Rethinking Eco-design Priorities; the case of the Econova television

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Abstract

Eco-design heuristics (defined as experience-based techniques for problem solving) can play a useful role in helping designers prioritize eco-design strategies. One of these eco-design heuristics (the 'use phase' heuristic) is: *Frequently used electric and electronic products usually have, over their life span, a dominant impact in the use phase.* Modern mobile devices like smart phones however have their dominant impact in the production phase and therefore challenge this heuristic. The paper asked whether this could be a trend and whether we might find more electric and electronic products that challenge the 'use phase' heuristic. We found that in general, the development of highly energy-efficient consumer electronics and the widespread shortening of product lifespans have indeed started to shift the focus to the materials and production phase of the life cycle. The case study of the Econova television showed that with a 'best in class' product like this TV, it is not possible to establish which life cycle phase is dominant. These findings led to several additions to the 'use phase' heuristic.

1 Introduction

Industrial designers integrate aspects of form, ergonomics, engineering, sustainability and management sciences into their design projects. In doing so, they need to balance many, often conflicting requirements, and need to draw on knowledge from very different domains. Industrial designers are not experts, they are generalists; this implies that their knowledge of the relevant domains needs to be just sufficient to allow them to make the appropriate choices in a given problem situation and within a given time frame. The inclusion of sustainability (or eco-design) requirements in industrial design projects is relatively new, with one of the first manuals on eco-design published in 1997, only 15 years ago [1]. Sustainability requirements add a complex, knowledge-intensive dimension to design projects, with environmental impacts to be considered across the life cycle of products (covering the extraction of raw materials, production, distribution, use, reuse, recycling and disposal).

The formal method to assess these impacts is life cycle assessment or LCA, laid down in ISO standard 14044:2006. One of the major drawbacks for designers is the time-consuming nature and the level of expertise needed to perform a scientifically robust LCA. For this reason, several fast-track LCA tools were developed [2] which can be performed in a relatively short time span. Nevertheless, for designers with no experience with LCA, the fast-track tools require a considerable upfront investment, as without prior training it is difficult to use these tools effectively.

The search for practical, 'hands-on' tools for designers also led to the development of eco-design guidelines [3, 4] which document the eco-improvements that were, over the years, made in products. Following such guidelines is commonly considered a necessary condition for designing 'good' eco-design products. The drawback of the guidelines is however their generic nature ("select low-impact materials"; "reduce impact in the user stage", etc.) and the contradictory advice they sometimes give [3]. According to Luttropp et al. [3], there is a need to "provide guidance for making compromises"; they suggest that designers could work with environmental experts to discuss the inevitable dilemmas that arise when trying to apply eco-design guidelines. This is probably sound advice, but it also exemplifies how difficult it is for designers to incorporate sustainability requirements in their projects without having to resort to environmental expertise. The development of experience-based heuristics seems to be a promising alternative approach. Judea [5] describes heuristics as strategies using readily accessible, though loosely applicable, information to control problem solving in human beings and machines. Bakker [6] recommends the development of heuristics for eco-design as a way to speed up the process of finding satisfactory solutions. Very few eco-design heuristics have been recorded in the scientific literature. Among eco-design researchers and teachers, however, they are often used to provide designers and design students with practical eco-design advice. An example of a heuristic, and the focus of this paper, is: *Frequently used electric and electronic products usually have, over their life span, a dominant impact in the use phase.* We will refer to this as the 'use phase heuristic'.

The 'use phase' heuristic is clearly more elaborate and specific than a general guideline such as "minimize energy and resource consumption in the usage phase". It is possible to trace back the origins of this heuristic through literature. For instance, Schischke at al [7], when discussing TVs, remark: "The use phase due to electricity consumption dominates the life cycle impacts in nearly all categories. This justifies a clear eco-design preference for energy efficiency measures." And Hansen et al [8] describe the environmental impacts of a professional drill (with dominant impact in the use phase) in the following way: "The graph highlights the significance of the use-phase. Based on a long-time experience in analysing products … this is a typical result and no surprise given one is dealing with an active product." Heuristics can be useful for making quick environmental assessments in the early stages of the design process to establish eco-design priorities. The 'use-phase' heuristic focuses the designer's efforts on electricity consumption and will help him/her develop an appropriate plan and set of actions to address this problem. An important condition for successful application, however, is the heuristic's reliability: it should be applicable in a majority of cases, with relatively few exceptions.

The aim of this paper is to test the validity of the 'use phase' heuristic. The research was motivated by the realization that (battery powered) mobile devices such as smart phones, tablet computers and laptops have their dominant impact in the production phase, as was demonstrated by Fehske and Fettweis [9], which makes these products an exception to the rule. Could this be a trend, and might we find more electric and electronic products that challenge the 'use phase' heuristic? Should the heuristic be revised? In order to answer these questions, in section 2 we provide a brief overview of relevant trends and developments in electric and electronic products, and in section 3 we present a fast-track LCA of the Econova television, winner of the 2010 EISA Green Award. Our conclusions are presented in section 4 and 5.

2 Trends and developments

In this section we briefly discuss the trends that are shaping the environmental impacts of electric and electronic products: decreasing lifespans, increasing energy efficiency and materials criticality.

2.1 Lifespans

A recent study by Huisman et al. [10] which models the Dutch waste flows of electrical and electronic equipment, shows that the average lifespan of this equipment (which includes household appliances, TVs, desktop computers, phones and laptops) has declined by 10% between 2000 and 2010. Lifespan is defined as the 'domestic service lifespan', which is the duration of the period when products function and can be put to use (by the first, second, etc., owner) and which includes 'dead storage' or 'hibernation' time (see also Murakami et al [11]). The study by Huisman [10] is one of the few to give quantitative evidence of decreasing lifespans, although many studies have commented on the phenomenon (for instance Cooper, [12]). As life spans shorten, for TV's for instance between 2000 and 2010 with a 17% drop in median lifespan [10], the environmental impacts in the use phase will become less dominant and will shift toward the production phase. Declining product lifespans lead to increasing material throughput in society and increasing waste streams. Addressing these issues requires a different set of design strategies (i.e. strategies that focus on product-life extension, product or component reuse or on recycling).

2.2 Energy efficiency

The per-unit energy efficiency of electric and electronic products has notably increased over the past decade. The International Energy Agency records efficiency improvements of 10–60% [13]. This is in line with the findings of Koomey et al. [14] who note: "… the power needed to perform a task requiring a fixed number of computations will fall by half every 1.5 years, enabling mobile devices performing such tasks to become smaller and less power consuming...". In some product categories the efficiency improvements have been particularly impressive, for instance with the shift from CRT to LCD technology in TVs [15]. An increase in energy efficiency generally leads to a decreased impact in the use phase (assuming people don't increase their usage of the product). It is however important to note that much of the energy efficiency improvements in electric and electronic products have been cancelled out by the demand for equipment which provides more functionality, or is larger or more powerful (i.e. bigger screens), and therefore uses more electricity [13]. It is thus unclear whether or not energy efficiency improvements challenge the 'use phase' heuristic.

2.3 Critical materials

Material criticality is concerned with raw material supply risks, a topic which has re-surfaced over the last few years. High-tech industry increasingly uses a range of critical materials (including, for instance, rare earth metals and platinum group metals) in order to realize high-performance product characteristics, such as energy efficiency [16]. When eco-design is perceived from the perspective of environmental business risks, the use of certain critical materials may have a high risk and should perhaps take precedence over other environmental impacts [17]. Lloyd et al [17] demonstrate this with a case study from Rolls Royce, a developer of gas turbine engines (that contain critical materials): "Environmental impacts from the 'in-use' phase dominate over the product life cycle. Understandably this is the focus for addressing environmental impacts, although this also means that environmental impacts from other phases of the life cycle can be overlooked." Material criticality puts the other trends in perspective and show that the use-phase heuristic should be used with some caution.

Overall, it can be concluded that given shortening lifespans and increasing energy efficiency, the use phase dominance of electric and electronic products is decreasing. Other issues that are not directly related to the use phase have surfaced, such as critical materials risks, which may need to be addressed by product designers.

3 Case study: Econova television

This section presents the results of a research project [18] which analysed potential eco-improvements for the energy efficient Philips Econova LED television.

3.1 Econova television

The Econova televion by Philips Innovative Applications N.V. (renamed to TP Vision Belgium N.V. in 2012) was chosen for the analysis. At the time, early 2011, it was one of the best examples of eco-design for TVs available, being the winner of the EISA Green Award in 2010. The EISA is the European Imaging and Sound Association, an association of 50 special interest magazines from 19 European countries best known for its annual European EISA awards [15]. The Econova television is a 42 inch LED-backlit LCD TV. The TV is backlit using an edge-LED lighting, which uses white LEDs arranged around the inside frame of the TV and a light diffusion panel to spread the light evenly behind the LCD panel. For the Econova, the optical sheets were improved, resulting in a reduction of LED lighting needed to achieve the required light intensity. Further reduction of electricity consumption was achieved through improved algorithms for image processing and the use of a more efficient energy supply unit. The Econova uses only 40 Watt in eco-mode and 60 Watt in standard mode (significantly less than its 2011 competitors [15]). Other energy saving features include the on/off switch, the very low electricity consumption in standby mode (0.06 Watt), the solar powered remote control, and the wall mount which doubles as a stand.

3.2 Methodology: fast track LCA

A fast-track life cycle assessment (LCA) was made to examine which life cycle phases of the Econova television have the greatest ecological impact. A fast-track LCA is different from a 'classic' LCA in that the output of a classical LCA (life cycle inventory and life cycle impact assessment) is input for the fast-track calculations. The methodological focus of a fast-track LCA is on the comparison of design alternatives [2]. For consistency, two fast-track LCA methods were used:

- ReCiPe indicator, a damage-based indicator with millipoints (mPts) as unit,
- Eco-costs, a prevention-based indictor (unit = €).

Both indicators make use of Ecoinvent 2.2 and Idemat 2012 databases. Excel sheets developed by [2] were used to execute the fast-track LCAs. The functional unit for the LCA of the Econova television was described as: "One television, providing 3 hours and 12 minutes of television per day (of which 25% in eco-mode) and remaining in standby mode for the rest of the day, over a period of 6 years." The duration of television watching was based on [19], who reports on a study across 89 countries showing that in 2009, on average, people watched 3 hours and 12 minutes of television per day. The 6-year period was based on estimates by [20]. The use scenario described here is referred to as the 'base case' scenario.

In preparing for the fast-track LCAs, an Econova TV and its remote control were disassembled, weighed and the different materials were determined. The cardboard packaging was considered as part of the product system and included in the LCA. During the analysis the following assumptions were made:

- The aluminium parts of the Econova consist of 60% post-industrial recycled aluminium. In the LCAs, use was made of the Idemat 2012 indicator value 'aluminium trade mix' (with 45% primary and 55% secondary aluminium).
- Transport of components (produced in China and South Korea) to Europe (for assembly and use) is done by ship and airplane, with some parts shipped and some flown in. Trucks are used to transport subassemblies and finished TVs within Europe.

- In the use phase, a second use scenario was calculated with a 'best case' user, assuming the eco-mode would be used all the time, and the TV would be switched off completely after 3 hours and 12 minutes (assuming 0 hours of standby mode). This was done to understand the sensitivity of the use phase to different consumer behaviours.
- At the end of life it is assumed the TV is recycled, resulting in recycling credits for several parts.

3.3 Results

Figures 1 and 2 show the impacts across the Econova's lifecycle. In the use phase, the variation in outcomes (different colour shades) result from the two different use scenarios that were calculated, with the 'best case' scenario displaying a lower impact than the 'base case' scenario. For the materials, transportation and end-of-life phases, error margins were included to account for data uncertainty. Taking the 'base case' use scenario as starting point, the use phase is the dominant life cycle phase in the ReCiPe indicator, but not in the 'Eco-costs' indicator, where the materials phase is dominant. In the case of the Econova, it is therefore not possible to decide which life cycle phase is dominant. This outcome challenges the 'use phase' heuristic.

Other notable results:

- The use phase is very sensitive to consumer behaviour (given the large difference between base case and best case behaviour). Significant benefits can be gained from stimulating 'best-case' user behaviour (use of eco-mode and on/off switch).
- Life span also has significant impact on use phase: halving the Econova's current lifespan (to 3 years) would also halve the use phase impact, and result in a dominant materials phase

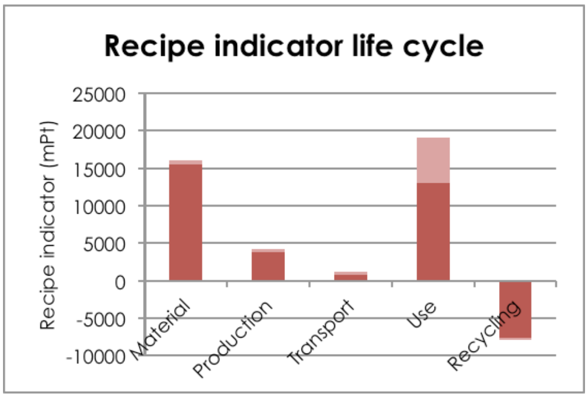

Figure 1 LCA of Econova using Recipe indicator

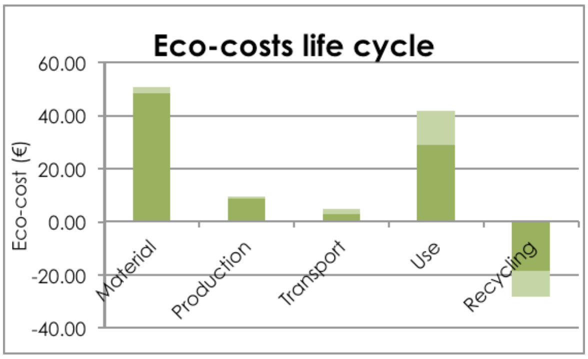

Figure 2 LCA of Econova using Eco-costs

3.4 Redesign

The outcomes of the fast-track LCA led to the conclusion that a sustainability-oriented redesign should focus on both use and materials phases of the Econova, and should enable recycling wherever possible. After exploring several options for remanufacturing, this was considered to be unfeasible in the current business environment of TP Vision, and it was decided to focus on design for optimal recycling. A second impact analysis was conducted (not explained in detail in this paper) to establish which materials have highest impact: printed circuit boards (only 5% of total weight of TV but some 25% of the ecological impact) and aluminium (with 43% of total weight, aluminium has approximately 50% of the eco-impact).

The final design:

- Makes it easier to turn off the television as the on/off-switch has been moved to the front panel, in clear view of consumers (and no longer hidden under the panel). This relatively simple design intervention might help trigger more sustainable behaviour, as it reminds people of the possibility to turn the TV off completely.
- Uses high-pressure die-cast aluminium (95% post-consumer scrap and 5% primary aluminium). The percentage of secondary aluminium has increased, lowering the impact score. This is highly feasible, because compared to wrought aluminium alloys, high pressure die casting alloys such as the common alloy A226 (En-AC-AlSi9Cu3) make relatively low demands regarding contamination, and are commonly based on post-consumer scrap to reduce costs.
- Applies a powder coating onto the die-casting that doesn't hinder recycling (cast aluminium used indoors does not need anti-corrosion protection, so the coating only has an aesthetic function; the 'bare metal look' alternative was considered briefly, but found unsatisfactorily for this application).

- Minimizes the use of aluminium by replacing the back cover by an organically shaped back plate. This back plate's shape was optimized for minimal materials usage through the bi-directional evolutionary optimization method (a software tool called BESO) of the Innovative Structures Group. The process is bi-directional: material is removed at locations where it is not needed (given a certain load), and added where it is needed to arrive at a uniform stress pattern. The resulting construction resembles naturally occurring growth patterns (adaptive growth is one of the nature's 'design' principles: it is the way natural structures build up materials at overloaded zones and reduce, or don't increase, material at zones without load).
- Is easy to disassemble: the TV can be opened by turning twelve quarter-turn fasteners. The fasteners are made of aluminium for compatibility in the recycling process. The printed circuit boards use placeholders instead of screws for easy separation from the housing during preprocessing. Separating printed circuit boards makes sense given their high impact scores (they contain relatively high quantities of precious and critical materials).

Figure 3 The back of the redesigned Econova TV

Figure 4 The front of the TV

This project was done to explore options for further improvement and innovation in TVs. It is interesting to note that the application of eco-design strategies can lead to high-quality designs. A second LCA (based on the redesign) showed a 15-20% improvement in the materials phase.

4 Discussion

The Econova is 'best in class' with regard to electricity consumption, and in this respect the TV was not improved any further. Based on the outcome of the fast-track LCAs, the designer's attention shifted to the materials and end-of-life phases of the television, and to influencing consumer behaviour.

The 'use phase' heuristic is probably still valid for many products (especially those that heat or cool, e.g. household appliances such as electric water kettles, dishwashers, tumble dryers) but the findings from the previous sections lead to several additions to the rule:

Frequently used electric and electronic products usually have, over their life span, a dominant impact in the use phase.

It should however be noted that:

- The shorter the lifespan, the more likely it is that the dominant environmental impact is in the materials & production phase. This is for instance the case in modern mobile devices like smart phones and tablet computers.
- The more energy efficient a product, the more sensitive its 'use phase' impact is to consumer behaviour.
- In highly energy efficient products, the use phase and materials & production phase may have approximately comparable environmental impacts (provided these products have a 'normal' lifespan)

This last point is still tentative and needs to be examined further. It is for instance difficult to define a normal lifespan (lifespans of electronic products have steadily decreased over the years, leading to changing expectations of what a normal lifespan is or should be).

5 Conclusions

Eco-design heuristics (defined as experience based techniques for problem solving) can play a useful role in helping designers prioritize eco-design strategies. They offer an easily accessible body of expert knowledge and a practical middle ground between time-consuming life cycle assessments, and large numbers of generic guidelines that give little direction to the eco-design process. The development of eco-design heuristics has not been given much attention in the academic literature, which is perhaps surprising, as heuristics are without doubt used in daily design teaching and practice. One of these eco-design heuristics (the 'use phase' heuristic) is the topic of this paper: *Frequently used electric and electronic products usually have, over their life span, a dominant impact in the use phase.*

Modern mobile devices like smart phones have their dominant impact in the production phase and therefore challenge this heuristic. The paper asked whether this could be a trend and whether we might find more electric and electronic products that challenge the 'use phase' heuristic.

We found that in general, the development of highly energy-efficient consumer electronics and the widespread shortening of product lifespans have indeed started to shift the focus to the materials and production phase of the life cycle. The case study of the Econova television showed that with a 'best in class' product like this TV, it is not possible to establish which life cycle phase is dominant. These findings led to several additions to the 'use phase' heuristic (summarized in section 5).

The paper also showed that designers will need to employ a wider range of eco-design strategies when (re)designing electric and electronic products, including product life-extension and end of life strategies (including durable design, reuse, remanufacture, recycling, etc.) and strategies that promote sustainable behaviour. It would be interesting to see whether the new set of 'use phase' heuristics is usable for designers – and to investigate what other heuristics are tacitly used (both by eco-design experts and design practitioners) that may need critical examination, given the dynamic nature of product innovation.

6 Literature

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