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Sustainable lighting product design

A new approach and an industrial case study

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This paper presents a new sustainable approach for lighting product design with the final aim to encourage/facilitate designers to adopt sustainable, easy to use and effective approaches, which will ultimately help to shift from traditional to sustainable consumption/production. The approach has been designed with the following stages: 1) Definition of the Life cycle of a lighting product, 2) Definition of the scope of eco-design action, 3) Review of Legislation directives related with lighting products, 4) Analysis of case studies of similar related projects, 5) Review of Life Cycle Assessment (LCA) prescriptive tools, 6) LCA Tools previously reviewed and other LCA analysis software-based tools were then combined/selected in a timely manner to match/support decision-making processes during various synthesis/analysis stages of the design process. This approach developed, explained and demonstrated through a case study, based on a lighting design project carried out with the lighting company ONA, Spain. To conclude, results and advantages/disadvantages of the approach are discussed.

Introduction

Today's production and consumption is causing a negative impact in the planet. Current industrial activities and consumer behaviour are leading to the depletion of our limited resources and the 'artificial' introduction of other harming sources (waste, emissions) in the environment. Statistics (EC, 2008) shows that our activities are having a profound negative impact in the planet; thus the need for tools to monitor and assess the impact of our industrial activities has become crucial. Monitoring and assessment is the first step towards the reduction/elimination of industries environmental impact. Integrated Product Policy (IPP) (EC, 2003) already is providing a set of mandatory (legislation) and voluntary tools in order to minimize/eliminate these impacts. The European Commission (EC) have been showing through environmental indicators the activities of industry regarding different criteria (energy, waste, etc.) in order to monitor the impact produced by industry, and assess their activities towards established targets set by the EC and the Kyoto protocol (UNFCC, 1997). The environmental indicators (EC, 2008) clearly demonstrate that a lot of the targets set by the commission have not been accomplished yet. For instance, The Kyoto protocol (in relation with green house emissions) which set a goal to reduce an 8% from 1991 to 2008-2012, it has not been accomplished so far, and the statistic-charts do not show a promising expectative for the future years (EC, 2008). Lighting products represent part of the total amount of consumer products produced by industry, therefore representing part of the impact produced in the environment. The impact produced by these types of products could be reduced/eliminated with the use by designers of effective sustainable design methodologies. Although there are already methods, tools and techniques to support (through prescription or analysis) design of environmentally friendly products (Brezet, H., and Van Hemel, C., 1997; Byggeth, S., and Hochschorner, E., 2006: 1420-1430; Dewulf, W., 2003; Graedel, T.E., and Allenby, B.R., 2003; Hur, T., Lee, J., Ryu, J. and Kwon, E., 2005: 229-237; Karlsson, M., 1997; Lewis, H., Gertsakis, J., Grant, T., Morelli, N. and Sweatman, A., 2001; Luttropp, C., and Karlsson, R., 2001; Meinders, H.-.P., 1997; Nordkil;, T., 1998; Pommer, K., Bech, P., Wenzel, H., Caspersen, N. and Olsen, S., 2001; Schmidt-Bleek, F., and Okodesign, 1998, Stevels, A., Brezet, H. and Rombouts, J., 1999: 20-26; Tischner, U., Schmincke, E., Rubik, F. and Prosler, M., 2000; Wenzel, H., Hauschild, M. and Alting, L., 1997; Bhamra, T., and Lofthouse, V., 2007; Weidema, B.P., 1997; Giudice, F., La Rosa, G. and Risitano, A., 2006; Graedel, T.E., 1998; Graedel, T.E., and Allenby, B.R., 1996; Guinee, J.B., 2002), these are usually focused on general products, not lighting products in particular. In addition to this, some current methodologies and tools can be time-consuming, thus not suitable for lighting product designers' tight-deadlines; and usually their implementation may not be applicable in different contexts (Guinee, J.B., 2002). This paper introduces the first stage of a new sustainable approach for designing sustainable lighting products through a real case study (lighting product) with ONA lighting company, with the final aim to develop from the on-going design process feedback an optimum, easy-to-use an effective sustainable lighting product design methodology for lighting designers.

Life-Cycle Design (LCD)

In the introduction it was mentioned the need for sustainable design methodologies/tools in order to reduce the environmental impact of lighting products. The majority of methodologies/tools already available for this purpose are based on Life-Cycle approaches (Vezzoli, C., and Manzini, E., 2008), that is, approaches that take into account the whole life-cycle of products. This holistic (or cradle to grave) approach takes into consideration every product's life cycle stages, from extraction of materials to End of Life (EOL) (Fig.1). This is necessary in order to find out and assess the total environmental impact of products; only then impacts can be reduced/eliminated.

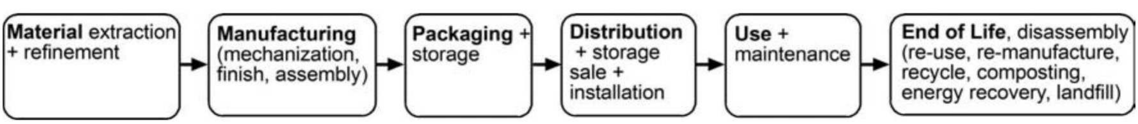


Figure 1. Lighting product life-cycle stages

One of the tools that adopts a life-cycle approach and can be used to assess the environmental impact of lighting products is the Life Cycle Assessment (LCA) tool. Today, standardization of LCA methodology has strengthen its status as perhaps the most important tool for assessing a project's overall environmental impact (Malmqvist, T. 2004). LCA-based tools can be classified in several types. In general, there are three types of LCA tools: "Prescriptive", "analytical" and databases. "Prescriptive" tools usually provide guidelines or "rules of thumb" which might be provided within manuals/handbooks, guidelines, ratings and some type of checklists, whereas "analytical" tools support the data analysis of a product system. Databases can be used alone, or to support the analysis of other software-based LCA detailed/streamlined tools. "Analytical" tools can be classified in detailed and streamlined/screening LCA tools, depending on the quantity/quality of the data assessed and the method to assess it (Finnveden, G., and Moberg, A., 2005; Vezzoli, C., 1999). Streamlined/screening LCA tools, are usually used when there are time or financial constraints, and represents a less thorough and quantitative exhaustive approach. These tools present a lot of advantages for identifying in a practical and easy (less time consuming) manner environmental strength and weaknesses within product system life cycle stages. As it will be seen in upcoming points different types (prescriptive, analytical and databases) of LCA-based tools have been used during the preliminary stages of sustainable lighting product design process.

Scope of the eco-design

The first step of the sustainable lighting design process is to define the design scope. In this case the aim of the design was to create a new sustainable lighting product, not to redesign an existent one by adding eco-features, thus this type of project could be considered an eco-innovation (Tischner, U., Schmincke, E., Rubik, F. and Prosler, M., 2000).

Problem definition

The second step of the process is to define the problem. This is defined through the briefing or specifications, which will guide the creative process. The briefing defines the boundaries or constraints that limit and filter the creative output (solutions). Thus, for solutions to be satisfactory, they will have to match or approximate the specifications stated in the briefing. Problem definition comprises a set of specifications related with criteria such as: cost, aesthetics, materials, manufacturing processes, weight etc. In the present project, these specifications were defined by ONA lighting company (ONA, 2010), according to their strategic objectives. The company wanted to develop a new lighting product taking into account a sustainable approach. Thus in addition to the usual set of specifications of a non-sustainable design project, new sustainable design specifications were added to the briefing. According to the initial briefing the product had to embody the following features:

- Modular, so it could be customized according to customer needs
- Aimed at contract/domestic markets
- Allow indoors/outdoors use (approx. IP 33)
- Provide the exact amount of light where needed, in order to avoid wasting light (and energy), so the quantity/quality/distribution of light has to be easy to control.
- Aesthetically coherent/neutral
- Allow different modular options, so customer could choose between different options using the same standard module.
- Use energy-efficient light sources
- Allow to be used as: hanging/wall/track lamp
- Allow the possibility to incorporate different type of transformers/power light sources.
- Produce different type of lights (i.e.: accent, ambient, etc.)
- *Be sustainable*: Sustainable design criteria was defined with data from legislation that affect lighting products, information from Life Cycle Assessment (LCA) carried out in other lighting products (case studies), eco-design guidelines, checklists, and rules of thumb. In the following points these elements which informed the briefing's sustainable design specifications will be explained in more detail.

Sustainable design specifications – legislation

The third step in the process is to find directives and legislation that applies and affect the design of sustainable lighting products (In Europe), in order to take them into account when creating the environmental profile of the product specifications. The main European directives are the following:

- *EuP (Energy using Products) directive* (EC, 2005): This directive will (among other things) ban the commercialization of incandescent lamps for *household lighting* as follows: (equal/more than 80 watts from 2009; equal/more than 65 watts from 2010; equal/more than 45 watts from 2011; equal/more than 7 watts from 2012; lamps with S14, S15 and S19 bases from 2013, lamps with bases E14/E27/B22d/B15d and voltages equal/less 60 volts, and lamps class C halogen energy saver. Also ban the commercialization of lamps for *street, office and industrial lighting* as follows: T8 halophosphate lamps, T12 florescent lamps, metal halide lamps from 2012, High pressure mercury lamps from 2015, and poor performing metal halide lamps from 2017. Special purpose lighting is not affected by the EU directive. Within special purpose lighting is included: Pet care-lighting: Aquariums, terrariums; Disinfection-lighting: Germicidal lamps; Display/optics: Stage and studio lamps, theatre lamps, TV lamps, studio lamps, photo lamps, projection lamps; heating-lamps: Infrared heat lamps for comfort healing, infrared heat lamps industrial applications, infrared heat lamps for animal rearing, infrared heat lamps for healthcare; Traffic/signalling: Aircraft signalling, train lighting (including signal lighting), signal lamps, automotive lighting/lamps; household appliances: Oven lamps, fridge lamps; other: temperature and shock proof lamps, mirror lamps.

- *The Waste Electrical and Electronic Equipment (WEEE) directive* (EC, 2002): It affects any importer, re-brander or manufacturer of products that requires electricity for its main purpose. These will have to finance the cost of treating (i.e.: mercury in lamps, PCB in ballasts, etc.) and recovering the types of products you import, re-brand or manufacture. For this purpose all these products should be marked.
- *The Restriction of Hazardous Substances (RoHS) regulations in Electrical and Electronic Equipment directive* (EC, 2002): This directive is concerned with the avoidance in products of some harmful substances such as: lead, mercury, cadmium, hexavalent chromium and brominated flame-retardants: PBB and PBDE.
- *The Packaging and Packaging waste directive* (EC, 1994): Its main objectives are: reduce packaging material excess, to eliminate/avoid specific hazardous substances/materials, inform the consumers about content of product/packaging, reduce the amount of waste at end of life of the packaging, to increase/promote the re-use and recycle of packaging waste, translate to the producer/manufacturer the responsibility to recuperate and recycle its packaging. This directive is not specific to lighting products only, and affects any type of product that uses any type (primary/secondary) of packaging.

Sustainable design specifications – case studies

The fourth step is to inform the sustainable design spec. with the usual highest environmental impacts of lighting products and the correspondent eco-design recommendations after the assessment. Because the aim of this project is to create an eco-innovation, not to re-design an existent product, it is necessary to create an "imaginary reference" (with ideal sustainable lighting product specifications) which will be used as a reference to create the new eco-innovation. In order to do this, environmental impact assessment results carried out in other lighting products (of similar type, if possible) have to be analysed, and highest impacts found taken into account as a "general" reference or points for improvement in the briefing.

The case studies (2) results analysed were assessed using the streamlined life-cycle assessment tool eVerdEE. The first case study (Profile lighting Ltd and Eco-SMEs, 2010) consisted in the assessment of a recessed fluorescent luminary (Ambience T5 luminary, from Profile lighting Ltd.) for use in offices and other commercial buildings. The luminary was made of powder-coated Zintec body with an aluminium reflective louvre and four 14-Watt fluorescent lamps, together with a number of other smaller components. High-frequency electronic ballast controls the start-up and operation of the luminary. Although the assessment shows that major impacts are focused on manufacturing of some components (85% of the total weight of the product), usually the major impact on energy-using products is focused on its use phase. However this simplified assessment did not take into account this stage, so the manufacturing stage becomes the one with highest impact.

Eco-design recommendations of this product were the following: 1) use aluminium or plastic instead of Zintec, as this is lighter, require less material, have good corrosion properties and is easier to recycle; 2) local sourcing of materials and components; 3) reduce overall volume of product and components; 4) reduce energy demand during the use-phase: by using energy-efficient light sources (i.e.: LEDs or more efficient fluorescent lamps), design of the lighting product so it can be sourced from renewable energies (i.e.: solar, wind, human) during its use, or incorporating automatic heat sensors to be more energy-efficient; 5) establish take back systems should be established /adopted in order to re-use/recycle materials and components; 6) reduce the number of different materials; 7) coating should be removed, or use compatible coatings with the base material; 8) use as less material (in case of using aluminium) as possible or use recycled aluminium; 9) avoid use of lead in components and welding.

The second case study (Urbis Lighting and Eco-SMEs, 2010) consisted in the assessment of a street lantern (Sapphire 1 street lantern, from Urbis Lighting). The luminary was made of die cast painted aluminium canopy, metallised polycarbonate reflector, polycarbonate protector, High Intensity Discharge (HDI) ballast, 50-Watt lamp, and various fasteners and moulded parts. Although the assessment shows that major impacts are focused on manufacturing of some components, usually the major impact on energy-using products is focused on its use phase. However this simplified assessment did not take into account this stage, so the manufacturing stage becomes the one with highest impact. Eco-design recommendations for this product were the following: 1) investigate ways of re-using the product main material (aluminium); 2) investigate ways to reduce the consume of non-renewable energy and encourage the use of renewable energies; 3) virgin aluminium material should be minimized by: Replacing virgin with recycled aluminium, reducing the size of the canopy, Investigate replacing aluminium with plastic or steel; 4) replace aluminium with other material which does not need coating (i.e.: plastic); 5) avoid use of lead in components and welding; 6) reduce ballast size, or use electronic ballasts which are more efficient and smaller; 7) use as few different materials as possible; 8) sourcing of local materials and components.

Sustainable design specifications – design guidelines, checklists, rules of thumb

The fifth step is to inform the sustainable design spec. with sustainable design guidelines, checklists and rules of thumb. Usually, in eco-redesigns, the environmental profile is created from the environmental impact assessment carried out in reference products (Tischner, U., Schmincke, E., Rubik, F. and Prosler, M., 2000). However, when eco-design action is focused on creating new eco-innovations, the environmental profile of the product cannot be informed from a reference product (from own company/other companies catalogue), but from the "imaginary" profile created by the company, which will contain ideal/desired specifications to be embodied in the solution. This set of ideal/desired sustainable design features, will be defined/supported by sustainable design guidelines, rules of thumb and checklists (Chitale, A.K., and Gupta, R.C., 2007; Eco SMEs, 2010; Gn-Teknik, The Institute For Product Development (IPU) and Danish Toxicology Centre (DTC), 2005; IDSA, 2010; Jedlicka, W., 2009; Jedlicka, W., 2010; Meinders, H.-.P., 1997; Nordkil, T., 1998; Shedroff, N., 2009; SIEMENS, 2000-2004; Tischner, U., Dietz, B. and Mabelter, S., 2000; UNEP and Delft University of Technology, 2006; Vezzoli, C., and Manzini, E., 2008; Yarwood, J.M., and Eagan, P.D., 1998). Whilst using reference (existent) products for eco-redesign makes sense, as new re-designs need a reference in order to compare improvements of re-designed products. Using reference-products may not benefit the design of *new* eco-innovations; due to the influence these references may cause in the solution (similar solutions may appear). The possible similarity of new designed solutions may be influenced by the need to have similar features embodied in both designs for comparative purposes, which is necessary in order to measure the success of the eco-design action.

The main (summarized) sustainable design spec. informed from design guidelines, checklists and rules of thumb classified by product life-cycle stage were the following:

<u>Raw material extraction and refinement stage:</u> Use as few materials as possible; use recycled/recyclable materials; use one/few quantity/type of materials in the same product; avoid the use of banned/toxic materials; source local materials, use materials which have established recycling facilities, use materials which are fit for purpose; when choosing recycled materials select post-consumer recycled waste, avoid the use of adhesives (specially solvent-based); Use light materials (low density); if using more than one material, they should be compatible for recycling; use materials that are durable (depending on design purpose), choose materials that achieve aesthetical properties over time; choose materials that do not require energy-intensive processes to be shaped, avoid composites/other thermo stable plastics, avoid using scarce/limited materials; avoid use energy-intensive extraction/refinement materials.

<u>Manufacturing (mechanization, finish, assembly) stage:</u> Avoid energy-intensive processes; choose processes that do not waste material, or recycle the material wasted (pre-consumer waste); choose processes that do not create harming emissions, use processes that do not produce liquid and solid waste, choose processes that use water and energy efficiently (if at all); choose processes that use renewable energies; design components that are multifunctional, specify re-manufactured components, design component with minimum volume.

<u>Packaging and storage stage:</u> Avoid the use of packaging if possible; design packaging with minimum weight and volume, design packaging to be re-used/recycled; avoid solvent-based inks in printed areas, use the required packaging for protection (not over package), other criteria from previous stages already mentioned also applies here, as packaging is a product in itself.

<u>Distribution, storage, sale and installation stage:</u> Choose efficient transport means (ship), avoid air transport; design efficient distribution/logistic systems; use transport which avoid damage of goods; provide instructions for installation and use to extend the life of the product.

<u>Use and maintenance stage:</u> Design modular products so parts/components can be up dated/repaired; design easy to dismantle products to encourage upgrade/repair of parts; provide spare parts/components as

well as a list with the product's components and the commercial references; provide customer service; design product which are dirt-resistant and easy to clean; design products that require little maintenance; indicate on the product how it should be opened for cleaning or repair; use solar/motion sensors or timers, dimmers to reduce the amount of energy used at different times; use energy-efficient light sources; use energy-efficient drivers; standardize components; locate components that might wear out in accessible areas; design products with devices that allow to control the quantity/quality of light in order to use the exact quantity/quality needed for each purpose; specify best-in-class energy efficiency components; permit users to turn off systems in individuals units, or as a whole; eliminate unused or unnecessary product features; identify and eliminate possible weak points of the product; design products for safe/self-explanatory use; for energy-using products, this is usually the most relevant phase from an environmental point of view.

End of Life (disassembly, re-use, recycling, re-manufacture, energy recovery, composting, landfill): Design products that can be separated by material (if there is more than one); avoid adhesives to join components; use as few fasteners as possible; use the same type of fasteners; use fasteners which do not require tools, or require standard tools; avoid welding joints, only join permanently materials that can are compatible for recycling; design products so different parts with materials can be separated easily and re-use/remanufactures/recycled depending on the component; reduce disassembly number of steps; avoid the use of paints or other surface finishes; avoid the use of labels, use emboss to mark components; use one single material for all the components, if possible; minimize the number and length of wires; use one disassembly direction to avoid reorientation; design for multiple detachments with one operation; facilitate reuse/recycling by using standard codes for identification (labelling) of materials/components; design the product so it does not need to be dismantled to be recycled; minimize the use of energy-intensive process steps in disassembly; the cost of disassembly has to be less than the cost of the material recycled; make sure that joining points are easily accessible and there is enough space to allow disassembly with tools; include symbols or pictograms to inform about disassembly process; use detachable joints such as snap-fit, screw or bayonet joints instead of welded, glued or soldered connections; use joining systems that can be dismantled after long periods of use; include symbols/pictograms to inform about disassembly process; try to concentrate in one area all components that can be recycled; avoid use of joints that require energy-dependent tools for disassembly;

Solution

The sixth step was to produce solutions informed by specifications (company and sustainable design spec.) mentioned in previous points. The concept which matched higher number of criteria from the total spec. was selected and developed in more detailed sketches (Figs: 2 and 3). In the images below it is explained the rationale of design features selected, and how they contribute to the sustainability of the lighting product. The concept selected was a modular lamp made of extruded post-consumer recycled aluminum (majority of the lamp) with no coatings. The source of light were LEDs feed with energy-efficient electronic drivers, which could be chosen with/without dimmers, and for different LEDs wattages depending on lamp model, price and customer requirements. The housing dimensions were designed to contain a wide range of drivers and LEDs types in order to allow customization and upgrading of components over time. Lighting units can be rotated 360 degrees (x axis) individually, and the whole lamp 360 degrees (Y axis), this altogether with the possibility to use different LEDs power in each unit allows flexibility of light distribution and intensity by the user. All units (lighting + transformer units) use the same extrusion matrix, thus saving energy and costs. The extrusion profile also allowed building several functionalities in one single component, thus reducing the number of components. All electronic components are installed in one tray which can be easily repaired/upgraded or separated at the End of Life (EOL). The weight and volume was reduced by using LEDs (requires small volume) and aluminum (light material).

Environmental impact assessment of the solution

The eight step was to assess the environmental impact of the product with Sustainable Minds (Sustainable Minds, 2010), a Life Cycle Assessment (LCA) software-based tool which is adopts Okala methodology (IDSA, 2010). This tool has been designed to carry out streamlined/screening assessments, during/after the design process. Therefore is very suitable for the initial stages of the sustainable design process, when initial proposals have to be assessed and modified along the design process. This LCA tool does not carry out a full detailed analysis; and although it is more reliable than matrix-based LCA tools, which rely on qualitative-subjective assessments, still is not totally objective and results should only used to guide decision making and not as a rule. A serial of assessments were carried out and results showed that total impact of the product using aluminum was very high.

Although recycling of aluminum was not considered in the first assessments, as usually there are no collection points established, the last assessments carried out not only considered the use of secondary (recycled) aluminum but also the collection of this to be recycled, resulting also in high impact. After these considerations, an analysis was carried out using secondary High Density Polyethylene (HDPE) which was also recycled at the End of Life (EOL) to check if this material was more suitable. The second option using HDPE resulted in much lower impact (Fig. 4) 65 against 100 in the aluminum version. Furthermore it was observed that impact differences were not dependent on the material used (in trials with recycled versions) but in the manufacturing (extrusion) process (Fig. 5), being more energy-intensive in the case of using aluminum than using plastic. In addition to this, the highest impact phase, as expected in energy-using products, was the use phase, followed by manufacturing. It has to be noted that packaging and LEDs + drivers was not considered in the assessment. The assessments provided useful data to inform possible modifications (Re-design) of product's materials.

Approach framework

As it can be seen in the conceptual framework (Fig. 6), the sustainable lighting product design approach implemented begins with a life-cycle or systems perspective, which takes into account every stage of the life-cycle of the product, thus creating awareness of the impact that might be caused in every single process/activity along the lighting product's life. Once an overall perspective is understood, the scope of the eco-design action is decided. The present case was focused on eco-innovation, not eco-redesign, thus there was no "reference" product to assess and compare to create the briefing; Instead, an "ideal reference" product was created in the briefing (problem definition), which comprised: traditional spec. (typical in other product design processes) and sustainable lighting product spec., being the latter informed by legislation-directives, Life Cycle Assessment (LCA) case studies, eco-design guidelines, checklists and rules of thumb related with lighting products. Problem solutions were then created to match or approximate both types of design spec; Solutions closer to fulfilment of all specs. were then selected and described in a process-tree (where boundaries were set) in order to understand the quantity/quality of processes and materials used, which were required for the screening/streamlined preliminary LCA carried out by software-based tools. Results from this assessment not only informed total impact of the product, and where (in which stage) took place, but also assisted in trying "what if" scenarios by modifying materials and processes and observing the effect these changes have in the total impact. This stage informed (feedback) the creation/modification of improved solutions in a continuous loop.

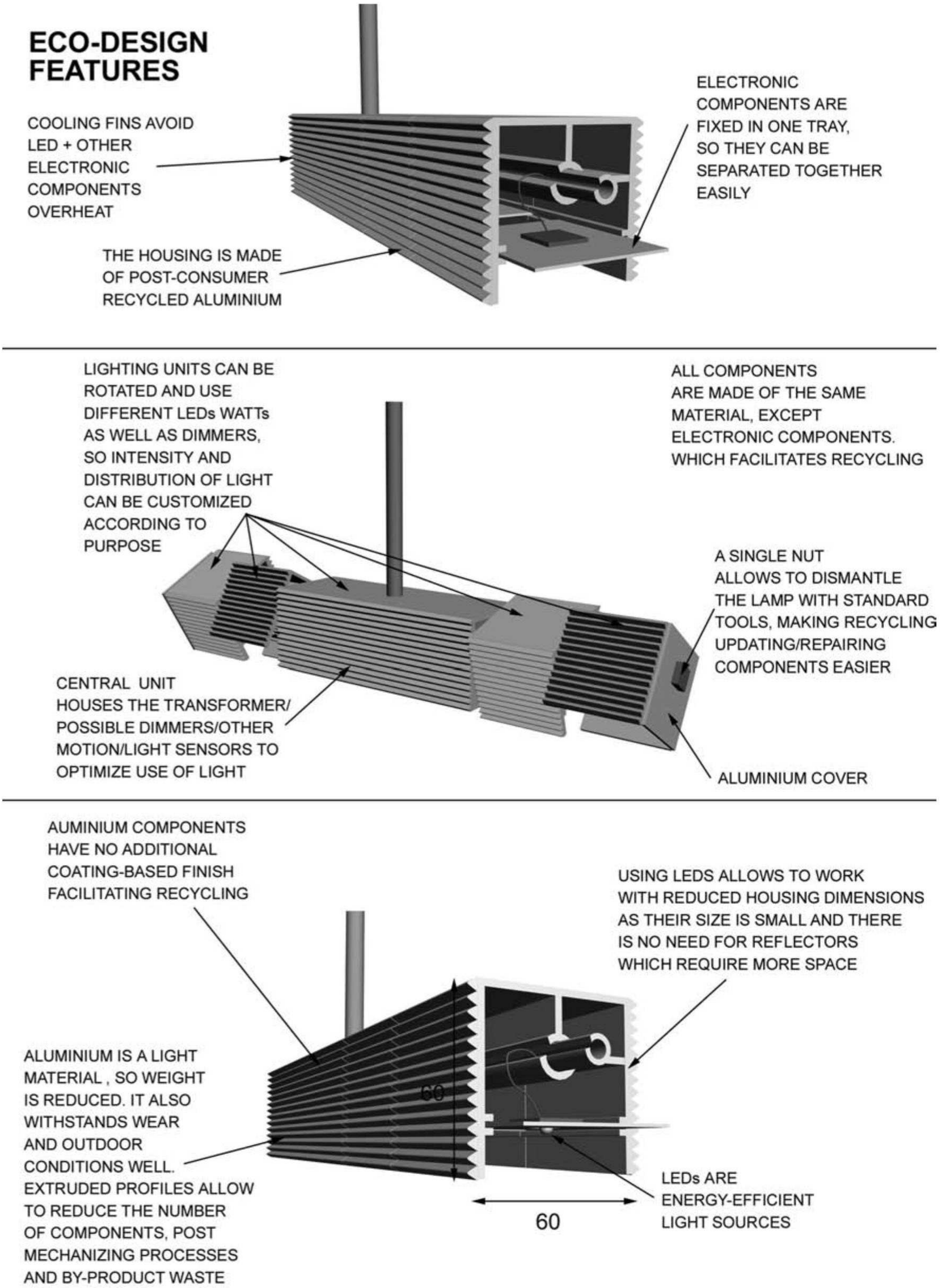


Figure 2: Lighting product eco-design features

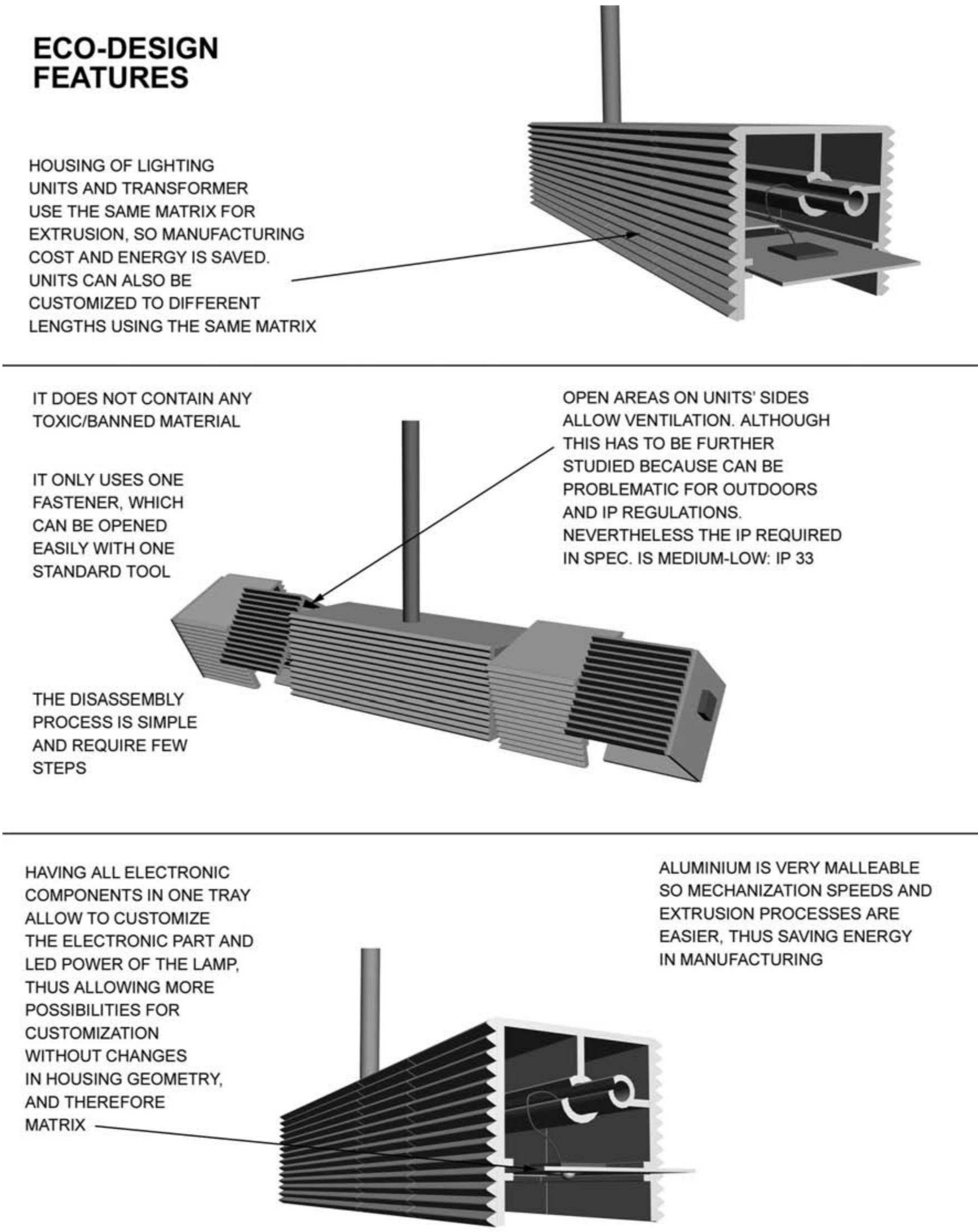


Figure 3: Lighting product eco-design features

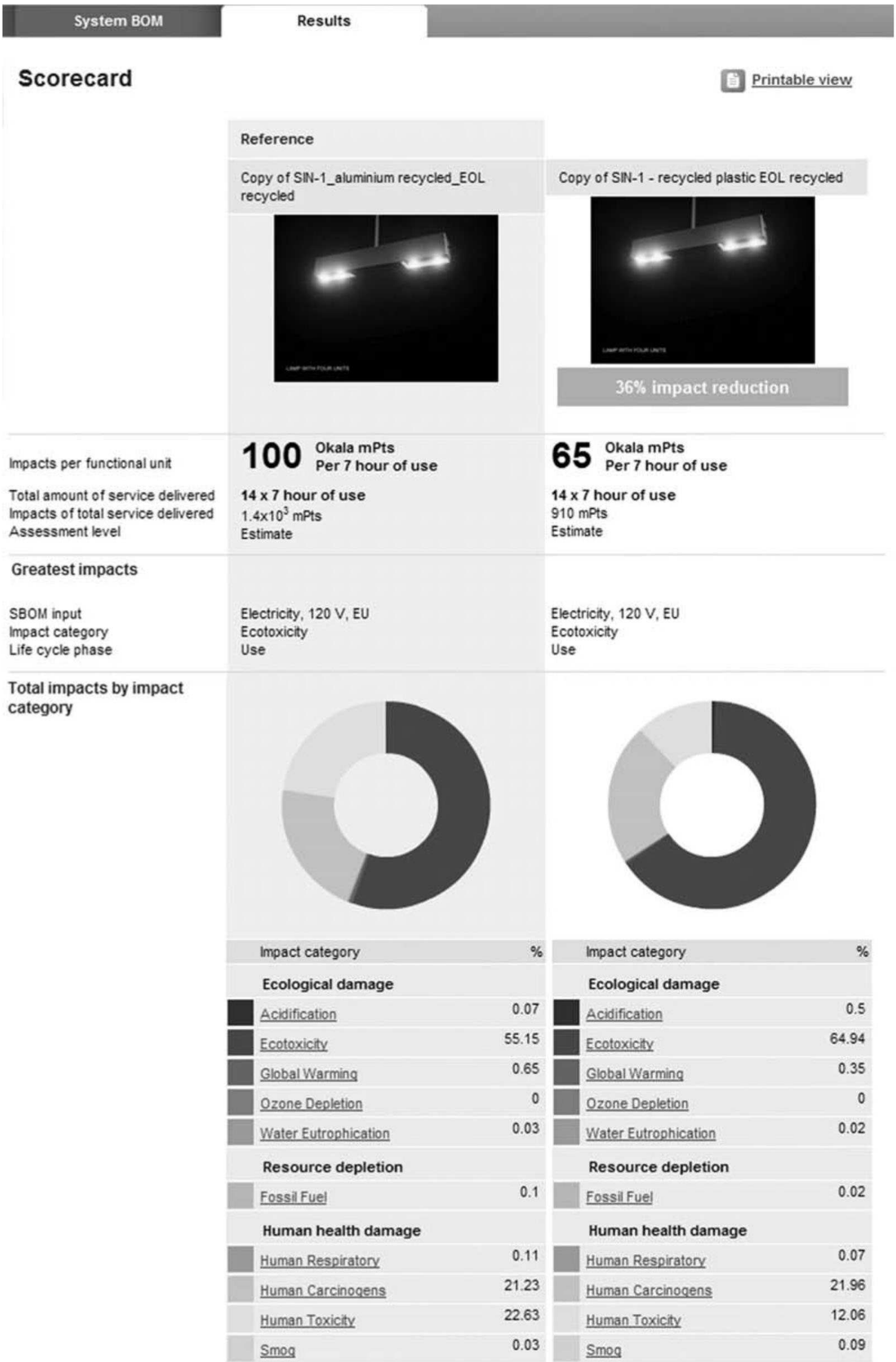
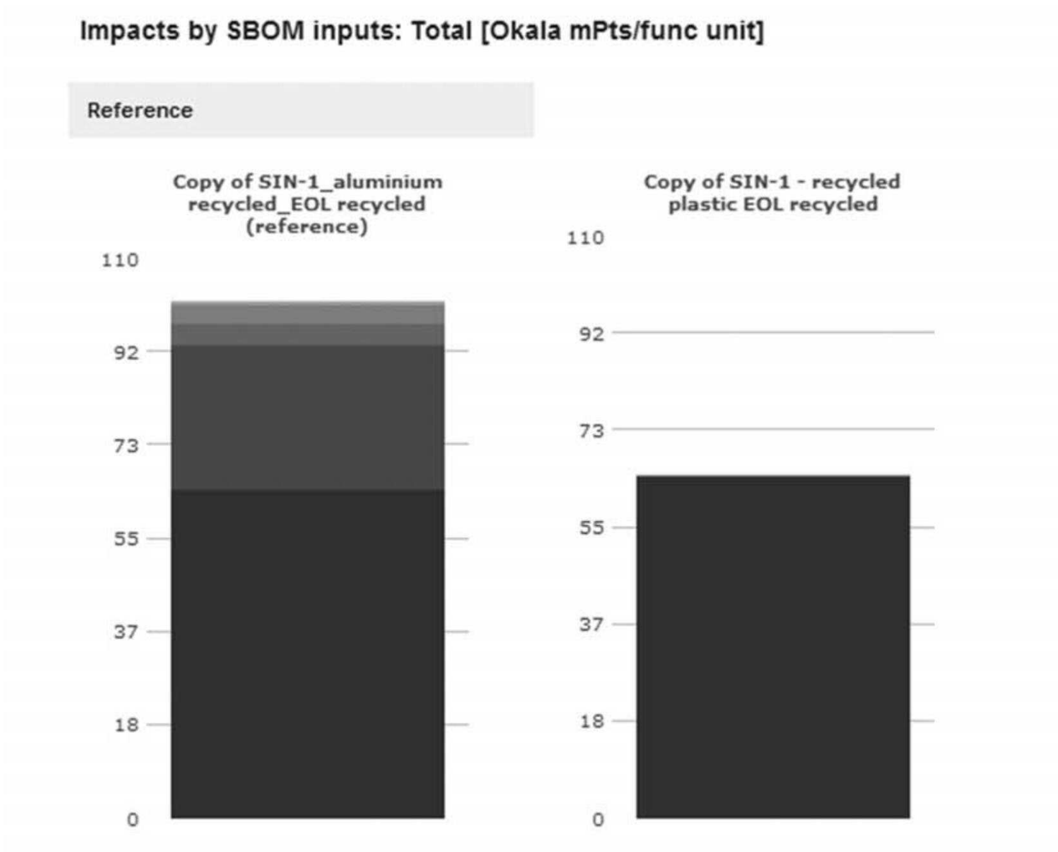


Figure 4: Environmental impact assessment and comparison of results using different materials (using impact category and total Okala score)



Total = 100 Okala mPts/func unit

Input	mPts/func unit
Use - Electricity, 120 V, EU	64.6
Process - Aluminum, secondary, old scrap: Extruding alum	28.4
Process - Aluminum, secondary, old scrap: Extruding alum	4.21
Process - Aluminum, secondary, old scrap: Extruding alum	3.68
Material - Aluminum, secondary, old scrap	0.605
Material - Aluminum, secondary, old scrap	0.0897
Material - Aluminum, secondary, old scrap	0.0785
Process - Aluminum, secondary, old scrap: Sheet rolling, al	0.0550
Material - Aluminum, secondary, old scrap	0.0448
Material - Aluminum, secondary, old scrap	0.0336

Total = 65 Okala mPts/func unit

Input	mPts/func unit
Use - Electricity, 120 V, EU	64.6
Process - Polyethylene, high density (HDPE), secondary: Extrusion, solids	0.267
Material - Polyethylene, high density (HDPE), secondary	0.0549
Process - Polyethylene, high density (HDPE), secondary: Extrusion, solids	0.0396
Process - Polyethylene, high density (HDPE), secondary: Extrusion, solids	0.0346
Process - Polyethylene, high density (HDPE), secondary: Calendering, rigid sheet	0.0202
Process - Polyethylene, high density (HDPE), secondary: Calendering, rigid sheet	0.0151
Material - Polyethylene, high density (HDPE), secondary	0.00814
Material - Polyethylene, high density (HDPE), secondary	0.00712
Material - Polyethylene, high density (HDPE), secondary	0.00407

Figure 5: Environmental impact assessment and comparison of results using different materials (using part + process input)

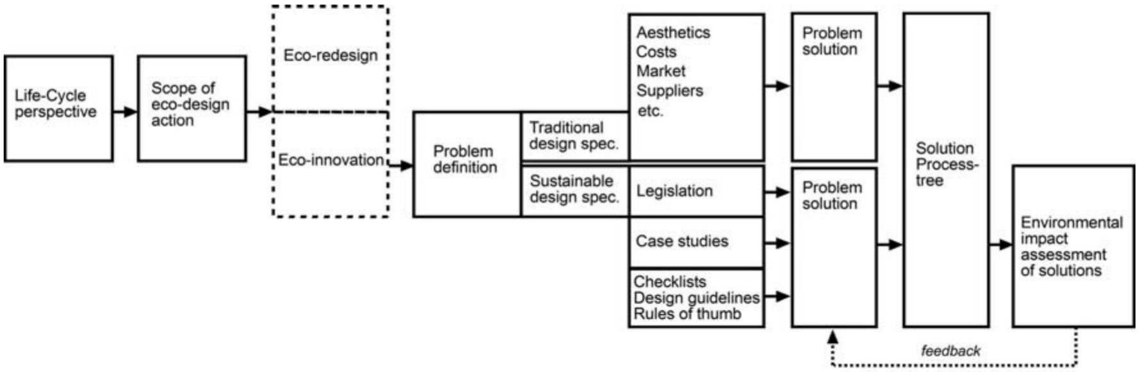


Figure 6. Approach framework.

Conclusion

This paper has shown through a case study the first stages of the development of a new approach for an on-going sustainable lighting product design. This approach has adopted a life-cycle perspective and has focused on eco-innovation where, unlike usual eco-design actions (eco-redesign), products are not taken as a reference to build the briefing or specifications. This fact creates the need to build an initial "ideal reference" with specifications from company's product strategy and sustainable lighting product design criteria; the latter being obtained from sustainable best practices, case studies, eco-design guidelines, checklist and rules of thumb. This methodology allows greater possibilities for eco-innovative lighting products, opening possibilities at the beginning of the design process, whilst keeping in mind sustainable design criteria. It also allows the possibility to "narrow down" or refine concepts through Life Cycle Assessment (LCA) screening/streamlined tools in order to find out quantitatively total impacts per product, and where (which phase) these take place, in order to make design modifications to reduce the total impact. This iterative loop of synthesis-analysis, aims to eliminate/reduce the impact of lighting products at the initial stages of the design process. However, this approach does not consider social impact, so it does not reflect a comprehensive sustainable assessment. In addition, although LCA screening/streamlined software-based tools suggested useful information having an effect in changes in the material used which were not detected after following design guidelines; these (because are simplified tools) may not offer reliable data and may provide quantitatively misleading data in an effort for simplifying a very complex assessment indeed. It remains a mystery to know how the scores of each material and process used in this software have been obtained and how these can be applied (generalised) to any context, when impacts are strongly dependent on context. Furthermore different software-based tools can provide different results?; confirming the problem of using simplified scores, and pointing out the core importance of databases and characterization and weighting methodologies. Nevertheless, they provide another aid to guide the complex sustainable design process.

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