the energy system [gram]	stored amount of electrical energy [Joule]	energy/weight factor [Joule/gram]
BayGen Freeplay	90	1670	162	0,09
Dynamo & Solar	32	68,8	2670	38
Grundig	58	33	37,0 (= 2 ZnCl	
Philips	33	batteries size AA)	10500	284

Table 1: Power consumption, weight and stored energy

Assumptions and data for LCA

The LCA is based on the assumption that the radios will be used in the Netherlands. Containers are used to ship the radios from the country of origin to Rotterdam harbour (at 0.44 mPt/tonkm). Inland transportation of the radios in the country of origin and from Rotterdam harbour is not considered. 'End of life' (EOL) data are based on the assumption that the radios will be treated as household waste. However, these EOL data do not include the electronics of the radio. Because of limited availability of data for the environmental assessment of electronics, the data used in this paper for printed circuit boards (PCBs) is supplied by the Philips EcoDesign group. A value of 1350 mPt/m2 was used for the production of PCBs. The environmental impact of the use of the radios is compared by defining the following 'functional unit':
1 hour radio at 70 dB(A) a day during a five year period. (5 x 365 = 1825 hours). This five year period is based upon estimated life time for the radios.

The battery consumption of the radios was measured by playing the radios until the batteries were exhausted. In the case of the Dynamo & Solar radio, the alternative energy system has not been used. Power consumption (see Table 1) was measured in order to compare the measured and calculated life time of the batteries. Only small differences (10%) were found between the life time test and the calculated values. The number of batteries used in the five year life cycle is an extrapolation of the average of tested and calculated battery lifetime; the Grundig radio uses 62 batteries in a five year period and both Philips and D&S use 32 batteries in the same timescale.

Studies show that the environmental impact of batteries mainly depends on EOL scenarios. In this report, the EcoIndicator 95 value for the production of batteries (0,44 mPt/battery, ZnCl, AAtype) is generated by the Philips EcoDesign group. Full recycling has been chosen as EOL scenario, assuming 1,6 mPt as EcoIndicator 95 value for EOL (source: Philips).

LCA results

In Figure 2, the results of the SIMAPRO analysis on production are presented. The high BayGen score is due to its large and heavy energy system (3,7 mPt due to steel spring) and resulting large and heavy housing, compared to the other radios (also see Figure 1). The difference between D&S, Grundig and Philips are mainly due to a larger PCB and the energy system of the D&S radio (2 mPt estimated for the production of the solar panel, 1 mPt estimated for the production of the NiCd battery).

The EcoIndicator 95 values for the total life cycle of the four radios have been calculated using SIMAPRO. The transport value for BayGen is high, due to its size and weight. EOL value for D&S is assumed as 1 mPt for solar panel and 2 mPt for NiCd battery. EOL values for Grundig and Philips are too low to be visible in the graph.

The next step is adding the EcoIndicator 95 values for production, transport, and EOL for each radio and values for the equivalent use of batteries each year. The result is shown in the graph in Figure 4.

Conclusions

The technical product analysis shows there is considerable room for the improvement of the design of radios with alternative energy sources:

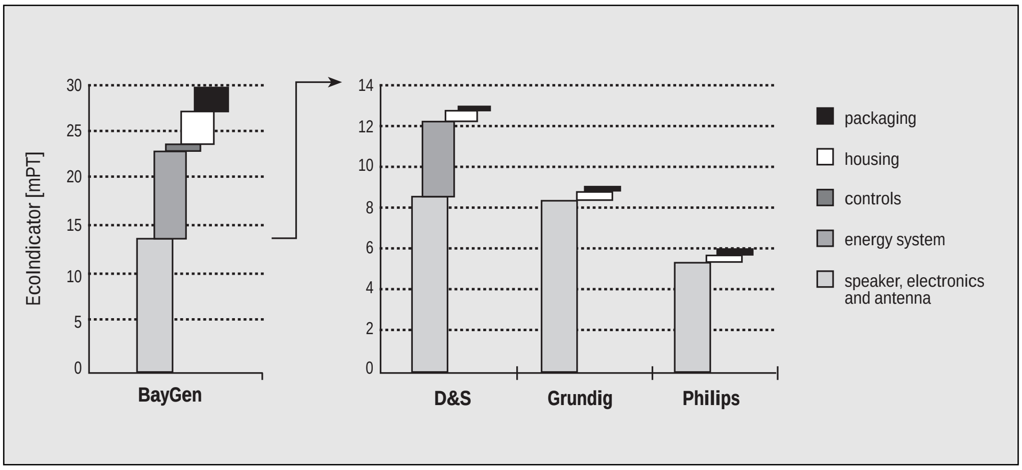

Figure 2: EcoIndicator 95 values for production. Notice that the y-axis scale has a different range for the BayGen (0–30) versus the D&S, Grundig, and Philips radios (0–14).

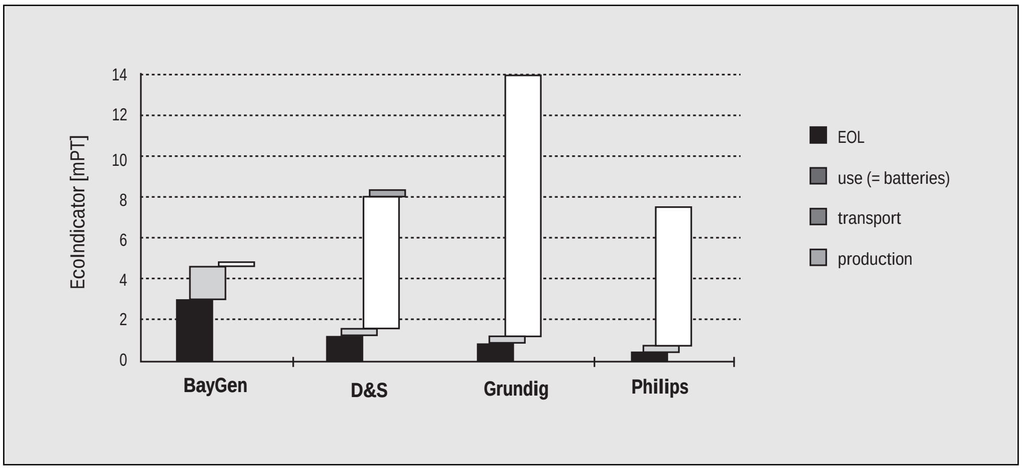

Figure 3: EcoIndicator 95 value for total life cycle of radios

- The NiCd battery inside the D&S radio cannot be taken out (unless soldered) before discarding the radio, which means that the battery will end up at a landfill or will be incinerated. Recently, products containing non-removable batteries have been prohibited in the Netherlands [Dutch Government 95].
- The improvement potential for the BayGen Freeplay consists of reduction of the size and weight of the housing, upgrading of the electronics and better packaging (no foam). This will reduce the EcoIndicator 95 value for production from approximately 8 to 10 mPt and will also affect the value for transport.
- In case the environmental load of products is dominated by the use of batteries, reduction of the power consumption has to be the first green option (also see Table 1 and 2).

When consumers consider products with energy systems other than batteries, they often conclude that the batteries will make the products 'greener'.

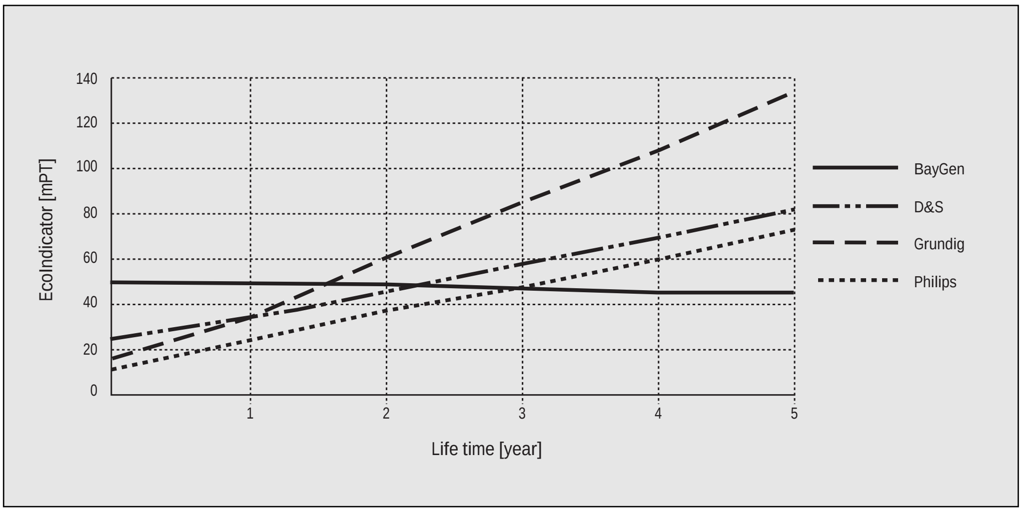

Figure 4: EcoIndicator 95 value during life time (starting point at 0–year consists of the sum of production, transport and EOL values)

This conclusion is not necessarily correct. Renewable energy systems based on Human Power may be an alternative for batteries in some products, but the environmental 'trade off' has to be watched carefully. The conclusions of this benchmarking study mainly depend on the chosen EOL scenario for batteries (in this case full recycling). Further studies should chart the effects of different EOL scenarios. •

Acknowledgements

The authors would like to thank Berno Ram, Fred Reijnen and Saskia van Leeuwen for their contributions in analysing the radios and processing the data.

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Special feature: O2 New York City (o2nyc)

Edited by Iris V. van de Graaf

O2nyc members who have contributed information include Scott Bolden, Wendy Brawer, Lewis Korn, Mark Randall, John Seitz, and Alexandra Sticher

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
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email: O2global@knoware.nl
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internet: http:www.wmin.ac.uk/media/O2/O2_Home.html

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

Eco-design update: news on eco-design projects around the world

New York Wa$teMatch

A materials exchange service called NY (New York) Wa$teMatch has been developed that helps companies save money by matching discarded industrial materials such as, wooden scrap and packaging waste with companies who can utilise these materials. Companies donating unwanted materials to non-profit organisations, schools and institutions can also benefit from tax deductions.

For further information contact Ivan Braun, Project Manager, New York Wa$teMatch
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World Studio Foundation

World Studio Foundation (WSF) is dedicated to exploring how creative professionals can integrate issues of social responsibility within their everyday professional decisions. Key issues include cultural diversity and identity; beyond the 'bottom line' policies relating to the workplace; and the environmental impact of design decisions. The Foundation's philosophy is being progressed through scholarships to disadvantaged and minority design disciplines students, mentoring programmes for 'at-risk' high school youths, and public awareness efforts to educate and inform the design industry. 'Atlas', their quarterly newsletter, provides practical tips on taking action within the workplace, market, environment and community. In addition, WSF published 'Sphere', a yearly magazine which reaches over 25,000 designers, artists, and architects. It is a forum to enable designers to discuss strategies to improve the ethical, aesthetic, and ecological standards of the design workplace. Articles range from environmentally conscious paper and wood-free plywood to Samuel Mockbee's innovative architectural work in low-income communities.

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Ecological design – manufacturing with recycled materials

Industrial Technology Assistance Corporation (ITAC) is a private non-profit organisation, working to improve the performance of small to medium-sized NYC (New York City) firms that create or produce technology or manufactured products. A number of new ITAC programmes have interesting environmental connections. For example, the NYC Design/Production Link, an Internet-based resource will allow firms to identify potential partners with specific capabilities by searching its listings of NYC designers, manufacturers, and financing sources. Users will be able to list and search in areas such as ecological design, manufacturing with recycled materials and eco-market connections.

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Bioneers

The Bioneers annual conference, took place this year from 31 October to 2 November 1997 in San Francisco. It brought together leading scientific and social visionaries who have developed practical solutions for restoring the Earth. During the conference there were 2 to 3 concurrent seminars on a wide range of topics including ecological design and architecture. The conference explored the work of the original 'Bioneers', the world's indigenous peoples, who viewed their principal duty as learning to live with the Earth.

For further information contact
Bioneers Conference, 826 Camino de Monte Rey, Building A6, Santa Fe, New Mexico 87505
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website: www.bioneers.org

O2 Focus: New York City

The goal of O2nyc is to foster environmental sustainability through design.

O2nyc provides learning and information gathering opportunities for a group of creative professionals who:

- see ecological issues as a challenging responsibility
- seek to educate and inspire people to integrate these new considerations into their daily practices
- share resources and support one another in the search for design solutions that help society progress towards ecological sustainability
- celebrate positive ideas and accomplishments.

The O2nyc website is located at http://www.hrc.wmin.ac.uk/O2/NY. The site started in 1997 and currently provides a brief introduction to the group, events and members. Updates are posted monthly on meeting announcements and upcoming events. In 1998 there is a plan to extend the site with more event coverage, images and a showcase of member's work. The site will reflect the members commitment to ecologically sustainable design and interest in helping others understand how ecological thinking can play a productive role in the way we shape our world.

'Design for sustainability' and 'environmental currency'

O2nyc recently joined forces with two other NYC groups to host an interactive design dialogue for over 70 designers of varying disciplines at 'Material Connexion', a materials library and resource centre. The Interior Design Committee of the American Institute of Architects (NYC Chapter) co-sponsored the event on 19 November 1997 in conjunction with 'Glamorous Green', an exhibition of ecological products and materials. The event was organised by Shashi Caan of Gensler Associates, who worked closely with several O2 members and George Beylerian of Material Connexion. The seminar was based on an interactive workshop developed by Scott Bolden, an O2nyc member and National Chairman of the Industrial Designers Society of America's (IDSA) Environmentally Responsible Design Section. This 'hands on' approach gave the participants a chance to acquire an understanding of the benefits and strategies of environmentally responsible design practices by engaging them in the process. 'We are trying to provide a set of useful and marketable tools for those people involved in design driven disciplines,' Bolden stresses, 'based on the concepts of "Design for Sustainability" and "Environmental Currency".'

'Design for Sustainability' refers to designing products and systems from the perspective of the entire product life cycle. This type of thinking attempts to recognise all of the potential impacts which the development, manufacture, use and retirement of a product has on the user and the environment. Performing this analysis allows design, marketing, distribution, engineering and business constituents to reduce negative eco-impacts during product development phases.

'Environmental Currency' refers to the process of identifying gaps and filling them with designed changes which improve (or have no negative effect on) overall product cost, performance, durability, aesthetic, manufacturability and energy efficiency. In this way, any embodied design changes represent improved 'bottom line' economics and performance while improving overall product sustainability.

Participants were split into four groups to explore the 'environmental gaps' in the following categories; product, lighting, interior and furniture designs. O2nyc moderators handed out a checklist of general guidelines for sustainable design developed by themselves. Each group briefly reviewed examples of design endeavours which illustrated sustainable thinking and achieved the goals embodied in the concept of 'Environmental Currency'.

The interactive portion of the exercise focused on using commonsense to examine the possible resources, energy and waste used or produced by a product during its life cycle. This type of Life Cycle Analysis (LCA) is accomplished by creating scenarios based on what we know and projections of what could happen during the following five phases:

- manufacturing
- marketing
- distribution
- use
- disposal.

To date, over 700 designers, students, engineers and architects have participated in these seminars at various design conferences including the last two IDSA national conferences.

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Green Map System

Wendy Brawer of Modern World Design has developed the Green Map System based on her original Green Apple Map of NYC's ecologically significant places. The Green Map System is a powerful tool for identifying, promoting and linking all the eco-resources in a city. This System started in 1995, and at present has 67 'Green Mapmakers' charting the places where nature and the built environment interconnect in their hometowns. The System has become truly global, with participants in 20 countries on six continents, eight of whom have already published their own Green Maps. In early 1998, the updated second printing of the third edition of the Green Apple Map will be available. Copies are free, thanks to the support of the NYC Environmental Fund and Interface, Inc.

For further information, contact Wendy E. Brawer, Director, Modern World Design
tel: 001-212-674-1631
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internet: www.greenmap.com

Solar cars

The Northeast Sustainable Energy Association (NESEA) is sponsoring the 10th annual NESEA American Tour de Sol, the nation's largest solar and electric vehicle race. The race begins in NYC. It will be organised on 7–10 May 1998 with a technical conference and exhibition. The 50 participating vehicles include production and prototype cars. New York is the only US state that has upheld the 1998 electric vehicle law mandating that 2% of any manufacturer's cars sold there must be 'Zero Emission Vehicles'. •

For further information contact NESEA
e-mail: nesea@nesea.org
website: www.nesea.org

Books

Eternally Yours: Visions on product endurance
Ed van Hinte (eds.)
010 publishers
Rotterdam, 1997
ISBN 90 6450 313 3
256 pages
£34.50

Don't attempt this book if you are looking for a practical, mechanistic guide to current best practice in product longevity. Do read it if you want to be stimulated, challenged and intrigued.

'Visions on Product Endurance' is an eclectic mix of lectures, theses and musings on the theme of product longevity and its role in sustainability. It sets out to unpack and explore this subject, rather than to attempt any conclusions or guidelines. It represents the current thinking of the Eternally Yours team – one of the very interesting groups of young designers in The Netherlands attempting to think beyond the current focus of 'Design for Environment' to completely new systems of consuming and producing.

A wide range of themes are examined; the relationship between product quality and longevity; the role of ritual; the importance of exclusiveness. There are several interesting challenges to current thinking in green design circles. For example, it is usually said that 'fashionable designs' will be less likely to meet longevity requirements than neutral or classic designs. However, because fashion has become decentralised, and change diffuse, products can survive as long as they have qualities other than just their fashion styling.

Another interesting observation is on the environmental advantages – or otherwise – of shared laundry facilities – one of the 'product-to-service' concepts which is often mentioned as an example of a more sustainable way of meeting our laundry needs. The shared laundry facility is found to have a much higher energy requirement than using household washing machines, which may undermine its apparent environmental advantages.

Those already familiar with the work going on in this subject area will recognise some familiar names and themes. Ezio Manzini is, of course, represented and referred to throughout, as one of the original exponents of 'immortal products' and dematerialisation. Stuart Walker's section on product aesthetics, and its relationship to culture, sets out some interesting ideas, including the 'sustainable aesthetic'. This is a subject worth exploring, since most work on sustainable product design has focused exclusively on functional and technical aspects. Tim Cooper's thinking on the economics of longer life products is a useful summary of his report 'Beyond Recycling', originally published by the New Economics Foundation.

For anyone who has not come across this area – and perhaps it has been more of a European interest than a US one – this book serves as a good starting point to the issues and complexities. Product longevity seems like such an obvious core theme of sustainability – but as this book shows, there may be many blind alleys. Solutions which may be right for one product group will be inappropriate for others. It is therefore sensible that this book throws out an array of ideas –

mostly fresh and intelligible – occasionally obscure and irrelevant – which serves to prompt our own imagination rather than to be prescriptive.

For a dense, philosophical medley, 'Visions of Product Endurance' is surprisingly easy to read. This is due partly to the unique and accessible mini format, partly to the admirable shortness of each chapter and partly to the stories and examples which are scattered liberally throughout. As with all compilations, there are stronger sections and weaker sections – but even the weaker sections usually contain a concept or a phrase which makes them worthwhile.

Some people may find this book maddening – unresolved, rambling, unstructured. Others will find it charming, entertaining, enthusiastic, provoking. Given that there are very few green design books one could possibly describe as charming, it deserves a place on the shelf.

Dorothy Mackenzie is founding partner of Dragon, UK, author of various publications on 'Green Design' and a Centre for Sustainable Design Advisory Board Member.

Factor Four: Doubling wealth, halving resource use

Ernst Von Weizsacker, Amory B Lovins, L Hunter Lovins
Earthscan Publications Ltd. London, UK, 1997
ISBN 1 85383 407 6
352 pages
£15.99

According to its dust jacket, Factor Four – the recent book by Ernst von Weizsacker and Amory and Hunter Lovins – will make you angry at the people who stand in the way of a wealthier and environmentally healthier future. We have the ability, the authors argue, to double our wealth, and do it cutting resource use in half – a 'factor of four' (4X) step toward a better life. We could do this now, if only... well, if only someone would get out of the way.

To show how easy it is to make the 4X improvement, the book reviews 50 cases where it has or could be done. Most of the examples save energy and several come from the Lovins' Rocky Mountain Institute. We learn, for example, that the Institute uses super-windows that save money, resources, and make their buildings more comfortable. Further afield, we learn that we could have better tasting yoghurt and save on transportation costs and energy if we made yoghurt at home.

Each case sounds like an exciting business-venture opportunity. Of course by the final idea, one begins to wonder why the authors are trumpeting these terrific opportunities so openly. Shouldn't they be off quietly rounding up venture capital so they can reap the handsome rewards? Indeed, they would be, the authors imply, if they had the time. But, they have bigger fish to fry. The same 4X improvement can be obtained on a larger scale by making some simple policy adjustments. Regulated utilities must be driven out and replaced by markets. This new free market should then be augmented with 'feebates' – 'a combination of a fee charged for inefficiency and a rebate rewarding efficiency. Transferring wealth from those whose inefficient choices impose social costs to those whose efficient choices increase social wealth' as well as other incentives. For example, buildings more efficient than 'normal' should receive subsides, while those less efficient should be taxed. Such reform is costless, they argue. At worst it will simply redistribute wealth to the more efficient, and it will probably increase productivity.

One might wish to know how 'normal' will be determined and how the feebate system will be administered, but the authors must move on to an even bigger issue: the planet's life is at stake. The Meadows' (who along with Jorgen Randers and William Berens wrote the doom predicting The Limits to Growth) may be right, the authors argue, the earth has passed the limits of sustainability, the crash is coming. Now is the time to act: invest in the 50 ways, change regulatory policy, make yoghurt at home.

As advertised, the book indeed made me angry. I found myself becoming more and more sceptical, and this made me angry at myself. The authors are clearly brilliant people. I have often cited their previous work. They have long and distinguished careers. They have championed important new ideas, and put many new and interesting ideas into this book. Their message is certainly right: opportunities exist, policy reform is needed, the future appears grave. Who am I to be cynical? My cynicism is standing in the way of a 4X better world.

But try as I might my scepticism grew. The authors seem to want to save resources for some vital but unstated reason and have pasted together a set of brightly coloured ideas to convince the reader to go along. All together, these ideas are dazzling, but upon inspection, many appear simplistic.

Disturbingly, for those who wish to believe the authors vision, the authors often tarnish their own proposals. Some of the shining ideas clash with their neighbours, suggesting inconsistent or flawed logic. For example, in the first half of the book the authors argue that people can independently benefit from saving resources, but then argue vehemently for regulation. Why, if energy is so beneficial, is regulation needed? In the latter half of the book the authors argue that regulation may increase growth, but then argue it must be enacted to prevent environmental catastrophe. Why do they need to justify regulation with predictions of environmental apocalypse if regulatory reform has no cost?

Thus, with the presentation of each glowing, monochromatic, victimless idea, I became increasingly sceptical. As inconsistencies between these ideas appeared, I became doubtful and resistant. Gradually, my anger at myself switched to anger at the authors. Indeed, I now wonder if the authors themselves don't 'stand in the way' of finding solutions to environmental problems. They seem to want to sell rather than convince, and this breeds doubt and distrust of their goals and their methods. This book would be far more convincing if they had openly discussed problems, difficulties and uncertainties. Couldn't some of the recommended policy changes backfire? Couldn't some of the 50 ideas actually reduce wealth? Even if home labour eliminated the transportation of yoghurt, won't it increase the transportation of milk?

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Wasted: counting the costs of global consumption
Michael Redclift
Earthscan Publications Ltd, London, UK, 1996
ISBN 185383 355X
173 pages
£12.95

Throughout his prolific career, Professor Michael Redclift has consistently asked uncomfortable questions about contemporary environmental policy and social movements, often revealing unfounded assumptions in the process. His latest book, 'Wasted', continues in this vein. In the introduction , Redclift claims that sustainability 'can only be achieved by incorporating a knowledge of the consequences of our behaviour into the behaviour itself.' According to the author, the behaviour that is in desperate need of attention is the industrialised world's addiction to over-consumption. Furthermore, because institutions designed to manage the environment do not correspond to the behaviour that transforms our environment, progress toward sustainable development will be difficult. This ambitious book examines the environmental consequences of over-consumption, the inadequacies of global institutions designed to deal with these consequences, and tangible policies for reaching sustainability.

Redclift begins with an historical perspective, discussing events leading to and subsequent to the 1992 Earth Summit. He examines how development and environment began to be considered together and how vital issues of equity, international debt, poverty, trade and population were ignored at Rio. These omissions, serious failures, according to Redclift, have undermined agreements ever since. The recent wave of international agreements such as the Climate Convention and the Biodiversity Convention have been inadequate responses, in part because of the political climate under which they were drafted. Chapter Three goes even further back in history, discussing environmental change as an historical process, beginning with the industrial revolution. His goal in doing so is to illustrate the co-evolution of social and natural systems, thus, showing how environmental targets imply social choices.

In this context, the book then enters and remains in the domain of global consumption. In one of the most engrossing sections of this book, Redclift explores the political economy of the 'hydrocarbon society,' focusing on North/South relations. He points that the developed world consumes nearly ten times the per capita energy of the countries in the South. This type of inequitable trend is further exacerbated by the way in which the environmental costs of the 'hydrocarbon society' are distributed. 'The production of wastes in the North,' he tells us 'is indissolubly linked to the environmental problems of the South, sometimes directly... but always indirectly' (p.90). The problem of global sustainability then is framed by existing relations of power which govern global economic interdependence. He then explores public policy, in this case energy policy, in Western Europe and Brazil, to understand the factors which are constructing the global agenda.

By framing global consumption in terms of politcal econmy and sociologic factors Redclift leads to a major contention: that global economic and environmental processes are linked to behaviour at the local level, and must therefore be dealt with at the local level. The final chapter of 'Wasted' examines case studies of local action. One strategy is the new Local Exchange Trading Systems (LETS) schemes that have sprung up in various countries. Another is the Fairtrade movement and campaigns such as The Farmers' World Network which links farmers in developed and developing countries in order to bridge inequalities in current trading systems and distribute food to where it is most needed.

Clearly, Redclift is treading ambitiously wide terrain, all within the confines of 170 pages. Unfortunately, his cogent initial arguments are hurt because the book discusses a long history and complex issues at a dizzying pace. For example, a section entitled 'International Environmental Problems in the 1980s', covers economic restructuring strategies, the legacy of the adjustment decade, the environment and social processes at the international level and the relationship between the economic crisis and the way it altered perception of global environmental management in just five pages!

Furthermore, Redclift is attempting many things simultaneously: to bridge sociological analysis with an analysis of the underlying social commitments which define consumption and global political economy; to develop a social construction of how we metabolise nature, to examine the political economy of consumption and the treatment of wastes, and more. This is not to say that Redclift is wrong for including all this. Too often these interrelated areas are isolated from each other, leaving the real complexity unarticulated. But by accommodating so much he has produced a dense and forbidding book.

It is also curious that a strong argument presented in the introduction; that sustainability must operationalised at the local level, is not revisited until the final chapter, and even then unsatisfactorily. This last chapter promised to be the strongest of the book by interweaving the various strands of arguments together with exciting case studies of new locally-based strategies. But we do not get a real sense of the potential for these initiatives; rather we are only presented with a brief description of how they operate.

To be sure, 'Wasted' is difficult reading. For those readers, especially decsion-makers within international NGOs and students of institutional analysis, who are willing to put forth the effort, the book should resonate widely. Redclift grapples with complex issues and thus provides insights into past failures and the necessary steps to reach future goals in the realm of sustainable development.

Virginia Terry, Researcher, Sustainable Product Design, The Surrey Institute of Art & Design, UK.

Managing eco-design 1: online conference

Managing eco-design 2: online conference

Textiles, design and environment: online conference

Towards Sustainable Product Design 2: online conference

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26 February 1998

Product design implications of draft directive on electronics waste conference
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2–6 February 1998

Life cycle approaches: improving environmental performance programme
Surrey, UK

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2–3 March 1998

Eco-efficiency: a modern feature of environmental technology
Dusseldorf, Germany

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13 March 1998

Update of environment legislation – packaging seminar
Manchester, UK

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17 March 1998

Clean technology workshop
Vancouver, Canada

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7–8 April 1998

Eco textile 98: Sustainable Development
Bolton, UK

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24–26 April 1998

Industrial Ecology III
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30 April – 2 May 1998

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May 1998

Next generation eco-design tools workshop
Surrey, UK

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2–4 June 1998

ET ’98
Birmingham, UK

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26 The Quadrant
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Surrey TW9 1DL
UK
✆ +44 181 910 7928
fax +44 181 910 7989
email: joanne.bowyer@reedexpo.co.uk

17–21 June 1998

1st International Factor 4+ Congress and Trade Fair Congress

Klagenfurt, Austria

✉ Jan-Dirk Seiler
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Wuppertal Institute for Climate, Environment and Energy
19 d-42103 Wuppertal
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✆ +49 202 2492 102
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9021 Klagenfurt
Austria
tel +43 463 56800 61
fax +43 463 56800 39
email: ktnmessen@mail.carinthia.co.at

July 1998

Towards Sustainable Product Design 3 conference

Surrey, UK

✉ Martin Charter/Anne Chick
The Centre for Sustainable Design
The Surrey Institute of Art and Design
Falkner Road
Farnham
Surrey GU9 7DS
UK
✆ +44 1252 892772
fax +44 1252 892747
email: cfsd@surrart.ac.uk

2–3 July 1998

Eco-management and auditing conference

Sheffield, UK

✉ The Conference Manager
ERP Environment
POP Box 75
Shipley
West Yorkshire
BD17 6EZ
UK
✆ +44 1274 530408
fax +44 1274 530409

26–28 August 1998

NordDesign '98

Stokholm, Sweden

Prof. Jan-Gunnar Persson
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Ph D. Kjell Andersson
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Jesper Brauer
✆ +46 8 7907447

✉ Royal Institute of Technology
Department of Machine Design
SE - 100 44 Stockholm
Sweden
fax +46 8 20 22 87
email: norddesign98@damek.kth.se

16–18 September 1998

5th international seminar on life cycle engineering

Stockholm, Sweden

Prof. Jan Gunner Persson
✆ +46 8 7907868
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Lic.c.Luttropp
✆ +46 8 7907497
email: conrad@damek.kth.se

✉ Department of Machine Design
SE-100 44 Stockholm
Sweden
✆ +46 8 202287

23–25 September 1998

Euro Environment 98 conference and exhibition

Aalborg, Denmark

✉ The Conference Manager
Aalborg Congress and Kulter Centre
Europa Plads
PO Box 149
DK 9100
Aalborg
Denmark
✆ +45 99 35 5555
fax +45 99 35 5580
email: euro@akkc.dk,

30 September – 2 October 1998

Environmental engineering and management conference

Barcelona, Spain

✉ Liz Kerr
Conference Secretariat
Wessex Institute of Technology
Ashurst Lodge
Ashurst
Southampton SO40 7AA
UK
✆ +44 1703 293223
fax +44 1703 292 853
email: liz@wessex.ac.uk

October 1998

Managing eco-design 3 conference

London, UK

✉ Martin Charter
The Centre for Sustainable Design
The Surrey Institute of Art and Design
Falkner Road
Farnham
Surrey GU9 7DS
UK
✆ +44 1252 892772
fax +44 1252 892747
email: cfsd@surrart.ac.uk

26–28 October 1998

Green Building Challenge 98

Vancouver, Canada

✉ Nils Larsson
Green Buildings Information Council
13th Floor
580 Booth Street
Ottowa
Ontario
KIA 0E4
Canada
✆ +1 613 769 1242
fax +1 613 232 7018
email: larsson@greenbuilding.ca

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 or Anne Chick
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: cfsd@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.
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