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Understanding requirements for a holistic tool for Ecodesign-first steps

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ABSTRACT

Today, technological developments increase very fast and plenty of hi-tech products are seen in the global market. With the influence of consumerism, these products are sold frequently and their life cycles become shorter. Hence, they have already begun to accumulate at the garbage dumps. Many of these products, such as electronic and electrical equipment (EEE) have a significant negative impact on the environment and the human health and cause resource depletion. Ecodesign is used as a set of proactive strategies which aims to reduce the total environmental impact of a product at the design stage and leads to sustainability. There are many methods and tools for ecodesign. Although they are widespread, they can not cover all design phases and there are still shortcomings in the tools for engineering designers as to accomplish ecodesign. To understand the requirements of designers in order to succeed in the ecodesign process, design experts from academia and experts from EEE producing companies have been surveyed. The results of the surveys can help to set up general requirements for the development of a holistic ecodesign tool.

Key words: Ecodesign Requirements, Sustainable Product Development, Engineering Design

INTRODUCTION

One of today's major environmental problems is the increase of wastes generated by high-tech products such as electronic and electrical equipment (EEE). Their fast expansion is driven by technological developments and consumerism. These products are sold frequently and their life cycles keep on decreasing in length. Hence, wastes of such products have already begun to accumulate at the garbage dumps because of this fast expansion. This accumulation comes along with significant negative impact on the environment and the human health. Electronic and electrical products such as mobile phones, mp3 players or tablet PCs for example, contain toxic materials that can merge into soil, water or to the air when they are landfilled or components are incinerated at their end of life. Further, components commonly found in EEE devices include lead, mercury, beryllium, barium, hexavalent chromium, cadmium, arsenic, nickel, zinc, and brominated fire retardants (BFR) in the plastics (Widmer et al., 2005). All people in direct contact with these substances classified as toxic substances catch serious, sometimes fatal diseases (Tsydenova et al., 2011). Non-environmentally and excessive production of such sort of products cause another Problem: resource depletion. Valuable metals and different types of energy, which are non-renewable resources, are consumed consistently. Many countries have promulgated legislation for particular product types, such as (WEEE, 2008; RoHS, 2008; EuP 2005; or ELV, 2000) to cope with these environmental problems. The implementation of these legislations regulates the improvement of reuse, recycling and other forms of recovery of wastes by giving quotes for permissible wastes, restricting the use of toxic substances or energy consumption during use (Gurauskienė et al., 2006). In order to improve the environmental performance of products through their whole life cycle stages, ecodesign methods and tools can be used by which environmental improvement potentials can be determined. By applying proactive ecodesign strategies product improvements can be realized and the total environmental impact of a product can

be reduced (Platcheck et al., 2008). However, existing ecodesign tools and methods pose an additional workload for engineering designers during the product development process. Experiences with industry have shown that this additional workload is one reason for the denial of the use of such tools. The incompatibility of some tools with the design and product development process may be another reason. While many tools are optimized to deliver good results discretely along the design process, the feedback gained from the conducted ecodesign analysis sometimes cannot be implemented in the same product development loop: the feedback may then be implemented in the next product concept or through a product improvement process. Many environmental evaluation tools require information which may not be available in the early stages of product design, when requirements are set and concepts are developed. Once the required information is available, the flexibility to change the design of the product for which the evaluation is carried out is strongly restricted, a phenomenon that is referred as to "design paradox" (Lindahl. M 2005). This may be a reason why the environmental parameter is pushed into the background in the spotlight of other design parameters such as functionality, quality, safety, ergonomics, aesthetics and costs to be optimized during the design process. Considering the environmental parameter through the design process is still by far not a matter of course but is rather regarded as an add-on allowing some competitive advantage.

There have been some efforts to provide ecodesign tools which can be used along the design process continuously. Lutropp et al (2006) differ between tools which can be used before the product specification phase and those to be used after product specification. The listing should be understood as a set of different tools suitable for different phases rather than a single tool. Lofthouse (2006) defines general requirements for ecodesign tools. Collado and Ghorabi have proposed an approach to compare the environmental performance of similar products already in early design stages (Collado, Ghorabi, Fuon., 2010). When aiming at developing one holistic ecodesign tool which can assist engineering designers through the entire design process, from product specification phase to prototyping, the requirements of designers regarding such tools have to be understood. Ecodesign requires cross-functional cooperation of the different departments in the company itself and integrates the external cooperation with partners (consumers, suppliers, recyclers, etc.) (Karlsson, Luttropp, 2006; Hera., 2007). In this paper, design experts from academia and industry have been surveyed and their expectations and requirements considering ecodesign tools have been analyzed. The results of the analysis shall be taken into considerations for the development of any new tool in future.

ECODESIGN METHODS & TOOLS

Since the early 1990s, different ecodesign methods and tools have been developed (Byggeth, Hochschorner., 2006). They are used for evaluating the environmental impacts of products and services over their life cycle and assist in finding strategies for the improvement of their environmental performance (Pigosso et al., 2010).

Methods are used for evaluating environmental impacts and defining the potential problems. Methods mainly used in Ecodesign are Life Cycle Assessment (LCA), Brainstorming, Configuration Management, Failure Mode Effect Analysis (FMEA), Quality Function Deployment (QfD) or TRIZ (Gurauskienė., 2006), (Gurauskienė., 2006; Sakao., 2007). Apart of the mentioned methods, companies use their own tools developed for their specific product development processes. Engineering designers can choose from a pool of different methods and tools to proceed in the ecodesign process of their product.

However, some of these methods and tools are not ecodesign specific and they can be used in any other design process. Moreover, even if they are used exclusively in the ecodesign process, designers may utilize them in different phases. The ecodesign process may raise additional concerns, i.e, environmental, economical or societal concerns, which need to be addressed among traditional design aspects (Luttropp., 1999).

The interaction of tools between the traditional design process and the ecodesign process may be a source for additional workload in the design process and a reason for the denial of ecodesign tools. Most ecodesign tools were optimized for being used after the product specification phase. However, the main parameters, e.g. product properties, functions etc., are defined earlier, when the specification is written. Hardly any ecodesign tool is suitable for the early product development phase when specifications are established (Karlsson., 2006). While brainstorming, trend studies, market research, benchmarking, checklists and guidelines are used in the early design phases for identifying needs, planning and conceptualizing design phases, other tools such as LCA, FMEA, QFD, TRIZ are developed to be used in the mid and late design phases. The latter mentioned tools require product information which becomes available in detailed design phases or during embodiment/prototyping.

Experiences gained through projects with companies which were starting to integrate ecodesign tools show that customized solutions deliver short-term results. In other words, a specific tool may be used in the one or other project, but barely became an integrative tool within the design process. The reasons therefore were stated to be: additional workload, incompatibility with the design process, complex data structure or high amount of data to be handled. For a long-term strategic ecodesign planning, more holistic tools and method integration seem to be needed (Pamminger., 2006). By researching available tools, it is clearly seen that there is a lack of a holistic ecodesign tool, which can consider the environmental aspect of all design phases and through all design activities. Thanks to the increasing interest in the concept of "environmental friendly products", tools for ecodesign became widespread. Nevertheless, being widespread does not mean fulfilling all the requirements of the ecodesign process. According to Lofthouse (Lofthouse., 2006) many of these tools lack in providing necessary information, specification and goal setting in the early design phases. These tools are mostly generic tools and don't give detailed assistance for some groups of products. Another problematic aspect of many available ecodesign tools is that they do not value the economical and social aspects of the product and focus solely on ecological parameters.

Ecodesign is a concept that integrates multifaceted aspects of design and environmental considerations (Karlsson., 2006). However, ecodesign tools are insufficient to consider the design process as a whole and to meet the definition of the concept. They should combine every possible aspects of production by prioritizing the "green" ones.

SURVEY

The survey is conducted in order to better understand the requirements of engineering designers to successfully implement ecodesign and strive for sustainable products. This survey can be seen as the first step of a long term study which aims to generate a holistic ecodesign toolbox. The survey questionnaire is completed by eleven engineering designers/experts working in international industrial and academics environment. Seven of the experts are from academia and the rest of them are working in private sector as industrial designers. The least experienced expert has only two years of background on design. The average experience year among the experts is 9.5 years. These people are chosen thanks to their ability to give actual valuable insight in their work. The survey starts with the investigation of the experts' background on ecodesign and sustainable product development. According to their answers, the survey is branched in two parts, for experienced and non-experienced designers in ecodesign.

For those who have already experience, the quality of their experiences, the methods they used and their tool requirements for different types of customers are asked. The designers with no experience in the field are asked why they have never used ecodesign tools and methods before and what they would need in order to use them. Both groups of designers were asked about their personal requirements to undertake an ecodesign process, the priority and importance of each requirement; their driving forces to start the ecodesign process, the possible tools to provide guidance and the departments needed to cooperate in order to succeed in the ecodesign process.

KEY REQUIREMENTS

Key aspects surveyed within the questionnaire were information, motivation, multi-disciplinary cooperation and creative environments in different ecodesign phases and context. These possible requirements are determined by having regard to related literature (Lofthouse., 2006) and with the consensus of the authors of this paper. They are discussed in the following.

INFORMATION

Providing the right information to designers for ecodesign is not an easy mission. There is a lot of information, which has to be considered when a designer wants to develop a new electrical or electronic product. The information has to be kept up to date to be useful at all. There are legislations, like the EU directives (WEEE., 2008; RoHS, 2008; EuP/ErP 2005), which have to be kept in mind.

And there are some additional requirements to be fulfilled, if it is an aim to get an eco-label like the EU Ecolabel (http://ec.europa.eu/environment/ecolabel/index_en.htm), the Blue Angel (http://www.blauer-engel.de/en/index.php), the Green Seal (http://www.greenseal.org/) or one of the many others. The major challenge is to offer the really valuable information at the right moment, in a way the designer is not too overwhelmed with technical and scientific terms or by the large amount of text or data that has to be processed. It is rather helpful to provide it in a visual way with a possibility to find further information, when needed (Lofthouse., 2006), (Ghorabi., 2009). Many designers find it useful to find examples for well-designed sustainable products and to have some benchmark information fore hand. Some efforts in this direction have been undertaken by Colladoz, and Ghorabi (2010). The crucial parameter is time. Any tool that is to be used in the design process has to save time and should not add to workload. Any kind of guidance is helpful and crucial: to guide where, when and how to start with the ecodesign process or which parts and components to consider first.

MULTI-DISCIPLINARY COOPERATION

With increasing complexity of a product's function and structure, product multi-disciplinary cooperation design becomes fairly necessary. Multi-disciplinary cooperation is about a conversation between departments, marketing teams, distribution chains, designers, engineers and manufacturers. Multi-disciplinary cooperative environments play an important role in idea generation and new product conceptualization. They improve the creative competencies and allow rich combinations of disconnected pools of ideas. They seem to conduce to better use of limited research capacities and the development of valuable and more radical ideas and solutions. Therefore, they are more effective in the pursuit of creativity, innovation and product development (Alves et al., 2007). As mentioned before, ecodesign has multifaceted aspects, such as economy, ergonomics, aesthetics, quality, performance and functionality (Karlsson, Luttropp., 2006). That is why designers should be in cooperation with other disciplines to get the required data and information while designing environmentally friendly products.

MOTIVATION

According to the application of ecodesign and product development in a company, the organization must assess factors regarding the company (internal) and the environment (external) (Borchardt, 2009). The motivation to conduct ecodesign in a company may come from internal and/or external drivers and can also be pushed by government, business partners, regulations, citizen groups, associations or customers' needs.

Designers are personally motivated by the sense of professionalism, problem solving and opportunities to be creative in the design process (Salter, Gann, 2003). For the ecodesign process, designers need additional motivation in order to overcome the pressure on them to change their usual working patterns and design habits.

CREATIVE ENVIRONMENT

Designing products with reduced environmental impacts will require the highest levels of creativity, the use of both

traditional and advanced technologies, and the collaboration of many diverse organizations. However, preserving the environment for future generations seems like a good reason for being creative and innovative (Roy, 2010).

Within such framework, the ecodesign process is based upon creativity and innovation in productive cycles. Designers and companies focus solely on the design phase, in a completely innovative way and with the possibility to use recycled materials (di Maschio, 2010).

This new environmental awareness is strictly connected with creativity and innovation. Creative design and breakthrough innovations in EEE companies are necessary for a rapid shift to an economically sustainable path (Fiksel, 2099). To reach the creative design, the designers require an adequate environment which can improve their creativity.

SURVEY RESULTS

In the survey conducted, the experts were asked 14 questions. However, in this chapter, only the most remarkable and representative ones which show the main direction of the study will be elaborated with the answers. 55% of the experts, 3 from industry and 3 from academia, who answered the survey questions, have used ecodesign methods and tools, and 4 of them stated that although they didn't use any ecodesign method and tool, they have already knowledge about ecodesign. According to the answers, the most important driving force for all designers to implement ecodesign is the environmental concern. If they didn't use any of the ecodesign methods and tools, the reason is mostly the additional workload. Designers mostly require multi-disciplinary cooperation with different departments and information to proceed with ecodesign, with 64% of experts' choice (see Figure 1). However the importance that the designers attach to the motivation as a requirement is higher than multi-disciplinary cooperation and information. As seen in Figure 2, the experts mostly voted for 1 about the motivation, in a scale of 1 to 5, from the most important to the least one. These results can be interpreted in the way that designers need multi-disciplinary cooperation and information in order to accomplish successfully the ecodesign process. However, to change their usual working patterns, they think they first need motivation.

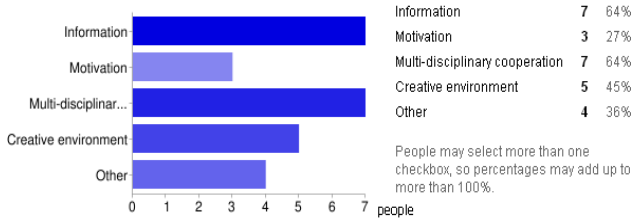

Figure 1. Designers' requirements

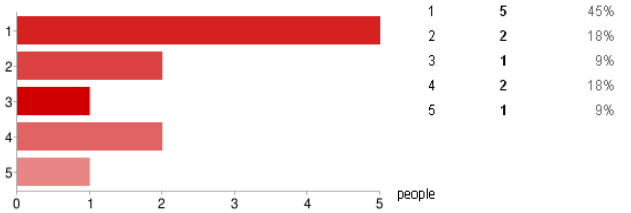

Figure 2. The importance ranking of requirements Motivation results

Designers need market and benchmark information for their sector more than legislations, ecolabel instructions and environmental impact categories, even in the ecodesign process (see Figure 3).

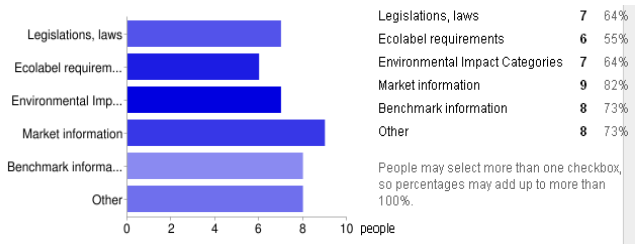

Figure 3. Different types of information that designers may need in ecodesign

As the cooperation with other departments, the cooperation with the production and environmental departments (see Figure 4) are highly required.

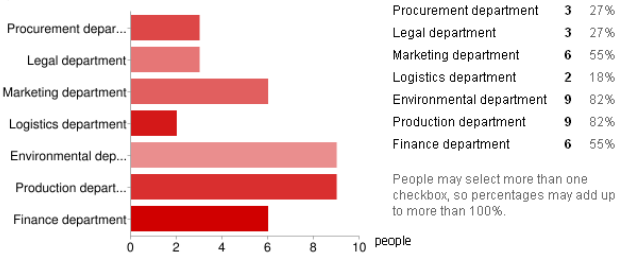

Figure 4. Different departments worked in cooperation

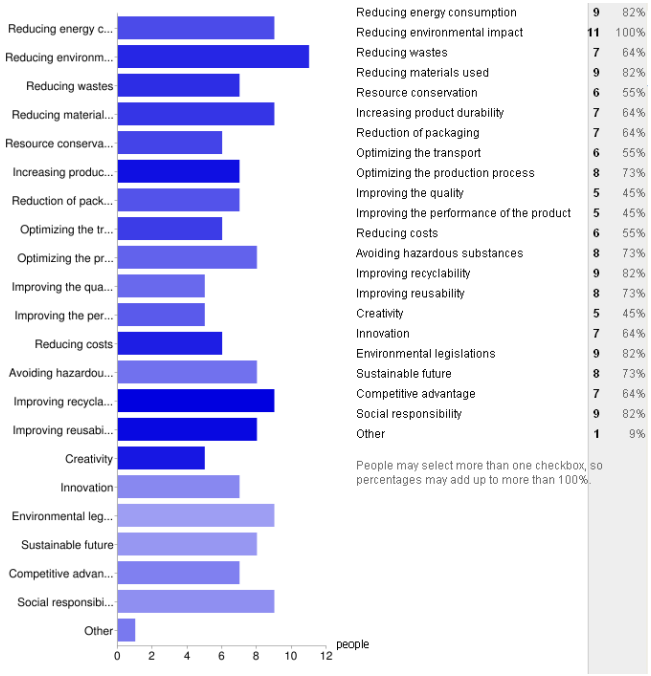

Figure 5. Conceptions related to ecodesign and sustainable product development

Creative environment is another requirement chosen by designers in the survey. 45% of the experts found creativity related to ecodesign and sustainable product development concept (see Figure 1 and Figure 5). Although design is a

creative process, it can be concluded from the survey results that only half of the designers think that ecodesign is also a creative process. The existing impression is rather that ecodesign is an additional process to the general design conception in order to reduce the environmental impact of the product, forced by legislations and social responsibility. Designers also need guidance, but mostly with the help of ecodesign strategies developed for their specific product types.

CONCLUSION AND OUTLOOK

From the survey results, a set of rule of thumbs can be postulated to be considered in any development of a new ecodesign tool. The requirements indicate a strong demand on better integration into the design process, facilitation of communication between different departments and provision of information flow. Many of these requirements can be already found for example in Business Intelligence (BI) tools or Product Life Cycle Management (PLM) tools. These sorts of tools are already well established in industry and commonly used. It may therefore be a good advice to look deeper into these tools and adapt the concepts behind these tools to ecodesign tools. Rule of thumbs generated from the survey results may be the following:

1- Provide information as necessary in the design process.
2- Avoid excessive information and data flow.
3-Cleary show how design activities influence the sustainability performance of the product.
4-Allow information sharing between different departments.
5-Avoid excessive involvement of designers with the tool.
6-Assist the engineering designer in all design phases.

Design is done by designers, and there will be no success of any tool that disregards the designer as a creative person within the design chain. Apart of the technical implementation and realization of any tool, it has to be insured that the designers' creativity is not blocked and their motivation is kept alive. First studies which analyze the influence of the environmental aspect in the design process on creativity have been conducted by (Collado, Ghorabi, 2010; 2011) which can serve as a basis for further research. Further short-term research activities include the investigation of the timing and density of how and when which kind of information has to be provided in order to enhance creativity in the design process. Results presented in by (Collado, Ghorabi, 2010; 2011) serve as a starting point. Mid-term research goals include the analysis of how the provision of information influences the sustainability of product concepts. Furthermore, meta-technical aspects, i.e. the motivation aspect, have to be considered in more detail. Obviously, this aspect is an important parameter for the success of any ecodesign tool. Long-term research goal will include the integration of the different mentioned aspects and the proposition of a new holistic ecodesign tool. Furthermore, based on the previous results, a suitable implementation method has to be found and the tool has to be tested in different industrial branches through longitudinal studies.

REFERENCES

Alves J., Maria José Marques, Irina Saur, Pedro Marques.Creativity and Innovation through Multidisciplinary and Multisectoral Cooperation. *Creativity and Innovation*, 2007, 16/1.27-34.

Borchardt M., Pereira G., Sellito M.A. The Assessment of Ecodesign Applications Using the Analytic Hierarchy Process: a case of study in three furniture companies. *Chemical Engineering Transactions*, 2009, 18, 177-183.

Byggeth S., Hochschorner E. Handling trade-offs in Ecodesign tools for sustainable product development and procurement. *Journal of Cleaner Production*, 2006, 14, 1420-1430.

Collado-Ruiz D. and Ostad-Ahmad-Ghorabi H., Fuon theory: Standardizing functional units for product design. *Resources, Conservation and Recycling*, 54-10, 2010, 683-691.

Collado-Ruiz D., Ostad Ahmad Ghorabi H. Influence of environmental information on creativity. *Design Studies*, 31(5), 2010, 479 - 498.

D. Collado-Ruiz, H. Ostad Ahmad Ghorabi. Influence of Environmental Information on Expert-perceived Creativity of Ideas in *Design Creativity 2010*, T. Taura, Y. Nagai (ed.); 2011, (Springer, London).

di Maschio V., The revolution of Eco Art, *Tafter Journal*, 15th December 2010 (see: http://www.tafterjournal.it/2010/12/15/the-revolution-of-eco-art/ accessed on 3rd January 2011).

Directive 2000/53/EC of the European Parliament and the Council of 18 September 2000 on end-of life vehicles.

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.

Directive 2008/34/EC of the European Parliament and of the Council of 11 March 2008, amending directive 2002/96/EC on waste electrical and electronic equipment (WEEE).

Directive 2008/35/EC of the European Parliament and of the Council of 11 March 2008, amending directive 2002/95/EC on the restriction of the use of certain hazardous substances in electrical and electronic equipment.

Directive 2009/125/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for the setting of ecodesign requirements for energy-related products.

Fiksel J., *Design for Environment*: *A Guide to Sustainable Product Development.* 2009, (McGraw-Hill, New York).

Gurauskienė I., Varžinskas. V. Eco-design Methodology for Electrical and Electronic Equipment Industry. *Environmental research, engineering and management*, 2006, 3(37), 43-51.

Herat S., *"Sustainable Management of Electronic Waste (e-Waste)", Clean Journal*, 35 (4), (2007). 305 – 310,

Karlsson R., Luttropp C., "EcoDesign: what's happening? An overview of the subject area of EcoDesign and of the

papers in this special issue", *Journal of Cleaner Production*, 14, (2006).1291-1298,

Lindahl M (2005) Engineering designers' requirements on design for environment methods and tools. PhD thesis, Kungliga Tekniska H¨ogskolan (KTH), Stockholm

Lindahl M., "Engineering desingers' experience of design for environment methods and tools – Requirement definitions from an interview study", *Journal of Cleander Production*, 14, (2006).487-496,

Lofthouse V., "Ecodesign tools for designers: defining the requirements", *Journal of Cleaner Production* 14, (2006).1386-1395,

Luttropp C. Eco-design in early product development. *World Conference Recycling R99*, Vol.99, Geneva, Switzerland, 1999.

Luttropp C., Lagerstedt J. EcoDesign and The Ten Golden Rules: generic advice for merging environmental aspects into product development. *Journal of Cleaner Production*, 2006, 14, 1396-1408.

Ostad-Ahmad-Ghorabi H., Collado-Ruiz D., Wimmer W., Towards Integrating LCA Into CAD. *International Conference on Engineering Design, ICED'09*, Stanford, August 2009, 301-310.

Pamminger R., Wimmer W., Huber M., Ostad Ahmad Ghorabi H. The Ecodesign Toolbox For The Development Of Green Product Concepts - First Steps For Product Improvement. *Going Green CARE INNOVATION 2006 Proceedings*, Special Issue of IJAA, Vienna, 2006.

Pigosso D.C.A., Zanette E. T., Filho A. G., Ometto A. R., Rozenfeld H., Ecodesign methods focused on remanufacturing, *Journal of Cleaner Production*, 18, (2010).21–31,

Platcheck E.R., Schaeffer L., Kindlein W. Jr. , Candido L.H.A. Methodology of ecodesign for the development of more sustainable electro-electronic equipments. *Journal of Cleaner Production*, 2008, 16, 75-86.

Roy, R., Sustainable product-service systems, *Futures*, Vol. 32, No. 3-4, 2010, pp. 289-299.

Sakao T., (2007), A QFD-centred design methodology for environmentally conscious product design, *International Journal of Production Research*, Vol. 45, Nos. 18–19, 15 September–1 October 2007.4143–4162,

Salter A, Gann D., Sources of ideas for innovation in engineering design, *Research Policy*, 32 (2003), 1309–1324.

Tsydenova O., Bengtsson, M. Chemical hazards associated with treatment of waste electrical and electronic equipment. *Waste Management*, 2011, 31, 45–58.

Widmer R., H. Oswald-Krapf, D. Sinha-Khetriwal, M. Schnellmann, H. Böni. Global perspectives on e-waste. *Environmental Impact Assessment Review*, 25, 2005, 436-458.