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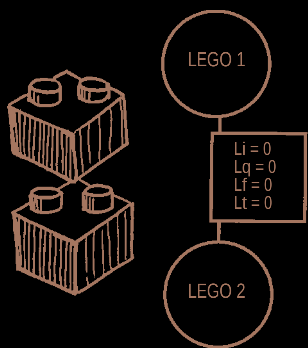
The Journal of Sustainable Product Design



ISSN 1367–6679

Recycled furniture
designed by Meta Morf

Gallery, page 41

Re-PAIR

Re-design will require looking at environmental issues in different ways through assembling new ideas and information

Re-DESIGN

Re-FINE

SS-BG30 Speakers made from ‘Tectan’, re-launched by Sony Wega Audio Group

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Baygen self-powered lantern, designed by the BayGen Power Group

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Re-THINK

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Editorial Board

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

Martin Charter

Joint Editor, The Journal of Sustainable Product Design

Factor 4 and beyond

The recent 'Factor 4+' conference in Klagenfurt, Austria highlighted that 'Factor 4' thinking provides a goal and focus for new product and service development amidst huge uncertainty. However, the transition towards such solutions will not be easy. The path towards a product or service that incorporates a 400% reduction in energy and material consumption throughout its lifecycle will require re-thinking and new thinking through strategies such as miniaturisation and/or a shift from products to services (de-materialisation). These approaches are often highlighted as routemaps for environmental sustainability, however, the practicalities are often poorly thought through and the impact on designers and those managing 'end of life' issues is often ignored.

'Factor 4+' solutions will be enabled through a mix of behavioural change resulting from better stakeholder education, and innovative new technologies and materials. Stakeholders will need to 'buy-in' to the change. Examples, can be derived from sustainable city projects where people have managed the transition from a dirty to a clean city eg. Chattanooga, US. A major success factor was recognising and involving all major stakeholders in envisioning a more sustainable city, giving people a stake in their future! Research into green product development indicates that companies often do not involve external stakeholders in the process for competitive reasons and/or because of 'not invented here syndrome'. To move 'Factor 4' forward will require smarter, *less inclusive* thinking, and new processes and systems.

Lifestyle shifts

This change will require lifestyle shifts, with significant increases in customer awareness and understanding. As consumption increases due to population growth, it will not be enough to focus solely on the materials and energy efficiency in product development. There will need to be a move towards sufficiency ie. less consumption. This will require education, demand management and potentially reduced choice, which may interfere with notions of freedom and freewill. How the global society constructs a more equitable consumption and production system is the key issue.

'Since goods are finite, wants should be reduced to enhance happiness.'

Professor Dr Ryoichi Yamamoto, Institute of Industrial Science, University of Tokyo, Japan 'Factor 4+' conference in Klagenfurt, Austria.

$$\textit{Happiness (increased 'quality of life')} = \frac{\textit{Goods}}{\textit{Wants or wishes}}$$

Role of designers

Designers should play a major role in 'Factor 4+' process, however cultural and professional awareness varies considerably across the world. The Netherlands have consistently stimulated eco-design throughout the nineties with central government funding. For example, in June 1998, Kaltalys was launched, a joint venture between TU Delft and TNO Delft focusing on sustainable product innovation. In Japan the focus on energy efficiency was not abandoned at the end of the 'oil crises' in the seventies, but rather it has continued and extended to materials efficiency. This has resulted in a range of eco-design solutions from

Japanese companies including Sony, Canon and Fuji-Xerox. However, many countries and companies are still focusing on 'middle of pipe' issues eg. waste minimisation, cleaner production and 'end of pipe' solutions e.g. air emission monitoring.

New tools

To enable eco-design will require a recognition that 'product design' is not generic and new tools need to be developed. For example, in designing a laptop computer, there are a range of designers involved, including electronic and mechanical engineers who are particularly interested in science and numerical data, as well industrial designers who are interested in aesthetics and pictorial representations. There is also a major need to conceptualise the complete product development process from idea generation to launch to 'end of life' and to develop a portfolio of 'green' tools for the range of stakeholders involved in the process. Many of the existing design tools have focused on environmental evaluation eg. LCA and have been costly and time-consuming. There is a clear and growing need for simpler tools eg. 'cut down' and simplified LCA's that enable quicker decision-making.

Innovation

A key opportunity is to use environmental and/or broader sustainability thinking as a provocative device at the 'front of pipe'. For example, Philips apply this process through its EcoDesign programme and have recently launched a range of green(er) products. Extracts from its 'Green to gold' leaflet highlight the companies approach:

Consumers throughout the world are looking for innovative products while at the same time, reaching out for a sustainable world… To integrate functionality and sustainability – balancing innovation with ecological impact… We strive for intelligent products with sustainable design. Products with brains – that automatically switch on when you are home and turn off when you are away. Products that will look great – that you'll want to keep forever… We focus on five areas to enhance environmental performance: weight; hazardous substances; packaging; energy; and recycling. These drivers led us to innovative options – options we implement because they provide added value for our customers… We believe that sustainable products are the products that will measure up in the future.

…and finally

The sixth issue of the Journal of Sustainable Product Design highlights the importance of the need for change: new tools, perspectives and frameworks. Fiksel, McDaniel and Spitzley of Batelle Memorial Institute (US) focus on the issue of measuring sustainable product performance, incorporating the need to explore social, as well as economic, environmental and considerations. Earl and Clift from the University of Surrey (UK) outline the results of a research project amongst purchasing managers which highlights obstacles to buying 'green' products, particularly printers incorporating recycled plastic and reusable ink jet cartridges. Luttropp from ETH Machine Design (Sweden) illustrates the need to 'factor in ' recycling and disassembly considerations early in the product development cycle. Lafleur, van Berkel and Kortman of IVAM Environmental Research (Netherlands) outline an eco-design tool aimed at linking environmental evaluation to environmental improvement, using an example of a lighting system. In the Innovation section, the Editor considers how SPDD relates to the process of the delivery of the product or service, as well as the final result and the need to increase the imbedded Sustainable Value of final results. The interview with Professor Ezio Manzini of Politecnico di Milan (Italy) highlights opportunities resulting from moving towards a more systemic view of SPDD, and the need to evolve a situation where the customer takes a share of the product's eco-impact, alongside the producer. Lastly, the O2 page highlights papers from o2's tenth anniversary conference. •

Measuring product sustainability

Joseph Fiksel, Jeff McDaniel and David Spitzley

Senior Director, Senior Consultant and Researcher, Battelle Memorial Institute, US

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Jeff McDaniel is a Senior Consultant in the LCM group of Battelle Memorial Institute (BMI). Upon graduation from Texas A&M University with a BS in chemical engineering, he joined General Electric. Jeff then completed the Corporate Environmental Management Programme at the University of Michigan where he obtained a MBA and MS in Environmental Studies. Since joining BMI, he has helped firms develop green accounting and performance measurement programmes.

David Spitzley joined the LCM group at BMI as a researcher in January 1998. Previously, he worked as a research assistant and project leader in the areas of life cycle design and LCA. at the University of Michigan's National Pollution Prevention Center (NPPC) where he also obtained a BS degree in chemical engineering.

Is our product or service sustainable? Many industrial firms are posing this question as they begin to embrace the long-term goal of sustainable development. While operational definitions of sustainability provide general guidance, the actual evaluation of sustainability for a specific product or service has proven challenging. The authors review current practices of leading companies, and then propose a Sustainability Performance Measurement framework that embodies three principles – separation of resource and value measures, explicit representation of the 'triple bottom line', and consideration of the full life cycle.

Introduction

Sustainability is a compelling concept – who can resist the argument that all products of commerce should contribute to preserving the quality of the societal and ecological environment for future generations? However, putting this concept into practice has baffled some of the best minds in leading global corporations. How does one distinguish a 'sustainable' product from one that is not? This question poses new challenges for the design community, extending far beyond the traditional scope of product development. Some of the difficulties that arise are the:

- lack of consensus on a pragmatic definition of sustainability
- breadth of scope of sustainability issues, many of which are beyond the firm's control
- potentially large amounts of information required to evaluate product sustainability
- difficulty in quantifying the societal and ethical aspects of sustainability.

Perhaps one of the most formidable difficulties is the challenge of business integration. To successfully develop sustainable products, a company must learn how to effectively integrate sustainability concepts into its product development process. Sustainable product design cannot be practiced in isolation; rather it must be one facet in a multi-faceted approach that considers cost, ease of use, functional performance, manufacturability, and other key product requirements.

However, trying to achieve this type of integration raises both organisational and technical

	Strategic	Tactical	Operational
Organisational	Company policy and commitment	Reward systems and accountability	Performance indicators and targets
Technical	Next-generation R&D strategy	Key design concepts and features	Design evaluation and improvement tools

Table 1: Scope of sustainable product design issues

issues. Organisational issues include the establishment of appropriate company policies and incentives, modification of existing business processes, capture and dissemination of sustainable design knowledge via training and information technology, and achievement of consistent practices across diverse business units. Technical issues include the implementation of various design strategies – eg. modifying the material composition of products so that they generate less pollution and waste, or changing the assembly requirements so that fewer material and energy resources are consumed per product unit – as well as systematic adoption of sustainable design guidelines, metrics, and tools.

These organisational and technical issues are equally important, and must be addressed from the strategic, tactical and operational perspectives, as suggested in Table 1. In reviewing this scope, one fact becomes clear: a fundamental element of any successful programme is the establishment of measurable goals and performance indicators. Without a concrete basis for measuring success, policy statements are ineffectual, accountabilities are ambiguous, and design evaluation remains subjective and imprecise. Therefore, this paper focuses upon the emerging field of sustainability performance measurement.

While a number of performance indicators have recently been developed to measure eco-efficiency, little work has been done on less tangible aspects of sustainability; namely, measuring the socio-economic impacts of products. Most organisations that have published sustainability indicators have focused upon macro-environmental features for a community or a society as a whole. In contrast, product developers need more focused indicators that address the beneficial or adverse impacts associated with particular design innovations.

To address that need, this article first characterises the current state of the art with respect to sustainability performance measurement, and then presents a conceptual framework that will support systematic development of performance indicators for virtually any type of product. Although sustainability as a business practice is still at an embryonic stage, a viable approach toward measuring sustainability can be forged by building on the general principles of performance measurement and on the lessons learned by companies during the past decade in establishing environmental performance evaluation systems.

Review of sustainability measurement practices

'Meeting the needs of the present without compromising the ability of future generations to meet their own needs.' – Brundtland Commission, 1987.

The original definition of sustainable development, provided by the Brundtland commission, proved to be too ambiguous to allow organisations interested in pursuing sustainability to establish meaningful goals and metrics. Therefore, several groups have revised this definition to include three key aspects of business performance – economic, environmental and societal.

Efforts to evaluate each aspect of this 'triple bottom line' of sustainability have progressed somewhat independently, and have reached different levels of sophistication. As shown in Figure 1, corporate reporting practices for these three aspects have evolved over vastly different time frames. Corporate financial reporting has been providing information on economic performance since the beginning of the 20th century, while corporate environmental reporting has been practiced for less than a decade. Corporate social reporting was first attempted in the 1970s, and has recently been revived. Corporate sustainability reporting, which combines elements of all three aspects, has been attempted only in the last few years, and is still in an exploratory phase. The sections that follow discuss the current 'state of the art' in each of the three aspects of sustainability performance measurement.

Economic performance evaluation

Economic performance evaluation has been practiced for almost a century, although, it is perhaps better known as financial reporting. Standards for externally reporting financial results are highly developed, and a variety of rigorous guidelines and standards exist for these financial indicators. In contrast to this high level of standardisation for external financial accounting, firms can choose from a wide variety of managerial accounting practices to support internal decisions. Over the last 20 years, the introduction of new accounting methods such as activity-based accounting and economic value added (EVA) accounting has helped to reveal the underlying drivers of economic performance and shareholder value (Blumberg, 1997).

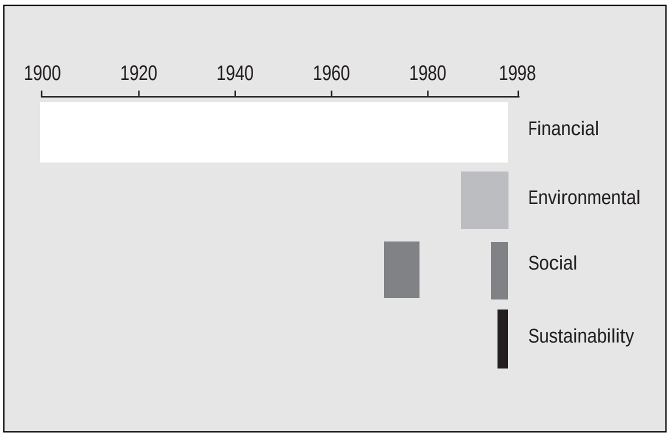

Figure 1: Comparative time frames of triple bottom line reporting

To address the full scope of sustainability, economic performance evaluation must evolve beyond traditional techniques based solely on profitability and cash flow. Specific issues include (Epstein, 1996):

- quantification of hidden costs associated with the utilisation of material, energy, capital, and human resources
- estimation of uncertain future costs associated with external impacts of industrial production and consumption
- understanding the costs and benefits incurred by various stakeholders (customers, employees, communities, interest groups, etc.) across the life cycle of a product or process.

A host of new research into life cycle accounting, environmental accounting, and full cost accounting has introduced new techniques that serve to highlight costs and benefits that are not explicitly addressed with conventional approaches. One of the leading practitioners of these new approaches is Chrysler Corporation. In designing several new automotive components, Chrysler considered the direct, potentially hidden and contingent costs associated with each design option. Direct and potentially hidden costs were evaluated with activity-based costing methods, and contingent costs were estimated with proprietary risk factors developed by Chrysler.

As an example, when Chrysler developed an oil filter for a new line of vehicles, they estimated the direct material costs, some of the potentially hidden manufacturing expenses, and possible liabilities associated with waste disposal (Armstrong and White, 1997). This evaluation revealed that the design option with the lowest direct costs (materials and production labour) did not have the lowest overall life cycle cost because the hidden and liability costs were greater than the direct costs. Chrysler's experience illustrates how these new life cycle accounting methods can help design teams to assess

Company	Current eco-efficiency practice
Novo Nordisk	Novo Nordisk has implemented an eco-efÞciency indicator that is calculated as the ratio of indexed turnover in constant prices to indexed resource consumption (NRTEE, 1997).
Northern Telecom (Nortel)	Nortel has developed a composite Environmental Performance Indicator (EPI) that is annually tracked and reported relative to baseline 1993 performance (NRTEE, 1997).
Sony Europe	Sony is utilising an EPI for batteries that is calculated as economic value added over the product life time divided by the sum of the non-recyclable material consumption and the production energy use (Lehni, 1998).
Dow Chemical	Dow utilises a unique EPI in their product environmental assessments Ð the Eco-Compass. This structure includes evaluations of mass intensity, risk potential, energy intensity, reuse, resource conservation, and extent of service. Each of these compass directions is evaluated using product life cycle analysis data and the results are intended for use in design decision making (Lehni, 1998) (James, 1997).

Table 2: The use of eco-efÞciency indicators

product sustainability in economic terms.

Environmental performance evaluation

As shown in Figure 1, corporate environmental performance reporting has been practiced for at least the past decade. Recent research has demonstrated a plausible connection between improved environmental performance and increased shareholder value (Feldman, Soyka and Ameer, 1997), and a growing number of corporations have begun to voluntarily report their product and company environmental performance (Blumberg, 1997). These reporting efforts, in turn, have led to an increased demand for standard environmental reporting criteria, similar to those for financial reporting. For example, in 1992 the Public Environmental Reporting Initiative (PERI), a consortium of global firms, developed an influential set of guidelines for environmental reporting. The types of performance indicators typically presented in conventional environmental reports include wastes and emissions, employee lost-time injuries, notices of violation, spills and releases, etc.

With the introduction of the ISO 14000 series of standards, an international consensus was developed on the elements of an Environmental Performance Evaluation process, documented in ISO 14031 (Fiksel, 1997). An even more recent standardisation initiative is the Global Reporting Initiative (GRI). Launched by the Coalition for Environmentally Responsible Economies (CERES) in the fall of 1997, the objective of the GRI is to standardise the methodology and format of corporate environmental and sustainability reports, and GRI hopes to propose standard indicators by the year 2000 (BATE, 1998). Although the standardisation debate continues, one indicator of environmental performance has been used by over twenty companies to measure environmental/economic relationships – eco-efficiency.

Eco-efficiency is generally defined as a measure of environmental performance relative to economic input or output, and has been implemented in a variety of ways, as illustrated in Table 2. There are currently several initiatives seeking to standardise eco-efficiency measurement; for example, Canada's National Round Table on the Environment and Economy (NRTEE) has enlisted a number of firms in a pilot test of material and energy intensity indicators (NRTEE, 1997). Such eco-efficiency indicators, whether intended for enterprise-level goal setting or for product design, will be essential components of any quantitative evaluation of sustainability.

Societal performance evaluation

In the 1970s, many organisations began developing standards for corporate social accounting (Epstein, 1996). While interest in social evaluation faded in the 1980's, efforts to measure and report social performance have resurfaced in the last few years. This change is due partially to the need for societal indicators in the evaluation of sustainability, and partially to the increased media interest in the social impacts of corporate operations. Companies such as Nike and Shell have discovered that stakeholder concerns about management policies and practices can rapidly generate adverse publicity, damage brand image, and alienate customers.

One company that has pursued social reporting aggressively is The Body Shop. The UK-based hair and skin care product manufacturer and retailer released its first Social Report in 1995. In this and in the 1997 Values Report (a combined social-ecological performance report), The Body Shop presents performance results on over 200 stated targets grouped into nine stakeholder categories. Although impressive in scope, The Body Shop's performance results are generally derived from surveys and results are presented as percentages of stakeholder responses. This type of information is no doubt useful in policy setting and internal performance tracking; however, it does not directly address the issue of sustainability. British Petroleum (BP) has attempted to evaluate its social performance in a slightly different manner. BP's 1997 Social Report provides case studies in social impact assessment. Despite being generally non-quantitative, BP's report acknowledges that an important aspect of their social performance is creating value in the communities where they operate. As companies advance toward more sophisticated sustainability performance measurement, the value created by products and operations will become increasingly important.

With the emergence of efforts like those of BP and the Body Shop, there is an increased need for social performance evaluation methodologies and tools. Responding to this need, the Council on Economic Priorities (CEP) has proposed SA 8000, a social accountability standard designed to follow in the path of other 'quality' standards. CEP hopes that like ISO 9000 and ISO 14000, SA 8000 will become the de facto standard for evaluating the quality of a company's social performance. Although SA 8000 makes significant advances in standardising the evaluation of corporate commitment to human rights issues, such as worker safety and equality, the issues covered by the standard include only a limited subset of the issues implied by sustainability (Ranganathan, 1998).

Recognising that existing approaches do not address the full scope of sustainability concerns, a coalition has recently formed to develop appropriate societal performance measures. The group, led by Shell, plans to develop indicators that enable a firm to evaluate its societal impact. Although the effort will be specific to Shell, the results are likely to have implications for sustainability evaluation in other organisations as well.

Sustainability performance measurement (SPM)

As standards and accepted methodologies have evolved in economic, environmental and societal performance evaluation, a few companies have begun to publish integrated sustainability reports. In 1997, Interface, a US carpet manufacturer, published what is believed to be the first sustainability report. This early reporting effort demonstrates that Interface is committed to sustainable development and has taken initial steps to identify potential sustainability indicators. However, this initial report does not clearly indicate a framework which will be utilised in future performance measurement and progress evaluation.

Monsanto, the newly emerged life-sciences company, has also published a sustainability report. The Monsanto report provides an initial framework for product sustainability evaluation. However, Monsanto admits that this framework has yet to be implemented.

The lack of quantified performance indicators in the Interface and Monsanto sustainability reports is not surprising, SPM is still in its infancy and these companies are attempting to expand the boundaries of available methodologies. These early attempts at integrated sustainability measurement highlight the need for a framework that facilitates meaningful indicator development.

The Sustainable Business Centre in the UK has developed a product design tool to address the need for sustainability measurement – the 'Sustainability Circle' (James, 1997). The circle is a graphical representation of product performance based on the results of 16 indicators. These indicators are grouped into categories which encompass the 'triple bottom line' perspective. The Sustainable Business Centre uses five categories to evaluate product sustainability, they are: physical environmental impacts, product attributes, social impacts, transport, and customer value. Indicator scores are provided to the decision-maker by shading the appropriate section of the circle a specific colour.

For example, if the design team determines that the product has excessive energy use, the corresponding section of the circle would be red. If the product has a major sustainability advantage, such as elimination of hazardous waste, another section of the circle would be shaded dark green. This process continues until each section of the circle has been assigned a colour, thus providing decision-makers with an easy to grasp visual display of the 'trade offs'. This type of graphical representation is universally understandable, and leaves it up to the product development team to determine what specific performance indicators would be most meaningful within each category of sustainability.

Influencing the product development process

As described above, a number of pioneering companies are adopting sustainability goals and beginning to introduce sustainability considerations into the product development process. Influencing this process is essential if a company is to achieve 'step changes' in performance, as opposed to incremental improvements. A first step toward sustainable product development is practicing eco-design, or 'Design for Environment' (DfE), which may be defined as systematic consideration of design performance with respect to environmental, health and safety (EH&S) objectives over the full product life cycle (Fiksel, 1996). This definition encompasses not only environmental protection issues but also traditional health and safety concerns that may be important considerations in product design. Indeed, many practitioners of eco-design find it a useful 'umbrella' concept that integrates a variety of related disciplines, including environmental risk management, product safety, occupational health and safety, pollution prevention, resource conservation, accident prevention and waste management.

The boundaries associated with eco-design are broader than those in the usual definition of a 'product system.' Rather than merely considering how the product interacts with its physical environment, it considers the entire supply chain – upstream processes that produce the components, raw materials and energy to fabricate the product, as well as downstream processes involved in its distribution, use and disposal. DfE also addresses how by-products might be beneficially used and how waste products may affect humans or the environment. A key approach in eco-design is the pursuit of eco-efficiency, enabling simultaneous improvements in resource productivity (which contributes to profitability), and environmental conservation (which contributes to sustainability). In other words, by eliminating waste and using resources more wisely, eco-efficient companies can reduce costs and become more competitive. However, the scope of sustainable product design must move beyond efficiency to also consider the societal aspect of the 'triple bottom line', including issues such as 'quality of life' and social equity.

The need for integration

For sustainable design to be adopted in a meaningful way, it must be fully integrated into the product development process. This requires an understanding of the primary product design drivers, including reduction in product development cycle time, continuous improvement in product quality, and responsiveness to the 'voice of the customer.' As an example, certain sustainability characteristics – eg. durability, modularity, waste elimination – are naturally synergistic with cost of ownership, which is an increasingly important customer criterion. However, to capture these types of synergies, a design organisation must incorporate sustainability awareness systematically into the daily work of development teams. This is a logical extension of the modern practice of Integrated Product Development (IPD), whereby cross-functional teams begin at the conceptual design stage to consider life cycle issues including quality, manufacturability, reliability, maintainability, environment and safety. Many companies use a 'stage gate' process, requiring that a product satisfy a variety of performance criteria before passing on to the next stage of development. Clearly, sustainability considerations need to be woven into this 'stage gate' process and the associated criteria.

The eco-design tools that are being used today tend to be relatively simple, ranging from rudimentary 'advisory' systems that provide on-line design guidance to performance tracking tools that represent multi-dimensional indicators. A number of companies have developed internal systems, although they are seldom fully integrated into the design automation environment. For example, a 'Green Index' software tool was developed by AT&T to assess a product's overall environmental performance. Hughes Aircraft has implemented a similar system called the 'Green Notes Environmental Rating and Measurement System', which is used to automatically provide ratings as designers develop their product and process specifications. A few companies are using streamlined life cycle assessment (LCA) tools to provide somewhat more rigorous product evaluations.

In today's exploratory phase, simple tools are preferable to help the rapid establishment of sustainable product design with minimal disruption to existing business processes. Eventually, new types of information technology, such as 'intelligent assistant' design tools, will facilitate the transformation from traditional ways of doing business to a more integrated approach. Once sustainability principles become embedded into decision support software tools, they will become more accessible to the vast majority of companies that are extremely busy meeting the needs of their stakeholders and do not have the time or resources for developing new processes and systems. These companies will be primarily interested in practical applications of sustainable product design, to the extent that it contributes to their success in the marketplace.

Creating a measurement framework

An essential element in the practice of sustainable product design is the capability to evaluate and predict product performance in objective, measurable terms. In this context, one of the key challenges is to incorporate a life cycle view of sustainability performance into measurement tools that can be easily implemented. The remainder of this article suggests how decision-makers can design and implement a Sustainability Performance Measurement (SPM) framework for their products, processes, or services. This framework is built upon the following three principles:

Resource and value

A sustainable product should minimise resource consumption while maximising value creation in the 'triple bottom line' sense. Here, resources are defined broadly to be natural or anthropogenic stocks that are required for the creation, use and disposition of a product. Examples of resources include materials, energy, labour, and land. Value is defined as a condition, attributable to a product, that benefits one or more of the enterprise's stakeholders. Examples of value creation include increased profitability, reduced pollution, improved nutrition, and liberation of time.

The first principle of sustainability measurement is that evaluations must address the dual perspectives of resource consumption and value creation.

Three aspects

Effective sustainability measurement should consider the complete 'triple bottom line' as it relates to the product in question. This means that both resource consumption and value creation should be considered in terms of economic, environmental, and societal aspects. For example, an automobile consumes economic resources in terms of operation and main-

An evaluation that focuses exclusively on one life cycle stage may fail to capture signiÞcant product beneÞts or impacts that occur in either upstream or downstream stages

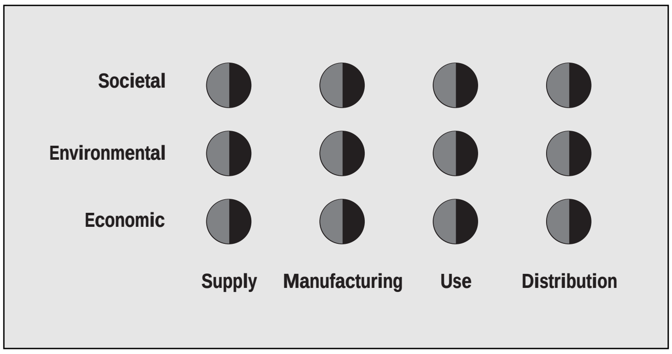

Figure 2: Sustainability Performance Measurement (SPM) framework

tenance costs, environmental resources in terms of fossil fuel, and societal resources in terms of personal time spent driving.

Most product indicator frameworks focus exclusively on economic or environmental performance, and very few address societal concerns (James, 1997). Based on the resurgence of attention to companies' societal performance, we anticipate an increased focus on the societal impacts of products and services.

The second principle of sustainability measurement is that evaluations must include economic, environmental, and societal aspects.

Life cycle

Finally, resource consumption and value creation, in terms of all three aspects, take place throughout the life cycle, including the supply, manufacturing, use and disposal of a product. An evaluation that focuses exclusively on one life cycle stage (eg. manufacturing) may fail to capture significant product benefits or impacts that occur in either upstream or downstream stages (Fiksel, 1996). Referring again to the automobile example, it is only recently that designers have begun to consider the 'end of life' stage, and the potential impacts of disassembly, recycling, recovery, refurbishment and re-use.

The third principle of sustainability measurement is that evaluations must systematically consider each stage in the product life cycle.

Holistic framework

These three principles can be integrated visually to create the framework depicted in Figure 2. The sustainability of a product can be evaluated by considering the economic, environmental and societal aspects of resource consumption and value creation throughout its life cycle. (In Figure 2 the halves of the circles represent resource consumption and value creation.)

This framework can be used to graphically depict the results of performance analyses. For example, once performance indicators have been evaluated (as discussed in the following section), specific half circles could be filled in

	Quantitative metric	Qualitative metric
Leading indicator	Sustainability training (number of employees trained)	Sustainability training (employees evaluation of training courses)
Lagging indicator	Product eco-efficiency (lbs. product/total lbs. input)	Product eco-efficiency (stakeholder satisfaction or number of awards)

note: lbs = pounds (weight)

Table 3: Examples of indicators and metrics

with a pre-determined colour or incrementally darkened to convey relative product performance. This would create a visually appealing, readily understandable representation of results.

Performance indicators and metrics

Once a SPM framework has been established, design teams can proceed to select appropriate performance indicators and accompanying metrics that best represent the contributions of their product to sustainability. A recommended approach to selecting indicators and metrics is discussed briefly below.

Basic concepts

A performance indicator is a specific, measurable product attribute that characterises its contribution to some aspect of sustainability (Fiksel, 1997). Performance indicators can be grouped into two categories: lagging and leading. Commonly used lagging indicators, also known as 'result' indicators, include air emissions released, environmental costs incurred, and customer benefits provided. These indicators can only be validated in a retrospective fashion once the product has been released. In contrast, leading indicators, also known as 'process' indicators, measure internal practices or efforts that are expected to improve performance; eg. employee training or quality control. Thus, the purpose of process indicators is not to measure results but rather to encourage a focus on product or service performance drivers.

Each selected performance indicator must be associated with at least one metric that defines a specific means of tracking and reporting that indicator. Metrics should ideally be verifiable, objective, and meaningful to decision-makers and stakeholders. A variety of metrics can be chosen for most indicators; eg. potential metrics for solid waste generation include annual volume (tons/yr.), annual improvement (% weight reduction), cost ($/yr.), or quantity avoided (tons recycled/yr.). Two broad categories of metrics exist: the first is quantitative metrics that rely upon empirical data and characterise performance numerically, eg. dollars of revenue ($). The second category is qualitative metrics that rely upon semantic distinctions based on observation and judgment. For example, to track a product's societal performance, a company could survey its stakeholders to determine how its performance was perceived. An illustration of the above indicator and metric categories is provided in Table 3.

Selecting indicators and metrics

The SPM framework, shown in Figure 2, can provide a starting point for designers when selecting the most appropriate set of performance indicators and metrics. One approach would be to qualitatively characterise each aspect of the product's performance (as done in the sustainability circle discussed earlier) as 1) an area of concern, 2) an area without significant weakness or strength, or 3) one of possible sustainability advantage. Under this approach, the design team

Societal		Employee injuries (number/year)		Public health risk (qualitative)
Environmental	Material intensity (lbs/year)	Toxic emmissions (lbs/year)	Genetic transference risk (qualitative) Pesticide use (gal/bushel) Fuel consumption (gal/bushel)	
Economic		Economic value added	Farmer productivity (bushels/year)	Food costs ($/bushel)
note: gal = gallon lbs = pounds (weight)	**Supply**	**Manufacturing**	**Use**	**Distribution**

Figure 3: Sustainability indicators for a biotech agricultural product

Economic	**Environmental**	**Societal**
Direct á Raw material cost á Labour cost á Capital cost	**Material consumption** á Product & packaging mass á Useful product lifetime á Hazardous materials used	**Quality of life** á Breadth of product availability á Knowledge or skill enhancement
Potentially hidden á Recycling revenue á Product disposition cost	**Energy consumption** á Life cycle energy á Power use during operation	**Peace of mind** á Perceived risk á Complaints
Contingent á Employee injury cost á Customer warranty cost	**Local impacts** á Product recyclability á Impact upon local streams	**Illness & disease reduction** á Illnesses avoided á Mortality reduction
Relationship á Loss of goodwill due to customer concerns á Business interruption due to stakeholder interventions	**Regional impacts** á Smog creation á Acid rain precursors á Biodiversity reduction	**Accident & injury reduction** á Lost time injuries á Reportable releases á Number of incidents
Externalities á Ecosystem productivity loss á Resource depletion	**Global impacts** á CO2 emissions á Ozone depletion	**Health & wellness** á Nutritional value provided á Food costs

Table 4: Illustrative categories of sustainable product indicators

would assess subjectively how their product will create value and consume resources throughout its life cycle. Such a qualitative assessment can be conducted through a workshop session involving an expert team, and the results can be displayed visually using the framework presented earlier.
The obvious advantage of this approach is its relative simplicity compared to the data-intensive steps required to quantify the entire life cycle performance.

A more rigorous and demanding approach would focus on the critical aspects of product performance and devise either leading or lagging indicators that could be quantitatively evaluated. In this case, the primary benefit of the framework is helping ensure that all relevant aspects are addressed. Table 4 illustrates a number of different categories of sustainability peformance indicators that could potentially be quantified. Generally, practitioners are advised to select as few indicators as necessary to address the most important aspects of product performance. Efforts to track numerous indicators (more than 12) have often proven burdensome and have eventually been scaled back.

In many cases, practical limitations of data, resources or methodology may hinder the ability of a development team to evaluate indicators over the full life cycle. In other cases, companies may wish to exclude certain life cycle stages from consideration because they are not relevant to business decision-making. Therefore, the intended scope and rationale for indicators should always be clarified. For example, rather than speaking of 'energy use reduction' we should specify 'reduction in energy use during manufacturing and distribution' or 'reduction in power consumption during product end use'.

Finally, a mixed approach uses quantitative indicators when the measurement data can be obtained cost effectively, and then relies upon qualitative indicators for the other critical aspects of sustainability. The application of this approach is shown in the following example.

A biotechnology example

Life science companies are currently developing a host of biotechnology-based products that they claim will enable a shift to sustainable agriculture. One class of these new agricultural products is pest-resistant crops; biotechnology enables the insertion of genetic material into the crops that can help deter a variety of harmful pests. Proponents claim that this technology will increase agricultural productivity and lower consumer costs, while opponents are concerned about possible health and environmental impacts. The three measurement principles proposed earlier can help internal and external decision-makers compare the sustainability of these biotechnology-based product systems to alternatives.

· How do these 'product systems' create value and consume resources?
· How will customers or stakeholders be affected economically, environmentally, and socially?
· What are the most significant impacts across the full life cycle of these 'product systems?'

In comparison to a conventional crop, biotechnology-based products create value by reducing pesticide use during crop production, with corresponding reductions in toxic emissions during pesticide manufacture. Similarly, both the raw materials required to produce the pesticides and fuel required to apply them are reduced. These indicators and several others that were derived using the aforementioned sustainability measurement principles are provided in Figure 3.

Conclusion

This paper has set forth a general framework for sustainability performance measurement and illustrated how it can be applied. The framework provides a comprehensive organising scheme for reviewing the many different ways that a 'product system' can have adverse or beneficial impacts upon the 'triple bottom line'. The framework embodies three principles – separation of resource and value measures, explicit representation of the 'triple bottom line', and consideration of the full life cycle.

Already, many companies have begun to incorporate sustainability measurement into their product development and performance evaluation processes, and we believe that the use of an organising framework will help to ensure consistency and thoroughness in the practice of sustainability measurement. Looking ahead, we anticipate that a number of trends will emerge:

· those companies that have committed in principle to sustainable development will begin developing practical ways of assessing the sustainability of specific products and services.
· in pursuing sustainability performance measurement, these companies will develop or adopt frameworks such as the one presented here to ensure that they address the full spectrum of relevant impacts or benefits.
· the implementation of product sustainability indicators will require some 'short cuts' such as relying upon qualitative instead of quantitative metrics. Many companies will choose to track and report leading indicators that are likely to contribute to sustainability.

The practices for measuring product sustainability will continue to evolve rapidly during the next several years. By understanding the principles of sustainability performance measurement, practitioners can design a process that is best suited to the needs of their organisation. •

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How important is environmental performance? A case study measuring the environmental preferences of 'business to business' consumers

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Increasing awareness of environmental performance, especially amongst customers, has not gone unnoticed by designers of electrical and electronic products. Unsurprisingly this has resulted in environmental performance becoming increasingly emphasised in marketing such products. Despite a wealth of research on 'green consumerism', it is not clear how environmental concerns stand in relation to other product attributes.

One potentially important group is 'business to business' consumers. In order to determine the importance of environmental performance to this group, a conjoint analysis methodology has been applied to investigate the buying preferences of company purchasing managers for two different products, an inkjet printer and inkjet cartridge.

This study shows the importance of price for most purchasing managers. Environmental performance is also shown to be an important product feature. However, perhaps surprisingly, the research shows that inkjet printers which use recycled plastic are not routinely preferred to equivalent printers made from virgin material, while inkjet cartridges which are reusable are not preferred to disposable cartridges. The principal drivers for this behaviour are investigated, as well as the implications for manufacturers.

Introduction

The growth in stakeholder interest in industry's environmental performance, especially amongst consumers, has not gone unnoticed by designers of electrical and electronic products. Unsurprisingly this has resulted in environmental performance becoming increasingly emphasised in marketing such products. A graphic illustration of this trend is the burgeoning number of electrical and electronic consumer products which are now being 'badged' with so-called 'green labels'.

In some instances manufacturers have designed their products to meet 'green label' criteria in direct response to purchasing requirements, for example to meet a public sector organisation's buying guidelines. However, in many instances the pursuit of environmental claims has been carried out without independent verification, as a way to differentiate a product from its close competitors.

There is evidence that consumers not only desire to purchase products which minimise their impact on the natural environment, but are also willing to pay more for them (Coddington, 1993). Taken from a company perspective, Earl et al (1998) has shown through specific industry case studies that investments which improve a company's environmental performance, and hence public image, can produce significant financial benefits for the company.

Despite these findings, what is not clear, and what the study (below) hoped to investigate, is how environmental concerns stand in relation to other product attributes.

Project aims

A research project was developed that aimed to investigate the relative 'trade offs' company purchasing managers make when purchasing electronic and electrical products. More specifically it aimed to answer the question 'Are 'business to business' consumers willing to forego performance or pay higher prices to improve a product's environmental performance, and if so by how much?'

To meet this aim the study chose to investigate two closely related products. The first, inkjet printers, are relatively long-lasting and involve an element of investment. The second product, inkjet cartridges, are much more frequently purchased and involve significantly lower per transaction cost. At the same time both products belong to a fast moving office equipment and consumables market which is increasingly being subjected to environmental performance pressures from stakeholders. Indeed both products share attributes which have significant potential to impact the environment, either through using up valuable resources (eg. energy, materials) or by creating large amounts of waste and potential contamination.

Essentially, customers can be classified into three broad categories:

· domestic
· intermediate, ie. retailers
· 'business to business' (includes both the public and private sectors).

This study chose to investigate the 'business to business' category, more specifically the behaviour of purchasing managers from the private sector. From the demand side, purchasing decisions from corporate buyers send strong signals to manufacturers. On the other hand, purchasing behaviour also indicates the company's own attitude towards the 'greenness' of suppliers' products, which is an important influence on attitudes within the purchasing company itself. Because of the uniqueness and purchasing influence of the purchasing managers approached, this study has not attempted to achieve the sample rate of other studies which have examined general consumer behaviour.

Conjoint analysis – a tool for measuring trade-offs

Conjoint analysis is a market research tool which can be used to measure consumers' 'trade offs' among products with many attributes. Conjoint analysis relies on the ability of respondents to make judgements about stimuli. For example, it is easier for a consumer to answer the question 'are you prepared to pay £1000 to upgrade from a similar Ford to a similar BMW?' rather than 'what is the relative importance to you of a car's brand and price?' This is exactly the type of question asked of the respondents by the conjoint methodology.

In conjoint analysis, the stimuli represent some predetermined combinations of attributes, and respondents are asked to make judgements about their preference for the various combinations of attributes. Conjoint analysis attempts to handle the problem of determining preferred features by systematically estimating how much each attribute is valued on the basis of the respondents' choices between alternative product concepts. Because questions are 'framed' closely and made concrete, conjoint analysis is distinct from the broad eco-nomic approach of contingent valuation. Also since the conjoint method converts consumer preferences for different performance attributes to a single variable, utility, it is possible to quantify the relative importance of these to the respondent.

Methodology and results

In line with the study's aim a conjoint experiment was designed to measure the relative 'trade offs' purchasing managers make when choosing inkjet printers and inkjet cartridges. Data from the study was analysed using conjoint analysis software developed by Bretton Clark. The methodology used covered the following basic stages:

Specification of separate conjoint experiments for each product

Appendix 1a and 1b summarise the performance attributes and levels used to describe the inkjet cartridge and inkjet printer experiments. Cartridge reusability and printer casing recycled content are the environmental performance attributes included in each design. The performance levels specified for these attributes were defined so that they did not imply any direct financial or operational gain or loss to the respondent (eg. purchasing manager). The idea was that utility values measured for these performance attributes would indicate only the respondent's preference for environmental performance.

Stimuli design

Conjoint analysis works by asking respondents to rank in order of preference a set of product scenarios which have been specified using a common set of performance attributes and performance levels (in this case those described in Appendix 1a and 1b). Whilst each product scenario is specified by the same set of performance attributes, the performance levels defined for each attribute will differ on at least one of the attributes. The most common way to display the product scenarios to the respondent (eg. purchasing manager) is through a set of cards. Each card carries a description of the product using the pre-defined performance attributes and performance levels.

Data gathering

The inkjet printer and inkjet cartridge conjoint experiments were carried out with 22 purchasing managers selected from 13 companies. On average two individuals were interviewed from each company; in each case these were chosen for their responsibility for purchasing IT equipment. The companies approached covered a wide spectrum in terms of size (ranging from small and medium sized companies to multinationals) and area of operation (consultancy to production and manufacturing).

Produce output results

Appendix 2a and 2b summarise the average utility and attribute importance calculated for the two experiments. A useful representation of this data is achieved by comparing utility levels with performance levels for each attribute. Figures 1 and 2 show the utilities for the environmental attributes for each of the two product groups.

Results

Price is invariably and not surprisingly an important attribute. However the detailed results show that, all other things constant, the lower priced inkjet printers and cartridges are on average not routinely preferred over higher price versions. For example, for inkjet printers only 22% of respondents consistently placed higher utilities on lower priced printers compared to higher priced ones, and for inkjet cartridges this figure was 14%. This behaviour suggests that respondents are inferring some kind of benefit associated with higher prices which are not defined on the conjoint card. Alternatively they may doubt the credibility of the lower priced products described on the conjoint cards.

The recycled content of the inkjet printer is on average an important negative feature. The utility function and data analysis shows that 85% of respondents prefer lower over higher recycled content. This behaviour implies that respondents simply do not wish to buy inkjet printers made from recycled plastics or that they associate some kind of product performance loss, to printers with a casing with higher recycled content (not defined on the conjoint cards)

The spent cartridge option attribute was deliberately defined so that the possible performance levels would not offer any financial incentive to the respondents. The value of each performance level would therefore relate solely to the importance placed on the cartridge's environmental performance. The detailed results show that nearly two thirds of respondents, all other things equal, prefer disposable cartridges over refillable or recyclable ones. The conclusion is that the purchasing managers prefer disposable inkjet cartridges: although they offer poorer environmental performance, they are easier to use, requiring no refilling or storing for recycling.

Conclusions and implications

The analysis has deliberately focused on the spent cartridge option and recycled content attributes, since these were introduced to 'capture' environmental performance as a selling attribute for the two products studied. In both cases, the environmental attributes were defined so that they did not directly imply financial benefits to the purchasing managers, and therefore did not elicit any preference for environmental performance.

In this study, purchasing managers were required to think about and articulate their 'trade offs'. Whereas a preference for environmental performance is often assumed, it is only possible to measure real preferences via 'trade off' decisions which include environmental performance as one decision criterion among several. The results from both conjoint experiments show that price and operational criteria are important for most purchasing managers. The recycled content of the casing and cartridge re-usability were shown to be important product features. To the extent that recycled content and re-usability, and therefore improved environmental performance, represent lower rather than higher performance is preferred.

Greenness is not enough

For inkjet printers, reference to Figure 1 shows that purchasing managers place lower utilities on (ie. are less satisfied with) printers with higher recycled materials content. This means that for two printers with equal cost, each offering the same operational performance, the printer made from 'virgin' material offers more utility (ie. is preferred) over the same printer made from recycled materials. There are two likely reasons for this behaviour;

- the purchasing managers misunderstood the experiment's definition of recycled.
- the purchasing managers perceive recycled products as inferior to new products.

The first reason is thought unlikely since a great deal of care was taken to fully define and explain each performance attribute. It was made very clear that the term recycled referred only to the material used to produce the printer's casing. Respondents were told they were comparing 'printers with different amounts of recycled casing content' and not 'recycled verses new printers'. It was also made clear that this attribute was totally independent of the printer's other attributes, ie. the printer's recycled content is not in any way linked with and can therefore not affect any of the other attributes used to describe a printer.

The second reason, driven by the purchasing manager's own perception of what recycled means, appears to be more likely. So, rather than acknowledging that recycled means 'as good as new', purchasing managers are more likely to perceive them as 'second hand'. Given that the purchase of a printer is longer term and can be seen as an 'investment decision', it is plausible to think that purchasing managers would be reluctant to invest in products perceived as 'second hand'.

This type of behaviour is not unusual. For years, Xerox have been marketing re-manufactured photocopying machines and have struggled to dispel the misconception that these machines are refurbished, use old components and are in some way inferior to 'brand new' products. In fact Xerox have found that the greatest resistance to their re-manufactured machines stems from public sector buyers. In some cases this is borne out by governmental selection protocol, which may stipulate that only 'brand new' products may be considered for tender. Even if this is not the case, Xerox have found that buyers using public money, who are therefore accountable to tax payers, are

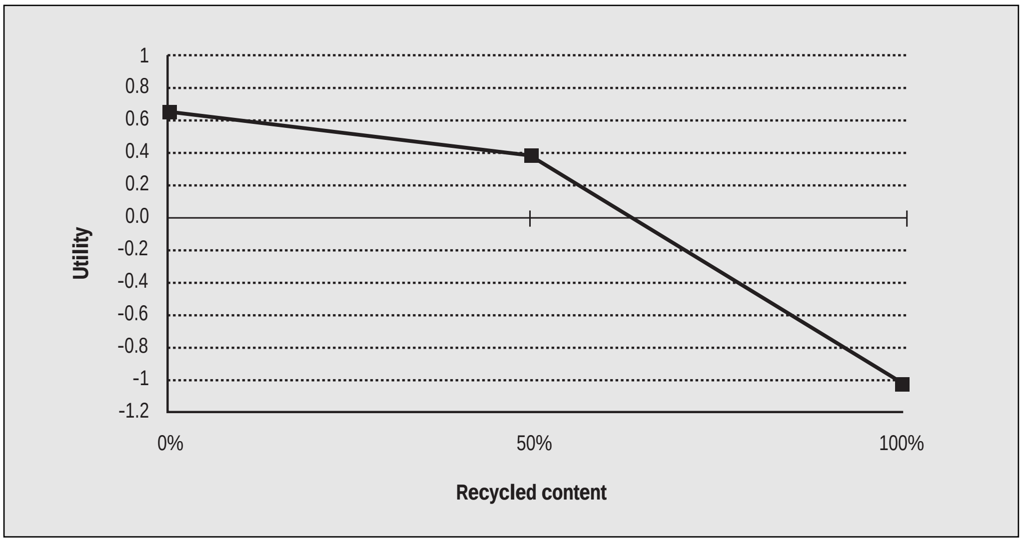

Figure 1a: Recycled content utility function for inkjet printers

reluctant to risk public disapproval by spending money on goods which are not 'brand new'.

Perhaps this partly explains why ICL prefer to market their products as 'second life' rather that 'Re-whatever', anticipating that the products are less likely to be devalued by the purchaser. However, the analysis suggests that the problem is deep-rooted, not merely semantic. As suggested earlier, it is much more likely to be driven by purchaser perceptions. The answer therefore is not simply to change the name of goods or hide the fact that a product is re-manufactured or incorporates recyclate; rather, it must address the cause, which seems to be a lack of understanding.

The preference drivers for printer cartridges seem to be slightly different. Because the purchase of an inkjet cartridge is unlikely to be seen as an investment, it is more likely that operational and logistical criteria drive the purchase decision. The conjoint analysis results (see Figure 1b) show that purchasing managers actively prefer disposable cartridges to refillable and recyclable ones. Given no financial benefit then the easiest and most convenient option is shown to be preferred. If the preference for disposable cartridges is seen as a proxy for convenience, then the analysis shows this is a much more important factor for the purchasing managers than any potential environmental gain.

Other supporting evidence

This behaviour is not altogether surprising. Although Kärnä and Heiskanen (1998) report that some manufacturers of electronic and electrical products claim to have noticed greater environmental awareness amongst 'business to business' consumers compared to domestic consumers. This type of behaviour has generally been limited to more aware countries such as Germany and Sweden where there are more social pressures to emphasise environmental performance. The implication is that 'business to business' consumers in countries such as the UK, where these pressures are weaker or absent, suffer the same misconceptions and lack of awareness as intermediary and domestic consumers.

Business in the Environment (BiE) in the UK carried out research on the level of environmental engagement of the FTSE 100 top UK companies and found a disappointing level of supply chain management amongst the UK's top companies (BiE 97). In reply to the question, 'Does your company have an environment-focused supplier programme in

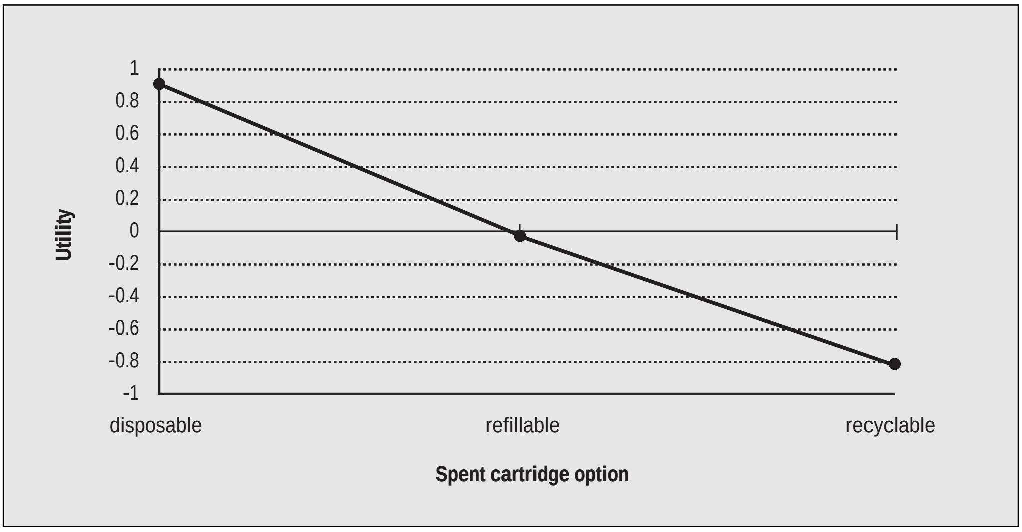

Figure 1b: Spent cartridge option utility function for inkjet cartridges

place?' the survey found that only 38% of the companies interviewed responded with a positive answer.

The solution for manufacturers wishing to specify and sell their products using 'green credentials' is clearly not simple. Manufacturers see a diffuse and unspecified demand for environmental solutions, as well as very little hard evidence to show reward for their environmental improvement endeavours.

Obviously there are exceptions to his rule, as identified by John Carew from Business in the Environment (Carew, 1997), for example:

- BT report that they use environmental considerations in their purchasing decision-making process
- IBM carry out eco-risk analyses of strategic suppliers
- Nortel work with suppliers on specific environmental issues – currently they are trying to tackle packaging issues by working together with Motorola
- B&Q uses environmental management in the supply chain to increase market share
- Sainsbury's is developing joint ventures in crop management.

Nevertheless the assumption that 'business to business' consumers are going to be the 'forerunners of the environmentally conscious generation of customers of the future' (Kärnä and Heiskanen, 1998) appears to be ill-founded. A major challenge suggested by this study is that there is confusion and lack of understanding even amongst purchasing managers of what some environmental claims actually mean, especially their implications for the product's performance and for the business in general. This problem is not helped by what also appears to be a lack of generally accepted environmental criteria for electrical and electronic products.

Barriers to greener purchasing

BiE have identified two fundamental barriers faced by 'business to business' purchasers wishing to improve their company's supply chain management. The first is gaining policy commitment and the associated mechanisms and procedures to back it up. The second barrier is the application of the poorly understood approach of 'whole life costing'. There is little or no evidence that 'whole life costing', which implies including the environmental imperatives of longevity, lower running costs and disposal costs, has been applied properly and as a matter of course in private and public sector procurement.

Underlying these barriers is a scarcity of available and reliable information about the environmental characteristics of products and services. In fact, Jean Cinq-Mars, Head of the Pollution Prevention and Control Division Environment Directorate, OECD, speaking at the 'Greening Government' conference (Cinq-Mars, 1997) suggests that lack of information is sometimes considered to be the major obstacle to greener purchasing initiatives as it limits the development of multi-criteria specification of environmental characteristics of products.

Eco-labels and regulation

Although third party labelling schemes may seem to offer a part solution, the role and significance of labelling are still unclear, especially since there seems to be little agreement on an internationally acceptable label. Recent analysis by the OECD (Cinq-Mars, 1997) on a few selected eco-labelling schemes concludes that such schemes have had little effect on consumer behaviour, except in those countries where consumers express strong environmental awareness.

Underlying all of this is an evolving regulatory environment. In the electronics sector the law is moving towards enforcing producer responsibility, with emphasis on 'end of life' management (EOLM) rather than eco-design. An example supporting this trend is the draft Directive on the management of waste from electrical and electronic equipment issued by the European Commission (1998). However, this European Union (EU) initiative does have considerable implications for the development and design of electrical and electronic products. The draft Directive outlines specific responsibilities for producers of electronic and electrical equipment, which taken together aim to:

- eliminate toxic materials
- increase recyclability
- increase dismantability
- increase the amount of recycled material
- improve the reverse logistics associated with these products.

For example, broad ranges have been proposed for a reuse and/or recycling minimum for all IT equipment. The responsibility for achieving this target is placed firmly with the producer. To achieve it, producers will need to provide users of electrical and electronic equipment, in particular consumers, with the necessary information about the return, collection and recovery systems available to them, and also to emphasise their role in contributing to the recovery and re-use and recycling of 'end of life' electrical and electronic equipment.

A basic strategy for effective green marketing

Taken together the picture for producers seems somewhat bleak. On the one hand the regulatory framework is looking to impose the responsibility for EOLM on the producer, to encourage the uptake of reusable and recyclable products and materials. On the other hand, this and other similar studies show that consumers, even supposedly better informed 'business to business' consumers show an unwillingness to switch to greener designs and products.

On the positive side the electronics sector is leading the way in the implementation of the international environmental management standard, ISO 14001. Because this standard aims to push companies to greater understanding of the direct and indirect environmental effects of products throughout their life cycle, it should help with the marketing of greener products. It would however be foolish to rely solely on ISO 14001 and emerging international eco-labels to solve the perception problems associated with recycled or reused products.

Form relations with stakeholders to reduce misconceptions

It is more sensible for manufacturers to become more proactive and start to develop in-house strategies for the specification, design and marketing of their products. As a starting point, conclusions drawn from this study suggest that any strategy must aim to reassure purchasing managers of the validity and implications of 'green claims'. Advice should be relayed back to potential manufacturers of products or components, that 'recycled' does not mean 'second hand', and that eco-innovations are needed.

Since customers (domestic or 'business to business') often distrust environmental claims, because they are perceived to be used to gain competitive advantage and can not easily be tested by customers themselves, it is critical that manufacturers are able to demonstrate their credibility and develop an honest and trusting relationship with their stakeholders. To help achieve this, the company must aim to identify what kind of information is used and needed by its different stakeholders, and then be pro-active in ensuring that this information and the way it relates to their products reaches the stakeholders in a systematic way.

Demonstrate the whole life value of the product

Secondly, and probably just as important, the strategy must ensure that if green claims are being made, these are linked wherever possible to overall environmental policy and associated financial and operational gains for the 'business to business' consumer. This means working together with the purchaser to show the benefits of using 'whole life costing' to differentiate between products. Using this approach, the manufacturer will be much better placed to demonstrate any 'down the line' cost reductions associated with improved environmental performance and, perhaps most importantly, the risk reduction benefits which can result through increased confidence amongst its stakeholders. This analysis confirms the views expressed, for example, by Stevels (1997).

Taking the example of inkjet cartridges, using 'whole life costing' principles will help to reinforce that reusable cartridges can in fact be cheaper for the purchasing company if potential disposal costs are factored in, or if the company is struggling with its environmental image. This research has shown that, unless links such as these are made, it is unlikely that purchasing managers will be willing to sacrifice convenience for the sake of environmental performance.

Education, training and communication

All of this must be underpinned through a basic platform of education, training and clear communications. No matter how good the eco-improvements that designers make to products, their potential to reduce environmental impacts is usually contingent on the behaviour of others, not least of which is customer demand which makes it possible to compete and sell into the market place. The best 'green' products can only reduce our environmental footprint if they are actually purchased and used in preference to products with poorer environmental performance.

Future research

This study represents a starting point in trying to quantify the importance of environmental performance as a decision-making criterion in purchasing. In this case, the research has concentrated on the importance of environmental performance to 'business to business' customers.

There are of course many other stakeholders who are interested in not only the environmental performance of the products but also of the manufacturing companies themselves. For example, as Stevels (1997) observed, company designers will benefit immensely and be better placed to develop sustainable product designs if they can integrate stakeholder priorities into the design process. So, rather than incremental product improvements, the aim must be to move towards radically re-thinking the way stakeholders' needs are provided for. 'Trade offs' have to be made between environmental and other criteria. To increase the credibility of these choices stakeholders must be involved in the decision-making process.

Future research must therefore look at ways to quantify the priorities, values and needs of a wider set of stakeholders, and to design decision-making processes which will allow these factors to be integrated into the traditionally closed, internal processes by which companies reach their decisions. •

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Appendices

Performance attribute

Name	Description	Levels
Price	The price of an inkjet cartridge for use in an average inkjet printer	£30 £22.50 £15
Life	The printing lifetime of the cartridge based on best quality print and approximately 3000 characters per page	750 pages 500 pages 250 pages
Colour	The colour capability of the cartridge	Black and white only Colour
Re-usability	The ability of the cartridge to be re-used after it has been used once. There is no cost cost advantage from reÞlling or recycling a cartridge.	ReÞllable. It is possible to reÞll the cartridge with ink and use it again. Recyclable. The cartridge is taken back to the manufactures for recycling When you buy a new cartridge you will be given the option of handing in your old cartridge Disposable. These cartridges can not be re-Þlled and will not be taken back by the manufacturer for recycling.

Appendix 1a: Performance attributes and levels: inkjet cartridge experiment

Performance attribute

Name	Description	Levels
Price	The purchase price of the printer	£300 £225 £150
Printer quality	The maximum print quality of the printer	Laser quality to describe a printer that can print up to 600 x 600 dot per inch
		Good quality to describe a printer that prints up to 600 x 300 dots per inch
		Average quality to describe a printer that prints up to 300 x 300 dots per inch
Printer speed	The maximum print speed of the printer when working in top quality mode, ie. not in draft output	6 pages per minute 4 pages per minute 2 pages per minute
Service and support	The service and support that comes as standard with the printer	Lifetime service/support. One year service/support
		No service/support
Reliability	The printer's intrinsic reliability performance	High reliability described through a 2% chance of breakdown in a year
		Medium reliability described through 6% chance of breakdown in a year
		Low reliability described through a 10% chance of breakdown in a year
Printer casing recyclate content	Total amount of recycled plastic material used in the manufacture of the printerÕs casing	100% recycled plastic content 50% recycled plastic content 0% recycled plastic content
Colour capability	The colour capability of the printer	Black and white printing only Colour printing capability.

Appendix 1b: Performance attributes and levels: inkjet printer experiment

Attribute	Level	Average utility	Relative importance
Price	£30	-0.35	19%
	£23	0.72	
	£15	-0.37	
Lifetime	750 pages	-0.26	36%
	500 pages	1.19	
	250 pages	-0.93	
Spent cartridge option	Disposable	0.86	29%
	ReÞllable	-0.06	
	Recyclable	-0.80	
Colour	No	0.47	16%
	Yes	-0.47	

Appendix 2a: Conjoint analysis results. Utility and relative importance results for inkjet cartridge experiment

Attribute	Level	Average utility	Relative importance
Price	150	-0.17	20%
	225	0.89	
	300	-0.73	
Print quality	300x300	-0.49	16%
	600x300	0.81	
	600x600	-0.32	
Print speed	2p/m	0.23	9%
	4p/m	-0.49	
	6p/m	0.26	
Recyclate content	0%	0.66	21%
	50%	0.38	
	100%	-1.04	
Reliability	Low	-0.17	10%
	Medium	0.50	
	High	-0.32	
Service and support	None	0.61	16%
	Limited	-0.73	
	Extended	0.12	
Colour capability	No	-0.38	9%
	Yes	0.38	

Appendix 2b: Conjoint analysis results. Utility and relative importance results for inkjet printer experiment

Design for Disassembly: a new element in product development

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Recycling is one of several essential factors that are needed to reach a more environmentally sustainable society. However, environmental demands together with economic reality and technical possibilities must be balanced. Recycling is not possible without the separation and sorting of waste. There is much to gain if this thinking is incorporated at the beginning of the product development process when there is still some design freedom and the possibility to make major changes. In this context, Design for Disassembly means design efforts in order improve the performance of a product with a focus on separation and sorting of waste.

Introduction

Sustainability as defined by the Bruntland Commission depends on many factors and recycling or 'industrial circulation' is one of them. Recycling must be based upon a comprehensive view so that sub-optimisations can be avoided. Before recycling is possible, waste products must be separated, sorted and transformed into flows of materials and components. Components must be good enough for reconditioning or instant reuse and materials must be clean/pure enough, or upgradeable, for the manufacturing of new products.

Sorting is only possible if parts and different materials can be identified – without identification, even energy recovery may be a problem. If the materials contain harmful or polluting components they must be effectively sorted to ensure that they are properly treated. (Luttropp):

- sorting is a key function in all reuse or recycling activities
- sorting is not possible without identification
- sorting is not possible without separation except in single material products
- separation and sorting, must be balanced against environmental, economic and technological considerations.

Product development and recycling

If a product is to be recycled or partly reused after its first service life, it is beneficial to take this into account in the early phases of product development when there is still a high degree of design freedom. However, it is difficult to make the best recycling decisions during early design phases. Even if there is a lot of design freedom, the information about the emerging product is limited.

Another problem is decision-making. The designer cannot decide to spend more time and perhaps use more sophisticated, more environmentally friendly materials in the product without acceptance from the product manager. Eco-performance will therefore depend on the ability of designers and management to cooperate (Luttropp).

The most common way of approaching the product development process is by seeing it as a chain of tasks with milestones and decisions at occasional points. This traditional and linear way of looking at the design process is still relevant, especially when the product itself is the focus.

Without going into detail the design process always starts with a conceptual/product planning phase with three typical steps. The first step is an analytical phase where the problem needs to be understood. What do the customers want? What price is he or she willing to pay for these functions? etc. In this phase the baseline for future work is established. In the second step – the creative phase – concepts are generated which are very difficult to guide. The third step is the evaluation of the concepts and this must be done very thoroughly and if necessary new analyses must be carried out.

Typically these three steps are repeated in an iterative way several times before a plan for

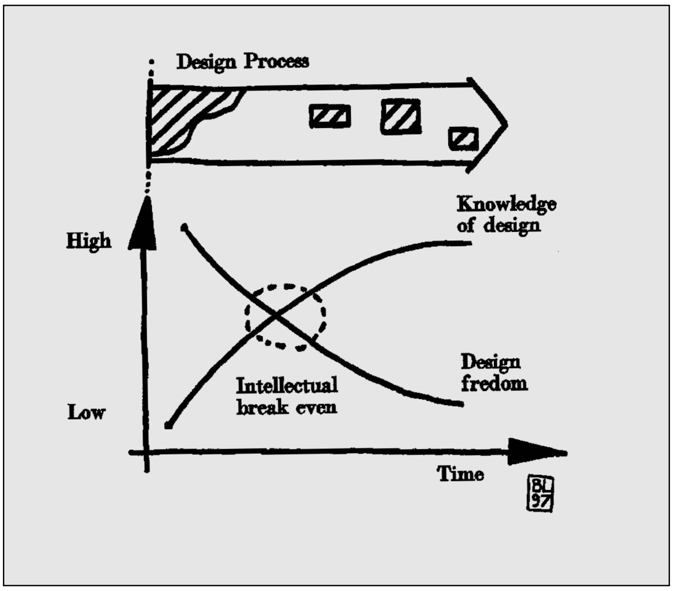

Figure 1: The 'patchwork' of creative design work and the milestone where the 'intellectual break-even' is situated

the product design phase is decided upon. In the product design phase the concepts from earlier phases are developed through drafting, dimensioning, prototyping, further market analysis, etc.

The conceptual design work is focused on the designer where understanding the problem, analysis, concept generation and evaluation of possible design solutions are blended in a randomised sequence (Luttropp). In Figure 1 the hatched areas inside the thick arrow aims to illustrate this 'designer's patchwork'. The thick arrow illustrates the total design process and the hatched areas illustrate what has been done in different downstream activities, up to the 'intellectual break-even'. This should include information concerning basic principles, customer needs, prototypes, manufacturing concepts and preliminary materials selection from different areas of product design. When the product is on the market the information is complete and the thick arrow then completely hatched implying that all information covering the new product has been determined. One of the elements in the figure shows the growth of knowledge over time and the other elements show how, at the same time, design freedom will lower.

In the end of concept design and before product design there is a very important 'milestone'. At this point substantial information concerning the product is present but there are still possibilities to make major changes. This is illustrated in Figure 1 by the two graphs passing one another. This situation may be looked upon as the

Management and design must co-operate since designers cannot spend additional design effort on developing more recycling friendly products if this is not sanctioned by the managers who are in charge of the additional costs that these design efforts will raise.

'intellectual break-even' in the product development process (Luttropp).

This is the perfect point for strategic decisions concerning the separation and sorting structures for the forthcoming product. The exact location of this 'break- even' is impossible to establish since it is more of an interval rather than a strict point. However, it is a good point to establish both the functional parameters connected to the use of the product, and 'end of life' considerations. This way, environmental demands will be balanced in the basic design concept against other functional and economical requirements. Management and design must co-operate since designers cannot spend additional design effort on developing more recycling friendly products if this is not sanctioned by the managers who are in charge of the additional costs that these design efforts will raise.

Recycling and design methods

A variety of methods have been established as aids to product development, including Quality Function Development (QFD), Fail Mode Effect Analyses (FMEA) and Life Cycle Assessment (LCA). LCA assesses the environmental impact of a product from 'cradle to grave,' from raw materials used to manufacturing processes, usage and 'end of life' treatment. Since the scope of a detailed LCA is very large, the procedure can be complicated and time consuming.

One other problem with LCA is that it doesn't account for the preferences. If several product design concepts are environmentally evaluated in a LCA process, the customer benefit from the different versions of the product should be constant to make the comparison valid. In practice, it is almost impossible to do this eg. there may be three solutions to a design problem with radically different 'LCA values' and customer benefits? For example an engine bonnet for a car may be evaluated in a LCA process and the material choices may be between steel, aluminium, thermoplastics or glass reinforced thermosetting plastic. These alternatives may not necessarily be perceived as possessing equivalent value to the customer – an engine bonnet is not universal. Even the sound of it when you knock on the bonnet is a part of the impression!

Customers may accept a slightly lower performance from a product if the environmental impact is radically lowered. But the benefit to the customer must be measured, evaluated, documented and compared to the environmental impact. Eco-performance should be measured by both environmental performance and customer benefit.

Structure of products from a recycling viewpoint

To achieve functions and principles that will allow for recycling it is important to prepare for this during early design phases (Luttropp):

- recycling of a product starts

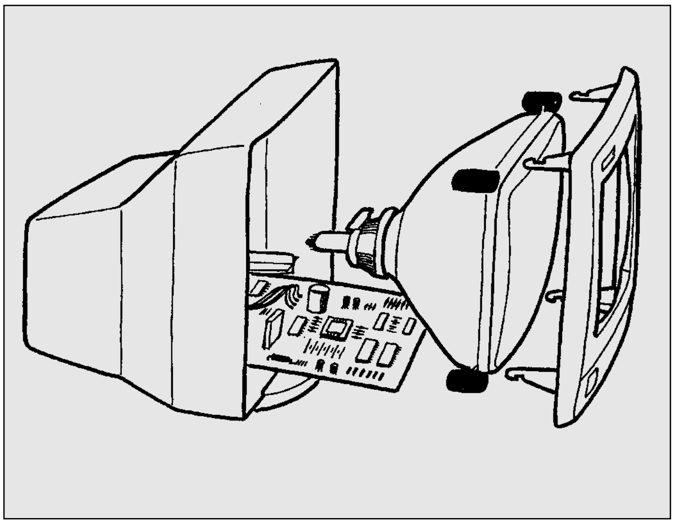

Figure 2: Example of a simple disassembly case

with disassembly

- in complex products sorting must be performed after disassembly/separation eg. into useful parts, useful materials and materials for energy recovery
- if this sorting is possible the product must be separated in such a way that identifiable fractions are created
- if these fractions or sub-assemblies are to be useful, they must be pure enough to use or possess upgrading possibilities.

The structure of a product from a recycling point of view consists of pieces of homogenous materials, useful sub-assemblies, parts for energy recovery, etc. The product can be regarded as a set of modules or 'sorting objects' with one or several separating surfaces where the object is connected or joined to other objects. These surfaces indicate where disassembly will take place when the product is scrapped (Luttropp).

From a recycling point of view, focusing on, for example, a personal computer (PC) monitor (Figure 2), this consists of pieces of homogenous materials, useful sub-assemblies, parts for energy recovery and nothing else. The fact that these objects have had a function earlier before the disassembly event is not particularly important except for objects that can be reused in their former function. Other parts are just pieces of material or amounts of energy.

In recycling, the sorting properties of the disassembled product are particularly relevant information. If it is possible to identify the different objects, then each of these objects are surrounded by a 'sorting border', which will have the following characteristics (Luttropp):

- 'sorting borders' enclose something that can be identified and if necessary upgraded, a sub-assembly, a labelled piece of material, etc.
- 'sorting borders' must be congruent with a 'separating surface' eg. products incorporating more than one material, otherwise the border will not appear

Resting loadcase
When opening eg. a PET bottle of water, a seal has to be broken by turning the cap anti-clockwise with a torque at some level. This is called a ÔloadcaseÕ: torque at some level in a certain direction, applied to, in this case, a cap. During transportation there are other ÔloadcasesÕ present, like for example the internal pressure from carbon dioxide (CO_2). The Ôresting loadcaseÕ related to breaking the seal is waiting for the consumer and resting before the Ôseal-breakÕ and is released afterwards.

Separating surface
The seal has breaking points where the material is separated destructively; an irreversible Ôseparating surfaceÕ. There is a contact between the cap and the bottleneck when the cap is closed. This contact surface is separated every time the cap is opened; a reversible Ôseparating surfaceÕ.

Sorting border
The cap of a PET bottle is of a known single material. It is possible to make a correct sorting of the cap and also of the bottle; both are surrounded by Ôsorting bordersÕ.

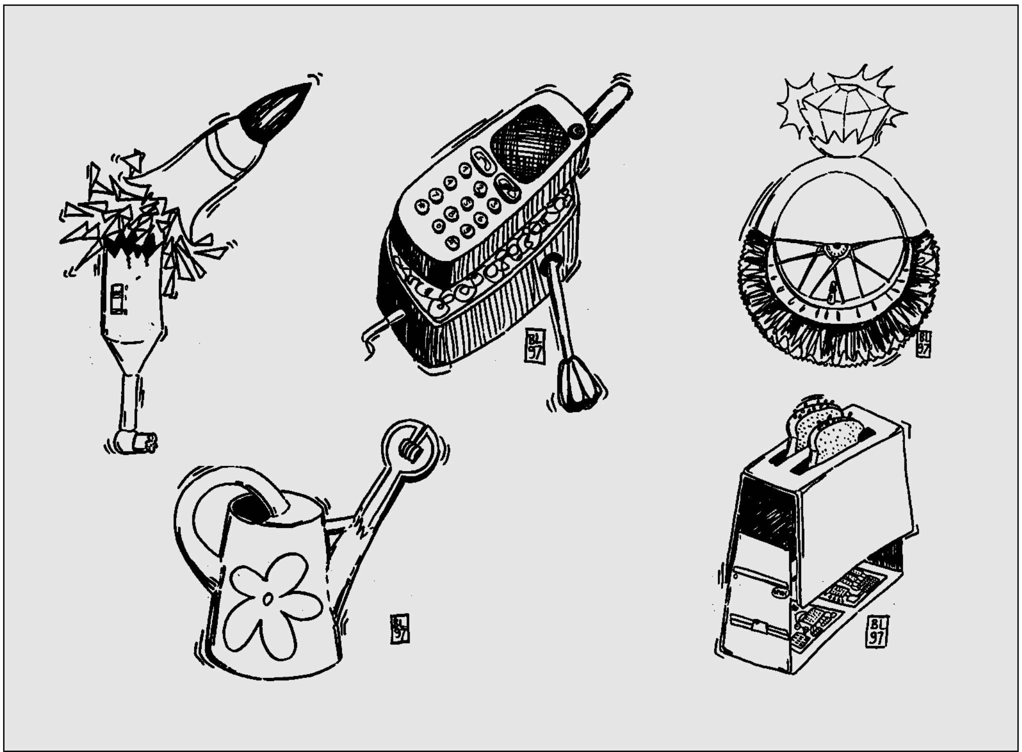

Figure 3:
Five different disassembly structures can be observed. Top from left to right: 'Shell', 'Hamburger', 'Twin'; and bottom from left to right: 'Rod' and 'Dressed design'. (Luttropp)

· 'sorting borders' are dependent on which order the different 'separating surfaces' are realised.

'Separating surfaces' can arise at several different joints such as screw-joints, snap-fits, glue-joints and also through a drop in strength somewhere inside the part. All joints that can be released during disassembly are 'resting loadcases' since these joints are released by applying a force of some kind in a new way that is not present during the service life of the product. A 'resting' disassembly function can be used at the scrapping event in disassembly actions. In the case of the PC monitor, there are only two 'resting loadcases'. The first is four snapfits in combination and the second is one screw joint in a hose hinge that holds the electronics round the neck of the tube. These concepts also can be integrated into CAD systems (Andersson and Luttropp).

Disassembly actions combined with product structure

Many products have a similar disassembly structure which means that overall layout does not differ very much. Products, such as spanners and watering cans, consist of only one material. The main task for the scrappers is to identify and sort the materials into fractions. Other products, such as computers and toasters, are built with separate components on a carrier with a cover. In this case, it will be more complex to identify and separate objects which are valuable and/or environmentally dangerous.

The PC monitor mentioned earlier has a main structure that can be visualised as a 'hamburger' with two halves, the front and the back, held together with four snap-fits. When released the rest of the parts free themselves.

Other PC monitors or for example toasters or computers are made with a central carrier where everything is mounted and finally there is a cover for electric security or simply for aesthetic appeal. These products can be visualised as 'dressed' designs.

Some products contain fluids or are meant to be waterproof and for that reason mostly have to be disassembled in a destructive way. Electric toothbrushes, ammunition and gasoline tanks are example of these 'shell' designs.

Many products contain only one material, such as a watering can or a spanner and from a recycling point of view these are like a 'rod'. Other products have several easy identifiable fractions like a combination of 'rod' of different materials like a 'twin' design.

More complicated products are usually combinations of these five concepts and often have subassemblies in several steps which have a structural variety of these five basic structures.

In disassembly the first actions will be the most important ones and the five product categories mentioned above can be organised in a matrix (Table 1) where the first two levels of action are noted. For example, the Hamburger which is characterised by an initial non-destructive loadcase which opens the casing and then everything is free and ready for sorting which is then the second step in disassembling Hamburger designs. The main objective of this approach is to get a better understanding of recycling layouts and conceptual disassembly principles. Each type of design has its own characteristics but inside each family the recycling strategies can be quite similar. The focus of this concept of design families is on what are the first and second steps when disassembling different products. (Luttropp).

The above concepts aim to help designers adapt products to increase recycling potential in early design phases. Even if many products don't fit perfectly into one of the product families, a

Table 1: Properties concerning disassembly. Separating can be destructive (D) or non destructive (ND) and the number of Sorting object (S_o) vary from family to family. This table of the five product structures shows how the activities differ on 1st and 2nd level

	Hamburger	Shell	Rod	Twin	Dressed
1st step	sep-ND	sep-D	sort	sep-ND/D	sep-ND/D
2nd step	sort	sort		sort	sep-sort
Sorting objects	(S_o)>2	(S_o)>2	(S_o)=1	(S_o)=2	(S_o)>2

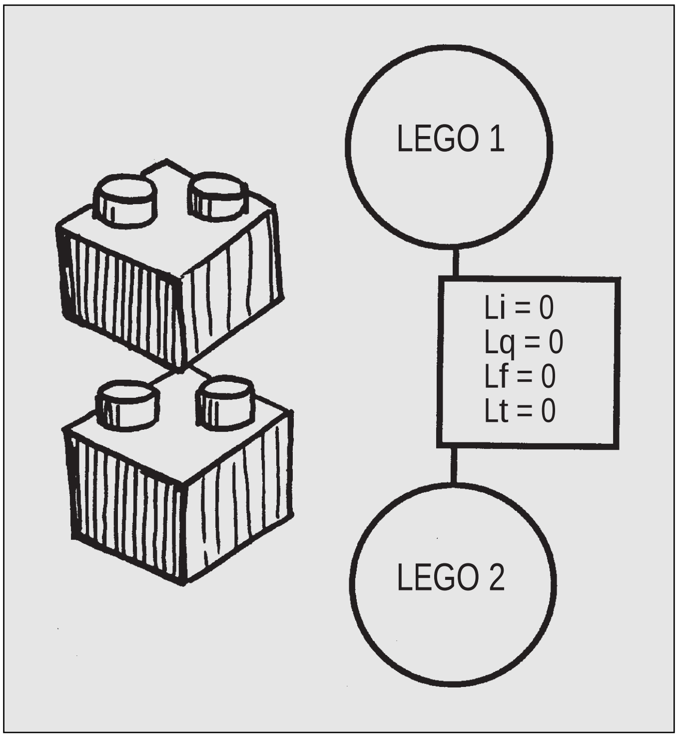

Figure 4: Two pieces are put together and the 'resting loadcase' between them is given loadcase indices.

conceptual recycling structure such as this will be helpful in early design activities. To a large extent, the benefits of recycling will be connected to the costs of disassembling and sorting. The first scrapping activities must be considered as the most important. In this model of five product families, each family has a pronounced difference when it comes to the first 1–2 events in scrapping (Luttropp).

Collaboration between designers and management

The structure of products, as described earlier, requires a system for evaluation of different design solutions and for collaborative decision-making between designers and management.

Loadcase indices and border indices are used to put scores or marks on different design solutions and for practical reasons the scale is mostly simplified to an interval 0–1. The numerical values are uncertain as they are based on subjective estimations. There are four loadcase indices and four border indices. The loadcase indices give information on how a specific loadcase is organised, what kind of action is necessary to operate the loadcase and the border indices give information on specific sorting objects that are surrounded by sorting borders.

The four loadcase indices are (Luttropp):

- Loadcase information Li=0 [0;1] Easy to understand=0 and almost impossible to understand the loadcase = 1
- Loadcase equipment Le=[0;1] No tools=0 and if special tools are needed to release the loadcase =1
- Loadcase force Lf=[0;1] How much force is needed to release the loadcase? Hands and fingers =0 and help from ie. power tools =1.
- Loadcase time Lt=[0;1] How much time is needed to release the loadcase? A lot of time =0, very little time =1.

In Figure 4 a simple example of loadcase indices on two LEGO pieces put together is presented. The loadcase is simple (Li=0), no equipment is needed (Lq=0), no extra force (Lf=0) and very little time (Lt=0).

Loadcases will look quite different to a professional scrapper and a consumer. Through this index system it is possible for designers and management to make decisions together concerning the disassembling functionality of eg. a new mobile phone. If the 'hamburger' concept is to be preferred and the initial loadcase to separate the two halves is to be made by the consumers the opening of the two halves must be easy to carry out and easy to understand. If then the product manager puts low understanding for the loadcase index when opening the two halves this is a signal to the designer that this special action must be easy to understand for consumers since consumer collaboration in disassembly is a part of the strategy with this product.

The inexperienced consumer needs much easier loadcases, with lower loadcase indices than the experienced scrapper. Sometimes it will be preferable that the consumer does not disassemble or even try to disassemble because of security etc.

There are also four 'sorting border' indices for the contents of the 'sorting objects' and the ease that 'sorting border' appears.

· 'Sorting border' information Bi=[0;1] Good understanding of what is in the 'sorting border' =0 and bad understanding=1
· 'Sorting border' economy Be=[0;1] Valuable object =0 and objects connected to costs =1
· 'Sorting border' destiny Bd=[0;1] Possible reuse in same position =0 and deposit =1
· Separating surface efficiency Bs=[0;1] The surface follows the 'sorting border' perfectly =0 and the surface does not follow the 'sorting border' at all=1.

In Figure 5 the system of indices is used on the PC monitor and the indices are organised in a connection map.

Product planning

One way of contributing to 'eco-performance' is to forecast the scrapping event at the 'intellectual break-even'. This forecast should be a plan concerning which parts of the new product are realistic to reuse in order to optimise the eco-performance (Luttropp).

To achieve the best eco-performance, economic, technical and environmental considerations must merge into a compromise. This complex situation could be looked upon as a disassembly structure of sub-assemblies and materials, in this way forming a modular structure of 'sorting objects'. The necessary 'separating surfaces' and 'resting loadcases' are all functional possibilities to be used during scrapping after service life.

Modules consisting of materials for energy recovery can be, and for economic reasons should be, assembled and joined without 'resting loadcases' since these parts will probably not be disassembled at the end of service life; just incinerated. There is no use in putting design effort into components that eco-management has forecasted as suitable for energy recovery.

Modules defined as having a valuable 'sorting border' should be connected to the rest of the design with great care because this is a module that might be reused or recycled at the end of product life. Suppose this valuable module is an electrical motor intended for reuse. There are of course a lot of borders and surfaces inside this motor that could be designed to be 'quick and dirty', since the motor anyhow will not be disassembled down to materials fractions; it will be reused as motor not as material. In upgrading strategies there should be good 'sorting borders' around modules which might be replaced during the service life (Luttropp).

A procedure like this must be carried out in different ways depending on the circumstances, the structure of the company, type of product, etc. But the following description may be helpful in establishing a company and product-specific conceptual scrapping plan or 'scrapping forecast.'

The proposed plan divides in four main parts. The first step would be to collect information through a questionnaire. This can be done together in a meeting where management and the design group exchange information. The second step will be to document and organise known facts, together with knowledge and assessments that are not fully established. This 'scrapping forecast sheet' will contain facts as well as conceptual assessments and maybe even include guesses.

At the third and fourth steps, a 'connection map' (see Figure 5) of the possible 'sorting objects' should be established together with indices on loadcases and 'sorting borders'. This map is just a concept and may be carried out in several versions depending on different design solutions.

The main goal of the map is to guess a scenario for the 'end of (service) life' for a specific product.

Step A: Collect available data

A questionnaire should be completed in a meeting with the design group and business and environmental management.

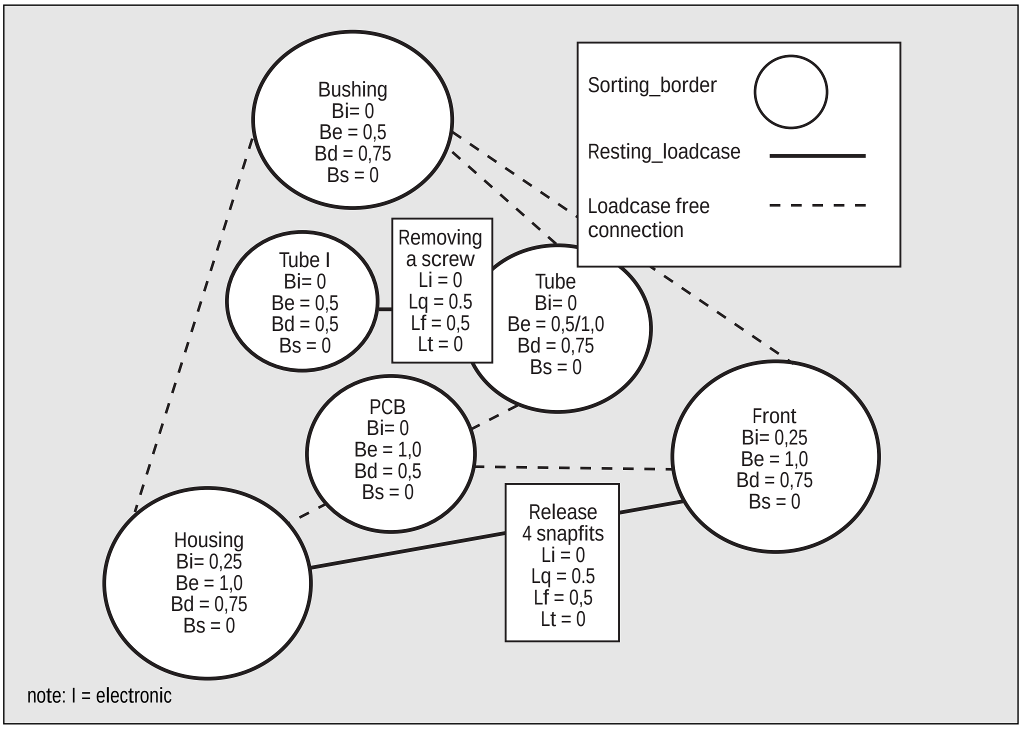

Figure 5: A connection map with indices on sorting objects and resting loadcases on the PC monitor in Figure 2 (Luttropp)

Question 1: What kind of product is it? 'a hamburger', 'a shell', 'a rod', 'a twin' or a 'dressed' design?

If the product contains fluids or materials in the form of gas there must be at least one sub-assembly with a 'shell' layout. If the product is supposed to be water or gas resistant then it is likely to be a 'shell' design.

Products containing electronics or electric motors are likely to be 'hamburger' or 'dressed' designs. When the product must be larger than the interior, due to aesthetic, handling or layout reasons, this will call for the 'dressed' design concept. If the product needs all the space inside the cover for sub-assemblies and parts, the 'hamburger' design is advantageous.

It is also possible with designs where for example the main layout is like a 'dressed' design and where sub-assemblies inside are carried out like 'hamburgers' or 'shells'.

For example, consider a product containing several parts including the cover – all suitable for incineration – and also a printed circuit board (PCB) – suitable for metal recovery and perhaps a Nickel-cadmium (Ni-Cd) battery that must be safely disposed of. One way of optimising this design from a recycling perspective would be to screw or glue the incineration candidates to the cover. This might be called a partly 'dressed' concept. The PCB and the Ni-Cd battery could be locked in by the cover in a 'hamburger' concept. This way there will be a concept with three 'sorting objects' (four if the cover fully divides into two

	Info.	econ.	dest.	Surf.		
N:o	Module	Bi	Be	Bd	Bs	Note
M1	Housing	0,25	1,0	0,75	0	ßame inhibitants
M2	Front	0,25	1,0	0,75	0	ßame inhibitants
M3	PCB	0	1,0	0,5	0	
M4	Tube	0	0,5/1,0	0,5/1,0	0	
M5	Tube electronics	0	0,5	0,5	0	
M6	Bushing	0	0,5	0,75	0	

Table 2: Scrapping Forecast Sheet (SFS) for a PC monitor

parts) all surrounded by 'sorting borders'.

In this case even a 'shell' design is possible as long as the product clearly indicates where to break the cover to get the PCB and the Ni-Cd battery out without damage.

Question 2: Are there any 'sorting objects' in the design with a positive economic value to the company? For example, an electric motor that can be reused, a housing of engineering polymers etc.

A conceptual bill of materials can be of help when answering this question, especially when the forthcoming product might be a 'rod' or a 'twin' design. In these cases it will of course be advantageous to minimise the number of materials used. 'Dressed' designs or 'hamburgers' often hold PCBs, electric motors, wiring, heavy metal batteries, etc. and each of them should be thought of as 'sorting objects'. This is also the time to start a list of expected materials.

Question 3: What must be managed because of its environmental impacts? Rechargeable batteries, toxic fluids etc.

A list of 'sorting objects' should be produced that is connected with special waste handling, environmental taxes etc. This list should contain all the objects that the company, in the future, will be forced to take responsibility for. Toxic fluids are often present in products in a 'shell' concept. Rechargeable batteries may be provided by suppliers and may therefore often be attached to the working parts in a 'hamburger' concept.

Question 4: What will be the most likely scrapping scenario for this product? Consumer disassembly and then energy recovery? professional disassembly and sorting? re-take?

Try to consider the first 2–3 steps a scrapper has to carry out to disassemble the forthcoming product. The following combinations will give some alternatives and will be very important for decisions during the product design phase.

Disassembly and sorting will be carried out by:
· consumer (initial sorting)
· maintenance company
· scrapper
· original manufacturer (re-take).

What is the possible destiny of the different sorting objects; what will be reused, recycled, incinerated etc.? This classification should later be transformed into indices and functional requirements suitable for designers to handle when evaluating different demands on loadcases, separating surfaces and sorting borders derived from manufacturing, the market etc.

Question 5: Would it be possible to change some of the parts and in this way give the product a longer or shorter life and this way achieve a better eco-performance?

Estimate the product's length of life as a whole and all its major sub-assemblies. Try also to estimate if any parts could benefit from a shorter or a longer length of life. Will there be any service relevance, etc?

Step B: Establish a Scrapping Forecast Sheet (SFS)

In this procedure the next step will be to map the forthcoming design through its 'sorting objects' by establishing a 'Scrapping Forecast Sheet' (SFS). Below is a table of the main sorting objects of recycling interest and a list of the elevant 'sorting objects' (M1-6 in Table 2). Estimate the Bi, Be, Bd and Bs indices, c.f. page 36 left column, for each 'sorting object'.

An example of this has been completed in Table 2 for the PC monitor which is illustrated in Figure 2. The Bs column is empty since there are no demands for a perfect separating surface.

This table highlights the example of a PC and the aim of the SFS is mainly to determine crucial facts about new products in the conceptual phase.

Step C: Establish a connection map of 'sorting borders'

The relevant 'sorting objects', M1-Mx, should be represented in a flowchart where the modules are, for example, circles and the connections are straight lines. If there is a loadcase between the modules use a straight line and use a dotted line if there is just contact.

A typical 'hamburger', ie. the PC monitor discussed earlier has one initial loadcase which opens the design and then the rest will be free and ready for sorting. This kind of design will typically have one straight line representing the opening of the cover and several dotted lines representing the separating surfaces that are locked in by the cover. A map of this PC monitor connection is presented in Figure 5.

Step D: Put relevant indices on 'resting loadcases'

The fourth step would be to define indices for connections between different 'sorting objects' and consider how and by whom the loadcases should be released and in what way the sorting is likely to take place.

The indices will be different depending on who disassembles the product and what is to be done with the remains of the product.

Sometimes the end user (consumer) would be the best stakeholder to perform a certain separation eg. removal of Ni-Cd batteries, which means that the loadcase information index in this case should be low. The rest of the product may have higher indices suitable for professional waste handling or retake.

Conclusion

Products with a well designed set of 'sorting borders', 'separating surfaces' and 'resting loadcases' will have improved recycling capability. If scrapping is made cheaper and more effective, and sorting made possible, this will affect the 'bottom line' in cases where products have to be managed from 'cradle to cradle'. This can be achieved in the product development process after the concept design phase and before more specific designing and drafting tasks. A structural viewpoint and collaborations between designers and management are essential for rethinking in product development for sustainable products. These decisions must be transformed into instructions, functional requirements and constraints for designers. The proposed procedure should inform management and designers about forecasting the appropriate recycling history of a new product, as it provides the opportunity to choose a basic recycling layout before the embodiment design has started. These concepts with 'sorting borders', 'separating surfaces' etc. should be incorporated into CAD systems and drawing and modelling work as an integrated part of design work. An initial attempt at such integration is made by Luttropp & Andersson (Andersson). Matching indices and scrapping forecasts can serve as means for this integration. •

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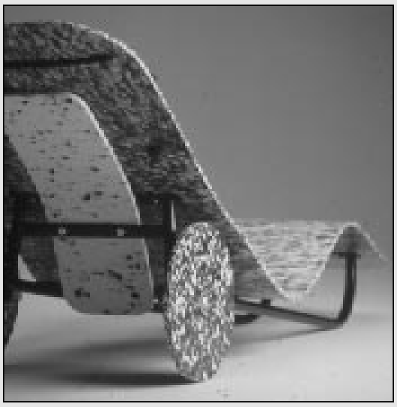
Recycled furniture

MetaMorf



American industrial designer Colin Reedy, partner in the design company MetaMorf, aims to demonstrate through their own practices how individual designers and small design companies can assist in minimising their impact in the environment. In Reedy's case this is through developing innovative furniture using recycled materials, predominantly plastic and steel. 'We are in a position to take many recycled materials and translate them into products for the marketplace.' The first generation of chairs and tables was made with primitive plastic 'lumber', but now a more thin and sturdy plastic sheet has been developed which allows more modernistic designs.

The plastic panels are made using a similar method to particle board – specific types of plastic debris are sorted by colour, turned into chips and placed into a particle board press which has been modified to handle plastic. Although still at an early stage of development, Reedy's ideal is to use regional waste to make regional products.

Baygen self-powered lantern

BayGen Power Group

BayGen Power Group, the company which is synonymous with Trevor Baylis and his objective of producing electrical appliances powered by alternative sources, has listed up to 150 domestic and industrial appliances which could use 'wind-up' power. The company has launched the second generation Freeplay wind-up radio and Freeplay self-powered lantern. This torch has a combination of rechargeable batteries and a wind-up generator and, while the batteries provide up to two hours shine time on their own, one single twenty second wind of the generator gives around four minutes of immediate light. Alternatively, the power generated can be used to re-charge the battery unit.

SS-BG30 speakers

Sony Wega Audio Group, Germany

Sony Wega Audio Group has recently re-launched the SS-BG30 speakers made from recycled material called 'Tectan' and made with low environmental impact. Tectan is produced from used drink cartons, and consists of 5% aluminium foil, 75% paper and 20% polyethylene. The returned drink cartons are cleaned, shredded and heated until they form a pulp which is then compressed into Tectan boards. The result is a consistent, colourful and bright surface which takes on the colour of the original cartons. The density and absorption capacity of this material offer a good acoustic response. The German edition of the magazine 'Audio' said: 'Respect for the environment and achieving maximum sound quality are not necessarily incompatible goals'.



Opportunities and constraints for product-oriented diagnosis tools

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ir. Jaap (J.G.M.) Kortman is coordinator Sustainable Building project and member of the management team of IVAM Environmental Research. He has managed projects in the field of sustainable building, the development and implementation of the LCA methodology, and green product development. One of his main activities is the development of instruments (Eco-Quantum) that can be used to calculate the environmental effects of a building based on LCA methodology.

At present, opportunities for the environmental improvement of products are identified in two phases: analysis of the environmental problems caused by the product and the generation of improvement options. A major bottleneck is that the environmental information generated in the first phase does not provide specific guidance for the identification of improvement opportunities, since this would call for technical information on product features. In other words, environmental analysis does not reveal which product functions and/or product components account for the largest share of the environmental burden. This reveals the need for a structured assessment of the relationship between product functions, components and materials on the one hand and their contribution to the overall environmental burden caused by the product on the other hand. A product-oriented diagnosis tool is proposed here, which is based on the allocation of parts of the environmental burden of the product to so-called product-related cause factors. The amount of energy used by a lighting system is for instance caused by the chosen source of energy (electricity), and the chosen electronic system and its specific efficiency. These cause factors in turn are divided in functional, physical and production factors. The application of this product-oriented diagnosis tool is illustrated with an example. This tentatively shows that the application of the tool eases the transition from environmental analysis to product re-design by targeting re-design efforts to key improvement opportunities and by providing an estimate of the potential reduction of the environmental burden of the product through re-design. The application of this tool for new product development has not been researched, but it is hoped that the implementation of this tool will provide greener solutions.

Introduction

Industrial Ecology (IE) aims to balance industrial development with the sustainable use of natural resources. It takes a systems view of design and manufacturing processes in order to eliminate or at least minimise the environmental impact of manufacturing processes and the use and disposal of products. At the enterprise level IE aims to integrate environmental considerations into all aspects of the business operation, including the environmental improvement of products and production processes. Several product and process-oriented tools have been developed to facilitate the introduction of IE in enterprises. It has been proposed (van Berkel, Willems and Lafleur) that an IE toolbox includes four functional groups: inventory, improvement, prioritisation and management tools. The application of this toolbox by designers, has been illustrated in two case studies (van Berkel, Lafleur and Willems). The ultimate goal of such a toolbox is to provide guidance for enterprises to select those tools which, given the type of operations and products, will most likely facilitate the efficient and effective achievement of the product and process-related environmental objectives. The present stage of development of product-oriented IE tools, however, still hampers the smooth application of the IE toolbox to products (van Berkel and Lafleur). An important deficiency is for instance the incompleteness of the toolbox. This paper focuses on one major issue; the 'missing link' between the results of a product-oriented environmental analysis and the improvement of a specific product. For example, the amount of energy used during the 'use' phase of a fax modem is for example caused by its electronic system and its efficiency. A key question is therefore: why is a specific electronic system chosen? Other authors have addressed this issue in other research (Wenzel et al). This paper therefore seeks to contribute to the development of a (new) product-oriented diagnosis tool. In section 2 the present development status of product-oriented tools is reviewed in order to define the framework for the tool. In section 3 the tool is explained and its application is illustrated with an example of a lighting fixture (section 4). This in turn provides a preliminary insight into the opportunities and constraints for the application of product-oriented diagnosis tools in 'Design for the Environment' (DfE) projects (section 5).

Review of present tools and practices

At present there are two stages in the environmental improvement of products. The first phase consists of an analysis of the environmental problems caused by the product over its entire life cycle (from raw material extraction to final disposal at the end of its useful application). In the second phase options to improve the product from an environmental point of view are generated.

The analysis of environmental problems generally consists of an inventory of the environmental impacts (eg. energy use, amount of resources, emissions to air, water and soil), the calculation of the overall environmental impact of the product over its entire life cycle and an evaluation of the relative importance of the various environmental effects. Various tools are available to perform this analysis. Examples of product-oriented inventory tools are the MET-matrix, the abridged Life Cycle Inventory or the Life Cycle Inventory (van Berkel, Lafleur and Willems). These inventory tools enable a systematic and comparatively standardised inventory and allocation of the environmental problems associated with the production, use and disposal of a product. However achieving a complete set of data and data of acceptable quality is still a major problem. Examples of prioritisation tools are the Life Cycle Evaluation or the Product Summary Matrix (van Berkel, Lafleur and Willems).

At present the improvement tools used in the second phase may be categorised as either 'design guidance' or 'design requirements' (van Berkel). *Guidance-type* tools provide the design team with general or more specific strategies to improve the product from an environmental point of view. *Requirement-type* tools contain specifications on eg. the use of certain hazardous substances. The application of these tools depends on the stage of the product design process. Figure 1 shows a schematic presentation of an idealised design process with the suggested improvement tools to be used at each respective stage. In the figure it is shown that during the design process the total number of design alternatives decreases slowly. However, the level of detail of the design increases as one moves closer to the final product. At each step important decisions are taken, then a new phase of the design process starts. At first many different

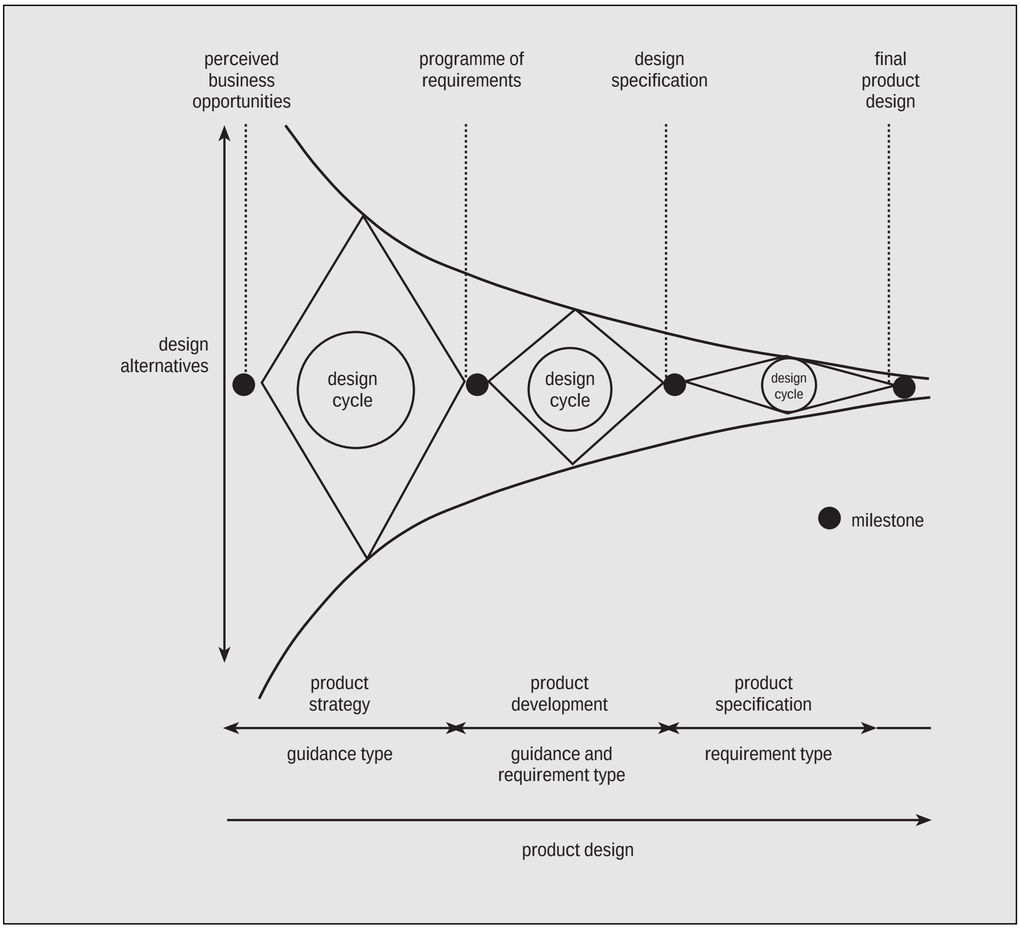

Figure 1: An idealised product design process [modified from (8)]

design alternatives will be generated. On the basis of environmental, social, legal and other considerations the alternatives can be prioritised and the most promising design alternatives will be chosen, which means the number of design alternatives decreases.

Examples of product-oriented improvement tools are (Behrend et al, and van Berkel, Willems and Lafleur):

- the ecological principles checklist (a *guidance-type*): in this list a division is made between thirteen ecological design strategies (design for disassembly, saving resources, etc.).
- the criteria checklist (a mixture of a *guidance-type* and *requirement-type*): later in the product design process more specific guidance is needed to operationalise strategies for a particular product or component. Each strategy is expanded into a list of generally applicable improvement directions or criteria.
- negative or positive material checklists *(requirement-type)*: in the product specification phase only detailed specifications can be used.
- product improvement approaches (a *guidance-type*): seven improvement approaches are identified which are used as a starting point for brainstorming sessions.

The above mentioned improvement tools have proven to be useful in the product design process. They can, for example, be used as checklists for the generation of product ideas in brainstorming sessions after the completion of the analysis of the environmental impacts. A major bottleneck is, however, that the environmental information generated through the application of the environmental analysis tools (inventory and prioritisation) does not directly result in information that can be used for the identification of product improvement opportunities, since this calls for technical information on product features, especially for complex products. For example, a major problem identified with an environmental analysis of a modem is the amount of energy necessary during 'use'. An environmental analysis does not reveal which product function and/or product component accounts for the largest share of this energy consumption. Therefore one needs additional information on the various components and functions of the product and why these components have been chosen. Since the link between the results of the environmental analysis and the product function(s) is not usually completed, research into the environmental problems of a product is often not followed by an inventory of improvement opportunities.

At present, this 'missing link' is partially addressed in brainstorming sessions through the involvement of both environmental and technical experts. If tools were available to compensate for this 'missing link', it is expected that this would greatly boost the generation of both obvious product improvement opportunities and radical product innovation opportunities.

The 'missing link' reveals the need for a diagnostic tool: a structured assessment of the relationship between product functions, components and materials and their contribution to the overall environmental burden caused by a (complex) product. From this perspective, we may define product functions and components causing an environmental impact as 'causes'. Once the causes are known, the generation of improvement options can focus on these causes. This improved product-oriented IE tool will be referred to as a product-oriented diagnosis tool.

Lessons learnt from cleaner production

Some lessons can be drawn from the cleaner production activities. For example on the basis of the results of a process anlaysis, (van Berkel, van Berkel and Molier) the generation of improvement options could be improved if a diagnostic step or cause evaluation was included. Therefore, lessons can be learnt from a cleaner production model where existing production processes are evaluated by first executing a 'source identification', followed by a 'cause evaluation' and 'option generation'. For the source identification an inventory should be made of the material flows entering and leaving the company. This results in a process flow diagram, allowing for the identification of sources of waste and emissions. The 'source identification' for production processes can be compared to the product-oriented inventory tools aimed at the identification of the environmental interventions caused by the product. The 'cause evaluation' is an investigation into the factors that influence the volume and composition of the waste and emission generation. Five categories are distinguished which can be used as a checklist to identify all possible factors influencing the volume and/or composition of the process waste streams and emissions. The option generation means that a vision is created on how each cause of emissions or waste generation can be eliminated or controlled. The 'option generation' for production processes is comparable to the product-oriented improvement tools.

It can be concluded that for product improvement the inclusion of a diagnostic step or evaluation of causes might optimise this improvement step in the same way as has happened for the identification of cleaner production options.

Development of a product-oriented diagnosis tool

The 'cause evaluation' for production processes is based on an analysis of the possible factors influencing the volume and/or composition of the material, energy, waste and emissions output on the basis of the five major cause categories. These factors have to be modified to achieve environmental improvement of the process. The 'cause evaluation' for complex products is based on an analysis of factors which influence the environmental performance of a product during all stages of its life cycle. It is proposed to differentiate between two categories of product-related cause factors, respectively:

· **functional category**: impact of product function(s) on the environmental profile of the product (for example: a front door in a house is there to keep warmth inside the house and unwanted people outside the house).
· **physical category**: impact of materials choice and design of the product on the environmental profile of the product (for example: the front door is made out of wood or steel and the thickness is 40 mm).

Each category consists of various factors. It is thought that these two categories cover the most important elements of a product. The function(s) of a product can be defined as the specific purposes for which the product is being designed, manufactured and marketed. The physical factors can be described as the geometrical and physio-chemical form of a product: in other words the components and the materials of which the product consists, the design of the product and the necessary production processes. It is assumed that performing a life cycle assessment (LCA) where results are linked directly to the functional and physical factors will generate a detailed insight into the relationship between these factors and the environmental impact that these factors cause.

The execution of a life cycle inventory, however, also leads to information on the environmental problems caused by the production, delivery and packaging of the product. These processes are necessary to enable the functioning of the product. Therefore it is suggested that a third category is added, ie.:

· **production category**: the environmental impact related to the production process, packaging, logistics, etc. of the product (for example: to make a door the right size, part of the wood will be lost and the door may be packaged in plastic film, etc.).

A key issue is how to determine the physical and especially the functional factors. An important element of the process of designing a product is the determination of a design specification statement: the goal of the development process, which incorporates the functionality of the product. It consists of the definition of all relevant objectives of the product (scaling and non-scaling objectives, requirements, wishes, standards, performance specification (Rozenburg and Eekels)). These objectives arise from stakeholders involved in the design process (consumers, producers, governmental organisations, etc.) and are thus a compilation of functional demands as well as safety, legal and economic demands. The 'environment' could also be part of these additional requirements, but for most products this is not yet the case (Keoleian). The specifications do not necessarily define which material has to be used, but it can at least be used to determine the functional factor and to a lesser extent the physical factor. The physical factor can also be determined by just looking at the product, talking to the technicians involved in an early stage of the research or by reading the design specification. The design specification can also be a useful instrument in other stages of a product-oriented diagnosis tool, for instance to enable the direct implementation of improvement options.

As indicated above, the analysis of environmental problems overcomes the 'missing link' between the environmental analysis of the product and the generation of improvement options. A 'cause evaluation' can now automatically follow the environmental analysis and makes the identification and implementation of improvement options the next logical step. Figure 2 illustrates the ideas presented above.

The first step of the product-oriented diagnosis tool consists of the determination of the functional and physical factors (A) of the product from the existing design specification. The next step is the environmental LCA (B). The combination of step A and B results in an overview of the environmental burden caused by the product for each relevant part of its life cycle, divided between the functional and physical factors. These results provide a starting point for the diagnosis (C). The division of the environmental burden over the functional factors of the product leads to better insight into the share each

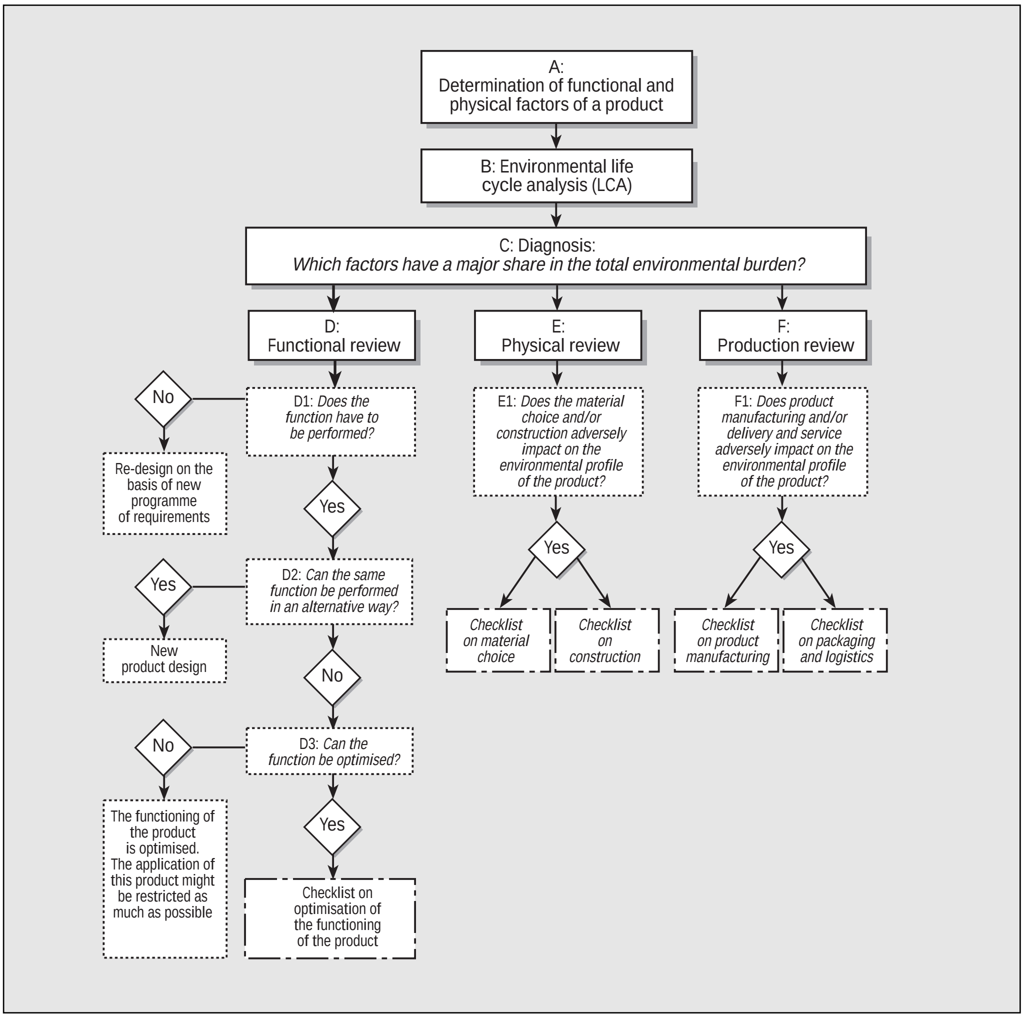

Figure 2: Schematic presentation of a product-oriented diagnosis tool

functional factor has in the total environmental burden. The division of the environmental burden over the physical factors gives insight into the share each physical factor has of the total environmental burden. The allocation to the various functional and physical factors will also generate insight into the life cycle stages in which improvements are most likely to significantly reduce the overall environmental burden of the product being assessed.

The next step consists of a more detailed review of the environmental burden caused by functional, physical and production factors in the functional (D), physical (E) and production review (F). The first step in the functional review (D) which consists of an assessment of whether the product function has to be performed at all. If the function appears not to be necessary, it might be decided to exclude the function and to re-design the product on the basis of a new programme of requirements. This will also result in a new design specification. If the function has to be performed one might ask whether or not the function might be performed in alternative ways. If there appear to be opportunities to perform the function in a (fundamentally) different way, a new product design can be produced in the product design process. For the elaboration of this concept, standard procedures for product design can be utilised. Ultimately this process results in a new design specification, with environmental requirements being an integral part. When it appears that the product functions cannot be completed in an alternative way, the question regarding the extent to which the functioning of the product can be optimised has to be posed. From this perspective it is important to look at all the stages of the life cycle which have a share in the total environmental burden caused by the functions of the product. This means that improvement options might be generated that lead to, for example, reduction of the amount of materials used in a product.

After the re-assessment of the functions of the product system, the environmental problems related to the physical factors are reviewed. The extent to which the material choice and design, negatively affect the environmental profile of the product

Figure 3: An example of a checklist on material choice (Behrend et al)

Criteria for saving resources	Relevant for the product	Characteristics	Score A	B	C	Data	Explanation
Material input		minimum material input					Product or part size is a measure of the extent to which material input reduction has been achieved. A potential for material saving can be found in the design and selection of materials for the casing of a model.
		size of product in accordance with function					
		over-sized					
Refurbishment		fully refurbished product					An efficient way to save materials is to refurbish a product for reuse. Most products are, until now, not designed for that purpose.
		use of refurbished parts					
		completely new product					
Use of recycled materials		high percentage recycled material					Recycling only makes sense from an environmental point of view if a market exists and companies are willing to use recycled materials in their products. Recycled materials can usually be substituted for new ones without any problems.
		medium percentage recycled materials					
		low percentage recycled materials					

system is reviewed. Based on this analysis and with the help of a checklist on material choice (including for instance minimisation of material content, use of renewable materials, design for recycling, etc) and a checklist on the design of the product (including for instance design for product reuse, design for recycling, design for durability design for disassembly, etc.), improvement options regarding the physical factors of the product can be generated. In Figure 3 an example of a materials choice checklist is given.

In the last step the share of the other parts of the product system, that is production and delivery and service, is determined in relation to the total environmental burden of the product system. Production is that part of the life cycle in which the product is manufactured. Therefore checklists on cleaner production and also packaging and delivery can be applied. The checklist on cleaner production contains elements such as preventing the generation of waste during the manufacturing process and minimising the amount of energy necessary for the manufacturing of the product.

The environmental improvement options generated through relevant checklists can be used for modification of the entire product chain, by re-writing the design specification, and through changes in production and delivery and service processes. The implementation of these improvement options should result in reductions in the environmental burden caused by the product over its entire life cycle.

In this section a general procedure has been presented which enables the integration of existing tools and instruments

Case study on a lighting fixture

Description

The environmental problems related to a lighting fixture were analysed to identify opportunities to improve the product from an environmental point of view. The results of this project (Behrend et al) illustrate opportunities and constraints of the application of the product-oriented diagnosis tool outlined above.

First the functional & physical factors (A) were determined. The functional factor consisted of one main function, namely to 'give light'. To perform this function two components are necessary: a light bulb and an electronic system. These components, together with an electricity plant, provide electricity which results in light. Other components such as the 'hanging system' or the protecitve cover are not part of the main function. Without a protective cover or a 'hanging system' the function of 'giving light' still remains. To determine the physical factors, the product is first subdivided in its main components. The product consisted of three components: the 'hanging system', the protective cover and the lighting system. Next all the materials were identified per component. The next step consisted of the execution of the environmental LCA (B), which analysed the environmental burden caused by the product during production, use and disposal. For this product the analysis focused on four aspects which were considered to be most relevant to the measurement of the product's total environmental burden, in particular;

- exhaustion of resources which are used for the materials of the product
- the amount of energy necessary for the production of the product, during 'use', etc.
- the amount of waste which is generated during production, use, after disposal, etc.

The functional unit which was used is the lighting efficiency (Lumen/Watt) from a fixture for an average amount of 4015 lighting hours per year during an average fixture-lifetime of 10 years. The fixture has a total weight of 865 grammes.

In Table 1 the results of step A and B are presented. The environmental burden over the entire life cycle is allocated to the functional factor, the physical factors and the production factors. It appears that in each case there is a so-called remaining category. When allocating the total environmental burden to the functional factors it turned out that the entire environmental burden could not be allocated to a defined function. An example is the environmental burden related to the production of the 'hanging system' for which steel is used.

	Production			Use	Disposal
	exhaustion	energy	waste (toxic & non-toxic)	energy	waste
	(GU)	(MJ)	(g)	(MJ)	(g)
Functional category					
Give light					
light	Ð	Ð	Ð	750	Ð
light bulb	?	?	?	2700	Ð
electronics	2000	0+?	200	1900	110
Remaining category containing the environmental burden that is not directly related to the function to be performed	8100	55	1530	Ð	790
Total	10100	55	1730	5350	900
Physical category					
Hanging system					
PA	Ð	0	0	Ð	10
EPDM	0	0	0	Ð	10
steel	7000	30	1310	Ð	210
brass	Ð	Ð	Ð	Ð	10
sendzimir steel	1000	0	200	Ð	30
lacquer/epoxy layer	0	0	0	Ð	20
Protective cover					
PC	100	20	20	Ð	340
paper/cardboard	0	0	Ð	Ð	110
Lighting system					
circuit print of starter	?	?	?	Ð	10
copper	2000	0	200	Ð	80
PBT	?	?	?	Ð	20
PVC	Ð	Ð	0	Ð	0
light bulb (3)	?	?	?	?	?
Remaining category that is not related to a material	0	5	0	5350	50
Total	10100	55	1730	5350	900
Production category					
Product manufacturing delivery and service	Ð	5	Ð	Ð	Ð
cardboard	Ð	0	0	Ð	40
PE	0	0	0	Ð	10
Remaining category containing all effects which are not directly related to manufacturing, delivery and service	10100	50	1730	5350	850
Total	10100	55	1730	5350	900

Table 1: Environmental analysis of a lighting fixture in relation to functional, physical and production factor (7)
NB: ? = no data available, and – = not relevant/not occurring

It might be concluded that from an environmental point of view the part of the product that causes this environmental burden is ÔoverdoneÕ, since it does not contribute to the functioning of the product.

The ‘hanging system’ is not part of the defined functional factor of the lighting system, namely to ‘give light’. To function the lighting system *might* also stand on the floor and still give light. This means that part of the environmental burden, that is the production, use and disposal of steel, is not caused by the function itself. It might be concluded that from an environmental point of view the part of the product that causes this environmental burden is over emphasised as it does not contribute to the function of the product. There is also a remaining category when the environmental burden is allocated to the physical or the production factors. The results of Table 1 are used for the diagnosis (C).

Evaluation

It can be concluded that a major part of the environmental burden related to the functional category is caused during ‘use’. Table 1 shows that only approximately 15% of the required energy is used to give direct, functional light, which is the main function of the product. Most energy is lost as a result of the process which has been chosen to perform this function (an electronic system that transforms electricity) and the kind of light source (a light bulb) which has been chosen. The consumer has a major influence on the total energy that is used over the life time. Copper has the largest share in the environmental burden caused by the materials used for the electronic system. However, data on the production of the printed circuit board and the light bulb are not included in the analysis and the use of fuels for the production of electricity is not accounted for. Therefore energy use does not score on exhaustion of resources. If fuels for electricity production were included, the exhaustion due to the use of these fuels during the ‘use’ phase of the product, would have been approximately a factor 1000–1500 higher than the total exhaustion related to materials use (10,100).

The environmental burden caused by the production of materials is part of the physical category. The ‘hanging system’ has the largest share, with steel and copper used in the lighting system with major shares. Due to application of so many different materials and the combination of these materials in its final components, it is difficult to reuse any parts of the product after its useful life has ended. This explains the large share of the physical factor in the disposal phase.

The total environmental burden of the production of the lighting system is relatively small, as in this case the producer is an assembly company. It is noticeable, however, that the transport distance for such a relatively small product is enormous, as the components and parts are imported from all over the world. The production of these components and parts takes place elsewhere and therefore the environmental burden related to that production is included in the physical factors. It is assumed that the environmental problems due to the assembly are negligible in relation to the total environmental burden. In addition, exhaustion of resources due to the use of fuels from transportation has not been taken into account, as data on transport is not complete. The production of the materials used as packaging materials is included in the production category. These materials are dumped after use.

After this analysis it was decided to review the function of the product, since the functional factor has a large share of the environmental burden caused during 'use'. The first question asked was whether the defined function is really necessary (D1 in Figure 2). Clearly, the function to 'give light' has to remain, which means the second question that has to be asked is whether the functions could be performed in a different way (D2 in Figure 2). It might be possible to think of a completely different product, like for instance a hole in the wall and the use of reflection mirrors to spread natural light. However, it was very unlikely that the producer would approve of this idea. Therefore the only possibility is to optimise the functioning of the product (D3 in Figure 2). It might be possible to highlight technical ideas to improve the efficiency of the device (a different light bulb for instance, time switch or another primary energy source (gas, solar)), as well as ideas to influence the behaviour of the user, since this might enable the reduction of the energy demand.

In a next phase the physical factor was reviewed (E). It was useful to identify options that would reduce the environmental impact of chosen materials. This would also produce a major influence on the possibilities to reuse the product as a whole, parts of the products, or materials from the product (for instance: ease of disassembly of fixture parts, material identification, etc.)

It seemed sensible not to put any effort into the identification of opportunities to reduce the environmental burden resulting from manufacturing and delivery and service. As the only option that might be considered was to find suppliers that were geographically closer, eg. reducing the transport distance.

Conclusion

This paper reviewed the present development stage of environmental product inventory, prioritisation and improvement tools. It was argued that environmental product improvement efforts might benefit from the inclusion of a diagnostic step in product-oriented tools. An outline for such a tool has been described and applied to a lighting fixture. The approach is based on the allocation of parts of the environmental burden of the product to so-called product-related cause factors. A division in functional factors and physical factors is made. Next, these cause factors were reviewed in order to focus the generation of product improvement options on those functional and physical elements of the product, which contribute most to the overall environmental profile of the product.

The inclusion of a diagnostic step in the product-oriented tools is thought to bridge the gap between the results of the environmental analysis of a product and its re-design process, thereby simplifying 'cause evaluation' and the identification and implementation of improvement opportunities. It does so by pointing to those functional and physical features of the product which should be modified (providing directions for such modifications) in order to reduce the overall environmental performance of the product. The application of such a product-oriented diagnosis tool calls for additional information on product functionality and design; in addition to material and energy input and output data regularly used for an environmental product analysis. Such information is often available or can be easily collected from design specifications, technical drawings, etc. The inclusion of the diagnostic step is thought to ease the transition from environmental product analysis to product re-design and thereby increase the efficiency and success of DfE activities.

The case study revealed that if the results of environmental analysis are allocated to the different cause factors, it highlights the extent to which the environmental burden caused by the product can be reduced. On the other hand it reveals which part of the total environmental burden cannot be reduced. If, for instance, the producer of the lighting system cannot change the process/ technique (electronic system with light bulb) for producing light, a major part of the total environmental burden (approximately 85%) caused during 'use' cannot be reduced.

The case study tentatively illustrated that the application of a product-oriented diagnosis tool may help to target the product re-design efforts to those environmental improvement options which are likely to result in a major reduction of the overall environmental impact of the product. The case study also showed that application of such tools is likely to identify promising short-term improvement opportunities and long-term innovative options at the same time.

Some elements of the analysis are problematic. For example, it is often difficult to define the main function of a product. A second problem is the choice of environmental impact categories (eg. greenhouse effect, exhaustion of resources, energy use, etc.). The case study also highlighted that important information was missing, eg. exhaustion of resources (oil, coal, gas) resulting from the use of fuels for electricity production and transport. Therefore it is important to develop a method in which the 'right' environmental impact categories can be chosen. In addition, there needs to be more research into the 'added value' that can be provided by product-oriented diagnosis tools in comparison to existing analysis and improvement tools. It is also recommended that this diagnostic tool is tested on new product development and not only on the improvement of existing products. •

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Professor Ezio Manzini, Director, CIRIS, Politecnico di Milano, Italy

Martin Charter

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Ezio Manzini is an engineer and architect. He is a Professor of Environmental Design, Director of CIRIS, an Interdepartmental Centre of Research on innovation for sustainability and Coordinator of the 'Dottorato in Disegno Industriale' (PhD) in Industrial Design) at the Polytechnic of Milan. He is a former Vice-President of Domus Academy, an international centre of training and research in the field of design. His work focuses on innovative production and consumption systems and, in particular, on the realtionship between product strategies and environmental policies in relation to sustainable development. As Director of CIRIS, he is responsible for a major project involved in developing an Italian data bank for Life Cycle Assessment (LCA), financed by the National Environmental Agancy (ANPA).

What is your vision of a more sustainable world and the products and services that might exist in that world?

The most positive image of a sustainable society is that of a modern and sophisticated sailing boat that utilises the best of technology and uses the crew's skills to sail according to winds and currents, adjusting its course sensitively, though without losing sight of its goals. The boat is resistant and light to enable it to sail unscathed through the worst of storms and reach its port of destination. However, it is not possible to determine exactly how and how long it will take for the boat to arrive. Furthermore, since it is driven by the wind, an inexhaustible but non-controllable energy, it can sail only thanks to the experience, attention and care of its sailors.

The problem now is how to convince people that it may be possible to switch from the big oil-tanker, in which we are living now, to this agile sailing-boat. Dropping this metaphor, it is about how we may turn from the present pattern of development to a different highly agile, dematerialised and service oriented system.

Within dematerialisation arguments of the movement from product to services there is clearly a need to manage the transition. What are your thoughts?

'Dematerialisation' is a learning process in which, on a planetary and on a regional level, we will have to learn to live, and if possible to live well, while relying on only 10% of the environmental resources that we (in industrialised societies) are exploiting today. The transition towards sustainability, in my view, is this – probably long and complex – learning process.

How could it happen?

We must consider the relationship between the direction in which we want to go, eg. towards a sustainable system of production and consumption – the 'sailing boat' – to the major dynamics of transformation in progress within business. The keywords are flexibility and globalisation.

Major restructuring of businesses means environmental reorientation (for example:

zero defects becomes zero waste, where waste becomes a 'production defect'; total quality becomes total productivity, as it does not produce emissions, refuse, scrap; just-in-time production and mass-customisation become the organisational formulae for flexibility that adapts to the spatial and temporal variability of the environment, and customisation of products becomes an approach to localisation).

Are you saying that globalisation and flexibilisation will 'naturally' lead to an highly dematerialised and service oriented system of product and consumption?

No. Statistics tell us that the combined effects of globalisation of markets and greater flexibility have caused a further increase in the environmental impact through increased production and consumption. And this is in spite of the fact that other statistics show that the use of materials and energy per product unit has dropped greatly. We have managed to 'do better' but, at the same time, we have been driven to 'do more'. The result is that to respond to the social demand for well-being, we need more materials and energy and we produce more waste and emissions, compared to the past.

The foundation concepts of the new 'paradigm of flexibility', are not structurally different from the needs for sustainability: to be lean, flexible, agile in modifications, quick to supply responses, skillful in the personalisation of products, and at the same time to increase productivity and eliminate defects... these are all qualities that could well find a place in the profile of a sustainable company. Or, more precisely, the profile of a company operating in a sustainable system of production and consumption (a system which, in turn, must necessarily be agile, capable of making the best use of resources and adapting to the multiplicity of geographical variations).

In conclusion, what the perspective of sustainability asks for is not to change this paradigm of flexibility, but to extend it to the whole production and consumption system. An extension that implies a shift from the present product-oriented economy to a new service-oriented one.

All these considerations are mainly related to a possible relationship between production flexibility and sustainability. Could you add something more precisely related to the process of globalisation?

The process of globalisation provides the capability of choosing where to locate different activities worldwide. However, choices will need to be made by considering the 'intensity of renewable resources and regenerated materials' and the 'intensity of transport' required for each unit of service wherever it is produced! And increasing the former and decreasing the latter will be a new fundamental criterion for the localisation of production activities.

This means that within the scenario of sustainability it is possible to imagine the development of new businesses that are simultaneously both global and local: businesses that globalise the flow of information by localising the flow of material with lower eco-impact. Combining the global dimension of the production and distribution of certain semi-finished products or components with the local, 'service' dimension related to the management of regionalised production activities and centres of production.

It is interesting to observe that, in this scenario, the global-local service-oriented companies that will appear, will have to localise a significant part of their activities near cities (if not inside them), and will also represent a potential contribution to the environmental and social improvement of the urban fabric.

It appears that these perspectives depend on the fact that the environment will – or will not – be perceived as a 'scarce factor'. But when and how do you think that it will happen?

Unfortunately nobody really can answer this question. This is the contradictory character of the 'transitionary scenario': we know – for sure – that a radical change will happen. But we don't now how and when.

In other words, the transition toward sustainability appears to be contradictory when viewed over the short term, the medium and the long term. In fact, over the long term, it is clear that the transition toward sustainability will imply a radical environmental reorientation of the entire society (this transformation will also combine with other major transformations in progress, from the spread of IT to the socio-cultural impact of telecommunications).

Over the medium term, certain characteristics of the 'transitionary scenario' can be seen as highly probable (costs, regulations and market demand will become more sensitive to environmental variables, evolving higher costs, stricter regulations, greater responsibility, and a focus, in the market, on environmental quality). But, over the short term, environmental issues represents an area of uncertainty for business (nobody knows when and how changes will happen).

It is why the re-orientation of business (and of the society in general) toward sustainability is a complex strategic activity – and not only a technical planning issue.

What is the role of strategic design in the sustainability debate?

We have seen that, in the short term, the limits and opportunities presented by the environmental question for businesses still appear to be contradictory, or difficult to interpret. The transition toward a clean and lean, customised and localised production system, therefore, this has to be promoted at the strategic level of companies, and in the area of research and technological innovation.

In this framework, the role of strategic design is to help companies to look at the environmental question as an 'opportunity for innovation': the opportunity to get away from 'business-as-usual' and to propose win-win solutions, based on new business ideas. These ideas will require strategic positioning: this means that they have to be the result of options that can be put into practice over the short term, but which are oriented towards the most promising solution over the medium and long term.

I like to add that many interesting examples already exist of companies that have successfully adopted strategic positioning: new business ideas based on concepts such as on-site production (for example: the production at 'point of sale' of bulky products), results-oriented production (for example: the sale of thermal well-being or photocopies instead of heating oil or photocopiers) or utility-oriented production (for example: innovative services for urban mobility, clothes washing or food preparation). In all these cases the role of strategic design is to propose – and to develop – new ideas for 'product systems' (ie. the integrated *packages* of products, services and communication) that produce intrinsically more sustainable solutions socially and economically, ie. *packages* that 'invent' a new market possibility of reorganising the system, introducing new technologies and/or changing the roles of the involved social actors.

How do you move designers' mindset from the 'micro-management' to a more strategic approach?

In my view the designer's mindset is changing. And this change is largely towards a more strategic approach which simply comes from the necessity to face the new context in which business operates: if competition is tough and the market unclear, you have to be able to continuously redefine your offer considering 'product, services and communication' as a whole. In my view, a strategic design approach to promote new business ideas is not so far from the one needed to develop new sustainable business ideas. You have to shift from imagining a product to imagining a solution. The only problem is to be able to imagine new solutions orientated in the right direction, ie. where success is proportional to the reduction of the consumption of environmental resources. This means new business ideas to enable people to live better, consuming less: this slogan, in my view, synthesises the challenge the designer will face in the future. And it is, mainly, a strategic design challenge! •

Sustainable Value

Martin Charter

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Martin Charter has held strategic planning, product development and marketing positions for Save & Prosper, Reed Exhibition Companies, the Creative Marketing Group, Greenleaf Publishing and The Earth Centre. He has over a decade of experience in 'buisness and environment' including publishing, consulting, training and research. He has an MBA from Aston University Business School and a postgraduate diploma in marketing. His publications include 'Greener Marketing' (Greenleaf Publishing, 1992), the forthcoming 'Greener Marketing 2' (Greenleaf Publishing, 1999), 'The Green Management Gurus' (Epsilon, 1996), 'Managing eco-design: a training solution' (The Centre for Sustainable Design, UK, 1997) and 'Environmental Management Websites' (Epsilon, 1996). He is currently the European Editor of 'The Journal of Corporate Environmental Strategy' (Elsevier, UK) and The Journal of Sustainable Product Design (The Centre for Sustainable Design, UK), and was the former editor of 'Greener Management International' (Greenleaf Publishing) and 'The Green Management Letter' (Euromanagement, the Netherlands). His training and research interests include eco- and sustainable product innovation, business creativity and electronic publishing.

Shell's recent experience with Brent Spar has highlighted the importance of societal sensitivity, alongside eco-efficiency, in the sustainable business debate. The 'soft agenda' is emerging but the issues are complex. This article presents some thoughts about this new agenda for sustainable product development and design (1). The issues relate not only to the physical product and service, but also the improvement of Sustainable Value and the reduction of negative sustainability impacts in the overall value creation process. This means considering not only economic and environmental issues, but also ethical and social implications in the delivery of products and services.

Balancing impacts and value

Every product or service has a sustainability impact. The aim of product developers should be to maximise the Sustainable Value embedded in the product, and minimise the negative impacts. Strictly speaking one cannot have a sustainable business or product, in an unsustainable world (2) but the company will have to define and understand its context, and explore strategies to maximise Sustainable Value. Each artifact or service should be designed to satisfy a human need. Traditional marketing focuses on the 'customer', however various stakeholders have a relationship with products or services, eg. suppliers have a social and economic stake in the process through employment and profitability. What individuals buy, in reality, is not only the function but also all the processes used to deliver that product or service. For example, if a consumer buys a solar powered calculator in the US, and the US company sources the product from a company in Sweden who purchases the components from an Indonesian company, whose factory has high environmental standards but employs child labour, but by employing children it allows a family of ten to live. These are some of the hugely complex relationships and issues involved in the process of delivering sustainable products or services or Sustainable Value.

The problem with sustainability is that it has come to represent maintaining the status quo. It sounds like the objective is zero, ie. 'I'll be less bad today than I was yesterday'. The goal ought not to be 'less bad', but 'how good?', or 100% sustainability. The way to 100% sustainability is innovation.

Professor William McDonough, University of Virginia, US.

Opportunity focus

If one is going to influence this process it is essential to be aware of sustainability issues early in the product or service creation process ie. at the idea generation phase. Therefore if one provokes the process at its earliest stage by introducing sustainability or environmental issues then one has an opportunity to explore how the overall sum of the Sustainable Value (in the product and process) might be made greater than the negative impacts. However, it is a question of balance, with many of the considerations being highly judgemental. If one starts to incorporate environmental considerations at the evaluation phase then one has missed a chance to stimulate new ideas. The process is beyond eco-efficiency and 'Factor X' (3) thinking that focuses on primarily on materials and energy efficiency, but ignores ethical and social considerations.

The importance of 'soft' issues has been highlighted by Shell's Brent Spar and Ogoni experiences, and Monsanto's positioning of biotechnology as a sustainable solution. Existing in a 'CNN world' (4) means that companies are more exposed to societal scrutiny and those that ignore these issues, ignore them at their peril!

Shell: six issues and dilemmas

· human rights
· climate change
· globalisation/MNCs
· politically sensitive regions
· industrial legacies
· renewable resources.

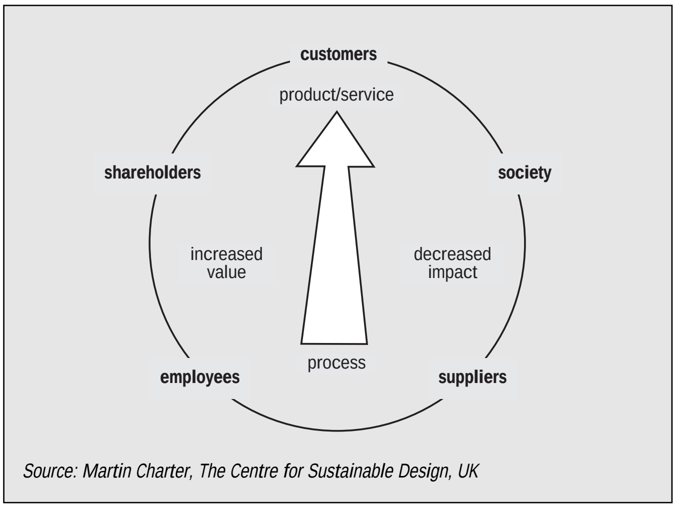

Figure 1: Sustainable Value

Stakeholder orientation

A major issue in the creation of Sustainable Value will be the need to satisfy stakeholders (see Figure 1) in the process of the delivery of the functional unit through the product or service. For example, customers may be satisfied but if employees and suppliers are poorly treated, new ideas and improved productivity will not be generated, and the company may fail, therefore reducing 'quality of life' for stakeholders. Therefore it is essential to aim to improve the 'quality of life' of all stakeholders in the process.

The toolbox

Companies are starting to get more comfortable with eco-efficiency, but are not comfortable with the impact of the 'soft agenda'. The tools available to those in the product development process reflect this, and are highly limited. The majority of tools revolve around Life Cycle Assessment (LCA), which is in effect an environmental evaluation device. Many existing LCA methodologies are starting to receive some criticism from business as being too time-consuming, costly and complex for use in the product development process. The demands at the level of eco-design are increasing focusing on simpler tools that enable decisions to be made, and don't slow the product development process. However, these tools are not designed for use in the idea generation phase and ignore the 'soft' issues.

Systems view

Within the eco-efficiency paradigm, a model has been developed by Stevels, Brezet and Cramer (see Figure 2) that illustrates some of the complex issues of progressing from eco-design to (environmentally) sustainable design.

Level	Eco-design	Example	Time horizon
4	sustainability	?	0Ð30 years
3	product alternatives	LCD TV	0Ð10 years
2	green limits	Ôgreen TVÕ	0Ð5 years
1	improvements	current better TV	0Ð2 years

Source: Philips Consumer Electronics/Philips Centre for Manufacturing Technology

Figure 2: Levels of eco-design

It illustrates that the bigger the shift, the greater change that will be required and the greater need for multi-stakeholder partnerships. For example, 'Factor 4' product innovations will require strong partnerships with suppliers of components, sub-assemblies or materials to reduce the mass of materials and energy used throughout each life cycle stage. 'Factor 10' products or services and those with greater intensity of Sustainable Value will require both customer ('business to business', intermediary and domestic) and supplier partnerships with significantly higher levels of education and involvement amongst each group in the value delivery process.

Screening for sustainability

Part of the move towards the development of more sustainable products and services will be a process of understanding the sustainability impacts, and looking for opportunities to increase the overall Sustainable Value. After the idea generation phase, a 'Sustainability Screen' (see Figure 3) should be used that takes account of e3s considerations in the delivery of the product or service, at each stage of the lifecycle: extraction, manufacturing, transport, use and disposal – this is well beyond LCA! Adding in the 'soft issues' will mean balancing qualitative judgements, alongside quantitative measures used to determine economic and environmental criteria.

Future

Shifting societal concerns are changing the sustainability agenda. Clearly, this means that there will be winners and losers, ie. those that produce cleaner products and those who don't! Part of the broader landscape will be how you manage the transition, particularly in relation to the move from products to services (dematerialisation). Understanding holistic sustainability impacts and increasing Sustainable Value will be a key challenge for product developers. •

Sustainability Screen

Economic (e1)

á cost
á revenue
á corporate image

Environmental (e2)

á energy use
á materials use
á use of renewables

Ethical (e3)

á use of child labour
á links to oppressive regimes
á equal rights

Social (s)

á direct employment generated
á indirect employment generated
á quality of employment

Source: Martin Charter, The Centre for Sustainable Design, UK

Figure 3: Sustainability screen (e3s)

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(4) 'ProÞts and Principles Ð does there have to be a choice?', The Shell Report 1998

Special feature: The Next Step event 98

Martin Charter

Joint Coordinator, The Centre for Sustainable Design, UK

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

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

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

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

In April 1998 O2 celebrated its tenth anniversary by organising a conference at the Danish Design school in Copenhagen, Denmark. The speakers included designers from the O2 Global Network worldwide and was sponsored by O2 Denmark and The Danish Design Foundation. http://o2.jones.dk/

The event produced a range of fascinating papers, some are highlighted below. Conny Bakker (Netherlands Design Institute) presented NDI's work on stimulating designers and industry to develop long-term views towards sustainability based on scenarios focusing on systemic thinking rather than the physical product. Kerstin Maxe (o2 Sweden) discussed the need to recognise the importance of knowledge, care and quality imbedded in old artifacts through craftsmanship. Sustainable products must seek to incorporate these values.

'Speaking to the public about ecological issues may not be the best way to convince them to think ecologically. The best way is to present them with various ecologically sound design options'.

Sally Beardsley (designer) and Niels Peter Flint (design producer) discussed this importance of re-thinking design.

'"Mind over Matter" is a way of thinking, where immaterial design, extensive dematerialisation of products and processes, respect for nature, and awareness of 'immaterial' values become a way of life… (it is)… a way of thinking ethically, aesthetically, holistically and sustainably in a spirit of experimentation, discovery and respect.'

Ursula Tischner (Econcept, Germany) discussed eco-design and the green purchasing 'awareness-action' gap amongst consumers in Germany ie. relatively high awareness but little action at the 'check-out'! She highlighted the existing obstacles to buying eco-efficient products, which included:

- higher prices
- poor distribution
- habitual use of conventional products
- lower effectiveness
- lower aesthetic appeal of eco-products
- perception that individual consumption does not affect the whole!

Finally, she also illustrated how the eco-design culture has shifted in Germany and the implications for designers and industry.

- Past: Bauhaus (design functionalism) and 'end of pipe' solutions
- Seventies: recycling design (provoked by the oil crisis)
- Present: recycling and energy efficiency
- Future: lifecycle design. •

Book

Clean and Competitive?
Motivating Environmental Performance in Industry
By Rupert Howes, Jim Skea and Bob Whelan
London, UK
Earthscan Publications Ltd, 1997
ISBN 1 85383 490 4 paperback
ISBN 1 85383 491 2 hardback
194 pages
£14.95

Clean and Competitive? explores the challenge of motivating industry to address environmental issues, drawing on work undertaken by Sussex University's Science Policy Research Unit (SPRU) and the Centre for the Exploitation of Science and Technology (CEST). The authors explore in some detail industry responses to some prominent environmental issues. They have provided a thoughtful, useful and high quality addition to publications on the subject.

The stated goal of the book is fairly modest – to understand what can be achieved in terms of reduced environmental impact within current patterns of organisation. Within this context it raises some key questions: Have environmental challenges been absorbed and mastered by industry as successfully as was hoped? What is the role of public policy? Can technology succeed in squaring the environment-economic circle and generate 'win-win' situations which promote environmental progress? While considering some of the issues relating to sustainability, it deliberately does not seek to answer the ultimate question – whether industrial activity, with its primary focus on profitability and regulated by fallible political institutions, is compatible with sustainable development.

The book addresses these and other questions by reviewing industry's response to seven environmental issues which have greatly concerned business during the 1990s and by assessing specific examples of different approaches to the management of environmental issues. The focus is on UK industry in the European policy and regulatory context.The book is divided into four parts:

The first part (Chapters 1 and 2) reviews evidence on how companies are managing environmental issues, for example whether they are seen as threats or opportunities, including drivers for improved performance and what companies are doing. It critically examines assumptions and hypotheses about business behaviour.

The second part (Chapters 3, 4 and 5) reviews the seven key problems. Chapter 3 covers global issues (stratospheric ozone depletion,, global warming and climate change), Chapter 4 covers transboundary and regional issues (air quality and transport, acid rain and emissions of volatile organic compounds (VOCs)), and Chapter 5 two key local environmental issues – water quality and contaminated land. Each of the last three chapters provides an overview of the issues, the present position on legislation, and examples of industry responses.

The third part (Chapters 6 to 9) examines four approaches to environmental management using case studies on regulation (specifically integrated pollution control), company-public sector partnership (the

Aire and Calder project), voluntary industry initiatives (the Industry consortium for Electrical and Electronic Waste Recycling) and economic instruments.

The final part of the book draws together the conclusions. Not surprisingly, it concludes that progress is being made but that success is patchy and much more is needed to put society and industry itself on a path of sustainable development.

Minor criticisms are that part and section numbering would make it easier to use the book as a reference, and some significant environmental issues are not covered, or only covered in passing, for example waste regulation, nuisance, resource conservation, nature conservation and biodiversity. It barely touches on the development of environmental management standards. Furthermore, since it is based on UK research it only refers to international experience to a limited extent. In its defence, however it does not set out to cover every issue or provide a global analysis. Also, when it was published ISO 14001 and EMAS had only just been launched.

These limitations aside, the book is well-written and informative. It provides a succinct overview and analysis of the issues covered while also providing a good level of detail and information. It is therefore of potential value to existing practitioners as well as those new to the subject. It is a useful reference not only for students and policy makers but also for environmental managers seeking to influence policy in a positive 'win-win' rather than negative way. In spite of its UK focus, it is broad enough in its scope to deserve a wider audience. •

Tom Clark is a freelance environmental consultant within the Environmental Management Advisory Group (EMAG). He has worked on a wide range of environmental projects and issues in the UK and internationally and has helped over 25 companies and sites gain ISO 14001.

Managing eco-design 1: online conference

Managing eco-design 2: online conference

Textiles, design and environment: online conference

Towards Sustainable Product Design 2: online conference

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24–26 September 1998

Perspectives and Employment on Environmental Engineering in Europe
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Toronto, Canada
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7 October 1998

The Business of the Future – Turning Visions into Reality, 3rd Annual Greenpeace Business Conference
London, UK
✉ Centaur Conferences
50 Poland Street
London W1V 4AX
UK
+ 44 171 970 4797
+ 44 171 970 4713
swarshal@centaur.co.uk

15–16 October 1998

European Waste Forum 2
Madrid, Spain
✉ Claudia Olazabal
European Waste Club
Capitan Haya 23 esc 1, 604
28020 Madrid
Spain
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cedewc@tpesp.es

26–27 October 1998

Towards Sustainable Product Design 3 conference
incorporating: Managing eco-design 3 conference
London, UK
✉ Martin Charter
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The Surrey Institute of Art & Design
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Farnham
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28–30 October 1998

The Demanufacturing of Electronic Equipment: Second Annual Seminar and Exhibit

Florida, USA

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

29 October 1998

Electronics R & D Needs: eco-design and 'end of life' management

London, UK

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4–6 November 1998

ENTREE '98 Innovation Strategies for Economy and Environment

Deventer, The Netherlands

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5–7 November 1998

O2 Sustainable Business Concepts Challenge International Design Workshop

Rotterdam, The Netherlands

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

15–18 November 1998

Partnership & Leadership: 7th International Conference of the Greening of Industry Network 'Building Alliances for a Sustainable Future'

Rome, Italy

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16–18 November 1998

Care Innovation '98 Eco-efficient Concepts for the Electronics Industry towards Sustainability

Vienna, Austria

✉ Mr Bernd Kopacek
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19–20 November 1998

International NWO Conference 'Beyond Sustainability'

Amsterdam, The Netherlands

✉ Gerard Barendse/Helais
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CML
Leiden University
PO Box 9518
NL 2300 RA Leiden
The Netherlands
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20–21 November 1998

Ecologizing Societal Metabolism: Designing Scenarios for Sustainable Materials Management

Amsterdam, The Netherlands

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25–27 November 1998

Third International Conference on Ecobalance

Tsukuba, Japan

✉ Ms Shoko Tsuda
Ecomaterials Forum
The Society of Non-Traditional Technology
Kotoharia Kalkan Building 3F
1-2-8 Toranomon
Minato-ku
Tokyo 105
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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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The Journal of Sustainable
Product Design
The Centre for Sustainable Design
Faculty of Design
The Surrey Institute of Art & Design
Falkner Road
Farnham
Surrey GU9 7DS
UK.
Email submissions should be
sent to: mcharter@surrart.ac.uk.

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

Presentation

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

Manuscripts should be arranged in the following order of presentation.

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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.

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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.

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