Environmentally Conscious Design – A Best Practice Guide

Introduction

There are many drivers for companies to consider environmental impacts when designing products. These include regulations and legislation such as the EuP Directive (Directive 2005/32/EC, 2005), social and market pull from environmentally-conscious consumers and environmental lobbyists, economic factors such as improved efficiencies and reduced waste, and technological opportunities to apply new materials and processes to address issues raised by shortage of raw materials or traditional fuels. As such, it is important for companies to be aware of the aspects that should be included within environmental design and how to apply or implement these. Eco-design takes into account the impact of a product throughout its lifecycle, from extraction of raw materials to production, transportation, use, recycling and final disposal and is based on lifecycle analysis. It is also referred to as Cleaner Design, Design for the Environment (DfE) or Environmentally Conscious Design. Design is recognised as a critical component of any environmentally conscious approach as it is widely recognised that up to 80% of a product's cost is impacted by its design; consequently a product's design influences up to 80% of its environmental impact (Envirowise, 2001).

Objective/Aim

The aim of this guide is to provide a generic overview for environmental design. There are many different publications, web sites, conferences and consultancies involved in this area, and so specific guidance for particular organisations can be sought if required. Some specific sources of tools, data and further information are included at the end of this guide. The purpose of this guide is to provide a holistic view and point to other sources of more detailed information as required.

Background Principles

For environmentally conscious design to be implemented effectively, there needs to be an integrated approach which extends beyond the organisation's design department, and indeed needs to extend beyond the organisation to be truly effective. This is because environmentally conscious design needs to take into account a product's entire lifecycle, illustrated schematically in Figure 1. This illustrates that while the designer has influence over the materials chosen for the product, and potentially the manufacturing processes employed, and can prescribe how the product should be used, they have little direct influence on the transport stages, raw material and end-of-life aspects. To ensure that each stage is properly considered, companies should employ an Environmental Management System (EMS) to include functions such as procurement and sales, rather than solely focussing on design. EMS is a management approach which enables an organization to identify, monitor and control its environmental aspects and includes organizational structure, planning activities, responsibilities, practices, procedures, processes and resources for developing, implementing, achieving, reviewing and maintaining the environmental policy. One particularly relevant international standard is ISO 14001: 1996 Environmental Management Systems – specification with guidance for use (for further details see http://www.14000-toolkit.com/).

To achieve ISO 14001 certification, an EMS framework must have the following elements:

- An environmental policy.
- An evaluation of significant environmental effects.
- Environmental objectives and targets.
- An environmental management programme.
- Regular audits and analysis of environmental performance.
- Regular management reviews of the EMS.

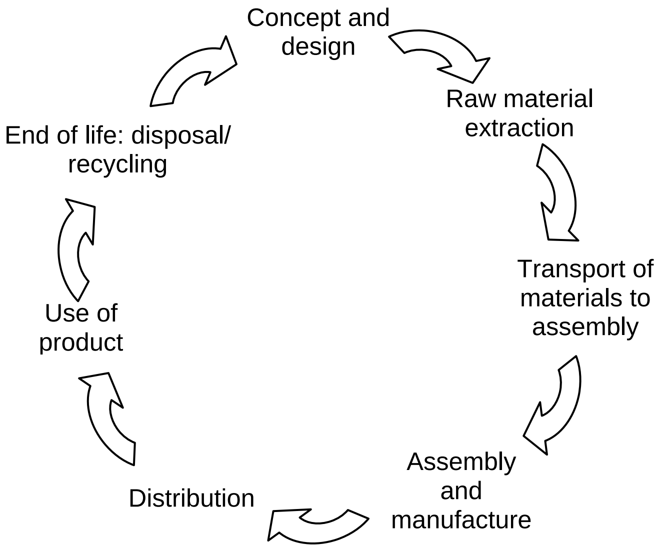

Figure 1 Schematic product lifecycle.

Figure 2 shows a model incorporating aspects that need to be included within environmentally conscious design, and shows that it can be based around a number of decision support tools, but that the system is most likely to work if it is well informed through management systems and external communication systems. The support of information management and communication mechanisms is key to ensuring that the right culture is in place, and that the knowledge of both legislation to be complied with, and consumer demand is understood. Information within and external to the organisation needs to be considered when knowledge management systems are designed. Many companies have quality and environmental systems in place, and it has been suggested that integration of these into a single system should both reduce costs and provide simpler compliance with legislation such as the EuP Directive. It is most important to have some system in place that will control documentation and ensure adherence to standards.

These management systems will help a planned approach to ensure that environmental aspects of products throughout the product lifecycle can be addressed without a negative impact on competitiveness. Environmentally conscious design must be consistent with the business objectives and preferably organisations will extend their approach outside their own organisational boundaries to a holistic system with their supply chain to realise the greatest benefits.

Fundamentally, there needs to be a culture that addresses lifecycle issues, involving functions such as sales, marketing and procurement rather than focussing solely on design. Indeed, management support and commitment to an eco-effective approach (Braungart *et al*, 2007) are necessary to ensure that there is a holistic approach incorporating economic, social and environmental aspects (Envirowise, 2001). Just as quality systems (such as ISO 9000) implemented in the past required buy-in from the whole organisation, so do environmental issues and attitudes. Some of the supporting systems to comply with legislative requirements will involve investment and management need to understand what is involved. Therefore, the attitude put forward by senior management can influence the burden or opportunity achieved by each organisation.

Greater numbers of companies are now looking at what it is that they are actually providing to their customers, and how best to provide this. There are case studies from several industries where the entire outlook has been changed in recent years (Envirowise, 2001); eg aerospace - companies not providing planes, but guaranteed time in the air; shop-fitting - companies providing guaranteed floor covering of a specified quality rather than selling a carpet. It may be that the product/service concept requires review for a more environmental and sustainable alternative. In this sense, the needs of customers have to be researched to determine exactly what product or service or product-service complement should be offered.

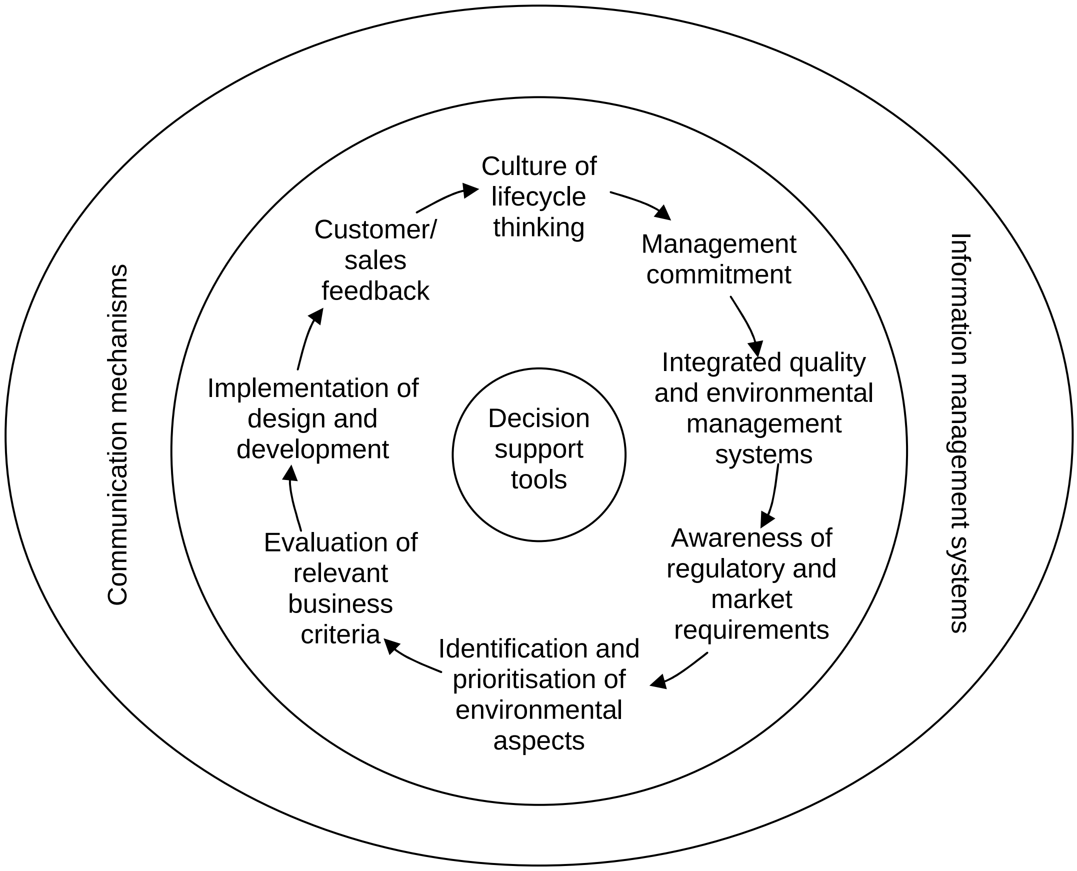

Figure 2 Model for environmentally conscious design implementation.

Once the product research has been undertaken, then priorities for environmental improvements can be reviewed. It is unlikely than any product can be optimised completely and even if this were technically possible, it may prove economically unviable. Therefore, environmental impacts of a product lifecycle should be investigated to identify the areas where changes in design could have the greatest positive environmental impact. These areas are discussed in more depth in the section on product lifecycle stages. Then design changes can be made or a new design prepared according to the impacts identified, but with equal consideration given to the sustainability (economic impacts of any changes).

Once any design is implemented, feedback should be sought through internal design reviews or external information from customers. This should include the environmental performance as well as the technical and economic measures used.

Benefits

There are several benefits to organisations of environmentally conscious design, especially if an integrated approach is taken, and these benefits primarily address the different stakeholder concerns driving forward the interest in this topic:

- Regulatory and legislative compliance.
- Improved product function and quality through review of customer requirements and focus on addressing these.
- Lower costs of production due to increased efficiencies and reduced wastes.
- Increased market share through new product/service development or appealing to the environmentally-conscious market.

- Improved environmental performance, such as reduced emissions, waste, energy consumption, or involvement of less toxic substances.
- Better upstream and downstream relationships throughout the supply network, resulting from better communication of needs, and shared profitability from improvements.
- Easier disassembly and increased potential for re-use, recycling or material recovery.
- Longer product design life.

Product Lifecycle Stages

Aspects to consider at each stage

To consider environmental aspects across a product lifecycle, CEN Guide 4 provides a basic checklist of areas to consider, as shown in Table 1. This checklist can be downloaded and used to review a particular product. This could form the basis for prioritised analysis of areas to be addressed and documentation behind environmental awareness that could make up an ecological profile for a particular product. Clear documentation should be available for each stage of product life, detailing the design choices made and an environmental justification or link to available best practice (Adams, 2007).

It is important to note across all product stages that the legislative drive (if not the green consumer drive) is for 'eco-efficiency' – an approach which tries to maximise environmental and economic benefits whilst simultaneously minimising the environmental and economic costs. That is, the drive to reduce environmental impacts should not be considered to be detrimental to commercial competitiveness.

Table 1 Initial checklist/matrix for environmental aspects obtainable from www.cen.eu/cenorm/workarea/advisory+bodies/environmental+helpdesk/fo051envcheck1.doc.

Environmental aspects (Inputs and outputs)		Product life cycle			
		Production and pre-production	Distribution (including packaging)	Use	End of life
		A	B	C	D
1	Resource use				
2	Energy consumption				
3	Emission to air				
4	Emission to water				
5	Waste				
6	Noise				
7	Migration of hazardous substances				
8	Impacts on soil				
9	Risks to the environment from accidents or misuse				

Material selection

It is important when selecting materials for a product that they are fit-for-purpose, but in many cases there are several materials that may be fit-for-purpose, and they will have different environmental impacts (and usually different costs). From an environmental perspective, it is valuable to consider use of materials with less environmental impact – this means consideration of accessing the raw materials: some may be more readily available than others or they may be available from sustainable sources. In some products it may be possible to avoid virgin materials and use recycled materials; or design so that the chosen material can be reused or remanufactured at end-of life. In general, use of fewer materials enhances recycling at end-of-life. Certain materials may require less processing and it may be possible to avoid the use of particular hazardous substances. In many cases, products continue to be made in a traditional fashion, without review of new materials, substances or treatments where technology allows the use of more sustainable resources that were not previously fit-for-purpose. It is also important to use less material where possible in a design. This has the obvious impact of using less resource, which should allow reduced costs, but also has the additional benefit of reducing a product's weight. This can have significant downstream effects on environmental impacts during transportation of products and the in-use phase of energy-using products. The sourcing of the most appropriate form of material should also allow the most efficient manufacture, reducing waste and cost.

Manufacture

The energy use and environmental impacts of manufacturing can be significantly lower than material extraction and in-use phases of the product lifecycle. Much will depend on the product design, the materials selected and the fabrication techniques used. Ideally environmentally conscious design will ensure that for manufacture, fewer resources are used both in materials and in the assembly processes. Potential environmental issues that could arise from production should be identified and addressed early on. These will include air, water and soil emissions, hazardous substances, energy use and waste or pollution. Processes should be reviewed where emissions are identified to see if there are opportunities to re-use by-products such as heat, in alternative areas of production. If waste is created then opportunities for recycling and re-use should be considered.

The impacts of the production processes on those carrying out the tasks must also be considered, with health and safety of workers a key consideration in reducing the use of certain substances, such as volatile organic compounds (VOCs). Application of techniques such as implementation of lean manufacturing or value stream mapping can address areas of waste to improve both financial and environmental impacts of a production process. Efficient use of equipment is critical within manufacturing to ensure that energy use is appropriate and cost-effective, therefore the assembly methods or joining processes used should be chosen carefully with the materials and material thicknesses in mind. Alternative processes may be developed as technology matures which are more efficient. Tools such as carbon footprinting can be used to map a process, to identify priority areas to be addressed for improvements or to review which stages of manufacture have the greatest environmental impact.

Packaging and transport

Despite the EC Packaging and Packaging Waste Directive 94/62/EC, there is still a lot of waste generated due to packaging. This is not only down to packaging that is discarded once the product has been purchased, but also the waste of space and weight during transportation and distribution. This obviously impacts other environmental factors such as fuel emissions. Key initiatives include activities to reduce or reuse packaging in some way. Companies should consider only protecting critical components or parts of a product, or using more robust packaging which can be reused. More overarching aspects to be addressed at this stage is whether or not it is possible to have production close to the use phase to reduce transportation, or whether parts can be produced which can then be transported effectively for assembly close to or at the use phase.

Use

Products should be designed so that users can install them in the most energy efficient mode, and clear instructions available with or on the product so that operation will be efficient. Design should be for optimal functionality and service life, allowing the best use of space and resources and ease of access for maintenance. Multi-functional products with modular design will use less initial resource than separate equipment and can be upgraded or repaired easily. To minimise resource use and waste, products should be designed so that consumables are kept to a minimum or can be reused or remanufactured once their original life is completed.

Equipment should be used with the most appropriate power source and rating for its functionality and this should be made clear for the user. To avoid cooling systems such as fans or chemical coolant, design should incorporate appropriate thermal dissipation. Products should be designed to make the most efficient use of resources such as energy and water throughout their lifetime. Increasingly, software can be applied to ensure automatic resource efficiency of machines.

For ease of maintenance and upgrade, products can incorporate modular design and use of easily accessible sub-assemblies. This can extend a product’s life by increasing functionality and allowing ease of repair. Maintenance schedules should be advised with the operating instructions so that proactively the equipment can be kept operational in the most efficient manner. This should avoid unnecessary air, water or soil emissions.

End of life

The waste hierarchy (shown in Figure 3) was first introduced into European waste policy in the European Union’s Waste Framework Directive of 1975. In 1989 it was formalised into a hierarchy of management options in the European Commission’s Community Strategy for Waste Management, and further endorsed in the Commission’s review of this strategy in 1996.

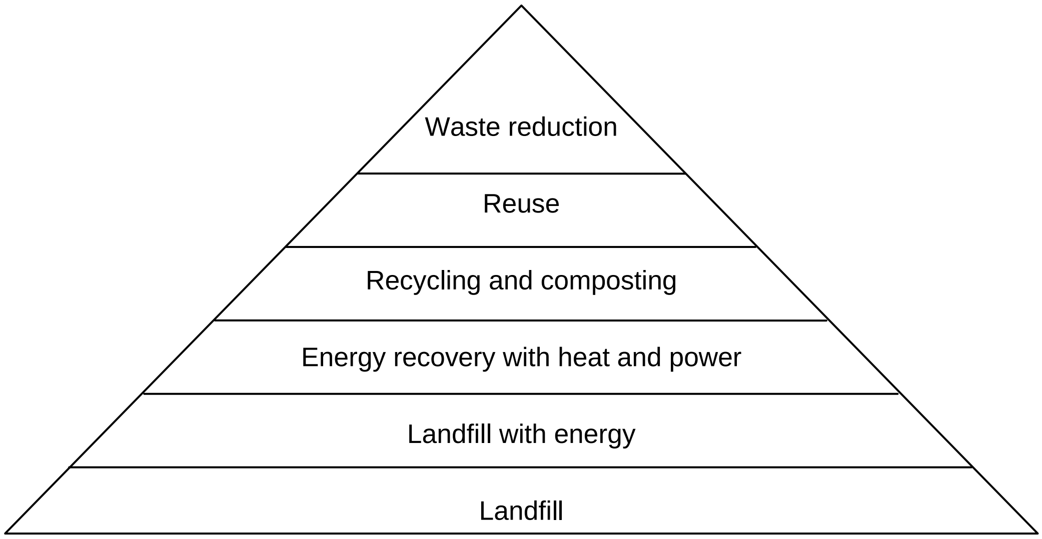

Figure 3 Waste hierarchy.

At the end of life, there are therefore several options for a product, with waste reduction considered the most environmentally benign and landfill without energy recovery the least environmentally aware. Therefore there are a number of options, many of which can be considered at the design stage, to prescribe good practice for the end of life of a product. Products should include clear instructions for users as to what the best practice is once a product has reached the end-of-life phase.

Waste reduction can be achieved through extending a product's lifetime, through initiatives such as modular design for repair and upgrade. Whole products can be reused, or resold to secondary markets by refurbishment of exterior and engagement with supply chain for recovery infrastructure. If a product is no longer working, it may be possible to design for refurbishment, replacing components and/or sub-assemblies that have failed, using sensor mechanisms to be interrogated for fault diagnosis. It may be necessary to ensure reuse of sub-assemblies and components by using modular design and improving the supply chain infrastructure for cost-effective component gathering.

When designing products consideration should be given to assisting opportunities to extract materials for recycling using design for disassembly and ease of access to separate materials and avoiding contamination with any hazardous substances. In general this involves consideration at the design stage of the joining techniques used for assembly, however it also requires knowledge at the end-of-life as to whether any contaminants have been introduced within the use phase. When designing for disassembly, thought should be given to:

- Reducing the part count and number of different materials used.
- Ensuring use of standard mechanical fasteners to avoid the need for specialist tools.
- Active disassembly techniques that allow modularisation once a trigger acts on a disassembly mechanism.
- Use of snap or mechanical fit techniques for assembly.
- Availability of a manual for disassemblers.

If materials cannot be recycled then designing to allow extraction of materials for energy recovery in a power plant, by designing sub-assemblies with high calorific value that can easily be separated is worth considering. The final option to consider within design is that if disposal to landfill is the eventual end-of-life option then, ensuring that hazardous materials can easily be separated for disposal as hazardous waste complies with environmentally conscious design.

Conclusions

The drive to reduce environmental impacts of products and services is increasing through legislation, public awareness and economic impacts of scarce resources. It is a topic which is unlikely to be removed from the agenda in the immediate future. This best practice guide has outlined a holistic model with aspects that companies should consider for environmentally conscious design. For effective implementation design must not be considered in isolation, but must be linked with business decisions, and functions such as purchasing, production and distribution. It is important that companies prioritise areas for improvement so that environmental efficiency is not achieved at the expense of environmental efficiency effectiveness.

This guide has provided specific information to be reviewed at different stages throughout the product lifecycle, and companies need to ensure that they address any specific stage with a view of the whole lifecycle so that an improvement in one area does not have a greater negative impact at another stage of the lifecycle.

There are many tools, techniques and sources of further information such as web sites, consultancies and standards which can be applied to particular industries or products. Some of these are listed in the following section, and further details can be obtained from the references to this best practice guide.

Environmentally conscious design is not a static nor linear process, but must be ongoing to identify new opportunities and technology watches can be very useful in this instance, as can registering for updated information on the legislation from the legislative organisations. Key to continuous improvement is the feedback from sales and marketing functions on which features and attributes are most valued by the consumers.

Tools, Techniques and Sources of Further Information

It is important to recognise the value these tools can add, but also that many of the software-based tools need a lot of data input and that their results must be interpreted with care. As environmental analysis continues to be high on the manufacturing agenda, an increasing amount of data is available, but it can take considerable investment to collate and verify.

A overview of methodology and tools is given in “EcoDesign and The Ten Golden Rules: generic advice for merging environmental aspects into product development” C Luttropp J Lage, Journal of Cleaner Production Volume 14, Issues 15-16 (2006) pp. 1396-1408

Simple top-level ‘eco-design health check’ published by SEEBA*
www.cfsd.org.uk/seeba/general/ecod-health.doc

Automotive industry
Eco-Design of Automotive Electrical and Electronic System: The SEES Project, Technische Universität Berlin, Institute for Environmental Engineering, Department of Systems Environmental Engineering, Berlin, Germany* www.mech.kuleuven.be/lce2006/061.pdf

Construction industry
Environmental design and construction www.edcmag.com/

Electronic goods
Ecolife* www.ihrt.tuwien.ac.at/sat/base/ecolife/index.html
DTI/DEFRA guide to sustainable design of electrical and electronic products*
www.eup-ecodesign.com/files/documents/guideSusDesign.pdf
IEC 62430 Environmental conscious design for electrical and electronic products and systems (working document)

Plastics
Eco-profiles of the European Plastics Industry* http://lca.plasticseurope.org/index.htm

General design tools
Ecodesign Pilot* www.ecodesign.at/
Eco SMEs* http://www.ecosmes.net
EDT Product Launch Eco-design Tool www.plestech.co.uk/edthome.html

General LCA
EIO-LCA* from Carnegie Mellon University www.eiolca.net/
European Reference Life Cycle Data System* - large database of tools and databases from EU programmes http://lca.jrc.ec.europa.eu/lcainfohub/index.vm
GaBi www.gabi-software.com/
Sima Pro www.pre.nl/simapro/default
TEAM www.ecobilan.com/uk_team03.php

Web sites
Envirowise – featuring a range of downloadable publications, advice and helpline (UK) www.envirowise.gov.uk/
NetRegs - provides free environmental guidance for small businesses in the UK www.netregs.gov.uk/
Norwegian University of Science and Technology (NTNU) ecodesign tutorial www.design.ntnu.no/fag/ecodesign/
Department of Business Enterprise & Regulatory Reform – sustainable development page www.berr.gov.uk/innovation/sustainability/index.html
Design for disassembly - paper by Tracy Dowie-Bhamra, University of Manchester www.co-design.co.uk/design.htm
World Business Council for Sustainable Development - Eco-efficiency Learning Module* www.wbcsd.org/web/publications/ee_module.pdf

* Free of charge

Information and assistance on eco-design is available from TWI Ltd
Please e-mail the Business Process Support Section of TWI's Manufacturing Support Group: business.support@twi.co.uk

References

Adams G, 2007: 'Smart Eco-Design Energy-using Devices (EuP) Eco-design Checklist For Electronic Manufacturers, 'Systems Integrators', and Suppliers of Components and Sub-assemblies', The Centre for Sustainable Design.

Braungart M, McDonough W and Bollinger A, 2007: 'Cradle-to-cradle design: creating healthy emissions – a strategy for eco-effective product and system design', Journal of Cleaner Production, Vol.15 pp1337-1348.

CEN Guide 4, 2005: 'Guide for the inclusion of environmental aspects in product standards' Edition 2, January.

Directive 2005/32/EC, 2005: 'Directive 2005/32/EC of the European Parliament and of the Council of 6 July 2005 establishing a framework for the setting of ecodesign requirements for energy-using products and amending Council Directive 92/42/EEC and Directives 96/57/EC and 2000/55/EC of the European Parliament and of the Council' [online]. [Accessed 16 May 2007]. Available from: http://eur-lex.europa.eu/LexUriServ/site/en/oj/2005/l_191/l_19120050722en00290058.pdf.

Envirowise, 2001: 'Cleaner Product Design: an introduction for industry' Crown Copyright.