

Design for the Environment Guidelines

Active Disassembly Research, February 2005
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1) Introduction

It is commonplace for designers to create product specifications that are related to function, form and the scale of production. These specifications are directly responsible for the amount of energy and resources used, as well as the amount of pollution that is produced for the manufacture of the particular design. If, however, designers are given access to the right information, then they can substantially reduce the negative effects their products have on the environment, without necessarily compromising their performance. Design for the Environment (DfE) guidelines can help designers achieve this.

In previous years, much of the environmental legislation aimed at manufacturers dealt with externalities such as air pollution and chemical waste from mass production processes. Unfortunately, this was only part of the problem. Looking at the product life cycle from a wider perspective, it can be seen that there is just as significant wastage during the product's use and disposal. Environmental legislation now targets the latter stages of the product life cycle and encourages manufacturers to become responsible for the safe disposal and recycling of used products. At present, the onus is on the designers to design products with all stages of the product life cycle in mind.

There is also the 'goodwill' factor achieved by designing responsibly. As businesses seek competitive advantage by improving product functions and aggressive marketing tactics, they ultimately reach a stage where it is difficult to distinguish themselves much further. However, by adopting a responsible, environmentally-sensitive approach to design and manufacturing, they can show consumers that they have greater depth and understanding of long-term sustainability and not just short-term profitability.

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2) Strategies

Product-Specific Eco-Design Strategies

Identification of product purpose and user requirements. By clearly determining the core functions of the product and what is required by the end user at an early stage, unnecessary features (which ultimately lead to resource wastage) can be screened out before time and financial constraints render any changes prohibitive. Thorough market research and intensive ergonomic testing methods, while initially costly, are nevertheless essential and will ultimately lead to an improved sales revenue and comparatively longer product life.

Modularisation of components. Separating components into individual modules allows for greater flexibility within design, allows for easier disassembly, and also allows for faster product development, especially when incorporating new technology. Modularisation allows for easier maintenance and re-manufacture at the product's end-of life.

Convergence and multifunctionalism. Improvements in technology and changing consumer trends mean that the advent of product multifunctionalism is very much present. The benefits aren't just about convenience and adding value to the product. Fewer resources are used per "unit function", i.e. producing a single product that allows you to fulfil two or more functions (e.g. camera-phone) uses fewer resources than producing the several individual products the fulfil the same number of functions. This includes both material use and energy consumption in storage & transportation.

Design simplification. Simplification through the reduction of parts and general form will not only reduce waste and provide for easier end-of-life treatment, but will also reduce both assembly and disassembly costs. It is important that the simplification of the design does not compromise its function or structural integrity. It is also important not to compromise the aesthetic qualities of the product, given how this may affect the product's perceived value and subsequent revenue.

Energy consumption feedback. It would be desirable for products to incorporate a feedback mechanism to make the user aware of the amount of energy used per single use of the product, in some relevant form. For example, a kettle could display the temperature of the water it contains, to prevent the user from unnecessarily re-boiling if the water is at an already adequate temperature for use. It is through subtle means such as this that we can perhaps educate consumers about their energy consumption habits.

Design for partial capacity operation. Products are rarely designed to operate constantly at full capacity. The product should be designed to operate at maximum efficiency under its most common conditions. If these conditions are subject to variation during its use, then the product should be designed to run efficiently over the full range of conditions. An example of such a system is the new Jeep Hurricane's multi-displacement system, which has 16 cylinders split into two engines for maximum power on steep inclines, but is capable of de-activating three-quarters of its cylinders when little torque is required (e.g. when at cruising speed).

Reduction of weight. Reducing the weight of the product will lead to reduced material consumption and improved transportation efficiency. In industries such as the automotive and aerospace industries, the use of lighter engineering materials can lead to improved fuel economy. However, there are certain health hazards presented by certain materials (e.g. fibreglass) so it is important that manufacturing facilities dealing with such materials have the safety procedures and equipment required to protect the health and safety of workers.

Reduce consumable dependence. Products such as printers, washing machines and trimmers require consumable goods in order to fully perform their function. In an ideal world these products would operate without the need for such consumables, but this is unlikely to be achievable, both from a physical and financial point of view – companies gain a steady income from the sale of these goods after the initial durable good sale. Unfortunately the resources used in production are spiralling upwards as a result. It is therefore important to try and reduce the quantity of consumables used during the lifetime of the product, either through improved efficiency or innovative design.

Design for disassembly. Designing for disassembly allows for greater flexibility during product development, shorter development timescales and reduced development costs. It also leads to reduced assembly/disassembly costs, as well as ease of maintenance. Implementing DfD into a design specification allows the product and its components to be better suited for re-manufacture or recycling when it has reached its end of life, thus reducing the scale of resources required to create new products.

Design using Active Disassembly. Active Disassembly (using smart materials) significantly reduces disassembly times and the level of energy expired per product disassembled. Active Disassembly ensures a consistent disassembly, thus preventing damage to components which may be retained for re-manufacture.

Design for longevity. Intended obsolescence plays a large part in many businesses' marketing strategies. From an environmental perspective, designers should aim to improve the durability of products and design for ease of upgradeability and repair. Incorporating less controversial or radical aesthetic styling may also help to preserve the longevity of the product in terms of desirability (e.g. certain classic cars are still considered very desirable).

Use of renewable energy sources. This issue is already quite important in countries where energy is not commonly available, although it is likely to be more recognised in developed countries, given the limited supply of fossil fuels. Solar powered and kinetic devices are improving in terms of practicality, and despite their relatively bulky nature, are an effective means of reducing non-renewable energy consumption.

Use of rechargeable batteries. Using rechargeable batteries reduces the number of batteries ending up in landfills after use, and subsequently reduces the leakage of heavy metals into the environment. Another benefit is the convenience factor which adds value to the product.

Re-manufacturing, re-distribution. Products with very short life cycles (e.g. mobile telephones, laptop computers) are strong candidates for re-manufacturing and re-distribution. It is often the case where the internal components are still in full working order or only a small component has malfunctioned and/or the external casing is out of date, with regards to the current styling trends at the time. Re-manufacturing products reduces waste and resource consumption, and also reduces production costs, provided the testing facilities and labour are available for re-manufacture, and the product is suitably designed for ease of re-manufacture.

Material-Specific Eco-Design Strategies

Minimisation of Material types. Reducing the number of materials used within an assembly makes the processing and separating of materials for recycling at the product's end of life much simpler, faster, and therefore more cost-effective. Reducing material types can also lead to better compatibility for recycling. It is important, however, to eliminate materials which are key towards the product's function.

Use of Recycled Materials. Using recycled materials prevents non-biodegradable waste ending up in landfills. They also require less energy in terms of processing, and provided there is no contamination from other materials, can last several cycles before becoming obsolete. Schemes operating within businesses which encourage consumers to send back old products can help to save waste disposal and material costs, and prevent material contamination in the recycling process. Reducing the number of additives used in materials can help reduce contamination and retain material properties.

Use of Biodegradable materials. The collection and composting of biodegradable materials at the product's end-of-life is often a more effective alternative to recycling, which in itself requires a considerable amount of energy to propagate. The ability to decompose and return nutrients back to the earth is beneficial, provided the facilities are present to store decomposing biodegradable materials (e.g. biogas chambers) – measures already exist to turn such materials into effective fuel alternatives. Unfortunately biodegradable materials do not always have the physical qualities that are required in today's products, although technologies are emerging (e.g. paper circuit boards) which will make biodegradable materials more commonly used in the future.

Glass Considerations. Glass is produced from a renewable resource, is non-toxic and relatively easy to recycle. It can add value to a product in terms of aesthetic appeal (thus lengthening the product life) and is relatively durable when maintained in normal conditions. However, due to its heaviness, it is not economically or environmentally practical to transport, nor is it safe during handling. It can also cause long-term damage to recycling facilities given its relative hardness.

Minimisation of composite material use. Composites are mixtures of materials which have been chosen to achieve a particular set of properties – examples being glass reinforced plastics (GRPs), Carbon composites, and MDF. They are (generally) more expensive than standard materials, require specific production techniques and are generally difficult to recycle. However, given their structural properties, they should not be replaced with sub-standard materials for high-performance or safety-critical applications.

Use of renewable material sources. It is becoming more common for plastics to be replaced with renewable materials such as woods from sustainable forests, particularly in the area of packaging and point-of-sale displays. Advertising that the product is produced from materials from renewable sources adds perceived value to the product, and can reduce waste if the material stems from agricultural waste.

Material Identification. Materials need to be adequately identified in order to be properly sorted and recycled (or in the case of biodegradable materials, composted). Improper labelling can lead to contamination within the recycling process. Hazardous materials must also be clearly marked, with some instruction given with regards to the safe disposal of the product. Etching/moulding identification into the material will help to prevent the loss of identification marking over time.

Avoidance of Toxic Material Sources. Toxic substances, including Volatile Organic Compounds (VOCs) and heavy metals, should be avoided where possible, as they pose a hazard to human health and the environment. Contamination of water supplies is a high risk, and implementing safety systems to handle the substances properly can be very costly. A full list of toxic substances and descriptions is available at: <http://www.atsdr.cdc.gov/toxfaq.html>

Process-Specific Eco-Design Strategies

Elimination of Hazardous waste production: As part of a waste reduction plan, the volume and type of hazardous waste should be identified at the source of generation. For each process that generates waste, the raw material inputs, processes, equipment, useful output (product) and waste should be clearly outlined. Implementing a technically and economically viable solution to reduce waste is likely to take time, and the externalities considered. Will there be a significant benefit to the external environment by eliminating the waste altogether? In some cases this is not possible, and the transportation of waste for safe disposal has to be considered.

Use of Clean Technologies. This includes both technologies used for production and in the product itself. There are significantly better alternatives to certain materials now than there have been ten years ago; e.g. lead-free solders and biodegradable inks/dyes. Solar power, electromechanical power and hydrogen-cell technology are examples of clean technologies, all of which play a significant role in reducing emissions.

Aiming for optimum efficiency. This involves preventing wastage at all levels and ensuring there are no leaks in a manufacturing system. Total Quality Management (TQM) is a valid method of maintaining such efficiency. Quality Standard ISO 9001 and environmental standard ISO 14001 are possible benchmarks for an efficiently-run manufacturing system.

Recycling/reusing waste in manufacturing. Minimising waste within the manufacturing process is important, but not completely avoidable. In some cases waste can be useful and retained for recycling purposes; e.g. excess flash trimmed from thermoplastic mouldings can be retained and recycled for re-use.

Design for manufacture/assembly techniques. Designing for manufacture and assembly reduces the time required for manufacture, and in doing so, reduces the level of resources used in production. This may involve designing parts which require less machining, tessellation of parts cut from a sheet to prevent wastage, creating part symmetry, and so on. Good design for assembly will also ensure that the product is sufficiently resilient to damage during manufacture (e.g. by having bosses and ribs), so that little or no wastage occurs.

Minimise packaging requirements. Products should be designed with packaging in mind at the beginning of the design process, as a means of integrating the packaging with the product; hopefully this would lead to reduced resources used in packaging. Also helpful is to analyse the packaging functional requirements, then attempt to transfer these requirements to other forms (e.g. information can be made available online as opposed to printed on the packaging) which could ultimately lead to changes in branding, distribution and availability of the product.

Disposal instructions. Disposal instruction should be displayed clearly on the product, clearly detailing the material types used and any hazard warnings where necessary. Contact information regarding end-of-life collection schemes can prove useful in these situations and should be made available from an up-to-date source (e.g. website).

Recycling/reuse at end-of-life. This is generally only effective where the infrastructure is available to maintain a long-term recycling system. Indeed the resources involved in

transporting products for recycling can outweigh the benefits of recycling. However, in the long run there are likely to be more facilities available as the demand for recycled goods increases.

Long-term Eco-Design Strategies

Product Service Systems. Systems which lend a product to the customer, who then pays for an associated service, can be described as a product service system. Examples include vending machines, and at a consumer product level, mobile telephones. The benefits of such systems are that the customer does not have to worry about maintenance, does not have to pay for the expense of the product itself, and can change the product (at the end of the contract) if circumstances change. Manufacturers then have an incentive to re-use or re-manufacture the products after the end of a life, and can significantly save production costs.

Supplier selection. Manufacturers need to ensure that the suppliers they choose to source their components/raw materials from are environmentally responsible and maintain strict environmental regulations, as well as being flexible, efficient and communicative. Companies such as Canon Electronics (Japan) employ a rigorous supplier selection program to ensure that they are getting the best from their suppliers.

Planning for change. Designing for durability and longevity has been discussed in these guidelines, and while they may be effective eco-design solutions, designers should bear in mind that maintaining the life of outdated or inefficient products can be equally as hindering. They should be able to think at least two steps ahead, which may have an influence in the technical design of the product. Will the existing casing of a product be able to accommodate technology currently in development? We are increasingly looking at a more upgradeable environment, which exists not only in the pc industry but also in other sectors.

Green Labelling. Products such as refrigerators have energy-efficiency labels prominently displayed on them. The key to better energy consumption may be in educating the public in the choices that are available and letting them make the right decisions. Products which meet various environmental standards (and display this to consumers) ultimately have a higher perceived value than those which don't.

Analysis of Energy Consumption. Analysing energy consumption is an effective method of determining whether a recycling system is effective or not, and where changes can be made to reduce energy consumption within the product's life. Reducing transportation distances and reducing weight are valid means of reducing energy consumption, bearing in mind that energy is equal to effort multiplied by distance travelled. What must also be considered is the energy required in processing materials (i.e. changing from one state to another). In general terms it is better to choose materials which require minimal or no energy input for processing.

Designing with LCA in mind. Designing with LCA in mind allows the designer to gain a broader perspective in terms of the product's life from raw material extraction to re-use and/or recycling. Analysing the product life cycle early in the design process is important as designers may find that later on there are fewer opportunities for implementing effective changes. Analyses can be both qualitative and quantitative, the latter being highly effective in terms of justifying significant changes.

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3) Life Cycle Analysis

Life Cycle Analysis (LCA), or "Life Cycle Assessment" as it is sometimes known, is a methodical study of the environmental impacts which occur throughout the course of a product's life. This spans from the extraction and processing of raw materials, covers the production of components, product assembly, product use and ultimately disposal. Issues concerned with LCA include the use of resources, waste production, water/soil/air pollution and climate change. Styles of LCA may vary slightly but generally cover the same areas.

For qualitative LCA, the following information is estimated and recorded:

	Materials	Energy	Waste	Emissions
Raw Material Extraction				
Manufacture & Assembly				
Distribution				
Product Use				
End-of-life				

Values entered in the table above can include amounts in terms of volume, energy and weight. Comparisons can then be made between products to give a rough overview of a product's environmental impact.

Quantitative studies are more precise and require more time and primary data collection. Firstly, the objectives and depth of study are outlined for the LCA. Secondly, a Life Cycle Inventory (LCI) is constructed, which lists the inputs and outputs for the system being analysed. The final stage of LCA involves modelling the emissions and consumed resources, then measuring the impact this has on the environment.

Standards detailing the conventions for LCA include:

ISO 14040
ISO 14041
ISO 14042
ISO 14043

Full details of LCA can be found in the "Life Cycle Analysis" Guidelines under "AD Guidelines" at <http://www.activedisassembly.com/>

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