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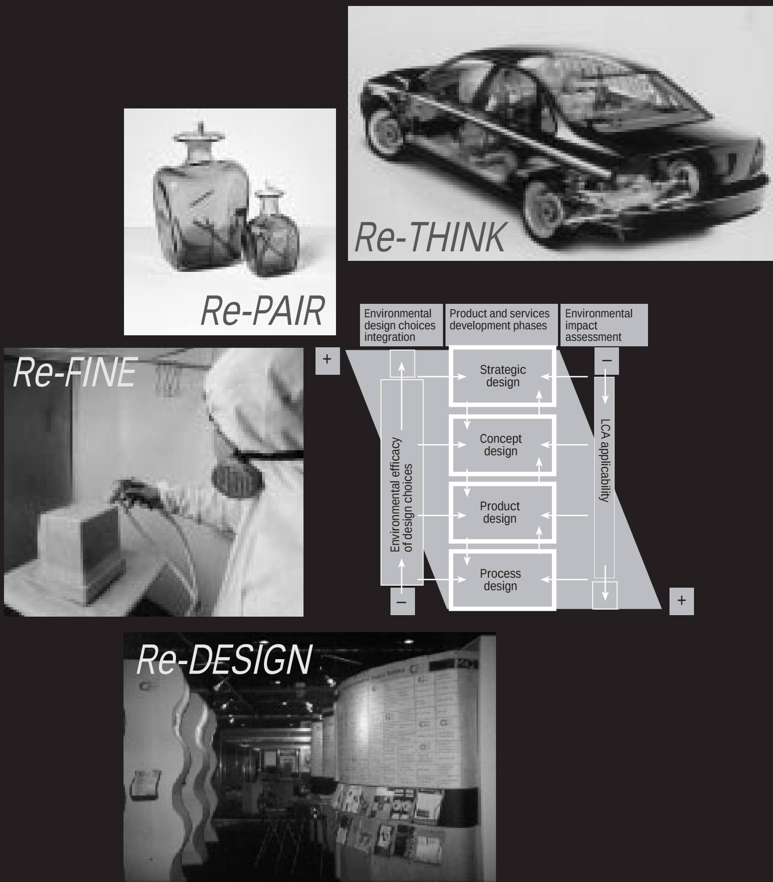

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Martin Charter: Articles, Interview, SPRN, O2 News and Journal marketing/ production

Anne Chick: Gallery, Reviews, and Diary.

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Editorial Board

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

Martin Charter

Editor, The Journal of Sustainable Product Design

Business sustainability

What will a more sustainable world look like in 2020? and how can we catalyse a process to enable it to happen? These are some of the issues that major companies and governments are considering and trying to think through. Key components of this are how we *green* consumption and how we *green* product development. Integrated Product Policy (IPP) may provide a useful framework to achieve greener markets. Some of its strengths are that it suggests a more holistic and strategic approach. For example, if a government is thinking about the launch of a eco-label (tool 1) it should also couple it with public information (tool 2) to raise awareness and increase understanding on the demand-side and then consider the use of, for example, grants for eco-product development (tool 3) and awards schemes (tool 4) to reward companies on the supply-side. As part of its consultation process, EC DGXI aims to publish its Green Paper on IPP in 3Q 1999 which will provide a positioning statement about what IPP really means. But, what we appear to be seeing is the emergence of a patchwork of different national approaches in some Euopean countries, eg. Sweden and the Netherlands.

Beyond IPP

However, IPP does not deal with the complex 'triple' (economic, environmental and social) or 'quadruple' bottom line (the above plus ethical). Let's just speculate what it might mean. What would a broader framework look like that encouraged more sustainable consumption and product(ion)? Well, inevitably it would need to be global. What would it mean? It would have to cover issues related to the changing and possible reduction of the *level* of consumption and the problems associated with the North-South divide. Who would police it? Could there be a role for the United Nations Environment Programme (UNEP) and the International Standards Organisation (ISO)?

At present companies create products or services to make profits for shareholders. However, what is being increasingly recognised is the importance of a stakeholder approach. To move towards sustainability means the need to equitably reward stakeholders for 'return of investment' of time, energy and money. This will require new frameworks to be established and these should not just be financially dominant. At the heart of this is the market-based economic system consisting of buyers (consumers) and sellers (companies). Therefore a key question is how do we create more sustainable markets?

Sustainability will require education and re-education of all stakeholders. This will not occur overnight. There will need to be clear strategic vision and leadership. For example, the Organisation of Economic Co-operation and Development (OECD) is focusing its sustainable consumption programme on the year 2020. Values will need to be shifted towards frugality, sufficiency and smartness rather than profligacy and ostentation. Of course this will mean questioning the relevance of the existing metrics of economic growth. Sustainability indicators will need to provide a guide for the new generation of *sustainable solutions developers*.

The bottom line being: Does this *solution* (product service or hybrid) improve the 'quality of life' whilst equitably rewarding all stakeholders?

Overview of this issue

Issue 9 of the Journal provides both a macro and micro perspective on eco-product development issues and highlights some of the real difficulties with existing tools at both levels. Derek Smith, Ernst & Young, UK, gives a summary of strategic issues related to Integrated Product Policy (IPP) and its component parts, and gives an insight into recent developments in Brussels. Professor Jacqueline Cramer, Akzo Nobel, the Netherlands, provides an analysis of 'design for sustainability' issues based on experience from pilot projects within a chemical company, also comparing this sector with the consumer goods sector to explore similarities and differences. Professor Ab Stevels, Professor Han Brezet and Jeroen Robouts, Delft University of Technology (DUT), the Netherlands, provide a critical review of the strengths and weakneses of Life Cycle Analysis (LCA) based on DUT's experience of working with companies. The article highlights an emerging gap between industry needs and the academic viewpoint. Professor Carlo Vezzoli, Polytechnic University of Milan, Italy, gives an overview of the key issues involved in undertaking an LCA and provides a summary of commercially available LCA software tools. Professor Winston Knight, Boothroyd Dewhurst, US, and Mark Curtis, Design IV, UK, provide a summary of the practical issues related to a 'Design for Environment' software tool which focuses on the 'end of life' phase. Inga Belmane, The Centre for Sustainable Design, UK, provides a case history on how IBM Sweden has worked with a designer to produce a glassware range using recycled glass from cathode ray tubes (CRTs). An interview with Dr Lutz-Günther Scheidt highlights Sony's practical experience of managing eco-product development, as well as the wider strategic issues surrounding business sustainability. There is a special feature on 'Design Sense', a recently launched awards scheme aimed at rewarding sustainable product and building design in the marketplace. A new section – Sustainable Products Research Network (SPRN) – highlights eco-design research being undertaken into refridgerants, Product-Orientated Environmental Management (POEM), textiles and IPP. The O2 Pages cover news from O2 NYC (New York City) highlighting a recent President Council on Sustainable Development's (PCSD) meeting in Detroit, with also background information on the activities of O2 Mexico.

As always, The Journal of Sustainable Product Design welcomes articles, book reviews, product images, information on events and any constructive feedback on articles and content. •

Integrated Product Policy

Derek Smith

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Derek Smith completed a BA in English at New College, Oxford, UK and a Masters in European Administration at the College of Europe, Bruges, Belgium. He is currently a Senior Manager in the Environmental Services Group at Ernst & Young. His expertise is in public policy analysis, evaluation and formulation. Derek has managed and conducted many such studies for the institutions of the European Union (EU). Prior to the work on Integrated Product Policy (IPP) he carried out work for the European Commission (EC) on the use of life cycle approaches in European industry and its implications for competitiveness, as well as studies on eco-labelling, and technology and industrial policy.

Increasing attention is being paid to the concept of 'Integrated Product Policy' (IPP) in policy-making and industrial circles. The European Commission, member state governments in the EU, and several international administrations are examining the potential of an 'IPP approach' to environmental policy making. This article explores what IPP is, and what its implications might be, particularly in the light of recent Ministerial discussions on the subject in the EU. The article is based on analysis and recommendations made by Ernst & Young and the Science Policy Research Unit (SPRU) in their report on IPP for the European Commission (1), and on subsequent discussions at national and European levels (2).

The origins of IPP

IPP is a new concept, and discussions on it are at an early stage. There is therefore, no universally accepted definition of IPP, and consideration of its content has only recently begun in earnest in the EU context. Nevertheless, there is now a growing body of support for a product-focused environmental policy across the EU. Tracing a product-focused component in environmental policy making can lead analysis back to the 1980s, when some of the initial incentive schemes for environmentally superior products were being launched, including a number of the first national eco-labelling schemes. If IPP is viewed in the context of sustainable development, then product-related thinking is evident in the 5th Environmental Action Programme of 1992, or even further back in the Brundtland Report of 1987. But, products have really become a strong focus of policy makers in certain European countries over the past five years, and a more widespread focus of attention in the last one or two.

Preliminary discussions on IPP were held under the UK Presidency of the European Union in the summer of 1998. In a workshop organised by DGXI in Brussels in December 1998, over 180 industry and other stakeholder delegates attended to learn about the IPP approach and discuss specific issues in smaller working groups. In May 1999, IPP was discussed by European Environment Ministers in an informal Environment Council meeting held under the German Presidency. This has confirmed the importance of the development and implementation of an integrated approach which deals with the entire life cycle of products, at member state and Community level. The Council have welcomed the Commission's intention to publish a Communication or Green Paper on IPP during the third quarter of 1999, and mooted the future involvement of other organisations such as the Consultative Forum on Sustainable Development.

In short, interest is strong and although it is in its early stages, a coherent view on future policy in this field is beginning to emerge. The recent backing of European Ministers for further attention to this area is an important 'green light' for work to be done which builds on the ideas so far.

Current interest in seeking to influence the environmental performance of products is founded upon the recognition that many important environmental problems are not associated with processes or site-focused problems, but are linked to the creation, use and disposal of products in the market. Traditional 'command and control' environmental regulation has focused on controlling processes (through setting emission limits for example) or substance control (through discharge consents, or lists of prescribed substances) or through a focus on particular environmental media (air, water, or land).

In the UK for example, the life cycle approach which characterises IPP has already informed the thinking within Department of Environment Transport & Region's (DETR) recent consultation paper 'Consumer Products and the Environment' (DETR, 1998). In addition, the House of Commons Select Committee on the Environment, Transport, and the Regions, will shortly be completing their inquiry into reducing the environmental impact of consumer products.

The IPP approach

IPP on the other hand focuses on reducing the environmental impact of product systems. It seeks to cover the whole product system, using a life cycle approach, avoiding the shift of environmental problems between different media, or between different stages in a product lifecycle. While traditional regulation has brought environmental improvement, consumption, and consumption-related emissions have been rising. For instance, Dutch research into volatile organic compound (VOC) emissions in the late 1980s highlighted that three quarters of emissions were consumption-related, in particular in the application of paints and during vehicle refuelling. Significant emissions of a number of key gaseous pollutants, such as nitrogen dioxide (NO_2) and carbon dioxide (CO_2) arise from the use of vehicles.

Not surprisingly, therefore, the Netherlands has been one of the countries who have taken a lead in Europe in developing thinking about product-related environmental policy. Following an international conference held in the Hague in October 1993, VROM (the Dutch Ministry of Housing, Spatial Planning and the Environment) published a policy document on 'products and the environment' in 1994. The Dutch and the Danish have issued framework policies which set out key principles, objectives and a range of market 'push and pull' instruments which could be used to address product-related environmental problems. More recently, other member states, including Germany, Sweden, and the UK, have shown interest in the approaches and ideas behind IPP. While each member state has come at the issue from a slightly different angle, there is growing consensus about the scope of the problems to tackle and the types of tools which can be used.

Existing product-related measures

Measures relating to products have been around for some time, including bans and prohibitions on substances within products (such as DDT), or product-related technical standards. For example, in some cases, tax measures have been used to give incentives to use different types of fuel. Eco-labels and take-back schemes have also been introduced with varying degrees of success, at national and European level. However, these measures do not constitute a fully-developed product-oriented policy. In practical terms, they have not been consistently applied in European countries, and the effectiveness of some of the measures, notably the eco-label, has been questioned. In conceptual terms as well, the approach embodied within IPP differs. First, is the holistic approach mentioned previously – IPP seeks to take into account the whole lifecycle of the product system. Second, it seeks to engage a wide range of stakeholders. Thus, the focus of attention is not solely on the producer and the processes which occur within the factory gate, but on a much wider group including raw material providers, retailers, and consumers, whether they be corporate, public sector or domestic consumers. The need to gain the active involvement of these various interest groups has been reiterated by European Ministers. Third, the measures which can be used to influence the performance of products should have an explicit focus on resource efficiency or environmental improvement. In this way, IPP is about securing environmental objectives and is not a framework for other policy objectives such as revenue raising. Fourth, it is suggested that the measures which could be used within an IPP framework are many and varied. They might include regulations, the development of product standards with an environmental component, voluntary agreements, fiscal incentives, best practice schemes, consumer information programmes and so on. The key is that the most appropriate measure is used to tackle the relevant problem, taking overall environmental policy objectives into account and having regard to the particularities of the product and the product system.

The ‘building blocks’ of IPP

Five core packages of policies, or ‘IPP Building blocks’ have been suggested, which are common to all contexts and are are made up of specific instruments. Taken together these measures organised within building blocks would form an IPP. Each building block is a cluster of policies which share a common objective:

- measures aimed at reducing and managing resources and wastes. These will include measures related to inputs as well as wastes, including ‘dissipative wastes’ (material wastes generated in ‘using up’ a product) and ‘non-dissipative wastes’ (material streams which may be recovered and reused or recycled). Measures in this category may currently be classified as chemicals or waste policies.
- measures targeted at the innovation of more environmentally-sound products: these will include measures aimed at stimulating the research and development of technologies and products, and steps to encourage the environmental management of products.
- measures to create and support the development of markets for more environmentally-sound products: these will be initiatives which encourage the adoption of environmentally-friendly products onto the market, both in the private and public sectors.

… the focus of attention is not solely on the producer and the processes which occur within the factory gate, but on a much wider group including raw material providers, retailers, and consumers, whether they be corporate, public sector or domestic consumers.

- measures for transmitting information up and down the product chain: these will be measures which encourage greater transparency about the environmental burdens and full environmental costs of product systems. These informational and price signals will serve to alter customer behaviour across the product system.
- measures which allocate responsibility for managing the environmental burdens of product systems: these will be measures which allocate legal and financial liability for the product system environmental burdens. This would include potential burdens (related to the design of the product), and actual burdens (related to the actual use and discard of products).

A wide variety of measures are represented within the IPP building blocks, some very product-specific (take-back regulations), others cross-cutting and general (a generic 'producer responsibility' policy). Variations on the building block theme have been suggested (3), by separating those which are 'cross-sectoral' from those which are 'specific'. But, in essence, all are connected in being aimed at improving the environmental performance of product systems.

The framework outlined is now under debate. The discussion on how it relates to other concepts such as sustainable consumption has also begun. In practice, product policy is likely to continue to develop in national contexts, as has been the case so far in a small number of leading member states, as well as at the European level. It will be interesting to see what mechanisms are used, or developed, to enable business, environmental and consumer group input into the policy development process.

The potential role of the European Commission

There are potential risks of product-related policies developing at a national level. The existence of different measures relating to products could create unevenness in the market. More positively, there could be potential benefits in having a consistent European framework, with clarity on the aims of policy and how this sphere of activity contributes to the goal of sustainable development. More specifically, initiatives could be launched which sought to support European firms seeking to innovate and improve competitiveness. For example, improving the comparability and availability of data on the environmental relevance of different products or product groups could provide a baseline against which firms can measure their performance and seek to improve. The introduction of an EU support scheme for sustainable product design, a kin to those which have been developed on national lines, has been suggested. But this may well be an area where it is more difficult to justify public sector intervention, given the strong interest in eco-design which already exists in the private sector.

Given the potential risks of inaction at EU level, and the capacity for the EU to play a positive enabling role, it is concluded that the European Commission has an important role to play in the development of this new arena of policy. The EC may take four key roles in IPP:

- to define a common understanding of IPP, and to articulate a vision of what it is setting out to achieve. A key task in this is being clear about objectives, and how the aims of IPP sit alongside other policy goals.
- to encourage the diffusion of best policy practice beyond the heartland of member states which have already taken concerted action, and so to harmonise the 'product policy context' across the EU. Progress on this is already occurring, through the informal development of networks across the EU. An important step here will be to ensure that this is not an exclusively northern European phenomenon, but brings in southern member states and considers the views of Europe's international trading partners. The fact that IPP has now been debated by EU Ministers from all member states will give impetus to this process of dissemination.
- to support the effective implementation of product policies through the integration of product policy aims in EU policy more generally. Some priorities for action are beginning to emerge, including a broad-based integration of products within the follow-up

to the 5th Environmental Action Programme, and more specific initiatives on topics such as public procurement and product standardisation procedures.

- to develop specific IPP measures where action at an EU level is justified, taking into account internal market provisions and the principle of subsidiarity.

This policy approach may be characterised as enabling, primarily concerned with capacity-building, encouraging convergence between policies at a national level, and enabling national policies to work effectively. It is not an approach reliant on traditional command and control mechanisms. It is well-attuned to the fragmented nature of current national activity and also to the principle of subsidiarity.

Key objectives and steps forward

It is clearly of prime importance to establish a common understanding of IPP, and to articulate that in a product policy 'vision'. This visioning activity needs to set out clear objectives. The EC's Communication later this year will be an important milestone, and should (at least) cover this. A second valuable step forward would be for interested groups, wishing to explore and give practical demonstration to the ideas which underpin IPP, to promote or launch pilot projects. It would be beneficial, for example, for firms or organisations involved in eco-design to open a channel of communication with the EC to explore the links between their activities and the policy goals which the Commission are trying to pursue. Once definitions and objectives have been clearly articulated, good policy practice can begin to be shared. In time, all of the potential areas of activity will be grounded in measures, possibly relating to the five building blocks suggested. For policy makers, the focus on products presents an opportunity to make a positive contribution towards achieving environmental policy goals through the use of a diverse range of instruments. For industry, IPP offers the prospect of a more targeted policy, with the most appropriate measure used to tackle the real environmental problem. For the consumer, the challenges are significant. In the short-term, product-related measures may help them make more informed decisions about what they buy, how they consume it and how they dispose of it. In the long-term, much more far-reaching issues arise about the sustainability or otherwise of current patterns of consumption. This, of course, is a challenge facing all stakeholders. It positions IPP firmly within the mainstream of the debate about sustainable consumption. •

References

Consumer Products and the Environment: A Consultation Paper (DETR, UK; October 1998).

Notes

(1) A study analysing national and international developments with regard to Integrated Product Policy (IPP) in the environmental field, and providing elements for an EC policy in this area. (Ernst & Young and the Science Policy Research Unit, University of Sussex). The Executive Summary of this report is available on: http://europa.eu.int/comm/dg11/ipp/home.htp. The views within the report are those of the author, and do not necessarily represent the official views of DGXI or the EC.

(2) Including the Workshop on 'Integrated Product Policy' (IPP), held in Brussels on 8 December 1998, supported by DGXI and DGIII, and papers relating to the Informal Environment Council meeting held under the German Presidency in May 1999.

(3) Seven building blocks are suggested by Frieder Rubik in the 'Background Paper on Product Related Environmental Policy' prepared prior to the Informal Meeting of EU Environment Ministers (April 1999).

Design for sustainability within the chemical industry: the case of Akzo Nobel

Professor Jacqueline Cramer

Senior Consultant, Akzo Nobel, the Netherlands

After working as an associate professor at the University of Amsterdam (1976–1989) Professor Dr Jacqueline Cramer joined the Centre of Strategy, Technology and Policy at the Netherlands Organisation for Applied Scientific Research (TNO), the Netherlands (1989–1999). From 1995–1997 Jacqueline Cramer worked at Philips Consumer Electronics as a senior consultant on strategic environmental management. Between 1997–1999 she has held a similar position at Akzo Nobel, focused on introducing eco-efficiency and product stewardship to the company. Since then she has also started her own consultancy company, Cramer Environmental Consultancy and has worked as a part-time professor in environmental science at the University of Amsterdam (1990–1996) and environmental management at the Tilburg University (1996–1999). She is member of various (inter)national advisory boards of governmental, industry and non-profit organisations (eg. member of the Dutch Council for transportation and waterworks; member of the Dutch Social-Economic Council and member of the Board of the World Wide Fund for Nature(WWF)/Netherlands).

The objective of this article is to evaluate the initiatives taken by the chemical company Akzo Nobel in the context of 'design for sustainability' and to compare the results with those achieved in consumer industries. The analysis is based on seven pilot studies in the four main product groups of Akzo Nobel: pharmaceuticals, coatings, chemicals, and fibres. These pilot studies have resulted in a list of environmental improvement options that managers intend to implement. This list covers many of the options mentioned in the literature on 'design for sustainability'. The types of options generated vary depending on the pilot studies. The Business Units (BUs) producing intermediate products tend to focus on improvements to their own production processes (throughput streams) and sometimes on their suppliers (input streams), while BUs producing final products pay more attention to improvements related to their customers (output streams). The latter BUs have more in common with the 'design for sustainability' efforts relating to consumer products.

Introduction

In recent years, industry has made considerable progress in designing for sustainability. Companies have begun to include environmental considerations in the development of their products, involving the entire lifecycle (from cradle to grave). Most of these efforts, however, focus on environmental improvements in the consumer industries, for instance, the textile, packaging, electrical/electronic, automotive, building and food industries. Far less attention is being paid to 'design for sustainability' in industries further away from the consumer market, viz. the feedstock industry (oil/gas, minerals and agriculture), the primary industry (eg. refinery/gas) – and the chemical industry. For these sectors 'design for sustainability' is also important as it will enable them to respond to customer demand for improved environmental performance of products. And more positively, these businesses can play a leading role in the generation of more sustainable products.

What does 'design for sustainability' mean for those industries farther away from the consumer market? Does the approach differ fundamentally from the one applied to consumer industries? These are the main questions addressed in this article. The analysis will particularly focus on a specific industry: the chemical industry. To give an insight into the potential strategies for 'design for sustainability', seven pilot studies were set up in different Business Units (BUs) of the chemical company Akzo Nobel headquartered in Arnhem, the Netherlands. It is a multinational with almost 90,000 employees and activities in more than 50 countries.

The pilot studies were co-ordinated by the author in close cooperation with a member of each BU's management team (usually the R&D manager). The underlying analyses were made together with the BUs and other experts working in the service units of Akzo Nobel. The pilot studies were carried out from May 1997 until July 1998.

Methodological approach

The seven pilot studies selected within Akzo Nobel represented examples of 'design for sustainability' initiatives taken in various phases of the product chain. Four pilot studies focused on intermediate products, two on auxiliary substances in final products, and one on final products. The seven pilot studies were carried out in sub-Business Units (BUs) of each of the four main product groups of Akzo Nobel: pharmaceuticals, coatings, chemicals, and fibres. Three pilot studies were performed within the chemicals group and two within the fibres group.

All pilot studies adopted a similar 'design for sustainability' approach, called STRETCH, which is the acronym for the Selection of sTRategic EnvironmenTal CHallenges) (Cramer and Stevels, 1997). The basic idea behind this approach is that the selection of promising environmental improvements over the whole lifecycle should be attuned closely to the sub-BUs' general business strategy and to the demands of external stakeholders (including suppliers and customers). In order to ensure that the STRETCH approach becomes an integral part of the general business planning, it is essential for it to be embedded structurally in the organisation and attuned to related activities (eg. ISO 14001). Therefore, the STRETCH approach consists of six steps (see panel).

Information about Step 1 was gathered through interviews with members of the management teams of the sub-BUs and through (partly confidential) documents about their business strategy. Data about Step 2 was collected via various methods, depending on the available information sources. Use was made of interviews with various sub-BU members (particularly the marketing people), results of customer questionnaires, and documents revealing the forms of environmental pressure.

Before the possibilities for improvement of the present

STRETCH methodology

Step 1
Survey the Business Unit's (potential) product/market strategies and the most important driving forces that determine business strategy in general.

Step 2
Monitor new developments and trends in the environmental debate and changes in pressure exerted by external stakeholders.

Step 3
Identify potential environmental improvements that can be made in the product chain.

Step 4
Select environmental improvements that can lead to the development of promising market opportunities or the avoidance of potential market threats in view of the previous steps, then formulate an action plan for short-term and long-term environmental improvements in the product chain.

Step 5
Embed the STRETCH approach in the organisation.

Step 6
Bring the results into line with related Business Unit activities, viz. ISO 14001 compliance, product stewardship, and product development.

environmental performance of the sub-BU (Step 3) was investigated, a shared vision and strategy on environmental issues was formulated to determine the scope of the environmental improvements to be proposed. To help identify potential environmental improvements in the product chain, three kinds of environmental data were gathered:

- quantitative data about the specific products selected by each sub-BU. These data were based on a Life Cycle Analysis (LCA) addressing the environmental impacts of products from cradle (raw materials production) to grave (the final waste stage). The depth of the LCA studies was dependent on the questions.
- environmental data about current transportation activities and alternative modes of transportation, particularly related to the production facilities.
- qualitative data based on strategic considerations of market opportunities derived from Steps 1 and 2.

Step 4 concerned the selection of the most promising environmental improvements in the product chain based on the results of the three previous steps. This led to a list of recommendations to be incorporated in the strategic planning procedures of the sub-BUs.

Step 5 focused on the way in which the STRETCH approach could be incorporated in the work of the main departments involved: R&D, Marketing and Sales, Purchasing, and Communications. Guidance documents were written to describe the main additional tasks to be carried out by these departments.

Finally, Step 6 made sure that the STRETCH approach was carefully attuned to existing activities related to environmental improvements in the product chain.

Results of the pilot studies

All pilot studies resulted in a list of recommendations about the environmental improvements that could be achieved in the short and long-term from a product chain perspective. Moreover, additional recommendations supporting the environmental improvements to be made were formulated eg. recommendations about marketing, communication, and the structural embedding of the STRETCH approach into the organisation. Most of the recommendations were adopted by the management teams of the sub-BUs involved. Very few recommendations were rejected as not being feasible.

In order to show the spectrum of environmental improvements adopted by the management teams, an overview of the recommendations is presented below. Some recommendations have been reformulated and are presented together as one recommendation. For the sake of simplicity the additional recommendations about organisational embedding and marketing and communication aspects have not been included. The environmental improvement options recommended in each pilot study are clustered around four groups:

- input
- throughput
- output streams
- transport.

Each group represents the phase in the product chain where environmental improvements should primarily be made.

The recommendations reflect the priorities for environmental improvements in view of the whole product chain set by each sub-BU. As a result specific cells have been left open. This does not mean that the sub-BU is not working on improving these aspects. However, in the context of this study they were considered less important.

For confidentiality reasons no detailed information is provided about the environmental improvements generated. On the basis of the LCAs completed it was possible to indicate roughly whether or not all improvement options together could substantially reduce major environmental impacts. More precise assessments can only be made after the potential improvements have been further explored.

Reflection on results

Through the STRETCH approach a variety of environmental improvement options were generated. These options have been clustered in Table 1.

The above list of environmental improvements derived from the seven pilot studies covers many of the options mentioned in the

Pilot Studies Phase in chain	Case 1: Intermediate products (Pharma)	Case 2: Intermediate products (Fibres A)	Case 3: Intermediate products (Fibres B)	Case 4: Intermediate products (Chemicals A)	Case 5: Auxiliary substance in final products (Chemicals B)	Case 6: Auxiliary substance in final products (Chemicals C)	Case 7: Final products (Coatings)
Input streams (suppliers)	· Review environmental performance of various solvents			· Closely follow developments in raw material A technology (particularly production based on renewable resources) · Minimise raw material B consumption	· Monitor new developments in the production of raw material A · Investigate possibility to buy raw material B from other suppliers with a less environmentally burdensome production process	· Consider buying raw material A from supplier using more environmentally sound production process x · Investigate whether production process y to produce raw material B is more environmentally sound than process z	· Include environmental requirements in the contracts with preferred suppliers
Throughput streams (own production processes)	· Continue to explore a new generation of production processes · Continue improvements in solvents' use (reduction, regeneration and reuse) · Continue water and fossil energy saving programs	· Improve present processes in general	· Reduce specific emissions and improve energy efficiency			· Improve current production process in the short term · Set priorities in improving process in the long-term	
Output streams (customers)				· Continue to explore whether the current product runs the risk of being substituted by a more environmentally friendly one	· Intensify monitoring of environmental and health risks in product applications · Investigate whether upgrading of product leads to reduction of the amount of product needed in final applications · Investigate market opportunities of selling a higher proportion of pure product · Investigate improvements in product packaging	· Prioritise the customers with whom cooperation can be strengthened to improve the production in the user phase · Formulate a short-term action plan for markets that could run into problems with authorities due to use of product · Strengthen long-term research aimed at developing alternatives for current product	· Intensify the service to the customers in the area of energy efficiency improvement · Improve environmental performance of current products x and y through specific measures · Develop new products in which specific additional environmental aspects are integrated · Pay special attention to specific users' conditions in growing economies
Transport and logistics				· Formulate transportation strategy	· Investigate benefits of modal shift (from road to water, rail or pipeline)	· Continue examination of feasibility of a modal shift from a road to rail at Dutch production site	· Continue to explore possibilities of modal shift from road to rail and boat · Reduce volume of goods to be transported through new product and packaging concepts
Environmental improvements	Moderate	Limited	Limited	Limited	Moderate	Substantial	Very substantial

Environmental improvement recommendations from the seven pilot studies literature on 'design for sustainability' (eg. Van Hemel, 1998). Compared with typologies based on consumer products, however, less emphasis is put on the optimisation of the lifetime of products (particularly easy maintenance and repair, modular product design) and new concept development (particularly 'shared use' of the product and integration of functions). These options are more appropriate to final consumer products than to the chemical industry sector.

Another difference with authors in the field of 'design for sustainability' is that they usually rely upon other typologies to cluster the various improvement options. For instance, Van Hemel distinguishes:

- product component level (selection of low-impact materials; reduction of materials usage and optimisation of production techniques)
- product structure level (optimisation of distribution system and reduction of impact during use)
- product system level (optimisation of 'end of life' system and optimisation of initial lifetime)
- new concept development.

Despite the differences in clustering, the list of possible improvement options is similar to the one derived from the seven pilot studies. The particular clustering used here better fits the style of working and thinking in the chemical

Input streams	· include environmental requirements in the contracts with preferred suppliers · replace raw materials based on fossil fuels by biofeedstocks · replace raw materials by other raw materials to reduce environmental burden · select raw material suppliers with the most environmentally sound production processes
Throughput streams	· minimise consumption of raw materials · regenerate/reuse raw materials · minimise consumption of energy and water · consider application of durable energy sources · reduce specific emissions and waste · prepare for a new generation of production processes
Output streams	· monitor health, safety and environmental risks in product applications · improve environmental performance of current products through specific measures · develop new, more environmentally sound products · improve product in the users' phase in cooperation with customers (eg. lower energy consumption) · investigate possibilities to reduce the amount of product needed in final applications · improve product packaging
Transport/logistics	· explore possibilities of modal shift from road to other transport modes (boat, rail and pipeline) · reduce volume of goods to be transported through new product and packaging concepts

Table 1: Summary of environmental improvement options derived from the seven pilot studies

industry rather than the typologies applied to consumer products. Additional pilot studies might lead to a further refinement of the items mentioned in Table 1. Based on other types of typologies, it can be assumed that the main improvement options are mentioned in the above Table 1.

The results of the various pilot studies show that the environmental improvement options in the product chain adopted by the management teams of the sub-BUs involved differ largely. Cases 1–3 mainly focus on improvements of their own production processes, case 4 deals with both suppliers and customers, and cases 5–7 include the whole chain with a major focus on customer relations. One of the major explanations for this difference in focus is the BU's position in the product chain.

Sub-BUs producing intermediate products are farther away from the final customer and often do not feel any direct pressure from the market to improve their product for environmental reasons. Therefore they tend to focus on environmental improvements related to their suppliers and their own production processes (input and throughput streams). Only if the pressure from the final customers also affects the composition of their intermediate products, will they respond to customer demands. This was not the case in pilot studies 1–3 but might become the case in pilot study 4. This explains the emphasis in pilot study 4 on monitoring developments in customer demands.

Sub-BUs producing final products or auxiliary substances in final products (cases 5–7) are close to the final customer and are the first to be addressed when the customer wants to improve the environmental performance of his products. It may also occur that the final producer himself approaches the customers to cooperate in developing environmentally more benign products. This happened, for instance, in case 7.

Besides this difference in position in the product chain, the diversity of improvement options can also be explained by three additional factors (Cramer, 1999):

- the degree of environmental pressure
- the degree of room for manoeuvre in altering the process and/or product in view of the whole lifecycle
- the degree to which the environment can be used as a competitive edge.

When managers think that environmental improvements of their products will not lead to competitive advantages, they usually do not give high priority to such improvements (cases 2, 3 and 4). Depending on the degree of environmental pressure (particularly from regulatory bodies) the managers tend to focus in such cases on step-by-step or more far-reaching improvements of their own production processes (sometimes in cooperation with their suppliers). In cases 2, 3 and 4 the direct environmental pressure was low. As a result the environmental

When managers think that environmental improvements of their products will not lead to competitive advantages, they usually do not give high priority to such improvements.

When the competitive edge of more environmentally benign products is more obvious for managers, they are more inclined to communicate and even co-operate with their customers to improve their products, thus addressing the output streams.

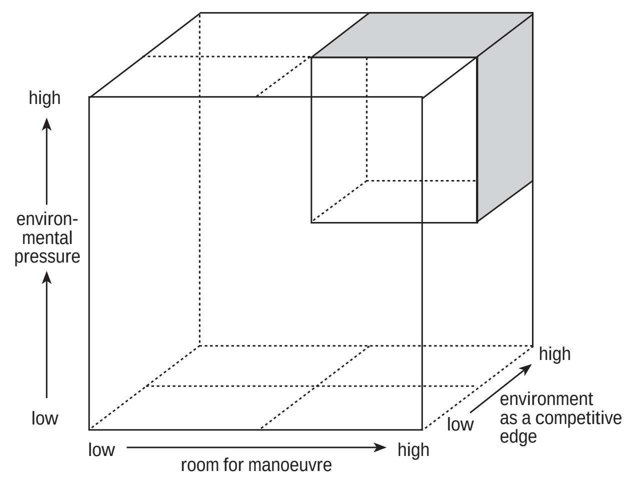

Figure 1: Responsiveness to environmental improvements in the product chain

improvements proposed in these cases were also limited.

When the competitive edge of more environmentally benign products is more obvious for managers, they are more inclined to communicate and even cooperate with their customers to improve their products (cases 1, 5,6 and 7), thus addressing the output streams. The product improvements proposed in these cases usually had an impact on the input and throughput streams as well. However, in case 1 the flexibility to change the products was very limited due to strict drugs regulations. Therefore, environmental improvements proposed here focused on the input and throughput streams.

In cases 5, 6 and 7 the room for manoeuvre in altering their products or processes was larger. As a result the interest in improving the output streams increased, depending on the degree of environmental pressure. In cases 6 and 7 the environmental pressure was much higher than in case 5, leading to more substantial environmental improvements in view of the whole product chain. In fact, cases 6 and 7 are the most obvious examples where substantial environmental improvements and promising market opportunities go hand in hand. This is due to the strong environmental pressure, the ample room for manoeuvre and the possibility of achieving a competitive advantage. These cases can be positioned in the right upper part of the cube presented in Figure 1.

If we compare these results with the 'design for sustainability' efforts implemented in consumer industries, cases 5, 6 and 7 have much more in common with those efforts than cases 1, 2, 3 and 4. The main explanation is that cases 5, 6 and 7 represent sub-BUS that are close to the final customer. In general, these BUs feel environmental pressure more directly and have more opportunities to use environmental considerations in their marketing compared to intermediate producers. Moreover, final producers are usually more flexible to change their product than intermediate producers who are usually bound to the specific product they produce. For a final producer it is often relatively easy to switch, for instance, from the use of material A to the use of material B. The producer of material A, however, has much more difficulties in completing a switch. If he/she cannot supply material B, then he/she runs the economic risk that the final producer will go to another supplier.

… and finally

Because of economic risks as illustrated above, the sub-BUs producing intermediate products should also remain alert and monitor the changes in environmental demands of the final customers. Whether the sub-BUs can respond adequately to these risks, also depends on the general policy of the company. If the current intermediate product becomes outdated in the future for environmental reasons, the recommendation to higher management should then be to promote the development of radically new products through special seed money programmes. For smaller companies producing few intermediate products, such initiatives are, of course, more problematic but still crucial for survival in the long run. •

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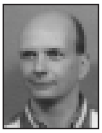

Application of LCA in eco-design: a critical review

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Ab Stevels studied Chemistry at the Eindhoven University of Technology, the Netherlands, and then was employed at Philips Electronics Eindhoven. In 1966 he received his PhD in Physics and Chemistry at the Groningen University. In 1969 he joined the Philips Research Laboratories and in 1989 he was transferred to the Consumer Electronics division where he has been senior advisor on environmental engineering since 1993. In 1995 he was appointed part-time professor in Environmental Design at the Faculty of Industrial Design Engineering, Delft University of Technology (DUT), the Netherlands.

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Jeroen Rombouts graduated in 1995 from the Faculty of Industrial Design Engineering at DUT. After working in a small design office for a year he is now working on a PhD research project and assisting with LCA training sessions. His research project is focused on using a knowledge-based system to evaluate product improvement options based on product characteristics.

Eco-design has now become a business issue in various sectors. To enable eco-design requires a wider range of tools, most of which are in their early stages of development. Life Cycle Analysis (LCA) has emerged as a key tool. The article is based on Delft University of Technology's (DUT) experience of working with industry on eco-design projects using LCA. DUT's experiences are highlighted illustrating the strengths and weaknesses of LCA and the growing gap between industry needs and academic research in this area.

Introduction

Within the Delft University of Technology's (DUT) Design for Sustainability (DfS) programme, at the Sub-faculty of Industrial Design Engineering more than a hundred industrial eco-design case studies have been undertaken between 1993–1998, through graduates, PhD students and staff.

DUT's eco-design approach advocates several types of Life Cycle Analysis (LCA). This refers both to the selection of 'attention fields' and the creativity phase (finding green options) as well as to the environmental validation of design improvement recommendations.

Research has highlighted that consideration of *both* the technicalities of eco-design and the management of eco-design processes are crucial for success or failure. This relates to both the front end (idea generation and concept development) and to exploitation of the results in the marketplace. In all these processes the availability of appropriate manuals and tools plays an essential role. DUT's contribution to these include:

- PROMISE, a promising approach to sustainable production and consumption (Brezet and von Hemel, 1997)
- EPAss, a manual for environmental benchmarking (Jansen and Stevels, 1998)

Tools include:

- LEADS, Lifecycle Expert Analysis of Design Strategies (Rombouts, 1998)

· IDEMAT, a material and process database for product developers containing mechanical, physical, financial and environmental data [IDEMAT].
· EcoQuest, a supplier eco-design self-audit tool (Brink, Diehl and Stevels, 1998)
· STRETCH, a methodology for advanced environmental product development (Cramer and Stevels, 1998).

The LCA methodology has a pivotal position in the eco-design process and tool applications at present. Particularly, in the selection of 'attention fields' and in the validation stage, the use of LCA is essential for environment-oriented product development. To a lesser extent this also holds for the creativity phase itself.

In this article, the DfS programme's experiences of the use of LCA in industry-based eco-design projects are evaluated. This has led to the identification of both limitations and opportunities for LCA and directions for action and further research.

The following seven aspects related to LCA will be discussed in this article:

· LCA from the problem-solving perspective
· methodological issues
· data issues
· LCA from the business perspective
· LCA as a stakeholder communications tool
· standardisation
· future of LCA.

LCA from the problem-solving perspective

· LCA is a very effective tool for the selection of product-related environmental impacts that need to be prevented or reduced. It is also useful in validating green design options when a mix of energy and, material application and process related aspects play a role. In a wide range of linear problems, good solutions can be found with a high level of sophistication and practicality.
· LCA is less effective in situations where toxic/hazardous substances are involved (embedded toxicity with time dependent release) (Tukker, 1998). Its use in tackling recycling issues is also fairly cumbersome due to assumptions that have to be made to satisfy system boundary requirements. A main problem with LCA is that it is primarily based on an inventory of flows as at a moment in time ('in-out') and not on a balance sheet principle. As a consequence, taking the future into account is problematic, particularly for resource use ('environmental investment').
· In terms of environmental validation and prioritisation of green design options and product performance, current LCA approaches generally provide satisfactory information, provided that the analysis is made organisation-internal and on a relative base (Stevels, 1999). There is also evidence that a single figure LCA score like the Eco-Indicator '95 performs well in this respect. The obvious advantage of indicators and abbreviated LCAs is their need for limited expertise, time and money, which makes it a very practical solution for internal product comparisons despite all the criticism from the scientific point of view. Tools that can be used are EcoScan, SimaPro (see References) and others. Due to a lack of a standardisation LCA is not yet appropriate for external comparison or absolute calculations.
· LCA is not suitable for generating green design options, because ideas generated by LCA often go beyond the influence of designers. This is due to the lack of separation between internal (eg. product properties) and external (eg. electricity generation and waste treatment) issues in LCA applications (Stevels, 1999). As a consequence, linking the eco-design concept with the creation of sustainable, new 'business' coalitions (joint ventures with suppliers, recyclers, users etc.) and markets cannot be done through LCA. Therefore this link, which ultimately defines the overall net environmental benefit of 'eco-designed' product-market combinations, needs to be based on additional models and tools, like 'scenario making' (simulation of future user perspectives and preferences), environmental accounting (assessing the environmental and financial-economic benefits of eco-design concepts) and innovation management theories. Good results have been

generated by benchmarking followed by supplier contacts (Brink, Diehl and Stevels, 1998) and green brainstorms (Cramer and Stevels, 1997). This generally leads to options within the designer's sphere of influence. In addition, the societal green context can be determined by using, for example, the Eco-Indicator 95.

Methodological issues

Currently worldwide efforts are being undertaken to enhance LCA methodology. It is the authors' opinion that some basic problems with LCA will remain which cannot be fundamentally solved (like time dependence, system boundary and momentary bases). The rating of impact categories, as one of the steps in LCA procedure, is and will remain a subjective issue, as long as environmental sciences are only able to provide a very complex impact model.

With the progress currently being made all these issues can be solved, but the application by non-expert users (like policy making bodies and industry) will become too complicated and too costly. For LCA to progress, this will be a fundamental issue eg. how to balance a maximum of scientific truth with a maximum of user friendliness while keeping cost and capacity involved within reasonable boundaries.

A further problem with the methodology is that LCA works reasonably well on the product level, however on the level of service systems, analysis is very problematic. In developing product-service combinations, like car-sharing services in neighbourhoods or at work, consideration of the infrastructure available (roads, parking lots) is an essential precondition for success. Other variables are also important, for example, the number of supportive products within the service (number, type of cars), the service co-ordination centre (space, use, energy) and the number and activities of employees involved. In selecting the products (cars), LCA can help us, but for making infrastructure choices standard LCA procedures are not or are less appropriate (only with a lot of artificial modifications). In addition, the effects of human labour should be included, which at this moment is usually omitted. When more fundamental system changes are discussed the exclusion of capital goods or infrastructure changes from the analysis makes discussion problematic (Goedkoop, 1999). To gain large improvements in sustainability there needs to be a move to more innovative solutions on a higher level than the product level. To improve eco-efficiency by a factor 20, which is often quoted as a sustainable level, an impact reduction of 95% needs to gained which will be impossible by just improving our present day products (Brezet, 1997).

There is a big opportunity for universities and research institutions to develop new methodologies, which can operate meaningfully on the system level.

Data issues

Both data accuracy and data accessibility (databases) are both issues currently posing dilemmas. On the one hand there is a clear need for higher accuracy and reliability of data, but this will drive up the cost of data collection tremendously and only in a few cases will LCA practitioners be able to afford such a high standard. Data collection for LCA goes to the heart of business and enterprises, and many proprietary items will have to be discussed, especially when a high level of accuracy and reliability is required. In Europe many of the parties involved in LCA are willing to cooperate; however the condition is that the data acquired will only be used in private/proprietary relationships and will not be made public. A key question is: what is the best choice for the time being? and what is the best compromise?

LCA from the business perspective

There has been an evolution in thinking by business about environmental methodologies like LCA.

Leading industries have moved from a defensive to proactive position, from necessity to opportunity, and from the standalone to full integration into the business.

The academic community (including the LCA community) has generally been (and still is) slow in following this shift of thinking. Therefore we are now confronted with a gap between the proactive industry approach and academic approach. See also Figures 1 and 2 (Stevels, 1999).

	step		
Industry			
	step 1 start with creative approach to environmental issues you can influence (benchmark, brainstorm)	**step 2** validate and prioritise according to LCA	**step 3** check prioritised options against company, customer and society benefits
	step 4 check feasibility (physical, financial)	**step 5** implement in programme	
Academia			
	step 1 do LCA analysis, holistic approach	**step 2** select internal and external improvement options	**step 3** start stakeholder discussion
	step 4 come to solutions	**step 5** implement in programme	

Figure 1: Industry and academic approaches: issues which can be influenced

The proactive industry approach is actor based with an emphasis on effective implementation (with ownership). LCA has a useful but not a dominating role. The academic approach generally is holistic (with no specific ownership) and is centered around LCA. With respect to business there is generally a self chosen 'green apartheid' or specialisation within companies which seriously hampers practical implementation. This gap is deeply concerning and DUT is focussing part of the DfS programme on closing it.

LCA as a stakeholder communication tool

· In all parts of the world (even in the most environmentally conscious countries) environment as such is an appealing factor to a minority (25 % or less) of the potential customers. A majority (75 % or more) of potential customers however are attracted by a combination of an environmental benefit and other benefits (like money, fun/ease/comfort or other positive emotions). For successful marketing and sales of eco-designed products the creation of a mix of the above consumer variables and values is an essential step. This also establishes the direction that environmental communications needs to develop. Environmental policy tools like eco-labelling should be replaced by a segmented approach, communicating an attractive mix of users' values, for instance:

- lower energy: good for the environment and good for your 'wallet'
- less packaging: fewer resources, easier, less hassle with waste
- more recycling: waste reduction, fewer resources, 'feels good'
- less hazardous: good for the environment, no fear any more
- less material: fewer resources, cheaper, etc.

It has been argued that the lack of buying of eco-labelled products by the general public is due to a lack of scientific thoroughness and as a result LCA based eco-labels have been proposed.

The authors believe the contrary: the general public is calling for simplification rather than for sophistication and wants to be communicated to in terms of a world they live in.

When communicating to professionals the approach should be different. Professionals which are intermediates between policymakers and manufacturers (journalists, environmental experts of consumer organisations, etc.) generally appreciate environmental issues in terms of LCA. As such this category is likely to be well disposed to receive more specific information.

This picture changes at the moment the target group for communication consists of the environmental specialists (for personal interest). In this context, LCA is likely to get a sympathetic reception but the methodology applied and data accuracy will be critically reviewed. In general it will be argued that the actors have not sufficient thoroughness in their approach and apply over simplifications. From their perspective this always remains true whatever action a company takes.

Standardisation

Before touching upon the issue of standardisation in the field of LCA, we will go back to the origin and nucleus of standardisation. This is an industry interest because standardisation makes it easy to compete on a global level playing field. Therefore initially, industrial representatives took a strong interest in standardisation issues and were – for instance – strongly represented in the International Standards Organisation (ISO) committees.

In the present wave of cost cutting and 'lean and mean' approaches, industrial participation in standardisation authorities has declined. Their position has been taken over gradually by institutional (often government sponsored) and academic representatives. This has resulted in a shift in character of the ISO standards (the ISO 14.000 series): standards have become more comprehensive, have a highly scientific context, but their applicability is diminishing.

This is leading to a strong criticism from industry of the LCA standards under development. As a result, industry is considering initiatives to develop a separate (sub)standard which is more workable/applicable in practice (Lehni, 1998).

From the governmental side there is also criticism. Ideally an LCA based legitimacy of environmental policies would be a good basis for policy. However even in countries where this has been seriously attempted (eg. the Netherlands) this point has not been reached. Apart from the politics – including environmental politics – there are strong emotional and social components. Both components are part of real life and as such are legitimate but they also are very difficult to reconcile within a rigid LCA approach.

Altogether the future of LCA standardisation and related items is unsure, there will be either a single set of standards, which will be difficult to apply, or two sets with a continuous debate about the shape and significance of them. Neither of these two scenarios is attractive.

Example

An example given in the table below (Figure 2) shows the shortcomings of LCA/Eco-indicator. This example refers to the development of the Green 'Brilliance' monitor at Philips Electronics Monitor Division located in Chungli, Taiwan. This project was undertaken by DUT and Philips Consumer Electronics (PCE) Environmental Competence Center (ECC) in Eindhoven, the Netherlands.

This table (Figure 2) shows the complete environmental design process with all the LCA issues cited in this article playing a role. The column 'remediation' indicates that the weaknesses of current LCA/Eco-Indicator can only be partially compensated for other ways and means.

Future of LCA

As things stand now, the future for the application of LCA in industry looks fairly bleak. The basic reason for this being is that LCA is a 'mix', that is a mix of scientific and practical elements, a mix of present and future, a mix of tangible and intangible issues. As things stand now this will be very difficult to sort out based on a consensus between

Stage	LCA issues/problems	Remediation
Idea generation		
Collect data, (benchmark, suppliers)	Toxics, scope, methodology	Separate assessment of hazardous substances and 'end of life'/recycling
Brainstorm	Methodology	None
Concept consolidation, execution of eco-design		
Address focal areas: · Energy · Materials · Packaging · Hazardous substances · 'End of life'/recycling	Not applicable, use common sense	Not applicable
Address lifecycle perspective	Toxics, scope, data	Separate assessment of hazardous substances and 'end of life'/recycling
Exploitation of results		
Validation of results	Methodology, scope	none
Communications, marketing	Business perspective, private customers, scientific community, standardisation	Very partly, communicate in bases of common sense (='unscientific')

Figure 2: LCA issues in the eco-design process.

stakeholders at a global level. What should companies do now? Two approaches are recommended:

· Develop 'environmental accounting' (which in the authors' opinion is the fundamental reason for LCA) identical to accounting systems in the financial world. It can be done and a tremendous benefit would be the comparability in treatment of ecological and economic issues – as it is the authors' belief that ecology and economy are highly correlated (approximately 75%). Within the DUT DfS pro-gramme part of the research effort is focusing on this issue (Vegtlander, 1998) (Gielen, 1999).
· Create a 'living space' for different levels of sophistication of LCA (as a validation method). This will prevent endless discussions between practical, fundamental and politically oriented practitioners, as described in the study on the adjustment of LCA methodology of Bras (Bras-Klapwijk, 1999).

The authors' experience indicates that there is one effective solution to the many problems that seem to be associated with LCA (and also for instance eco-design) – that is: experience of 'practice will show the way'. The DUT DfS programme will research industry's experiences with LCA, and will model them into computer-aided tools (like described by Rombouts, 1998; Brink, Diehl and Stevels, 1998; and others) for both large industries and SMEs and will thus play its role in the development of a more sustainable future. •

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Bras-Klapwijk, R.M., 'Adjusting Life Cycle Assessment for use in public Policy Discourse', Doctoral dissertation, DUT, Delft, 1999

Eco-design tools

EcoScan
LCA-tool developed by Turtle Bay (in cooperation with Philips), Rotterdam, the Netherlands.
http://www.luna.nl/turtlebay/index.htm
http://www.luna.nl/turtlebay/index.htm

EcoQuest
An Ecodesign self-audit tool for suppliers of the electronics industry.
http://www.io.tudelft.nl/research/dfs/ecoquest/Ecoquest.html

IDEMAT
Material selection tool with LCA data on material production.
http://www.io.tudelft.nl/research/dfs/idemat/index.htm

LEADS
not yet available

SimaPro
LCA-software developed by Pré-consultants, Amersfoort, the Netherlands.
http://www.pre.nl/ http://www.pre.nl/

STRETCH
Cramer, J., Milieumanagement: van 'fit' naar 'stretch', Uitgeverij Jan van Arkel, Utrecht, 1997. DfS
http://www.io.tudelft.nl/research/dfs/
www.io.tudelft.nl/research/dfs/

An overview of life cycle design and information technology tools

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New environmental requirements mean that all life cycle phases will need to be considered in product design. The concept of Life Cycle Design (LCD) has begun to be integrated into product development processes in a range of companies worldwide. Information technology (IT) can play an important role in helping companies deal with this increase in complexity. The paper firstly gives a brief overview of the approaches, methodologies and software tools that have been developed in this area. These are classified into two main categories: methodologies and tools for the quantitative analysis and assessment of the environment impact of products, eg. Life Cycle Assessment (LCA); and dedicated design support tools for environmental performance improvements (eg. 'design for disassembly' software tools). Throughout the article, examples are presented that illustrate the recent trends in the of development of LCD tools. Recent research has focused on analytical tools, both for the achievement of more reliable and specific LCA inventory data and on the development of methods and tools to enable faster and simpler evaluations (simplified LCA), as well as increasing the features in design support tools to consider the whole life cycle from product conceptualisation to launch (not only limted to the improvement of specific environmental performances). Finally, possible guidelines are defined for the development of LCD tools, aimed at developing specific solutions to specific problems whilst enabling dialogue with the various actors in the product development process.

Introduction

Part of the research activities of the Inter-departmental Research Centre, Innovation for the Environmental Sustainability and innovation (CIR.IS) based at the Polytechnic University of Milan, Italy is dedicated to the monitoring, study and development of software tools for environmental sustainable product design (SPD). A synthesis of the main trends and perspectives, in relation to the role of the IT tools is presented here. This article investigates the 'state of art' through descriptions of software related to Life Cycle

Design (LCD). Finally, some considerations and conclusions will be outlined.

Life cycle design (LCD)

One of the major future requirements of a product will be its environmental soundness throughout its life cycle. In this context the LCD concept has emerged – where the product is designed to consider all the life cycle phases (pre-production, production, distribution, use and disposal). Given an objective to minimise environmental impacts during all life cycle phases, approaches to LCD will vary from case to case with regards to product type, industry sector, firm's size, life cycle costs and stakeholder responsibilities. The first phases of product development are key and environmental requirements should be considered, together with cost, performance, and cultural and aesthetic needs.

The following section summarises the software tools that take account of environmental considerations and the lifecycle concept. Two approaches have emerged. Firstly methodologies have been developed for the quantitative analysis and assessment of the environmental impact of the products eg. LCA; these tools were created in order to enable quantitative evaluations in comparison with alternative concepts. Secondly, design tools have been developed for the improvement of specific environmental performance (dedicated tools), particularly in relation to the 'end of life' phase.

Methodologies and tools for quantitative analysis of the environmental effects based on the life cycle perspective

LCA is internationally recognised as a useful methodology (ISO 14040) for the environmental assessment of products. However, because of the complexity of the relationships that an LCA must analyse and evaluate, there are several limitations to this methodology. For example:

- the nature of the choices and assumptions in a LCA are subjective
- the models are not able to describe the whole spectrum of the environmental impacts
- the models are not adaptable to all applications
- on a global level, the results and the criteria can be inappropriate for local applications
- the lack or the low quality of the data can limit the reliability of the results.

LCA's goal, scope definition and the inventory phases are usually well defined; but the evaluation phase is critical and various software tools have been developed to support analysis which is often time consuming and complex. Below are some of the most well known, commercially-available LCA evaluation methods.

LCA and product development: the limits

Although LCA is currently the most useful methodology for assessing the environmental impact of products, there is still

Overview of the most well-known LCA evaluation methods

BUWAL methodology
Developed by BUWAL, the Swiss Department of Environment. The method is based on the use of Swiss national targets for environmental impact reduction. The inputs and outputs are transformed into eco-scores with regards to the energy and raw material consumption, and emissions to air, water and soil. The total impact may be expressed by a single value.

CML methodology
Developed by the CML at Leiden University in the Netherlands. It allows the user to define various environmental effects (greenhouse effect, acidification, eutrophication, etc.) from the input and output data of processes. It is the basis of the most evaluation systems in Europe.

EPS methodology (Environmental Priority System)
Developed by the Swedish Environmental Research Institute (IVL). Mainly used in Scandinavian countries, it uses a single unity (ELU – Environmental Load Unit) which assesses various environmental impacts of a product.

Overview of software tools for LCA

Boustead database
Produced by Boustead Consultants in the UK. It is primarily a tool for the Inventory phase with the output interface covering the following categories: energy, combustibles and emissions to water, air and soil.

LCA inventory Tool
Produced by CIT EkoLogik, in Sweden. This program has been developed to aid environmental analysts rather than designers. Its focus is the Inventory phase of the LCA.

PIA
Produced by Bergen and Jurgens in the Netherlands. It includes a database on the production phase. However it is not possible to aggregate and compare data.

Greenpack
Produced by the Italian Institute for Packaging. It is based on the BUWAL methodology and focuses on packaging.

TEAM-DEAM
Produced by Ecobilan in France. The Inventory and Evaluation phases are managed by two separate programs. Its best feature is the presence of primary data derived from companies.

SIMATOOL
Produced by CML at Leiden University in the Netherlands. There is a database for the Inventory, with the Evaluation stage using the CML methodology. The interface is mainly designed for environmental analysts.

SIMAPRO
Produced by Pré in the Netherlands. It includes a version, for analysts and a version for designers. It allows comparison of different complex products or product's alternative design options in terms of environmental effects (CML and other methodologies) or as single eco-score value (Eco-Indicator 95 and others).

concern over its use in the implementation phase of product design. Below are the most important issues.

- variety of products and sectors: design specificity of every product versus general and decontextualised LCA data
- ability to choose: discriminating power versus scientific reliability
- incisiveness of the decisions: first phases of product development versus LCA applicability
- variety of the stakeholders in the product development: differences in the procedural attitudes versus rigidity of the LCA interface.

Variety of products and sectors

Often it appears that implementation problems occur due to lack of product-specific process data, eg. public databases or low-cost accessible data do not have complete information on all the processes.

Ability to choose

The easiest way to choose between two or more product (development) options, occurs when each of the alternatives is defined by one value only (eg. one value that summarises all environmental impacts); in other words, in an LCA as the result's aggregation increases (in Figure 1, from inventory phase to evaluation phase), the ability to select the best option decreases. In fact when comparing the environmental impact of two or more products it is easier to state which is best when the results used are those of evaluation phase (one value for each of the alternatives), rather than those of the inventory phase (two inventory tables with all the inputs and outputs from all the processes). Figure 1 schematises a hypothetical situation: in the inventory phase, product A results are better than the product B in relation to chlorofluorocarbons (CFCs), but worst for carbon dioxide (CO_2); that means it is not easy to state which is a better option. In the evaluation phase, product A results are better than product B; hence, it is clear which is the best alternative (in Figure 1, A is better than B).

Given what was discussed above, the problem is that a reliable result is inversely proportional to its scientific reliability. In fact, a reliable LCA result comes from considering all possible effects evaluated using the most scientific possible methods, but typically what happens during

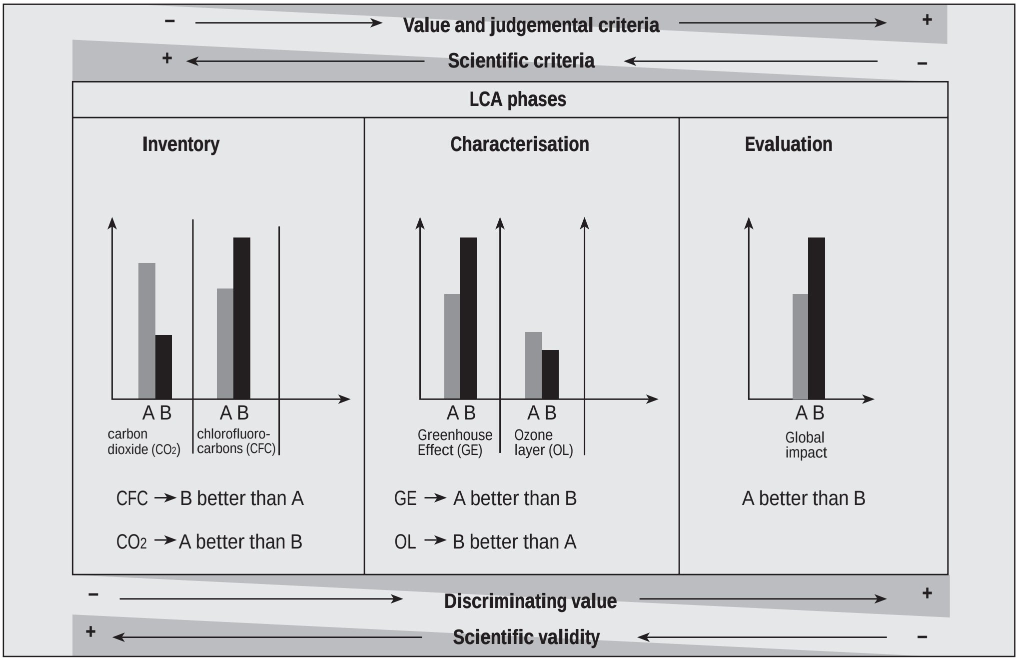

Figure 1: Relationship between the LCA results and its scientific validity

the evaluation phase of an LCA is that:

- as the number of impact categories increases, the ability to identify credible methods of aggregation decreases
- as the degree of aggregation increases, the scientific level of the evaluated results decreases (the use of the value and judgmental weighting increases) ie. the scientific validity of the LCA results decreases as it passes from the Inventory to Characterisation, and then toEvaluation (see Figure 1).

In summary, there is an inversely proportional relationship between the scientific reliability of the results and their degree of aggregation, or, in the ability to select between product options.

Incisiveness of the decisions

In general, during the development process, as the product becomes more defined and specified, the LCA methodology can become increasingly effective. This is because the methodology requires data, which is unknown during the first design phases. In the design phase when the brief of a new product is produced (in Figure 2, the strategic design of a product strategy) the complex processes relating to its future life cycle are not known. That means it is difficult to apply an LCA as it requires quantitative data. During the design phases the processes relating to the product's life cycle phases become increasingly clear and, hence, LCA becomes more useful (eg. in Figure 2 as one moves from the strategic design of a product strategy, to concept design, to product design to process design (engineering)). At the same time, the possibility of reducing the environmental impact of the product is greater in the first design phases, as there is a higher potential for innovation (and hence a higher potential level of environmental improvement). Therefore, the integration of environmental requirements at the level of strategic design or concept design, usually leads to a greater environmental improvement, compared to introduction at the engineering phase (process design).

Variety of the stakeholders in the product development

Because of the variety of actors involved in the product development process (project managers, designers, marketers, process engineers, etc.) a range of different decisions will need to be taken in the product creation process. In other words, during the various design phases (ie. strategic design of product strategies, concept design, product design, process design) there are differences in approaches, procedures and tools needed by different actors. Current LCA tools are highly structured, ie. at present LCA interfaces have been developed for environmental analysts. The major problem with LCA is the difficulty of using it by the various actors involved in the product development process.

It is important to underline that LCA's prime purpose is environmental analysis and assessment and not to provide design guidelines. In short, LCA indicates where the environmental problems are, but it doesn't suggest ways to solve them.

Design tools for dedicated environmental performance

There is an other category of tool that has been developed to address particular environmentally oriented-issues – the dedicated design tool. This includes tools to enable:

- the selection of low environmental impact materials
- the minimisation of toxic and harmful materials
- 'Design for Recycling' (DfR)
- 'Design for Disassembly' (DfD)
- 'Design for Re-manufacturing' (DfRM)

These dedicated tools include manuals, guidelines or indexes and software aided design tools.

Below are listed some of main software programs on the market.

Overview of main software tools for dedicated environmental performance

REStar
Developed by the Green Design Initiative of the Carengie Melon University, US. This is a software program to support the design for disassembly, recycling and repair.

DFE (Design For Environment)
Developed by the Boothroyd, Dewhurst Inc., US and by the TNO (Institute of Industrial Technology), in the Netherlands. This program analyses products throughout disassembly and provides opportunities aimed at optimising recycling.

Eco-Design-Toolkit
Developed by the Fraunhofer Institute for Manufacturing Engineering and Automation, Germany. During the development process, this software tool helps to adjust product features to recycling requirements. There are three modules to the tool: assessment, guideline catalogues, evaluation.

RECREATION (Recycling Resources And Technologies InformatiON)
Developed by the IPA at the Frankfurt Institute, Germany. It is a database with information on recycling processes and the recycled materials suppliers.

RECOVERY (REmanufactoring Cost Optimisation Extended Reuse St. [and disassemblY])
Developed at the IPA of the Frankfurt Institute, Germany. It is software program aimed at identifying the most economic strategy for a product re-manufacturing, through the evaluation of its disassembly.

IDEmat
Developed by the Technical University of Delft in the Netherlands. It is a program for the selection of low environmental impact materials, which includes a data bank containing information on the physical, mechanical, economic and, environmental characteristics of several materials. It is possible to query the programme through the specific characteristics of the material. The environmental data is expressed in terms of Eco-Indicator 95 and EPS.

SW tool for disassembly
The Mechanics Department of the Politechnic University of Milan has developed a software prototype aimed at facilitating disassembly and optimising the dismantling procedures.

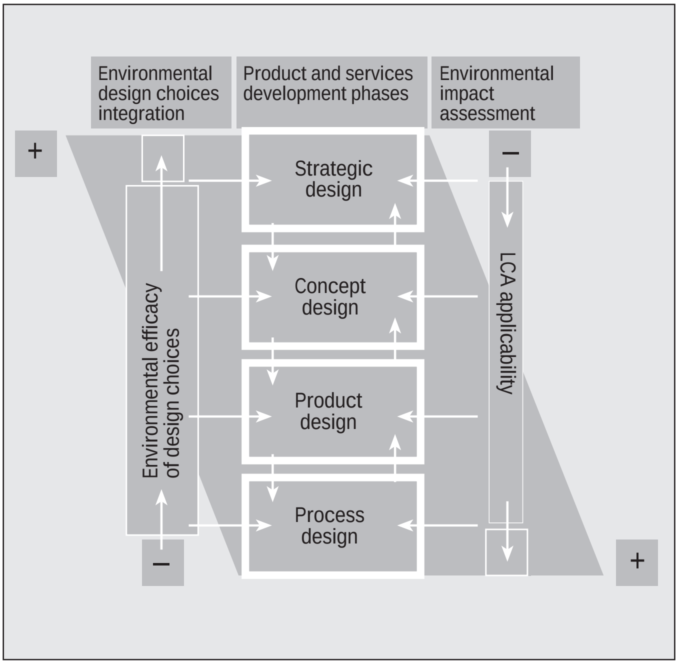

Figure 2: Relationship between the LCA applicability, the environmental efficacy of design choices and the product development phases

Limits of software aided design tools for dedicated environmental performance

Although these tools are useful for minimising environmental impact, however they focus on specific environmental issues only. They may neglect the most serious problems (or phases) for a specific product-system. For example, in the case of transportation products consuming a high quantity of energy during the use phase, the selection of recyclable materials (eg. avoidance of composite materials) could be misleading if related to the lifecycle conceptualisation of the product (in which the selection of composite light materials could be an environmental priority). There is also be a problem with the integration of many different design tools with current design procedures eg. the integration of software tools for environmentally sound material selection
and 'design for disassembly', with conventional CAD and CAM systems.

Development trends

LCA and dedicated tools are starting to converge and integrate. New simplified LCA methodologies are being developed that aim to be easier to use and cheaper, and therefore more likely to be used in the first design phases. In addition, dedicated design support tools are widening their features to illustrate how design activities can reduce the environmental impact throughout the whole life cycle. These development trends will be

PWMI database on plastic materials

The European Association of Plastics Producers (APME-PWMI) has financed a project, resulting in inventory tables (input and output) for the production of polymers. This has provided primary data on a European level.

Italian data bank for the LCA

The ANPA (Italian Environmental Protection Agency) has commissioned the Polytechnic University of Milan to develop an Italian data bank for the LCA. The objective is to provide Italian enterprises, research institutes, educational structures and the public bodies with a series of reliable data covering the specific of the Italian situation. The categories of processes to be included are materials, processing, energy, transportation, and recovery and disposing. It will be highly modular, to fit most recent SPOLD standards.

Eco-Indicator 95, Eco-it and Ecoscan

Eco-Indicator 95 was developed in the Netherlands by Prè, Philips, Oce, Nedcar and Cool, with the government support. A series of processes have been assigned an eco-score (for unity of measure) defining the extent of the environmental impact. These eco-scores, calculated with the LCA methodology, are applied simply by multiplying them with the quantities of the processes characterising the product life cycle.

Pré in the Netherlands has produced the Eco-it software in which the life cycle processes of the product are evaluated throughout the calculation of the above mentioned Ecoindicators.

Turtle Bay in the Netherlands has produced the Ecoscan software in which the life cycle processes of the product are evaluated utilising the above mentioned Ecoindicators. A key feature is the facilitation of calculations of transport distances, energy use and geometry of the product.

illustrated by some following examples.

Evolution of LCA

Without good data on the processes no one environmental impact evaluation method can be used with certainty, as the data is often too general and de-contextualised.

Some recent research has focused on the achievement of reliable and specific data, for a wider variety of product types and sectors, as well as for different production scenarios (eg. geographical areas). Two examples are presented here (see panel), the first one being specific for one category of material (plastics), the second one being specific for one geographical area (Italy).

In addition to the collection of specialist LCA data, thinking is starting to focus on methods and tools to enable faster and simpler evaluations (simplified LCA). The problems associated with this are the validity and the transparency of the data and the results. Particularly, as these tools are simpler, these methods can be used by individuals who are inexperienced in environmental analysis (this is an advantage), but they can easily lead to evaluation errors (this is a danger). An example of an extremely simplified LCA is presented here together with two software tools.

Overview of life cycle design support software tools

DFE (Design For Environment) second version
It has been developed by the Boothroyd, Dewurst Inc., US and by the TNO (Institute of Industrial Technology), the Netherlands, and is an upgrade of the first software version.

EDIP: Environmental Design Strategies, Environmental Specification, Environmental Design and Rules
Developed by the Technical Universirty of Denmark in Denmark. EDIP is a whole spectrum of software tools to support the decisions for different design phases, integrated between each other and with an LCA system.

ECODesign tool
Developed by the 'Design for the Environment' Research Group at Manchester Metropolitan University and Nortel in the UK. It is a program based on expert rules to support the designer while he/she takes decisions in the various design phases and can be interfaced with a CAD tool. This program is one of the outcome 'Design for Environment Decision Support (DEEDS)' project funded by the Engineering and Physical Sciences Research Council (EPSRC) in the UK.

TEIME DFE
Developed by the Ecobilan, France, for the electronics sector, to be used in the various phases of the life cycle and by the various actors.

Eco-Composit V1.0
Produced by the Fraunhofer-Institute for Manufacturing Engineering and Automation, Germany. This software tool supports the designer in the development of electronic products by making him/her aware of environmental issues. It creates customised guideline catalogues for individual components.

LEADS
The Technical University of Delft in the Netherlands developed a project that aims to create a software tool for environmental product development (EPD) by providing general guidelines for EPD, a communication format, and indications of environmental load.

LCD multimedia educational tool
The Products and Services Research Unity of the CIR.IS together with the METID (Centre for Innovative Methods and Technologies for the Didactic) has initiated a project to produce a multimedia educational and training software tool for the study and the development of sustainable products on a life cycle approach. It will based on simplified LCA and on expert rules LCD. It will be founded by the ANPA (Italian Environmental Protection Agency).

Evolution of the dedicated design support (environmentally) tools

Dedicated design support tools are evolving and widening their potential and effectiveness with regards to reducing environmental impact throughout the whole life cycle. In the panel opposite there is a brief description of some of these software tools.

Conclusions

A series of interesting tools have been/are being developed covering LCD and LCA. Further efforts are required to transform these projects into approaches that can be used on a wider basis. It is important to increase the visibility of the initial experiences and define possible guidelines for future developments. Using a life cycle approach it is evident that design activity is becoming more complex eg. environmental requirements have to be extended to all life cycle phases and to all stakeholders in the process. In practical terms there is a need for more information on the relationship:

- between the system of production and consumption and the environment
- between the various stakeholders of the system of product development
- between these actors and whoever is involved in the product life cycle.

In this highly complicated design context, IT (software) assumes an important role due to its ability to hold, analyse, circulate, compare, highlight and present in various forms (with different interfaces) large amounts of information. The benefit of IT (software) is its ability to manage this increased degree of complexity.

The development of the new eco-design support tools will have to deal with the following issues:

· the widening of focus to the whole life cycle
· the integration of simplified LCA into the various product development phases
· the integration of expert rules into various product's development phases
· the customisation to different product sectors or product types and by-products
· the adaptability to various stakeholders in the product development process
· the integration with today's design tools and the procedures (eg. CAD and CAM)
· the adaptation to an integrated mix of products and services.

The development and use of new IT (software) tools that aim to support design activities is not the solution to the integration of the environmental considerations into design; as the changes required to move towards sustainability are on a systemic level, which will require innovations on a social and cultural level as well as a technological one. There will never be one tool able to solve all the design problems in an effective manner. More realistically, in the future, tools will need to be developed to solve specific problems and, at the same time these tools will need to be able to interact (when necessary) with other tools, as well as effectively interface with the various stakeholders in the product development process. •

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'Design for Environment' software development

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This paper describes the development of a software tool for determining the financial and environmental effects of 'end of life' disassembly. The environmental impact from initial manufacture of the product is also determined. Environmental assessment is achieved through the single figure indicator, MET points. A procedure for optimising the disassembly sequences to release valuable or environmentally beneficial items as early as possible is included. The program expands the range of predictive analysis tools for use in concurrent engineering to enable the design of more environmentally friendly products. This programme has been developed jointly with the TNO Industry Centre, Delft in the Netherlands.

Introduction

Experience with product design for manufacture and assembly (DFMA) has shown that:

- early design decisions concerning product structure, materials and processes determine the majority of manufacturing costs for a product.
- the further into the development process for a new product the greater is the reluctance to make changes because of rapidly increasing modification costs and the effects on time-to-market.

This emphasises the need to make the right decisions first time at the early stages of product design. It has been found necessary to provide design teams with predictive analysis tools, which quantify the effects of design attributes on manufacturing and assembly costs to facilitate early design decision making. This is the basis of DFMA, which has been shown to be very effective in many industries and numerous case studies of the development of more competitive products have been reported (Boothroyd et al, 1994). Fundamental to this approach is placing the analysis tools in the hands of the designers in an easy to use form to enable early design decisions to be based on sound information.

When 'end of life' disassembly and environmental impact are of concern, the same conclusions can be drawn. The ease of disassembly and the environmental impact of products are determined by decisions made by designers early in the development of a product, when initial choices of materials and assembly methods are made. In general designers and engineers have little training or background in environmental assessment and must either rely on the advice of experts or be provided with the necessary information to make the appropriate decisions. Thus, suitable product analysis tools should also be available to designers with this emphasis, if these aspects of product design are to be effectively evaluated. Such tools should be easy to use by product designers, without the need to rely on lengthy studies by Life Cycle Analysis (LCA) experts and industrial ecologists.

Recently a software analysis tool has been developed which is aimed at fulfilling this need and which can be used in conjunction with current DFMA analysis tools. This Design for Environment (DfE) software simulates 'end of life' disassembly of the product and quantifies the economic and environmental effects as disassembly proceeds. Although this appears to be a DfE analysis tool primarily dealing with 'end of life' management issues, assessment of the environmental impact of the whole life cycle of the product, including initial manufacture, is obtained. Simulating 'end of life' disassembly is a convenient way of considering every item within the product. This software has been developed jointly with the TNO Industry Centre in Delft, the Netherlands.

Modelling of the disassembly of products has received considerable attention, usually with the aim of evaluating the costs of disassembly or the most appropriate disassembly sequence (Zussman et al, 1998, Johnson and Wang, 1994). Similarly tools for environmental assessment have also been developed (PRe Consultants, 1997). However as far as is known, the DfE tool described in this paper is the only available that enables financial and environmental factors to be considered in a single analysis.

Product analysis procedures for disassembly

The purpose of the procedures for product analysis is to effectively simulate disassembly at 'end of life' disposal and then to quantify for design teams the resulting cost benefits and changes in effective environmental impact. The following main outputs are provided:

- a picture of the financial cost or return at each stage of disassembly of the product
- a summary of the effective environmental impact of the product at each stage of disassembly
- an assessment of the environmental impact of manufacturing the product and the materials used
- a determination of the best disassembly sequence for a proposed product design.

The analysis procedure readily allows different design configurations, including alternative material and process selections to be evaluated and compared.

In order to meet these aims the following developments were necessary:

- data for determining disassembly and 'end of life' disposition costs
- a method for environmental impact evaluation, which is readily usable by designers together with associated data for material production, material disposal, material recycling and for manufacturing processes
- a procedure for determining the most appropriate disassembly sequence for a given product.

Financial analysis of disassembly

Disassembly costs are determined from time-standard databases developed specifically for 'end of life' disassembly processes (Girard and Boothroyd, 1995, Rapoza et al, 1996). This database is a modification of that developed previously for disassembly for design for service evaluations (Dewhurst and Abatiello, 1996). Increased time penalties are associated with disassembly problems such as difficult access and so on. Disassembly costs are determined by multiplying the times by an appropriate labour rate. Any profit or cost from the disposition of each item is determined from recycling values and disposal costs for different materials in a materials database. Each item in the assembly is allocated to an appropriate 'end of life' destination (recycle, reuse, regular or special disposal and so on) based on its material content and this information, together with the item weight, enables the possible costs or profits to be determined. An initial disassembly sequence can be entered directly by the user or is preferably generated automatically from a design for assembly (DFA) analysis, by effectively reversing the initial assembly list. The user is able to edit this sequence, in particular to form groups of items which will not be taken apart at 'end of life', but will be recycled or disposed of together.

Material cycles	Energy use	Toxic emissions
Exhaustion of resources	Greenhouse effect	Ozone depletion
	Acidification	Human toxicity
	Smog	Ecotoxicity
	Eutrophication	

Figure 1: Grouping of effects for MET points

Environmental impact assessment

Environmental impact analysis of products and processes can be accomplished through a full LCA, in which a detailed inventory of all inputs and emissions is developed. Such analyses are usually carried out by experts and frequently yield large amounts of difficult to interpret data. Thus, in practical terms, detailed LCAs have two major obstacles to effective use during early design:

- the results of a LCA are often hard to interpret, as they contain data on a wide range of emissions, etc.
- the time to carry out a full LCA is excessively long to be useful during early product design.

For these reasons there has been emphasis on the development of more streamlined procedures for the environmental evaluation of products and processes, which nonetheless embody much of the information that would be obtained from a detailed LCA study. The approach is to develop databases of environmental or eco-indicators, which are derived from detailed LCAs. Typical of these systems are EcoIndicator 95 (Netherlands NOH, 1995) and MET points (Kalisvaart and Remmerswaal, 1994), in which the total environmental effects for materials and processes are presented in the form of a single figure indicator. In conceiving this software, it was felt strongly that the environmental analysis of the product should be presented to the design teams in a meaningful way, for this to have the greatest impact on product design. Thus one of these so-called single figure environmental indicators for impact assessment was judged to be the most suitable. In this case the indicator called MET points, developed by the TNO Industry Centre in Delft in the Netherlands, who collaborated in producing the software, was chosen, although one of the other indicators, such as EcoIndicator 95, could have been used.

The MET points indicator takes into account the eight environmental effects listed in Figure 1 and further divides these into three sub-groups (Material cycles, Energy use and Toxic emissions). This allows separate figures for these sub groups to be investigated if required, thereby indicating the nature of the environmental impact in somewhat greater detail than a single figure.

As with other single figure indicators, MET-points are based on calculations from a LCA of a material or a product and the procedure for deriving MET points is based on the guidelines for LCA's outlined by SETAC (Fava et al, 1991). First an inventory of emissions is drawn up and then the various emissions classified into their contributions to the eight evaluated effects using the CML classification (Heijungs et al, 1992). The resulting effect scores are then normalised by dividing by the total environmental effect per person per day in each classification for a region under consideration, in this case, the Netherlands. Finally, a weighting is applied to each effect score based on how close the current total effect for the region is to agreed target levels. In this case weightings based on Dutch target levels for the eight effect classes have been used. The reader is referred elsewhere for more details of the determination of these points (Kalisvaart and Remmerswaal, 1994).

It is not necessary for the users of the software to carry out this form of LCA, as the software is provided with a comprehensive database of M, E and T scores for a range of materials and manufacturing processes. If additional data should be required to be added to the database, then the analysis process outlined above should be used. For materials, MET scores are included in the database for the following:

- material production
- material recycling
- material disposed of in a regular landfill
- material disposed of in a landfill with special treatment.
- material disposed of in a regular incinerator
- material disposed of in an incinerator with special treatment.

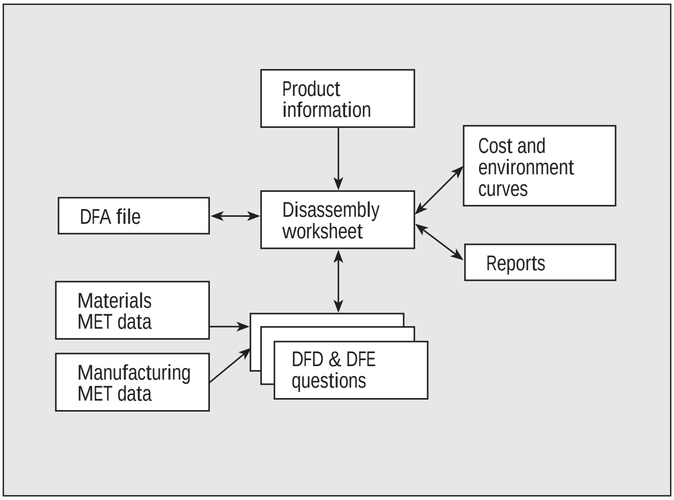

Figure 2: Structure of the DfE program

Utilisation of the software

The structure and data flow for the DfE program is shown in Figure 2. The main working window is a worksheet which lists all items in the product in disassembly order and which includes results, which contribute to the financial and environmental analysis of the product. The general sequence for using the program is as follows:

- build an initial disassembly list for the product – this can be done using the program stand-alone, but preferably should be obtained automatically from a previous DFA analysis
- edit the disassembly list as necessary, usually to remove or replace inappropriate disassembly operations or to group items together, which will not be separated at disassembly
- For each item, enter the materials and manufacturing processes used during manufacture – these are selected from drop down lists corresponding to categories in the materials and processes database
- specify an 'end of life' destination for each item (reuse, recycle, landfill or incinerate) and indicate if special waste treatment is required; for materials which are recycled a value is obtained from the materials database
- assign disassembly precedence to each item – this entails indicating which items must be removed immediately prior to an item in order to release it from the assembly; the procedure for doing this is outlined later
- use the program to determine the best disassembly sequence using a procedure also described below
- display the results of the financial and environmental analysis of the product – these are summarised in a graph containing a financial and an environmental line.

Financial assessment line

A typical financial assessment graph is shown in Figure 3 for the disassembly of a 386 PC. This shows the return or cost as disassembly of the product progresses and is plotted against disassembly time. A point on this curve represents the profit or net cost if disassembly is stopped at this stage. Thus the first point represents the costs of product disposal by landfill or incineration (user selected) without disassembly, which includes the take-back costs of the product (collection, inventory, etc.) and the product weight multiplied by the appropriate disposal cost per unit weight. Included in the contributions to each point on the graph are the following:

- the take-back cost of the whole product
- the cost of disassembly up to this point (cumulative disassembly time multiplied by labour rate)
- the cumulative value (from recycling or reuse) of items disassembled to this point
- the cost of disposal of the remainder of the product yet to be disassembled (rest fraction). It should be noted that it is assumed that the rest fraction is disposed of by special waste treatment (landfill or incineration) as long as any item requiring such treatment remains in the rest fraction. Special disposal is in general more expensive than regular disposal.

Generally at the start of disassembly small items (fasteners, etc.) are removed – when the cost of disassembly is greater than the value of any material recovered. Some items will have a significant positive effect on this financial return analysis. This will be the case for items that have high recycling values, are reused or are toxic (the rest fraction of the product becomes less costly to dispose of once these items are removed). These items are referred to as critical items. For the curve shown in Figure 3 it was assumed that some of the items, such as memory SIMMs, disk drives and power supplies, have significant resale value when removed from the assembly.

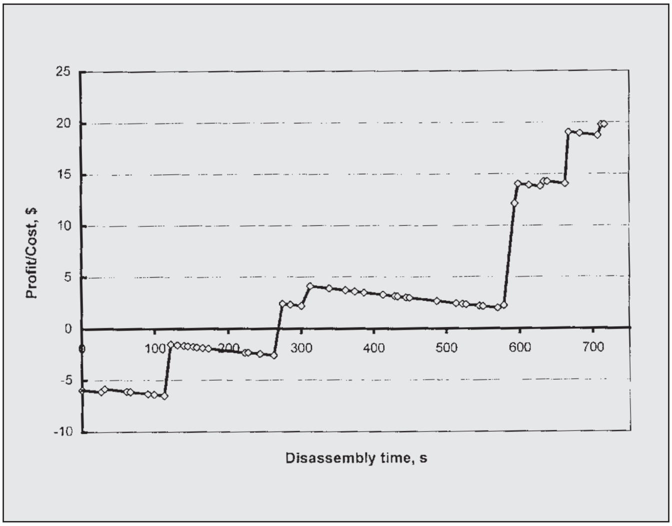

Figure 3 Financial line for 386 computer

Environmental assessment line

The environmental impact assessment results are summarised in curves which show the net MET points from initial manufacture of the product and 'end of life' disposal at any stage of disassembly. Figure 4 shows a typical example for the 386 PC. In a similar manner to the financial assessment curves, a specific point on the curve represents the net environmental impact of the product if disassembly is stopped at this stage. The main assumptions that have been made in all analyses are as follows:

- the disassembly processes for the product have negligible environmental impact (MET points) since manual disassembly methods are assumed.
- recycling of an item results in effective recovery or release of the MET points for initial material manufacture (modified by a quality factor to account for contamination, etc., if necessary). This means that if a material is recycled then the environmental penalty of producing the material from raw materials is assumed not to be paid again.
- reuse or remanufacture of an item results in effective recovery of the MET points for both initial material manufacture and the initial manufacturing processes for the item. This means that effectively the environmental penalties of both initial material production and component manufacturing are not paid again.
- the rest fraction of the product at any stage of disassembly is assumed to be disposed of by special waste methods as long

as an item requiring special waste treatment (referred to as toxic) remains in the rest fraction, after which regular waste disposal methods are assumed. It should be noted that for all materials, special waste disposal results in lower MET points per unit weight than regular waste disposal methods.

For the environmental curves the vertical axis shows MET points for the product as disassembly proceeds. The contributions to each point on the curve are as follows:

- the MET points for initial material and processes for manufacturing the whole product
- the cumulative effect of reprocessing for recycling and disposal for all items disassembled to this stage
- the MET points for disposal of the rest-fraction of the product
- fewer MET points 'recovered' for items disassembled so far which are recycled or reused (remanufacture)
- the MET points associated with take-back of the whole product (transport, etc.).

Note that all MET points are negative, since they measure effects on the environment through emissions, use of scarce materials, etc. Remanufacturing or recycling of items effectively reduces the negative effects of products' initial manufacture and 'end of life' disposal. The first point on the curve represents the environmental impact from the initial manufacture of the whole product plus the environmental impact of the disposal of the whole product either by regular or special waste treatment, whichever is applicable. As disassembly proceeds, the curve moves up if items are recycled or remanufactured, as some of the initial MET points for product manufacture are effectively 'recovered.' The curve will also move up or down if items are removed which result in the rest fraction being changed from special waste to regular waste disposal. This will normally happen when the last item, which has to be treated as special waste, is removed from the assembly. Note that at this point, the curve may in fact move down, because of the increased environmental impact for all materials processed as regular waste relative to special waste, but at correspondingly lower cost.

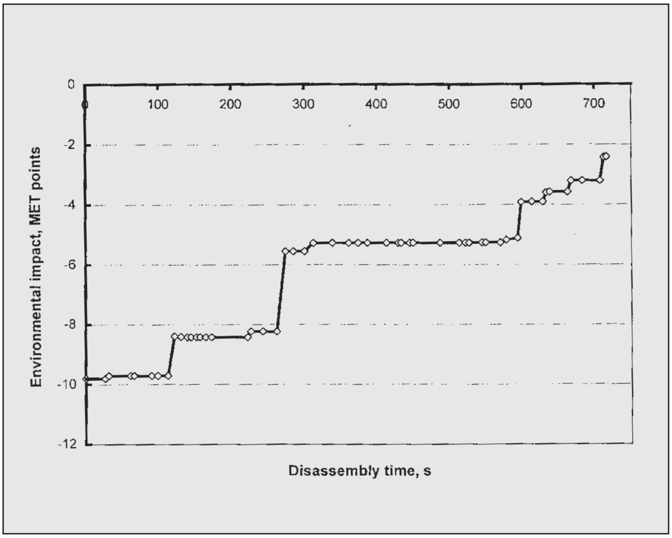

Figure 4: Environmental line for 386 computer

Optimisation of disassembly sequences

In complex products there are a wide variety of possible disassembly sequences, limited by the disassembly precedence for each item. For example many items in sub-assemblies can be removed without first removing the sub-assemblies or the sub-assembly can be removed before disassembling further to reach the required item. Determination of the most appropriate disassembly sequence for a product is therefore of interest. This requires a procedure for capturing the disassembly precedence of the product, a criterion for judging the most appropriate sequence and a strategy for reordering the sequence. The criterion for moving items forward in a disassembly sequence is based on the greatest rate of improvement in profit (cost) or environmental impact.

The program contains a procedure for the user to assign disassembly precedence to each item. This consists of highlighting a specific item and then selecting other items that need to be removed immediately prior to it for it to be released from the product. In selecting the immediate predecessor, any predecessors of this already assigned are indicated to the user by highlighting in a different colour. The precedence assignment process is best achieved by starting at the top of the list and working down. Continuous checks for circular precedence assignments and so on, are built into the procedure. This process is very useful since it forces the user to carefully consider all disassembly constraints and leads to suggestions on design changes for releasing valuable items more easily.

A procedure has been developed, which will reorder the critical items (those which produce significant steps in the financial curves) as early as possible in the disassembly sequences, but limited by the precedence constraints input with the initial disassembly sequences. The order in which items are moved forward in the disassembly sequence is determined from the greatest yield (rate of improvement).

A critical item, which produces a large positive jump in the curve, should be moved forward in the disassembly sequence. The yield of an item is defined as:

Yield = $\Sigma E/\Sigma T$, where ΣE is the sum of all costs and profits and ΣT is the sum of all disassembly times for the necessary items to be removed to release the item under consideration alone.

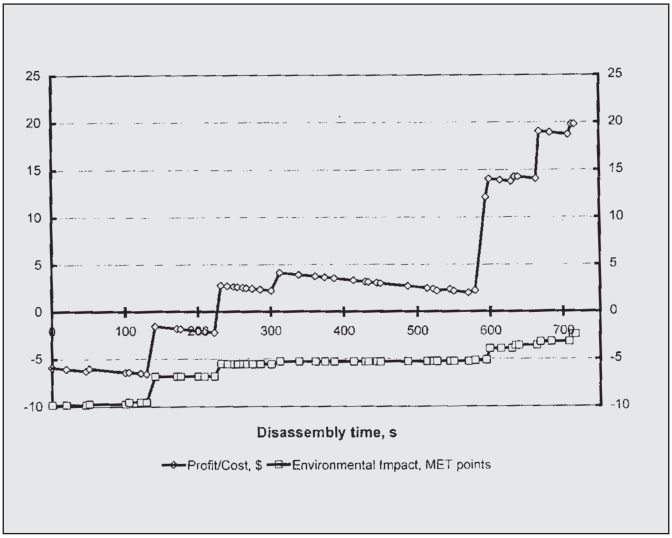

Figure 5: Results for 386 computer after moving power supply earlier in sequence

Yields are calculated for all critical items and then the item with the highest yield is moved forward, along with its predecessors, as far as the precedence will allow. Subsequently the yields of the remainder of critical items are recalculated and the highest yield item moved forward as far as possible up to the previously moved item and so on. In practice the yields must be recalculated at each stage as the different critical items will often have common items in the lists of precedents.

Example of product analysis

In order to illustrate the application of these product analysis procedures, the disassembly of a 386 PC will be considered. As a first step in the disassembly analysis process, a Design for Assembly (DFA) analysis was carried out using DFA software. The DFA analysis showed that the product consisted of 99 parts with 3 sub-assemblies and had a total of 102 items assembled, plus 18 additional operations. The DFA assembly time was estimated to be 1071s. The PC weighed 7.32 kg.

The initial disassembly sequence was arbitrary, being a reversal of the DFA assembly lists. Some editing of the disassembly steps was necessary, so that parts made of the same or of compatible materials that would not have to be separated for the purposes of reuse, recycling, or special disposal, were combined and treated as one item. Also, appropriate disassembly procedures were assumed where soldered wires were simply cut for example. The financial line and environmental line for this

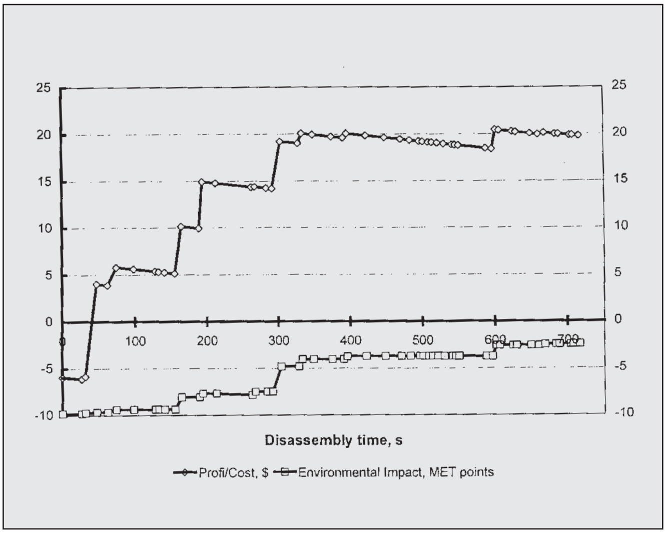

Figure 6: Results for 386 computer with optimal disassembly sequence

edited sequence are shown in Figures 3 and 4. As can be seen, with the assumptions made for the 'end of life' destinations for each item, a profit of around $20 could be realised for this product, but complete disassembly of the computer would be required for this initial sequence. The point of least effective environmental impact also corresponds to complete disassembly and this is often the case.

The program allows different disassembly sequences to be investigated in two ways. The first by allowing the user to move selected items forward in the disassembly sequence alone and the second by implementing the optimisation strategy outlined above. Item 21 in the initial disassembly sequence is the power supply, which is assumed to have a resale value of $5 and produces a corresponding step in the financial line. By selecting this item, a procedure whereby the selected item is moved forward as far as possible, but limited by the precedence assigned, can be used. The financial and environmental lines for the new disassembly sequence are shown in Figure 5, with the power supply now at position 9 in the disassembly order. The user can continue moving individual items in this manner and hence investigate a wide range of disassembly sequences. However, utilising the optimisation strategy described above is more useful. Figure 6 shows the financial line and environmental line for the financially optimised disassembly sequence. In this case, the maximum financial return of $20 occurs with the removal of item number 24, the hard drive, at a disassembly time of around 400s. From the financial viewpoint disassembly should cease at this point, but for least effective environmental impact almost complete disassembly of the computer is required.

Concluding remarks

The use of decision support tools, which predict quantitatively the effects of initial design decisions, can significantly influence the concurrent engineering approach to product design. Following on from the success of design for manufacture and assembly techniques in industry, the range of analysis tools available for early design application has been extended to cover recycling and environmental impact. These will enable greater consideration of recyclability and environmental impact to be given during product design. These procedures have been developed into a software tool for use in a concurrent engineering environment, as a joint development with the TNO Industry Centre. Different design configurations for products can be easily compared using the program, which is now being used in industry for product analysis and benchmarking. •

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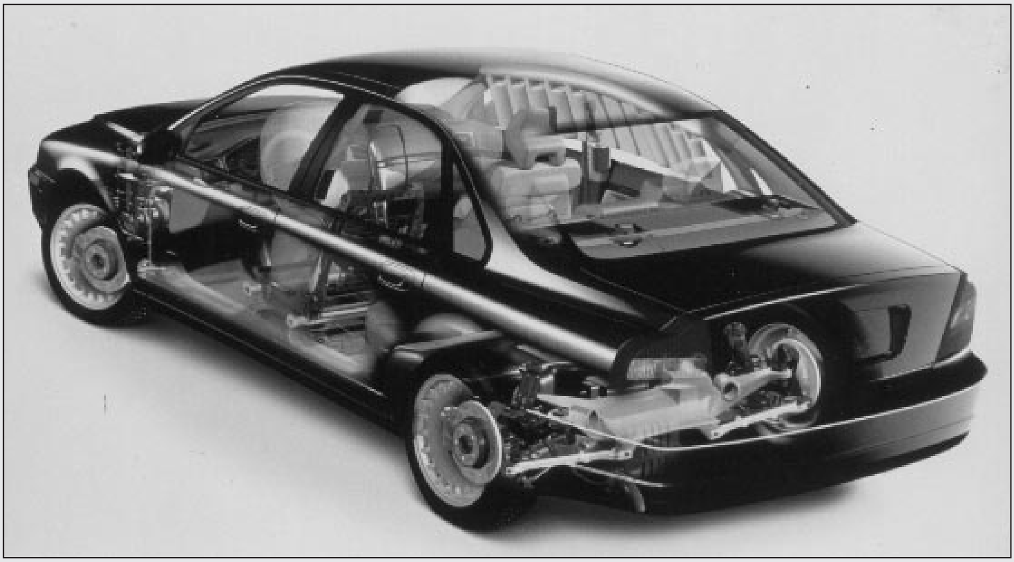
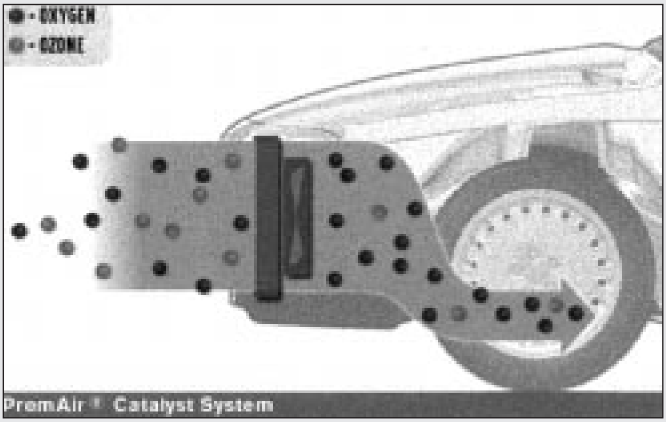


Volvo Clean Air Initiative



Volvo has launched a new technology that converts its car radiators into catalytic converters.

As air passes through the treated radiator, ozone (O_3) molecules are converted into oxygen (O_2) and the conversion increases with increasing ambient air temperature, increasing coolant temperature in the cooling system and increasing ozone (O_3) content in the ambient air. The conversion works from approximately 10°C ambient air temperature and after a few minutes' driving.

Low-level ozone (O_3), the principal component of photochemical smog, is formed when nitrogen oxides (NO) and hydrocarbons from traffic and other sources are exposed to sunlight. A high ozone (O_3) content in urban air is not only a health hazard to people, especially the young and elderly, but also to vegetation, for example by affecting crop yields.

Volvo is the first car manufacturer in the world to commercialise this technology which has been developed and tested together with the US-based Engelhard Corporation. The Volvo S80 will include radiators treated with Engelhard's PremAir catalyst system and they will also be fitted to other future Volvo models.

Volvo's decision to introduce the technology on its new S80 has been supported by the Environmental Protection Agency in the US and also by the California Air Resources Board, one of the world s leading proponents of clean-air initiatives. Tests conducted around the world in numerous different conditions have shown that as much as 75% of the ozone (O_3) that flows through the radiator is converted to oxygen (O_2). The purification effect on hot days and when the air has a high ozone (O_3) content will partially offset the level of ozone (O_3) production from the exhaust of a modern car equipped with a catalytic converter.

ICL reconditions unwanted PCs for small business and home user market

PCs, delivered from large corporate organisations, awaiting reconditioning

The reconditioning of a PC involves the removal of dust particles from inside the machine via air suction

ICL, the IT systems services company, is offering its large customers a unique recycling service in which unwanted PCs and notebooks are fully reconditioned and sold through dealers to UK consumers who can buy them at a fraction of the cost of a new machine.

The service is branded STAR (Second Time Around). It seeks to emulate the success of Network Q in the second-hand car market, by providing consumers with highly affordable products through a vetted network of reputable dealers. The STAR service is aimed at the growing small business, home office and home user market which does not necessarily require high specification machines.

The PCs, which are acquired from large corporates, will be wiped clean of data, refurbished, resprayed, reliciensed, have a new keyboard and new mouse fitted, repackaged, and complete with Microsoft Windows software loaded and a 90 day warranty.

Key to the STAR service will be a standard price list which dealers will not be able to undercut. ICL will ensure that all STAR dealers are vetted and provide telephone support, installation and have the ability to provide extended warranty services.

The STAR initiative is an important part of ICL's Recycle programme which will help ensure the environmental performance of their end-of-life management projects.

Philips Semiconductors' GreenChip

Research by the UK and German governments shows that at least 11% of total power consumption is wasted by equipment, such as monitors, TVs and VCRs, in standby mode waiting for someone to activate them usually by remote control. VCRs are the worst performers with nearly 90% of their power consumption being used for standby. The Department of Energy in the USA estimates that Americans spend nearly $1 billion each year just powering their TVs and VCRs while on standby. And these figures are likely to increase as more items become fitted with remote control units.

Philips Semiconductors has devised a solution to this problem with the invention of a new device called GreenChip . This can reduce the typical power consumption in standby mode from between 5 to 10 watts to just 1 to 2 watts and yet is able to supply full power in less than one second. This can be reduced even further to between 0.1 and 0.5 watts by the addition of a second GreenChip giving an overall power saving of up to 99% when going from 10 watts to 0.1 watts. The secret behind the power saving capability of the GreenChip is a special process that enables Philips Semiconductors to build chips that combine the ability to be programmed to control the energy usage efficiently with tolerance to mains voltages. Normally, chips can only operate at a few volts and would be destroyed if mains voltages were applied to them. These new chips have a special structure that reduces the high voltages down to a level that the chips can handle.

These GreenChips are now designed into TVs and VCRs and are available in the shops.

Making a stand

The UK Council for Environmental Education (CEE) commissioned the Surrey Institute of Art & Design, University College, UK, to design and build them an environmentally considered exhibition stand. The Environmental Studies Core, Interior Design and Design Management degree programmes organised a team of third year students, design staff and technicians to undertake this project. In addition, an educational video was produced documenting the project by the Film & Video programme at The Surrey Institute and Farnborough College of Technology, UK. This video is provisionally programmed to be screened on national television.

The final exhibition stand was opened at the National Education Show by Alan Meale, Under Secretary of State for the UK Department of the Environment, Transport and the Regions.

The aim of the design team was to minimise the environmental impacts of the exhibition stand through its whole life cycle. This has meant considering all aspects of the design and construction of the stand, from the selection of raw materials and production processes through to making the stand reusable and highly durable. The project was a real challenge to the students, as the stand had to also communicate and promote the aims and activities of CEE, as well as the environmental attributes of the stand.

An important part of the process was a strict environmental procurement policy in relation to suppliers, materials, processes and products.

Below is a brief summary of some of the environmental attributes of the materials, products and companies used in the construction of the final stand.

Text panels: Birch Areoply was used for the exhibition stand's text panels. The product used is thin plywood. The raw material (birch wood) is grown and then manufactured into Areoply by UPM-Kymmene. The wood was sourced from their sustainably managed forests in Finland and then manufactured into the end product using considered manufacturing processes. UPM-Kymmene has an environmental policy and an environmental management system (EMS) in operation.

Major structural support units: recycled spiral-wound fibreboard tubes were used for the exhibition stand's major structural supports. 100% post-consumer carton board waste (used corrugated boxes and carton board) and water-based glue are the only materials used in the production of these tubes.

Carpet tiles: the carpet tiles used on the exhibition stand were donated by Interface, a pioneer in sustainable business practices. Interface is the first carpet company to achieve ISO 14001 and BS7750.

This process has resulted in a large percentage of the materials and products utilised in the construction of the stand being supplied by companies who have at least an environmental mission statement and have begun the task of implementing an EMS. Where factors such as cost have allowed, companies have been selected who have received or are working towards becoming accredited with ISO 14001.

Designing in an environmental way always involves companies and this project was no exception. Certain materials had to be used because of their reliability, cost-effectiveness and flexibility, rather than being the most environmentally-sound material or product on the market.

An exhibition stand with environmental integrity was created, which will act as a benchmark for the exhibition industry.

Dr Lutz-Günther Scheidt

Director, Environment Center Europe, Sony International (Europe) GmbH, Germany

Martin Charter

Coordinator, The Centre for Sustainable Design, UK

Lutz-Günther Scheidt joined Sony in April 1990 and holds a doctorate in Information Technology from the Dresden University, Germany. He is the responsible Director of ECE (Environmental Center Europe) and procurist of Sony International (Europe) GmbH. Lutz-Günther is developing comprehensive environmental management systems and environmental R&D (Research & Development) for Sony in Europe. In 1994 he initiated the Eureka umbrella CARE 'VISION 2000'. He also represents Sony at the WBCSD (World Business Council for Sustainable Development) acting as Liaison Delegate. Dr Scheidt is one of the Directors of the Foundation for Business and Sustainable Development (Geneva and Oslo).

What do you think are the key impacts of sustainability on product and service development?

The initial phase of business sustainability has focused on eco-efficiency of processes, as well as 'end of pipe' technology. However, there is now a shift to exploring the reduction of environmental impacts of products at the beginning of the product development process eg. at source. Eco-efficiency is a concept developed by the World Business Council for Sustainable Development (WBCSD) and provides a good platform for thinking and practice, the idea is to reduce resource and energy consumption of products and services but importantly to 'add value' to customers (see also http://www.wbcsd.ch/aboutus.htm). The business sustainability challenge is complex and will require long-term strategic thinking, approaches and implementation that involves all stakeholders. WBCSD is doing pioneering work in this area through it scenarios project for the electronics sector.

The wider definition of sustainable product development is a new and challenging area, the model as yet has not been clearly formulated. Social alongside economic and environmental considerations are an integral part of the 'triple bottom line' for business and a key opportunity is to address these elements in the product development process. For example, issues that should be considered include consumer use, number of people employed and displaced through the development of a new eco-efficient or more sustainable products. Clearly, business sustainability requires new ideas, this has been well illustrated in Claude Fussler's book with Professor Peter James on 'Driving eco-innovation', which provides a wide range of interesting ideas and examples for eco-product developers.

What are the major issues that need to be addressed if we are to move towards more sustainable consumption?

A key issue is how you choose to define 'sustainable consumption.' Does sustainable consumption imply less consumption overall? Or could it also be understood to mean consuming differently? – for instance sharing or leasing products.

Within the electronics industry, the focus of eco-design has been on product improvements – for instance, reducing the energy consumption of a TV by an improved design in the power board component. This technical and engineering effort has been done mostly in the absence of a complete appreciation of the consumption-side of sustainability; for instance, consumer behaviour in relation to the purchase, ownership, maintenance and disposal of products. This is primarily because in its first phases environmental management and eco-design have been dominated by technical and engineering specialists, rather than broader strategic business people. To give the correct picture, it is essential to understand consumer behaviour and product use in relation to the purchasing and 'take back' of green or non-green products. At present, this is poorly understood. This is particularly important when one considers that the biggest environmental impact of electronics products is in its use phase. Smart technologies and on-line information could help consumers make better purchasing decisions and improve the consumer-product relationship during the active-life and 'end of life' of a product.

There may be opportunities for innovative partnerships in this area, for example, in the clothing market some clothing, detergent and white goods companies are working together to explore the reduction of eco-impact in the use phase of clothes cleaning. However, there is a range of examples, where green products have failed simply because manufacturers have forgotten to talk to the consumer! Therefore, it is important to think laterally and explore initiatives from various business sectors to provide new perspectives. Information technology and the dematerialisation process provide major opportunities to shift from owning physical products to the purchase of services. Dematerialisation is a useful strategy but it is not a panecea, and new tools need to be developed to help measure the eco-impact reduction potential of product-service shifts. However, all of this does not address the fundamental and difficult issues of a growing worldwide population and finite resources. At present no-one has the answers. However, the work by OECD, UNEP and WBCSD on sustainable consumption is providing useful insights into the role of business in this process.

From your experience what are the key issues in developing, implementing and managing an eco-product development programme?

The first is being clear about what you want to achieve. Eco-product development, as opposed to eco-design is about the complete product development process from idea generation to product and 'end of life' management, considering the environmental impacts of the product or service from 'cradle to grave'. At present the

Eco-product development, as opposed to eco-design is about the complete product development process from idea generation to product and 'end of life' management, considering the environmental impacts of the product or service from 'cradle to grave'.

development of tools to help understand this process is limited, particularly when one focuses on service development and eco-innovation. Knowledge, sound judgement and experience are key resources in eco-product development and eco-design.

At Sony we use a set of specific, measurable environmental requirements for both the design and manufacture of a product, and also for the business support areas of sales, promotion, communications training and accounting. Examples of these requirements on a product level are:

- a 60% reduction in product power consumption by 2002 compared with 1990 levels
- reduction in stand-by product power consumption to 0 watt by 2002
- use of lead-free solder in all Japanese models by 2000 (and by 2002 for models made outside Japan)
- elimination of Halogen Flame Retardants in products sold in all areas by 2002.

Tangible design progress is already happening. For instance the Sony KV-29DR5 colour television has standby power consumption of 0.4 watts and an energy-saving mode that can be selected using the remote control.

There are a range of business benefits resulting from eco-product development: cost savings; enhanced product/brand differentiation; risk reduction; legal compliance; and innovation opportunities. The most challenging issues relate to technology change in materials, customer acceptance and the difficulty of involving all the corporate power-brokers in an optimal product development scenario. Product engineers, product planners, sales specialists, distributors and retailers should all be engaged in an optimal corporate business strategy for product designs that incorporate environmental attributes.

What impact do you think Integrated Product Policy (IPP) will have on European business, and how will companies manage the IPP agenda?

The definition and objectives of IPP are still in their early stages. It is important that a level playing field develops, as it will be difficult for business if a range of national IPP approaches develop worldwide (as is already starting to happen in Europe). Businesses will require clear guidance on IPP. It remains to be seen how improved clarification will come about without the undesired effects of an over specified and inflexible set of policies.

For those companies that have concrete and comprehensive approaches to eco-product development and eco-design, IPP may provide competitive advantage, but for those ill-prepared it will create problems. A key point about IPP is that it is a government toolbox that aims to *green* consumption (which business has no direct influence over) and to *green* product development (which business can influence). It is important therefore for businesses to have robust systems to manage the eco-product development process with clear objectives, strategies and programmes. The IPP agenda is emerging and immature, and it will be interesting to see what arises from the Green Paper being produced by DGXI in Brussels later this year. The message is two-fold; first, be alert and start developing green product development processes that do not isolate product development from green consumption issues; second, start partnerships with the makers of IPP, as sound business guidance will be a critical factor in the final acceptance and success of the IPP framework. •

Eco-innovation: cathode ray tube recycling at IBM Sweden

Inga Belmane

Researcher, The Centre for Sustainable Design, UK

Inga Belmane is a researcher at The Centre for Sustainable Design, UK, currently working on Integrated Product Policy (IPP) and eco-product development project at the Centre. She has a BSc in Business Administration and has worked for both government and private business in Latvia. She holds an MSc in Environmental Management and Policy from the International Institute for Industrial Environmental Economics at Lund University, Sweden.

IBM Sweden together with the artist and designer Jonas Torstensson have designed glassware made from the recycled cathode ray tubes (CRTs). The project started in 1995 when Hans Wendschlag, environmental manager at IBM Sweden, initiated a project to recycle CRTs from old computers into glassware. A valuable 'spin off' of the recycled glassware project is an environmental message which is communicated both internally to IBM employees and externally to its customers and other stakeholders.

Introduction

Cathode ray tube (CRT) recycling has literally become an art in IBM Sweden. CRT glass has been transformed into attractive glassware pieces by Swedish glass designer Jonas Torstensson. The project shows how creativity plays a role in reduction of a waste stream.

In 1995, IBM took the first step in Sweden to recycle old display tubes. Since then, IBM Sweden has offered its customers a take-back programme to scrap old computers in an environmentally correct way. Customer requirements have been the major driver for the take-back programme (with take-back obligations now stated in purchasing contracts, mainly with customers in the public sector) (Wendschlag, 1999).

The environmental problem

Cathode ray tubes (CRTs) are used as picture tubes in computer installations (eg. monitors), television receivers, as visual display screens in radar-receiving equipment, and in oscilloscopes. They pose a major difficulty for recycling since the phosphorus based coating used to provide the necessary luminiscence contains heavy metals and other toxins, while the glass itself is loaded with lead and barium. Finding a process that will handle the recycling of large quantities of CRTs of varying age and specification is not easy (Bras, 1998).

Old computers scrapped today in IBM Sweden are approximately 10 years old and on average 70% of the old computers are re-used or recycled. However, for the CRT glass, until 1995 there was no established recycling method on a larger scale at IBM Sweden (IBM, leaflet).

'Green' glassware from recycled CRT glass, designed by Jonas Torstensson

The objective of the CRT recycling project

IBM's Environmentally Conscious Product (ECP) programme was established in 1992, where one of its objectives was to develop products from recycled materials (IBM, 1998). IBM's goal was not only to find a way to recycle 'end of life' materials, but also to visually demonstrate IBM's commitment to environment and to show what environment means for the company. The 'green glassware' project was initiated by Hans Wendshlag, environmental manager at IBM Sweden. The idea was to develop an exclusive glassware range, made from recycled CRTs, that demonstrated the value of environmental considerations both internally and externally, to IBM employees, customers and other stakeholders (Wendschlag, 1999).

The process

The project started in 1995 when IBM undertook research into glass tube recycling at the Swedish Institute of Glass Research (GLAFO). GLAFO was asked to conduct a chemical analysis of the CRT glass fragments. The face of the CRT (the only part which is recycled into the glassware now) contains no harmful lead, and comprises two thirds of the weight of the glass. It means that the majority of the material can be recycled. The other parts, called the 'neck' and the 'funnel', contain toxic materials, eg. lead, and can be recycled into CRTs again, which is completed at IBM Holland in the Netherlands.

Hans Wendschlag wanted to show how environment could 'add value' to electronics waste. As a result, he commissioned the Swedish designer Jonas Torstensson (Torstensson Art and Design Sweden AB) to design glassware from old visual displays. He created carafes and other glassware that could be used by IBM departments to reward employees and customers for environmental accomplishments, and as business gifts for corporate partners. The research by GLAFO has proven that the glassware contains no hazardous materials. GLAFO regularly analyses and controls the contents of the glass and has confirmed that these glass products are safe to use in contact with food and beverages (Wendschalg, 1999).

The amount of scrapped computers is increasing, and so are the recycling volumes. In 1995, around 2–3 tonnes of CRT were recycled into the 'green' glassware range, compared with 10–15 tonnes today. However, it is a small fraction of total CRTs glass volume (less than 10%) scrapped at IBM Sweden. The rest of the glass is sent to a high-volume recycling facility at IBM Holland (the Netherlands), where the CRTs are made into new CRTs (Wendschlag, 1999).

The outcomes

Communications

The environmental department was the project initiator and leader. The value of the 'green' glassware lies in its ability to communicate an environmental message internally within the company. For example, it has been an 'awareness raiser' for the marketing department which does not usually 'buy into' environmental management. By means of individually designed glassware, the environmental message is conveyed to IBM customers and other stakeholders. The sales and marketing departments have used the glassware for various business purposes, and it has become a popular incentive amongst the salesforce. IBM has realised that the glassware provides a good and unusual platform to communicate environmental issues to non-professionals (Wendschlag, 1999).

Resource savings

However, the recycling of CRTs into customised glassware cannot be compared to high-volume recycling, where the most important driver is resource savings and value of recycled materials. However, in general, the glass recycling reduces the use of raw materials, energy and solid waste generation as compared to glass production from virgin materials (Noyes, 1993).

Lessons for eco-designers

Education, training and raising of environmental awareness are key issues when speaking about involving designers in eco-product developemnt (Wendschlag, 1999). Designers have to realise that there are a lot of opportunities for creating/redesigning products out of the waste stream. There needs to be more training, education and experience in eco-product development, both from management and technical perspectives. For example, designing products using the waste stream requires much more knowledge as compared to the use of traditional materials, since the qualities of the materials are not so well known and there is a lack of experience working with them.

Waste

Some say that waste is raw material at the wrong place. The challenge is to put it in the right hands.
IBM Sweden

Next steps

There is regular and on going co-operation between IBM Sweden and the designer Jonas Torstensson and new concepts are being explored. The legislative pressures for the take-back of computers have an important role to play in driving eco-innovation, eg. the forthcoming EU 'producer responsibility' (PR) legislation (Directive on Waste from Electric and Electronic Equipment), national PR legislation on electric and electronic waste, (eg. the Netherlands, Denmark, Norway and Sweden), and the CRTs and monitors landfill ban by US EPA in 1992 (Matthews et al, 1997).

New possibilities

'To create products from recycled materials is an exciting and stimulating challenge which constantly gives new possibilities for shapes and expressions.'
Jonas Torstensson, artist and designer

'The challenge with the environmental programmes is to never settle down but to constantly develop and find new solutions.'
Hans Wendschlag, Environmental Manager, IBM Sweden

Conclusions

This example shows how a product itself can be a conveyer of an environmental message inside and outside the company. The 'green' glassware range is a valuable example of innovation and environmental communication, although the recycling of CRT into individually designed glassware does not seem to have created substantial environmental gains.

A broader issue is prevention, ie. how to eliminate the hazardous materials (eg. lead) in CRTs in future and whether there is a potential for alternative technology with less environmental impact. •

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Noyes R., 'Pollution Prevention Technology Handbook', Noyes Publication, 1993, p. 287.

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Design Sense

Design Sense is an award launched by the Design Museum in association with British Steel, with endorsement from the Royal Institute of British Architects (RIBA), The Centre for Sustainable Design (CfSD) at The Surrey Institute of Art and Design, University College and Blueprint magazine. Design Sense is supported by the Rufford Foundation. The media sponsor for the award is the Guardian newspaper.

The Design Sense awards form a key part of British Steel Design Futures which aims to help designers of all kinds achieve sustainable solutions in building, packaging, auotmotive and product design.

Deadline for submissions is 23 July 1999.

What is Design Sense?

The Design Museum in the UK launched the Design Sense awards in London on 25 May 1999. Design Sense is one of the world's first major competitions on sustainable design in the market place. It is focusing on the disciplines of industrial design and architecture. Its goal is to identify and reward world-class examples of products and buildings that conform to the highest criteria of sustainability and improve the quality of people's lives. Design Sense is intended to raise the level of debate in business about sustainability issues and encourage greater understanding about the impact of design on the environment.

What awards will be made?

An overall shortlist of up to twelve submissions will be considered for the first prize. All those short-listed will be invited to an interview on 6 October 1999, with the announcement and awards presentation made on 7 October 1999 at the Design Museum, London. To be short-listed will in itself be a considerable achievement. In addition, work will be featured at an exhibition at the Design Museum, covered in a publication about the prize and short-listed entrants will each receive a certificate.

Entrants will be fully credited in all publicity materials surrounding the announcement of the prize. Design Sense's first prize of £40,000 will be awarded to the overall winner. It is hoped that the prize will enable the recipient to further their knowledge and understanding of sustainable design. The winner will also be presented with a certificate and trophy.

What will the judges be looking for?

The judges will be looking for evidence of sustainable value in products and completed buildings as well as design quality. Judges will consider the overall environmental impact of the submission and its contribution to sustainable development throughout its lifecycle. The panel will also want to know about the methodology and tools used to achieve environmental improvements. An overarching theme that will be considered at every stage of judging is whether the product or building improves the quality of people's lives.

On the submission form, information on products or buildings should be listed in chronological order according to its lifecycle. The following graph is intended to act as an illustration of this process although certain areas will not necessarily be applicable

Criteria	Materials	Energy	Water	Packaging	Process	Social
Raw materials extraction						
Manufacturing construction						
Transport (of goods and services)						
Use Occupation						
End of life Demolition Re-use						

Above: Sustainable design matrix

to both products and buildings. Packaging for example is likely only to be relevant to product submissions.

Key questions for companies that wish to submit an application to Design Sense will include:

Materials

What reduction has there been in the use of materials; to what extent have recycled or local materials been used; have materials from sustainable sources been used; what reduction has there been in the use of toxic materials or the production of toxic waste?

Water

How has water consumption been considered or reduced; to what extent is water collected or recycled?

Packaging (Product only)

What reduction has there been in the use of materials; to what extent have recycled materials been used; what take-back or recycling systems are/were employed; how has waste been reduced?

Process

How efficient were the processes of construction/manufacture; how was waste disposed of; how was toxic waste reduced; what take-back systems are/were employed; what type of land was used and how does your submission prompt more efficient use of transportation systems?

Social

Does the product or building improve the quality of people's life; what impact did it have on the creation of employment; what effect does it have on

Product design judges

Ross Barbour, Rufford Foundation, UK

Professor Han Brezet, Delft University of Technology, the Netherlands

Tim Brown, IDEO Europe, UK

Martin Charter, The Centre for Sustainable Design, The Surrey Institute of Art and Design, University College, UK

Tim Cooper, Centre for Sustainable Consumption, Sheffield Hallam University, UK

Thierry Kazazian, O2 France, France

Professor Ezio Manzini, Milan Polytechnic, Italy

Mike Monaghan, Ricardo Consulting Engineers Ltd, UK

Robert Nuij, European Commission DGXI E4, Belgium

Peter Snow, BBC Tomorrow's World, UK

Paul Thompson, Design Museum, UK

Ursula Tischner, ec[o]ncept, Germany

Architecture judges

Guy Battle, Battle McCarthy, UK

Stefan Behling, Foster and Partners, UK

Marco Goldschmied, RIBA, UK

Geoff Hooker, British Steel plc, UK

Anthony Hunt, Anthony Hunt Associates, UK

Eva Jiricna, Eva Jiricna Architects, UK

Christopher Nash, Nicholas Grimshaw and Partners, UK

Richard Parnaby, University of the West of England, UK

Ian Taylor, Bennetts Associates Architects, UK

Nicholas Thompson, Cole Thompson Associates, UK

Lorna Walker, Ove Arup & Partners, UK

consumption habits and what consideration was given to the end user in the design process; what effect does your submission have on the local environment?

Timetable for Design Sense 1999

Submissions deadline: 23 July
Interviews: 6 October
Awards presentation: 7 October.

For more information contact:
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Sustainable Product Research Network (SPRN)

Martin Charter

Coordinator, The Centre for Sustainable Design, UK

SPRN aims to disseminate information on current and future research in eco-design and sustainable product design.

SPRN will publish summaries of PhD, post doctoral or other research projects.

SPRN provides a resource for researchers to network and keep up to date with new research.

Areas of coverage include:
· sustainable product development
· sustainable consumption
· management of eco-design
· green marketing
· eco-design strategies
· eco-design tools
· life cycle costing
· new materials

Sustainable development of mechanical systems using replacement environmentally acceptable refrigerants

The new hydrofluorocarbon refrigerant HFC-134a is currently being used in domestic refrigerators as a transitional replacement for the chlorine-containing refrigerant CFC-12. Experimental observations reveal that the removal of chlorine (Cl_2) from the refrigerating system effects the tribological characteristics on highly loaded surfaces within the domestic refrigerating compressor. Although new synthetic lubricants are currently being developed to enhance this lubricity effect, characteristics of wear and friction need to be addressed to ensure product reliability and durability. To ensure the development of a sustainable product, the consequences of these design constraints need to be addressed from a whole product life cycle point of view. An increase in the energy consumption during the product use phase as well as an increase in the production rate of the product may augment the indirect release of carbon dioxide (CO_2) due to the burning of fossil fuels resulting from the operation and the manufacturing of the product. This release of carbon dioxide (CO2) is an environmental burden the new refrigerants were intended to reduce.

This three year research project, which commenced in February 1998, is being funded by the Engineering and Physical Science Research Council (EPSRC) in the UK as part of the Design for Whole Life Cycle Programme.

✉ *Ing. Christopher Ciantar, Tribology Design Research Unit, School of Design, Engineering and Computing, Bournemouth University,UK cciantar@bournemouth.ac.uk*

Product-Oriented Environmental Management (POEM)

Since 1997, Frank de Bakker has worked as a PhD candidate in the research area of the organisation of Product-Oriented Environmental Management (POEM). POEM is defined as:

'an approach to organising and operating a firm in such a way that improving the environmental performance of its products becomes an integral part of both operations and strategy.'

The research aims at gaining insights into the introduction, implementation and improvement of the organisation of POEM from a firm's perspective. The main theoretical inputs are an analysis of the natural resource-based view of the firm, a stakeholder approach (using elements from Total Quality Management (TQM) and environmental management), and product development and innovation. The above inputs plus case studies will provide a framework to describe and analyse the organisation of POEM. The first two case studies have been carried out in chemical industry, where POEM is operationalised as Product Stewardship. Further case study analyses should result in a set of recommendations for organising POEM.

✉ *Frank de Bakker, Faculty of Technology & Management, University of Twente, the Netherlands F.G.A.deBakker@sms.UTwente.nl*

E-Co Challenge

E-Co Challenge is a DTI Sector Challenge research project in the UK, involving the Manchester Metropolitan University and Cranfield University in the UK and six textile and clothing companies ranging from small and medium-sized enterprises (SMEs) to large multinationals. The project runs from December 1997-99 and is concerned with novel approaches to the product development activity, particularly, Concurrent Product Development (CPD) and Design for the Environment (DfE) practices. This project draws upon examples of successful CPD and DfE implementation in other industry sectors, in particular electronics, and explores some of the potential benefits to the UK textile and clothing industry of adopting these approaches.

✉ *Dr Joanne Heeley, Department of Textiles and Fashion, Manchester Metropolitan University, UK J.Heeley@mmu.ac.uk http://home.hollings.mmu.ac.uk/staff/ecochallenge/*

Integrated Product Policy (IPP) and eco-product development (EPD)

IPP is a new product environmental policy area in the EC. The IPP approach suggests that governments and companies should address all product systems throughout the whole lifecycle. One of the key issues addressed in the current discussion on IPP is the development of 'greener products' or eco-product development. The Centre for Sustainable Design (CfSD) is undertaking a study on the role of eco-product development (EPD) within IPP (IPP-EPD project), with a particular focus on electronics and white goods sectors. The objective is to encourage a two-way information and knowledge exchange process between different stakeholder groups and CfSD. The main objectives of study are:

- to define the IPP toolbox for products (supply) and consumption (demand) sides
- to interpret what IPP might mean for industry (implications on product development and management),
- to gather views of main stakeholder groups (industry, policy makers, consumer groups, distributors (eg. retailers), and environmental NGOs) on IPP and EPD
- to develop recommendations for further development of IPP.

The project will run until the beginning of September 1999, and the report will be available for project participants.

✉ *Inga Belmane (ibelmane@surrart.ac.uk)/Martin Charter (mcharter@surrart.ac.uk), The Centre for Sustainable Design, UK*

O2 NYC and O2 Mexico

Martin Charter

Coordinator, The Centre for Sustainable Design, UK

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

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

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

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

O2 NYC

In May 1999, the President's Council on Sustainable Development (PCSD) held its National Town Meeting for a Sustainable America (NTM) in Detroit with governmental, corporate and NGO representatives from across the US. Considering the amount of learning that has taken place during the six years of the PCSD, there was much to criticise at the NTM; for example, Detroit's Big Three auto companies showed their alternative fuel and recycled-content cars, but other forms of mobility were altogether absent. There was little reference to the rest of the world, to Agenda 21, or to other species. However, there were some signs of hope that America is beginning to understand what sustainable development means, and speakers like Professor William McDonough and Ray Anderson, CEO of Interface, both brought sustainable design to the forefront of their presentations. For the optimists, there is the proposal that the federal government establish a cabinet-level Office of Sustainability after the advisory PCSD's charter runs out in June 1999, and for realists, networks were strengthened and batteries recharged.

Four past O2 NYC chairs attended the event. Wendy Brawer presented an exhibit featuring the 21 Green Maps she has published worldwide to date. The exhibit showed how to put the info-web to work in service of ecology. The Green Map System was honoured by the PCSD and Renew America and given the National Award for 'Sustainability for Telecommunications' and 'New Communication Tools' during the NTM (see www.greenmap.org). Darren Port of Green Logic Design showed an exhibit of natural building materials, in front of the conference hall. The solar powered straw-bale building section was designed so that everybody, from conference attendees, local law enforcement and FBI bomb-sniffing dogs (who secured the NTM for VP Al Gore), could interface with this appropriate building technology. Darren observed, 'It's amazing how people open up to the idea of building their own places naturally'. Carolyn Nunley of Consumer's Union came to the NTM directly from the annual meeting of the UN Commission on Sustainable Development (CSD) to find out how the event would address consumption issues. At the CSD meeting, governments agreed to adopt new policies on tax and subsidy reform, and controls on advertising and environmental claims. Caroyln found 'Unfortunately, there was no mention of this important new development at the NTM.' Jacquelyn Ottman of J. Ottman Consulting gave a well-attended learning session on 'Design For Sustainability', covering specifically how sustainbility can act as a stimulus for innovation.

Despite the NTM's mixed message, in the closing session the Post Office announced their new programme to motivate product take-back, the Department of Defense launched their environmentally preferred buying programme (half the US annual budget goes to the military so this is truly significant) and other agencies and corporations presented recent changes in the way they conduct business.

In the final day's plenary, a roundtable of American youths from rural areas presented. All were members of 4H (animal husbandry) clubs, but generally new to sustainable development. For them, the NTM illustrated that sustainability is about responsible daily life, community and education, celebrating diversity and long-term thinking. Their report may provide the leadership and direction needed to turn this big ship on its true course.

For more information contact
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O2 Mexico

The global village, the information revolution, pollution, economic crises, are some of the main issues that define our way of living at the end of the century. The world is changing day by day, minute by minute at extreme velocity and with permanent acceleration. We are in the middle of a change towards a new world order, based on the concept of the new economy. This new era in economics is bringing a radical change in the way people do business in every corner of the world. O2 Mexico believes there are two fundamental factors for successful business strategies for the future:

Strategic innovation in business management, production processes, human resources development, market strategies and product/service development will be the leading and permanent competitive advantage.

Sustainable product design as the key for sustainable development. This is the opportunity to bring the environmental and business perspective together. This may be the only way to achieve economic development and a healthy environment. This is the perfect chance for design to become a respected and valued profession in society.

O2 Mexico: background and activities In September 1998, O2 Mexico was formed, initiated by the design and innovation consultants ECO, and the designer Pedro Alan Martinez (O2 Global Network liaison in Mexico). O2 Mexico is a non profit organisation created to promote information and knowledge exchange between consultants, executives, academics and entrepreneurs, involved in business strategies and sustainable product design (SPD), in Mexico and Latin America. O2 Mexico is part of the O2 Global Network and its activities include:

- newsletters, published monthly and distributed by e-mail which inform of O2 Mexico activities and events
- special publications include articles and case studies that explore aspects of strategic innovation and sustainable design from different and multidisciplinary points of view
- O2 Mexico website communicates information about O2 Mexico and O2 Global Network activities. It is sponsored and produced by MATIZ design magazine
- courses, workshops and events are organised to introduce O2 concepts to designers, consultants, business executives, academics and students in Mexico.

O2 Mexico looks forward to international collaboration and networking with designers and product developers interested in SPD and eco-design. •

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Book

Timber in Context: a guide to sustainable use
Anne-Marie Willis
& Cameron Tonkin
Construction Information Systems,
Australia, 1999
ISBN 0-9586187-04
180 pages
$45.00 (plus $6.00 postage and packing for sales outside Australia)

For those of you expecting this book to be a complete guide to sourcing timber and specific timber data, you will be disheartened. However, as a source book for introducing the global issues associated with timber use, it is an excellent buy.

Throughout 'Timber in Context', Willis and Tonkin present a balanced view of, as the book suggests, the context of timber – in origin – in sourcing – in production – in design – in use – in disposal. It is one of the most complete overviews that has been produced in this area. The clarity of discussion and the arguments presented are as interesting to the expert as they are relevant and explanatory to the novice; the latter group will find this an excellent introduction to issues associated with sustainability in general.

The tone of the book is up-beat but realistic, and in this sense, is a refreshing, insight into both the opportunities and barriers associated with attempting sustainable activity in the timber industries. However, the complexity of this subject matter must not be underestimated '…the accounting of environmental impacts is not straightforward. Nor are there simple guides that can give the green light to some materials and the red light to others.'

The authors question the logic of an eco-materials-focused perspective. Although this perspective often does greatly reduce the environmental impact of new products, there is an undercurrent within the text that suggests that this can be over-emphasised at the expense of other, maybe longer-term ecological objectives that question the economic system in which we currently operate. The authors stress that 'relational designing begins with a recognition of the inter-relatedness of ecological systems as the basis for designing for sustainability', and in so doing, highlight new parameters for design thinking which help question the current status quo, not only in the timber industries, but in all industries.

Complex information concerning the life cycle of timber and the design process associated with timber is presented with clarity and focus which allows the reader to find a logical path from the origins of timber through to the disposal of timber product. Again, because of a purposeful generality here, these descriptions hold true across the wider arena of all production, design and development.

There is also mention of reflexive impacts, an area often overlooked in commentary in this field. Here a positive ecological evaluation of one material may have adverse affects on the demand for that material and ultimately distort the initial validation of the material. The authors provide instances of this within the timber industries and illustrate that everything is connected – that there is a push and pull dynamic – and extremes of action can distort ecological impacts. It is maybe for these reasons that for much of the book the authors steer clear of presenting hard and fast rules concerning the detail of what is acceptable from an ecologically perspective and what is not; only in Chapter Five and the Appendices do they venture to suggest timber applications and associated, more 'ecologically sound', timber sources.

My main criticism of the book is that as a non-Australian reader, I found it frustrating at times where examples of activity are almost exclusively Australian based; where the comments on legislation and government activity in this area are likewise often locally focused. In its defence the book doesn't claim to be global in its overview, but I feel a greater reference to the variety of global initiatives would give the book wider readership appeal.

This book is indeed '... a guide to sustainable use'. As an accessible reference book, it provides us with a comprehensive insight into the timber industry, timber applications and timber source data. And maybe, as importantly, it provides a sound base to work from for all those interested in, or involved in, implementing sustainable oriented products and initiatives. •

Dr Emma Dewberry, Department of Design Studies, Goldsmiths College, of London, UK, is research coordinator for the 'Design for environment Multimedia Implementation' (DEMI) project – a sustainable design multimedia education research collaboration between a number of UK universities and design associations.

27–28 May 1999

Natural Fibres Forum
Copenhagen, Denmark

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Vans Hauen Conferences
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Amaliegade 36
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1–3 June 1999

Renewable Energy Europe 99
Frankfurt, Germany

✉ PowerGen
Europe '99
Bates Business Centre
Church Road
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+44 1708 342222
+44 1708 379344
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1–3 June 1999

Waste & Water 99 (2nd International Conference on Integrated Sustainable Waste & Waste Management)
Copenhagen, Denmark

✉ Bella Center A/S
Center Boulevard
DK-2300
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6–7 June 1999

The 8th Annual Corporate Environmental Leadership Seminar
New Haven, USA

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Environmental Studies
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7–9 June 1999

Eco1999
Paris, France

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8–10 June 1999

ET99
Birmingham, UK

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9–10 June 1999

Environmental Performance & Competitiveneess – Sustainable Business Strategies in Global Markets
Hanover, Germany

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15–18 June 1999

Industry and Innovation in the 21st Century
New York, USA

✉ Conference Secretariat
Summer Study Office
American Council for an
Energy-Efficient Economy
1001 Connecticut Avenue
NW Suite 801
Washington DC 20036
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+1 202 429 8873
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23–26 June 1999

The 5th International Interdisciplinary Conference on the Environment
Baltimore, USA

✉ Demetri Kantarelis/Kevin L Hickey
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Assumption College
500 Salisbury Street
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1–2 July 1999

Eco-Management and Auditing Conference
Leeds, UK

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12–13 July 1999

'Towards Sustainable Product Design', 4th International Conference
Brussels, Belgium

✉ **Martin Charter/Russell White**
The Centre for Sustainable Design
Faculty of Design
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Falkner Road
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15–17 July 1999

Renewable Energy Fair
Gloucestershire, UK

✉ Jo Badham
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16–17 September 1999

The 8th Annual Business Strategy and the Environment Conference
Leeds, UK

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3–5 November 1999

Business for Social Responsibility Conference
San Francisco, USA

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San Francisco
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http://www.bsr.org www.bsr.org

14–17 November 1999

Sustainability: Ways of Knowing/Ways of Acting
North Carolina, USA

✉ Stuart Hart
1999 Greening of Industry Network
Conference Co-ordinator
c/o Monica Touesnard
Kenan-Flagler Business School
University of North Carolina
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14–17 November 1999

1999 Greening of Industry Network Conference
North Carolina, USA

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5–9 June 2000

R2000: Recovery, Recycling, Re-integration
Toronto, Canada

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Director of Congress
SeefeldstraBe 224
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2–4 July 2000

Renewable Energy 2000
Brighton, UK

✉ Rob Schulp
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3–6 September 2000

Tribology in Environmental Design 2000

Bournemouth, UK

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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:
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Editor
The Journal of Sustainable
Product Design
The Centre for Sustainable Design
Faculty of Design
The Surrey Institute of Art & Design
Falkner Road
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UK.

Email submissions should be sent to: mcharter@surrart.ac.uk.

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

Presentation

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

Manuscripts should be arranged in the following order of presentation.

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

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

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

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

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

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

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

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

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

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

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

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Proofs

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

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