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Ecodesign Directive version 2.0

From Energy Efficiency to Resource Efficiency

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Foreword

This present report reports on the main findings of the project Ecodesign Directive version 2.0 - from Energy Efficiency to Resource Efficiency. The project is financed by the Danish Environmental Protection Agency and ran from December 2012 to June 2014.

We could like to thank all of those, who participated in the interviews.

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Konklusion og sammenfatning

Ressourceeffektivitet er højt på den politiske dagsorden i Europa, og Europa Kommissionen har udgivet tre centrale dokumenter om emnet: flagskibsinitiativet et ressourceeffektivt Europa; Køreplanen for et ressourceeffektivt Europa i 2050; og meddelelse fra Kommissionen: Mod en cirkulær økonomi – et program for et affaldsfrit Europa. I køreplanen for et ressourceeffektivitet Europa i 2050 bliver ecodesign direktivet fremhævet som et af de instrumenter, der spiller en vigtig rolle i at opnå et mere ressourceeffektivt Europa.

Formålet med denne rapport er derfor at kortlægge, hvordan ressourceeffektivitet er implementeret i gennemførelsesbestemmelserne og de i frivillige aftaler under ecodesign direktivet på nuværende tidspunkt? samt hvordan dette kan blive forbedret fremadrettet?

Der er i EU regi udarbejdet projekter om, hvordan ressourceeffektivitet kan implementeres i ecodesign direktivet. To centrale projekter er Joint Research Centres rapporter om integration af ressourceeffektivitets- og affaldshåndteringskriterier i gennemførelsesforanstaltningerne under ecodesign direktivet samt studiet af Bio Intelligence service om implementering af materialeeffektivitetskrav i ecodesign metoden (Methodology for the Ecodesign of Energy-related Products - MEErP). Ændringer i MEErP er vigtige for at implementere materiale- og ressourceeffektivitetskrav i gennemførelsesbestemmelserne og i de frivillige aftaler, men de gennemførte ændringer af MEErP er små, og vil ikke alene være i stand til at sikre implementering af materialeeffektivitetskrav i gennemførelsesforanstaltningerne og de frivillige aftaler.

En gennemgang er foretaget af de 23 nuværende vedtagne gennemførelsesforanstaltninger og frivillige aftaler med henblik på at identificere eksisterende ressourceeffektivitetskrav udover energieffektivitetskrav. Gennemgangen viste, at ressourceeffektivitetskrav allerede findes i gennemførelsesforanstaltningerne og i de frivillige aftaler. Men de fleste krav er generiske informationskrav. Der blev fundet informationskrav rettet mod ressourceeffektivitet eller produkternes affaldsfase i 16 af de 23 gennemførelsesforanstaltninger og frivillige aftaler. Informationskravene var enten rettet mod slutbrugeren eller genvindingsvirksomheder. Der var få specifikke ressourceeffektivitetskrav. Der var specifikke ressourceeffektivitetskrav i fem gennemførelsesforanstaltninger: tre som dækker lysprodukter, en som dækker støvsugere, og en som dækker husholdningsvaskemaskiner og en frivillig aftale som dækker printerudstyr. Det er derfor vurderingen, at der i fremtidige revisioner og nye gennemførelsesforanstaltninger og frivillige aftaler kunne implementeres langt flere specifikke ressourceeffektivitetskrav.

To case studier blev lavet af gennemførelsesforanstaltningen for støvsuger og af den frivillige aftale om printerudstyr. Disse to blev valgt, fordi de havde de mest ambitiøse krav til ressourceeffektivitet. Formålet med disse to case studier var at undersøge, hvorfor det i disse to tilfælde var muligt at implementere ressourceeffektivitetskrav. Case studierne viste, at ressourceeffektivitetskravene var muliggjort af, at ressourceeffektivitet blev identificeret som en væsentlig påvirkningskategori under de forberedende undersøgelser. I begge tilfælde blev ressourceeffektivitetskrav dog betragtet som sekundære i forhold til energieffektivitetskrav og noget, som skulle reguleres på et senere tidpunkt. Men i begge tilfælde endte ressourceeffektivitetskravene alligevel i den endelige version. Det tyder derfor på at identificering af ressourceeffektivitet som væsentlige i de forberedende undersøgelser ikke var den eneste årsag, der var på spil. Studierne viste også, at pres fra diverse interessegrupper var afgørende for inkluderingen af ressourceeffektivitetskravene. Derudover var det i begge tilfælde muligt at påvirke industrien eller dele af industrien til at acceptere ressourceeffektivitetskravene. Det faktum at ressourceeffektivitet var på den politiske dagsorden spillede også en væsentlig rolle i implementeringen af ressourceeffektivitetskravene. Afslutningsvis, de to case studier viste også, at det forhold, at der fandtes standarder for hvordan man kunne måle og teste kravene samt eksisterende miljømærkeordningerne med lignende krav, var af afgørende betydning for deres implementering.

En kortlægning blev lavet af drivkræfter og barrier i forhold til implementering af ressourceeffektivitetskrav i ecodesign direktivet. Kortlægningen var baseret på kvalitative interviews med interessenter involveret i processen. Kortlægningen viste, at de vigtigste drivkræfter var at ressourceeffektivitet ligger indenfor rammerne af ecodesign direktivet. En anden vigtig drivkræft var at der lige nu er politisk vilje og opmærksomhed på ressourceeffektivitet. Endelig så er interessenterne, især NGO'erne og Generaldirektoratet for Miljø, vigtige drivkræfter, og de har presset på for at få implementeret ressourceeffektivitetskrav i gennemførelsesbestemmelserne og i de frivillige aftaler. Kortlægningen identificerede imidlertid også barrier for implementering af ressourceeffektivitetskrav i ecodesign direktivet. For det første så er det Generaldirektoratet for Energi og Erhvervspolitik, som har hovedansvaret for ecodesign direktivet, og de har traditionelt haft deres primære fokus på energi. For det andet er måle-, test- og kontrolmetoder for nogle ressourceeffektivitetsparametre ikke fuldt udviklet, og derfor kan markedsovervågning være udfordrende. Derudover er der, for nogle ressourceeffektivitetskrav, ikke de samme indlysende fordele for forbrugerne som ved energieffektive produkter. Derfor kan det være vanskeligt for producenterne at anvende ressourceeffektivitet til at differentiere deres produkter overfor forbrugeren. Dette er dog ikke tilfældet for krav til for eksempel holdbarhed og reparation, hvor der er indlysende fordele for forbrugeren. Endelig kan man for visse ressourceeffektivitetskrav forvente en vis modstand fra producenterne, da krav til for eksempel øget holdbarhed kan påvirke salget af nye produkter. Dog ser dele af branchen ressourceeffektivitet som en mulighed for at differentiere sig fra deres konkurrenter, hvilket måske især gælder producenter af højkvalitetsprodukter.

Endelig er der blevet lavet en gennemgang af hvilke ressourceeffektivitetskrav udover krav til energieffektivitet, der allerede findes i fire frivillige mærkeordninger: det nordiske Svanemærket, EU-miljømærket, EU's retningslinjer for grønne offentlige indkøb (GPP) og Electronic Product Environmental Assessment Tool (EPEAT). Dette er undersøgt for de tre produktkategorier: printerudstyr, computere og vinduer, der alle er energirelaterende produkter. Derudover diskuteres, hvordan disse krav kan overføres til ecodesign direktivet. Gennemgangen viste at krav til ressourceeffektivitet allerede er almindeligt anvendt i de frivillige ordninger. Der blev fundet ressourceeffektivitetskrav i de frivillige ordninger indenfor følgende kategorier:

- Tærskelværdier for RRR
- Demontering
- Deklaration af og tærskelværdier til indholdet af genanvendte materialer
- Oversigt over materiale indholdet i produktet
- Identifikation af plastkomponenter
- Forurening af materialer
- Monomaterialer
- Brug af bæredygtigt træ
- Effektiv brug af materialer i brugsfasen
- Holdbarhedskrav
- Affald fra produktionen
- Emballage
- Informationskrav

Der findes inspiration fra disse frivillige ordninger til fremtidige ressourceeffektivitetskrav i gennemførelsesforanstaltningerne og i de frivillige aftaler, og det er muligt at overføre nogle typer krav til ecodesign direktivet. Dog er produktkategorien afgørende herfor, hvorfor der er behov for en individuel vurdering for hver produktkategori. Derudover skal det også vurderes om kravene kan opfylde kriterierne i artikel 15 i ecodesign rammedirektivet. Afslutningsvis skal det understreges, at ecodesign direktivet og miljømærker er yderst forskellige instrumenter, hvilket bør overvejes før en eventuel overføring af kravene.

Summary and Conclusion

Resource efficiency is currently high on the European political agenda, and three main documents have been published on the issue: the flagship a resource-efficient Europe; the roadmap to resource efficiency; and the communication on the circular economy. In the roadmap to resource efficiency, the Ecodesign Directive was identified as one of the instruments, which can play an important role in the change towards increased resource efficiency in Europe. Hence, the objective of this study is to examine how resource efficiency requirements can be further implemented into implementing measures and voluntary agreements under the Ecodesign Directive.

Several projects have been initiated on implementing resource efficiency requirements in the Ecodesign Directive. Two of the main initiatives are Joints Research Centre's project called *Integration of resource efficiency and waste management criteria in the implementing measures under Ecodesign Directive* and the study made by BIO Intelligence Service on *The implementation of material efficiency in Methodology for the Ecodesign of Energy-related Products (MEErP).* Changes in MEErP are important for the implementation of material efficiency and resource efficiency requirements in the implementing measures and the voluntary agreements under the Ecodesign Directive. However, the current changes to MEErP are minor and will not alone be able to ensure that material efficiency requirements are implemented in the implementing measures and voluntary agreements.

A review was made of the 23 currently adopted implementing measures and voluntary agreements under the Ecodesign Directive with the purpose of identifying existing resource efficiency requirements. The review showed that requirements targeting resource efficiency were included. However, the majority of these requirements were generic information requirements. Information requirements focusing on resource efficiency or end-of-life were found in 16 of the 23 implementing measures and voluntary agreements. The information requirements targeted both consumers and the recyclers of the end-of-life products. Few specific requirements targeting resource efficiency were found in the implementing measures and voluntary agreements. They were found in three implementing measures covering lighting products, one implementing measure covering vacuum cleaners, one implementing measure regarding domestic washing machines and one voluntary agreement covering imaging equipment. It is therefore assessed that this could be further unfolded in future revisions and development of new implementing measures and voluntary agreements.

Two case studies were made of the voluntary agreement on imaging equipment and the implementing measure on vacuum cleaners. These two product groups were selected, because they included the most ambitious resource efficiency requirements. The purpose of these two case studies was to examine: what made it possible to implement resource efficiency? The case studies disclosed that what made it possible to implement the resource efficiency requirements were; firstly, that resource efficiency was identified as a significant impact category during the preparatory studies. However, in both cases resource efficiency requirements were considered secondary to energy requirements and something to implement at a later stage. Yet, in both cases resource efficiency requirements ended up in the final version. This indicates that the identification of resource efficiency as significant in the preparatory study was not the sole reason for the uptake of the requirements in the final version of the implementing measures and voluntary agreements. Other aspects were at play. Secondly, the studies also indicated that pressure from stakeholders was crucial for implementing resource efficiency requirements. Thirdly, in both cases it was possible to convince the industry by different means to accept the resource efficiency requirements. Furthermore, the fact that resource efficiency was on the political agenda also played a significant role in implementing the resource efficiency requirements. Finally, the two studies also revealed that the existence of measurement and test standards and ecolabelling schemes were important for the implementation of resource efficiency requirements.

Based on qualitative interviews with stakeholders involved in the Ecodesign process, a mapping was made of what they perceived as drivers and barriers in relation to implementation of resource efficiency requirements into the Ecodesign Directive. The main drivers identified were: firstly, resource efficiency requirements are within the scope of the Ecodesign Directive. Secondly, there is currently a political willingness and attention on resource efficiency. Finally, stakeholders involved, especially NGOs and DG Environment, had put pressure for additional resource efficiency requirements in the implementing measures and voluntary agreements. However, many barriers were also identified during the interviews. Firstly, DG Energy and DG Enterprise have the main responsibility for the implementing measures and voluntary agreements, and they have traditionally had their main focus on energy. Secondly, measurement, testing and verification methods for some resource efficiency parameters are not fully developed, and therefore market surveillance may be challenging. Thirdly, part of the resource efficient requirements may not provide the same obvious benefits for the consumers as energy efficient products have done. Hence, the producer may have difficulties in applying resource efficiency to differentiate their products. However, this is not the case for requirements such as durability and repairability with obvious benefits for consumers. Finally, opposition from parts of the industry could be expected for certain resource efficiency requirements such as durability requirements, because it may compromise sales. However, part of the industry may also see resource efficiency requirement as a good possibility, especially producers of high-end products, because it may remove some of their competitors' products with lower performance.

Finally, a review was made of resource efficiency requirements in four voluntary instruments: the Nordic Ecolabel, the EU ecolabel, EU Green Public Procurement (GPP) Guidelines and Electronic Product Environmental Assessment Tool (EPEAT) for imaging equipment, computers and windows. Furthermore, a discussion was made of the transferability of the requirements to the Ecodesign Directive. The review revealed that resource efficiency is already widely applied in voluntary instruments covering energy related products. The instruments included criteria on:

- Threshold of RRR ratio
- Disassembly
- Declaration and threshold of recycled content
- Bill of materials
- Identification of plastic components
- Contamination of materials
- Mono-materials
- Sustainable wood sourcing
- Efficient use of materials during the use phase
- Durability requirements
- Waste from manufacturing
- Packaging
- Information requirements

Inspiration for future requirements in the implementing measures and voluntary agreements under the Ecodesign Directive could be found within these voluntary instruments and it could be possible to transfer some requirements to the Ecodesign Directive. However, their transferability will depend on the product category. Therefore, an individual evaluation is needed to examine if the requirements are suitable and that it can fulfil the criteria given in article 15 of the Ecodesign Framework Directive. Furthermore, it should be emphasised that the Ecodesign Directive and the Ecolabels are very distinct instruments with very different target groups and this should also be considered before transferring the criteria.

1. Introduction

1.1 A Resource Efficient Europe

Resource efficiency is currently high on the European political agenda. In 2011, the European Commission published the flagship initiative *a resource-efficient Europe* (European Commission 2011b) and the *Roadmap to resource efficiency* (European Commission 2011d). Furthermore, a communication on circular economy from the European Commission was published in 2014 (European Commission 2014b).

The flagship initiative on resource efficiency is part of the Europe 2020 Strategy. The purpose of the flagship is to create a framework for policies that supports the change towards a resource efficient and low carbon economy. The flagship initiative underpins the importance of resource efficiency for the European and global economy and for securing jobs and growth in Europe. The roadmap, however, sets more specific targets and objectives. The roadmap to resource efficiency puts forward a vision, milestones and actions to be carried out by the Commission and the member states on how to achieve a more resource efficient Europe. The roadmap identifies four focus areas when moving the European economy onto a more resource efficient path. These focus areas are:

- sustainable consumption and production,
- turning waste into a resource,
- supporting research and innovation and
- removing environmentally harmful subsidies.

In addition, seven resources are identified along with milestones and action on how to improve their resource efficiency. The identified resources are ecosystem services, biodiversity, minerals and metals, waste, air, land and soil and marine resources. Finally, key sectors are identified, which should be in focus in the European initiatives. These are addressing food, improving buildings and ensuring efficient mobility (European Commission 2011ep. 17-19).

In relation to the focus area on sustainable consumption and production, the Ecodesign Directive is identified as one of the instruments that play a vital role in the change towards increased resource efficiency, "*An approach using both voluntary and mandatory measures - as the EU's lead market Initiatives and the Ecodesign Directive - should be considered for a wider range of products and services and include more resource relevant criteria*" (European Commission 2011d, p. 5). Hence, the Ecodesign Directive is in the Roadmap assigned a significant role in transforming the European consumption and production towards more resource efficiency. Up till now, the requirements in the implementing measures and voluntary agreements under the Ecodesign Directive has primarily targeted energy consumption in the use phase (Dalhammar et al. 2014, Bundgaard, Zacho & Remmen 2013, Huulgaard, Remmen 2012) even though it is possible to set environmental requirements to the entire life cycle of the product. However, with the resource efficiency agenda high on the political agenda in the European Union, this might change. Therefore, it is interesting to examine how far the Ecodesign Directive has come in implementing resource efficiency requirements, and how it could be further developed.

1.2 The objectives of this study

The main objective of this study is to examine how resource efficiency requirements can be further implemented into the implementing measures and the voluntary agreements under the Ecodesign Directive. The project is mainly a knowledge-building project; however, specific recommendations will be made throughout the report on what could be done to improve the implementation of resource efficiency requirements in the implementing measures and the voluntary agreements. These recommendations can be applied during the revisions of existing measures or when developing new implementing measures or voluntary agreements. To examine these aspects, the following activities were conducted:

- A review of the current initiatives related to the Ecodesign Directive and resource efficiency in relation to the European Union.
- A review of existing resource efficiency requirements in adopted the implementing measures and voluntary agreements.
- Two detailed case studies of the voluntary agreement for imaging equipment and the implementing measure for vacuum cleaners for which resource efficiency requirements are already implemented. The purpose of the review is to examine what made it possible to include resource efficiency requirements for these two product categories and how these leanings can be applied in setting new resource efficiency requirements.
- Interviews with stakeholders on barriers and drivers, when implementing resource efficiency requirements into the Ecodesign Directive (producers, NGOs, waste managers, trade organisations and policy makers).
- A review of existing resource efficiency criteria in four ecolabels: the Nordic Swan, the EU Ecolabel, the EU Green Public Procurement and EPEAT for three energy related products: windows, computers and televisions with the purpose of examining their transferability to the Ecodesign Directive.

1.3 Definition of resource efficiency

Resource efficiency is in this study defined based on a broad understanding of resource efficiency as illustrated in figure 1. In this understanding, resource efficiency can be improved through reduction, maintenance and repair, reuse and redistribution, remanufacturing and refurbishment and recycling of materials.

Hence, resource efficiency is about *reducing* materials and energy use in the entire life cycle of the product from mining of the materials, production of the product, use of the product and final disposal of the product. Furthermore, resource efficiency of a product can be increased by improving the *recyclability* of the materials used in the product, such as reducing or eliminating harmful substances hampering the recycling of the materials. However, resource efficiency can also be improved by increasing the potential for *remanufacturing or refurbishment* of the product to enable the product or component to have multiple use-cycles. Examples of this could be improving the reparability of the product or by giving access to spare parts for a substantial period. Then resource efficiency can also be improved by ensuring *reuse or redistribution* of the product again to enable multiple use-cycles. This can be done by e.g. enhancing leasing services or standardise reuse of electronics such as the PAS 141:2011 on Reuse of used and waste electrical and electronic equipment (BSI 2011). Finally, improving the possibility for *maintenance* of the product, by making maintenance guidelines or repair guidelines available, can expand product lifetime and enhance resource efficiency.

Some cross-cutting requirements such as to *durability* can improve both the products' and components' possibilities for maintenance, reuse and redistribution and remanufacture and refurbishment. In the conceptual understanding of resource efficiency, energy is considered an important resource. However, in this report the focus will be merely on resources excluding energy. Therefore, energy will not be further discussed in the following sections and chapters.

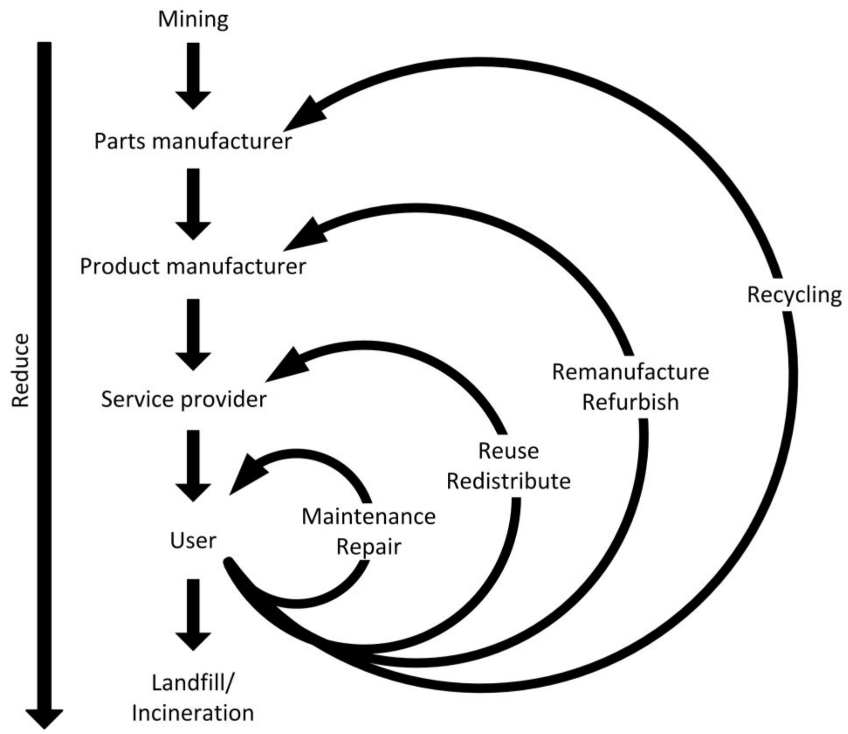

FIGURE 1: ILLUSTRATION OF THE PROJECT'S APPLIED UNDERSTANDING OF RESOURCE EFFICIENCY.

2. Methodological Framework

A document review was made of all adopted implementing measures and voluntary agreements with the purpose of identifying all existing resource efficiency requirements. When identifying resource efficiency requirements, the understanding of resource efficiency described in section 1.3 was applied. Based on the review, two product categories were selected (imaging equipment and vacuum cleaners), because they had some of the most ambitious resource efficiency requirements. Two detailed case studies were then made of the two product categories. The main purpose of these two case studies was to examine what made it possible to set the resource efficiency requirements, and how these experiences could be used when setting future resource efficiency requirements. The two case studies were based on reviews of the background documents made when the requirements were developed, stakeholder comments from the consultation forums and qualitative research interviews with actors involved in the process (table 1).

Additional qualitative research interviews were made with stakeholders involved in the process of developing the implementing measures and voluntary agreements and waste managers (table 1). The purpose of conducting these interviews was to capture the different viewpoints of the stakeholders and identify possible opportunities and barriers in the process of implementing resource efficiency requirements into the Ecodesign Directive. In addition to the interviews, we participated in workshops and conferences in Bruxelles dealing with the topic Ecodesign and/ or resource efficiency in order to follow how the discussion on the Ecodesign Directive and resource efficiency is developing and the different stakeholders' perspectives.

Finally, a review was made of the existing resource efficiency requirements in the four eco-labelling schemes Nordic Swan, EU Ecolabel, EU Green Public Procurement and EPEAT for the three energy-related product groups: windows, computers and televisions. Again the understanding of resource efficiency described in section 1.3 was applied in the identification of which requirements could be identified as resource efficiency requirements. The purpose of this review was to identify resource efficiency criteria and their transferability to the Ecodesign Directive.

Interviewee	Organisation	Description
Karl Edsjö	Electrolux	Producer
Stephane Arditi	European Environmental Bureau	NGO
Ewout Deurwaarder	DG Energy	Policy Officer Energy Efficiency/Ecodesign and Energy Labelling
Robert Nuij	DG Energy	Head of Sector Energy Efficiency of Products
Ferenc Pekar	DG Environment	Policy Officer
Interviewee 1	Representative from EuroVAprint	Trade association
Interviewee 2	Representative from EuroVAprint	Trade association
Anders Moberg	Ecolabelling Sweden	Product Manager for the Nordic Swan
Simon Zittlau Halvarsson	DCR Miljø	Waste manager
Tom Ellegaard	Averhoff	Waste manager
Adrian Tan	BIO Intelligence Service	Project manager

TABLE 1: OVERVIEW OF INTERVIEWS CONDUCTED

3. The Ecodesign Directive and Resource efficiency

3.1 The Ecodesign Directive

The Ecodesign Directive was adopted in 2005. In the outset, the Directive sets ecodesign requirements for energy-using products. However, the Directive was expanded in 2009, and it now covers energy-related products. The Ecodesign Directive establishes, *“a framework for the setting of Community ecodesign requirements for energy-related products with the aim of ensuring the free movement of such products within the internal market”* (European Union 2009a, p. 4) When setting requirements, the whole life cycle of the product should be included, and the most significant environmental aspects should be targeted together with significant improvement potentials. The generic and specific requirements are laid down in implementing measures or in voluntary agreements made with the industry.

The implementing measures set the specific and generic requirements for the individual product groups, and they are legally binding when adopted by the Commission. Once an implementing measure has been adopted, a product cannot be put on the European market until the manufacturer or its authorised representative ensure that the product is in conformity with all the requirements in the implementing measure. If the product complies with the requirements, it can obtain the CE-marking, which allows it to enter the market. Hence, the purpose of the implementing measure is to remove the environmentally worst performing products from the European market by not allowing them to obtain the CE-mark.

Industry can chose to develop self-regulation, also known as voluntary agreements, instead of setting up the implementing measures. As expressed in the Ecodesign Framework Directive, "*priority should be given to alternative courses of action such as self-regulation by the industry where such action is likely to deliver the policy objectives faster or in a less costly manner than mandatory requirements*" (European Union 2009a p. 12). The voluntary agreements work a bit differently than the implementing measures. In the voluntary agreements, the industry agrees on the requirements. Then the Commission acknowledges the voluntary agreement, if they find that it is a good alternative to an implementing measure. For a voluntary agreement to be valid, it should have market coverage of at least 70 %. Hence, the voluntary agreement has to be signed by producers covering 70 % of the European market. Furthermore, at least 90 % of the products placed on the market by the signatories need to comply with the requirements in the voluntary agreement. It implies that the voluntary agreement does not per say remove the worst performing products from the market as the producers of these products can choose not to sign the voluntary agreement. Instead, it strives to move 70 % of the market voluntarily in a more environmentally friendly direction.

As of January 2014, implementing measures and voluntary agreements had been adopted for 23 product categories (21 implementing measures and 2 voluntary agreements). However, many implementing measures are under development for new product groups.

3.1.1 The process of setting the generic and specific requirements

The main steps in the process of developing specific and generic requirements under the Ecodesign Directive are illustrated in figure 2. For a product category to have implementing measures or a voluntary agreement, it first needs to enter into the working plan. The working plan specifies the product categories that should be considered for implementing measures or voluntary agreements. For a product group to be selected for a implementing measure or voluntary agreement, it shall represent a significant volume of sales and trade (more than 200,000 units per year), it shall have a significant environmental impact and it shall present significant potential for improvement in terms of its environmental impact without entailing excessive costs (European Union 2009a).

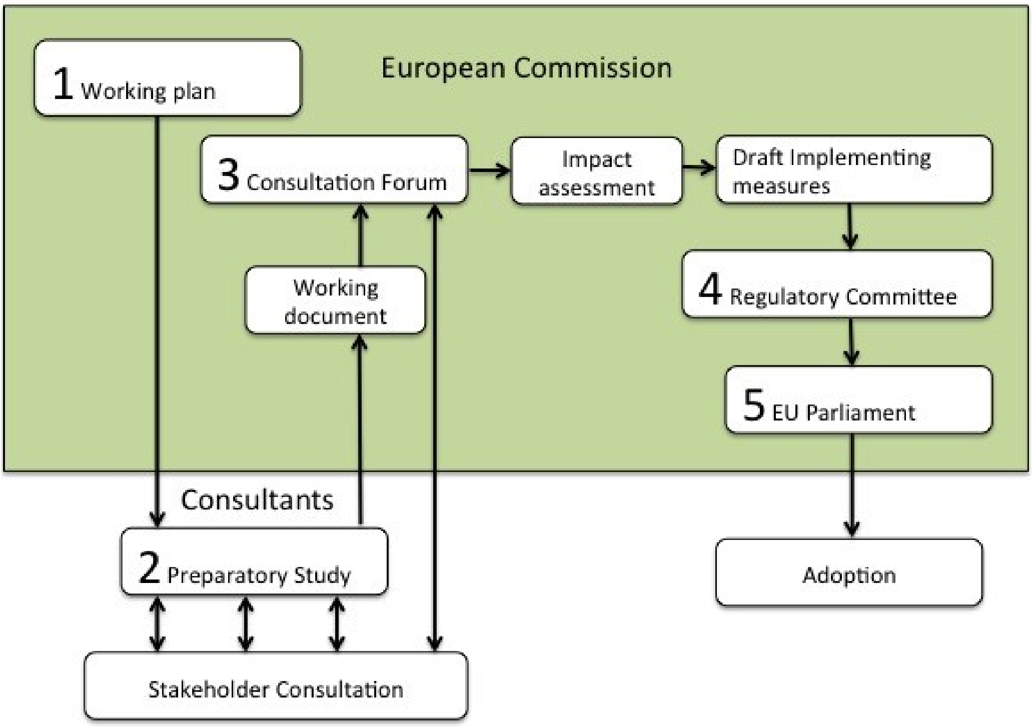

FIGURE 2: THE MAIN STEPS WHEN DEVELOPING IMPLEMENTING MEASURES INSPIRED BY (MUDGAL, TAN 2010)

The next step is to develop the preparatory study. External consultants conduct the studies in close dialogue with the stakeholders. A methodology is developed on how to conduct the preparatory study called the Methodology study for Ecodesign of Energy-related Products (MEErP) (Kemna et al. 2011) former known as the Methodology study for Ecodesign of Energy-using Products (MEEuP) (Kemna et al. 2005). The purpose of MEErP is to create a methodology that can be used to evaluate if and to what extent a product is eligible for implementing measures. The MEErP divides the preparatory study into 8 tasks: (1) product definition, standards and legislation, (2) economical and market analysis, (3) consumer behaviour and local infrastructure, (4) technical analysis of existing products, (5) definition of base-case, (6) technical analysis of best available technology, (7) improvement potential and (8) policy, impact and sensitivity analyses. The end result of the preparatory study is a Working Paper, a set of recommendations, which is sent to the Consultation Forum for discussion. In addition to MEErP, there also exists an ErP EcoReport Tool. The purpose of this tool is to facilitate the translation of product specific characteristic into environmental impact indicators (Kemna et al. 2005, p.8). This tool can also be seen as a life cycle assessment tool.

The next step is the Consultation Forum. It is a meeting, organised by the Commission, where the working document is presented to stakeholders invited by the Commission. In the end, an impact assessment is formulated and sequentially a draft for the ecodesign regulation. The draft is submitted to the Ecodesign Regulatory Committee (eceee n.d., Mudgal, Tan 2010). Before the implementing measures can be adopted, it needs to be approved by the Ecodesign Regulatory Committee. The Committee consists of representatives from the Member States and observers from associated countries. The implementing measure is approved through a majority vote, where the voting power for each member state to a large extent is determined by the size of their population (eceee n.d.). After the approval in the Regulatory Committee the implementing measure is sent to the EU Parliament for scrutiny. Finally, the Commission adopts and publishes the implementing measure (eceee n.d.). After this adoption, it needs to be implemented in the Member States. However, the implementing measures are binding after the adoption by the Commission. The individual member states are responsible for market surveillance.

Voluntary Agreements

Industry can develop self-regulation measures instead of implementing measures, which are often referred to as voluntary agreements. The process of developing voluntary agreements is a bit different from the process of developing implementing measures, and the process was not formalised until the publication of the guideline on the self-regulation measures in 2013 (European Commission 2013e). The guideline explains the legal framework for developing voluntary agreements. The purpose of the guideline is to facilitate the implementation and the establishment of self-regulation measures and to ensure consistency in the voluntary agreements' structure and content. The guideline specifies nine non-exhaustive criteria, which the voluntary agreements need to comply with. These are:

- The voluntary agreement must be open to participation from e.g. third country operators.
- The voluntary agreements must give added value. Hence, the voluntary agreement should go beyond business as usual.
- The signatories should represent a large majority of the economic sector. In principle, at least 70 % of the total sales of the products placed on the market should be covered by the voluntary agreement.
- The objectives should be quantified and staged.
- Civil society should be involved to ensure transparency.
- The voluntary agreement should be monitored and reported.
- The administration of the voluntary agreement should be cost-effective.
- The voluntary agreement should be sustainable and in line with the objectives of the Directive.
- Other incentives and factors should be compatible with the voluntary agreement.

In addition to the nine criteria, the guideline also includes a description of the elements it should be comprised of, along with requirements to how these elements should be handled. These elements are: objectives, signatories and market coverage, the scope of its application, the requirements, rules on reporting compliance, rules on the independent inspector, conformity reports, auditing, monitoring of the effectiveness of the voluntary agreement, access to background data, management of the voluntary agreement, voluntary withdrawal of a signatory, exclusion of a non-compliant signatories, revision of the self-regulation measure, termination of the voluntary agreement and cooperation with the signatories to other self-regulation measures.

The process of developing voluntary agreements has many similarities with the process of developing implementing measures but also some differences. Firstly, the product group also needs to be included in the working plan. Secondly, a preparatory study should be developed. Then, if the companies want a voluntary agreement, they should in principle give the Commission a draft proposal before or during the preparatory study. However, it can also be submitted after the preparatory study. Subsequently, the voluntary agreement is submitted to the Consultation Forum for comments. These comments need to be taken into account; before, it can be recognised by the European Commissions. If the Commission recognises the voluntary agreement, they will publish a report explaining why the Commission has refrained from establishing implementing measures along with the text of the voluntary agreement.

The compliance with the voluntary agreement along with market coverage should be documented and controlled by an independent body. However, the European Commission should bear the cost. The independent inspector should make a compliance report each year documenting ,if the signatories comply with the requirements in the voluntary agreement. At least 90 % of the products placed on the market by the signatories must comply with the requirements in the voluntary agreement. Additionally, the inspectors should perform audits of the signatories.

3.2 Current Projects on Resource Efficiency under the Ecodesign Directive

The European Commission has initiated two projects focusing on implementing resource efficiency requirements into the Ecodesign Directive. The first project "*Integration of resource efficiency and waste management criteria in the implementing measures under the Ecodesign Directive*" (Ardente et al. 2011c, Ardente et al. 2011a, Ardente et al. 2011b, Ardente, Mathieux & Forner 2012, Ardente, Mathieux 2012a, Ardente, Mathieux 2012b) was made by Joint Research Centre with the main purpose to analyse the feasibility and opportunity of developing resource efficiency requirement under the Directive. The second project "*Material-efficiency Ecodesign Report and Module to the Methodology for the Ecodesign of Energy-related Products (MEErP)*" (BIO Intelligence Service 2013c, BIO Intelligence Service 2013a, BIO Intelligence Service 2013b) was developed by BIO Intelligence Service with the purpose to assess the possibility of enhancing material efficiency aspects in MEErP along with an update of the EcoReport Tool to incorporate material efficiency.

3.2.1 The work by Joint Research Centre on the Implementation of Resource Efficiency in the Ecodesign Directive

Joint Research Centre (JRC) has in 2011 and 2012 developed six comprehensive reports on implementing resource efficiency requirements in the Ecodesign Directive. A detailed review of these six studies can be found in appendix 1. The first phase of the reports, called *Integration of resource efficiency and waste management criteria in the implementing measures under the Ecodesign Directive (2011)*, is comprised of the following three reports:

- Deliverable 1: Review of resource efficiency and end-of-life requirements.
- Deliverable 2: In-depth analysis of the measurement and verification approaches, identification of the possible gaps and recommendations.
- Deliverable 3: Contribution to impact assessment.

The second phase of the reports, called *Integration of resource efficiency and waste management criteria in European product policies - second phase (2012)*, is comprised of the following three reports.

- Deliverable 4: Analysis of Durability.
- Deliverable 5: Application of the project's methods to three product groups.
- Deliverable 6: Refined methods and guidance documents for the calculation of indices concerning reusability / recyclability / recoverability, recycled content, use of priority resources, use of hazardous substances, durability.

3.2.2 Material-efficiency Ecodesign Report and Module to the Methodology for the Ecodesign of Energy-related products (MEErP)

As mentioned, the purpose of this study was to assess the possibilities of enhancing materials efficiency aspects in MEErP. The study consists of two parts. Part one is a general study of material efficiency and its practical application along with recommendations on what to implement in MEErP (BIO Intelligence Service 2013a). Part two is an update of MEErP and the EcoReport Tool including a guideline on how to use the new features (BIO Intelligence Service 2013b). Finally, the updated EcoReport tool has been tested on two product categories TVs and washing machines (BIO Intelligence Service 2013c). The first part of the study identified highly relevant material efficiency aspects and parameters. These are listed in table 2.

Aspects	Parameters
Quantity of material used over life cycle	Consumption of materials per functional unit
	Material Input Per Unit of Service (MIPS)
	Material Footprint
Environmental impacts of extraction, production and end-of-life of materials	Abiotic Depletion Potential; mineral, fossil
	Recyclability benefit rate
Recoverability of materials/ product	Recoverability benefit rate
Origin of materials	Recycled content, Re-used components
	Raw materials with sustainable origin
Reusability of components/ product	Reusability benefit rate
Reparability and durability of components/ product	Lifetime and warranty

TABLE 2 MATERIAL EFFICIENCY PARAMETERS EVALUATED AS HIGHLY RELEVANT IN THE STUDY BY BIO INTELLIGENCE SERVICE (BIO INTELLIGENCE SERVICE 2013A)

However, some of the parameters cannot be applied in praxis. Therefore, only the following parameters were implemented in MEErP:

- Recyclability benefit ratio,
- Recycled content,
- Lifetime and
- Critical raw materials. (BIO Intelligence Service 2013b)

The four parameters have subsequently been implemented in the EcoReport tool. Hence, a recyclability benefit rate is added as a new feature in the EcoReport Tool. More specifically, it implies that it is possible to assess the potential benefits of recyclable plastic parts in a product. However, due to data constraints only data on recyclability benefit rate for bulk and technical plastic is included. Furthermore, a dataset on recycled content has been added to the tool. The dataset makes it possible to model products with recycled material as input material. However, again due to data constraints, only data on paper, PVC, PET and HDPE has been included in the EcoReport Tool. (BIO Intelligence Service 2013b)

Lifetime was already part of the EcoReport tool. However, alterations have been made making it possible to present the data in an alternative way. These alterations make it possible to get the results, not only as a total number over the whole lifespan, but also per year of use. This should make it easier to compare products with different lifespans and the effect of an extension of the product lifespan. Critical raw materials (CRM) were also already part of the EcoReport tool with the CRM index. However, the index has not yet been applied in any preparatory study. The CRM index describes the scarcity of a material based on economic considerations. The CRM index is calculated based on a characterization factor. The factor is based on the consumption, import dependency, substitution and complement of the recycling rate of the specific material. Hence, the CRM index makes it possible to analyse the difference between various product designs in terms of critical raw materials. (BIO Intelligence Service 2013b)

Generally, the MEErP methodology has not been changed significantly. The alterations made to the EcoReport Tool are minor and to some extent updates of existing elements. Hence, despite the good intentions to include material efficiency into MEErP, the current update and expansion of MEErP will properly not be enough to ensure a focus on material efficiency in future implementing measures and voluntary agreements. However, MEErP is important and changes are needed to ensure that, not only material efficiency, but also resource efficiency is included in future implementing measures and voluntary agreements. However, this will require that not only the EcoReport Tool includes resource efficiency parameters, but also that the MEErP methodology is constructed in a way that ensures focus on resource efficiency in the preparatory studies when relevant for the product category under examination. Though, it could be questioned, if changes in the MEErP will be enough to ensure implementation of resource efficiency in future implementing measures and voluntary agreements, or if such a change will require larger more thorough changes in the focus and attention of stakeholders and policy makers involved in the Ecodesign Directive.

4. Review of Resource Efficiency Requirements in the Implementing Measures and the Voluntary Agreements

This chapter provides a review of the requirements targeting resource efficiency in the 21 currently adopted implementing measures and the 2 recognised voluntary agreements under the Ecodesign Directive. All implementing measures and voluntary agreements set requirements to energy efficiency and energy consumption, and many of these requirements are continuously tightened until the implementing measure or voluntary agreement is revised. All implementing measures and voluntary agreements also include various information requirements like technical documentation and instructions manuals. Moreover, the implementing measures include additional requirements like performance requirements, requirements to emissions, requirements to the level of uncertainty in the measurements and the availability of certain functions. However, as this review only focuses on requirements targeting resource efficiency other than energy. Hence, the next section will merely go into detail with the requirements targeting resource efficiency. The review is presented in table 3 and divided into two categories, that is resource efficiency requirements and information requirements targeting resource efficiency. When evaluating if a requirement targets resource efficiency the understanding of resource efficiency described in section 1.3 is applied.

Product groups	Resource efficiency requirements	Information requirements targeting resource efficiency
Space and combination heaters (European Commission 2013c)		Information relevant for disassembly, recycling and/or disposal at end-of-life
Water heaters (European Commission 2013d)		Information relevant for disassembly, recycling and/ or disposal at end-of-life.
PCs and servers (European Commission 2013a)	For the next revision the review shall consider noise, material use efficiency, including requirements on durability, dismantlability, recyclability, standardised interfaces for rechargers, as well as information requirements on the content of certain Critical Raw Materials and minimum number of loading cycles and battery replacement issues.	Information on the minimum number of loading cycles that the batteries can withstand (applies only to notebook computers). For product with an integrated display containing mercury, information on the content of mercury as X,X mg. If a notebook computer is operated by battery that cannot be accessed and replaced by a non-professional user, the manufacturer shall make this information available on free-access websites and on the external packaging.

Product groups	Resource efficiency requirements	Information requirements targeting resource efficiency
Televisions (European Commission 2009g)		Information on hazardous substances, if the television contains mercury or lead. The content of mercury as X,X mg and the presence of lead.
Fluorescent lamps without integrated ballast, for high intensity discharge lamps, and for ballasts and luminaires able to operate such lamps (European Commission 2009c)	Lamps: Requirements for lamp lumen maintenance factor. Requirements for lamp survival factor	Lamps: Information on rated lamp lumen maintenance factor, rated lamp survival factor, lamp mercury content as X,X mg. Luminaries: Product information requirements on luminaries should include: maintenance instructions to ensure that the luminaire maintains as far as possible its original quality throughout its lifetime, disassembly instructions.
Directional lamps, light emitting diode lamps and related equipment (European Commission 2012a)	Lamp survival factor, lumen maintenance, number of switching cycles before failure, premature failure rate, rated lamp lifetime.	Information on: Nominal life time of the lamp in hours, number of switching cycles before premature failure, rated lamp life time, lumen maintenance factor at the end of the nominal life. If the lamp contains mercury, then information on: Lamp mercury content as X,X mg, instructions on how to clean up the lamp debris in case of accidental lamp breakage, recommendations on how to dispose of the lamp at the end of its life for recycling.
Non-directional household lamps (European Commission 2009b)	Lamp survival factor, lumen maintenance, number of switching cycles before failure, premature failure rate, rated lamp lifetime	Information on the nominal lifetime of the lamp in hours, number of switching cycles before premature lamp failure, rated lamp lifetime. If the lamp contains mercury then information on mercury content as X,X mg, indication which website to consult in case of accidental lamp breakage to find instructions on how to clean up lamp debris, recommendation on how to dispose of the lamp at its end-of-life.
Electric motors (European Commission 2009e)		Information relevant for disassembly, recycling or disposal at end-of-life.
Ventilation fans (industrial fans) (European Commission 2011a)		Information relevant for facilitating disassembly, recycling or disposal at end-of-life. Information relevant to minimise impact on the environment and ensure optimal life expectancy as regards installation, use and maintenance of the fan.
Circulators in buildings (European Commission 2012d, European Commission 2009f)		Information concerning disassembly, recycling, or disposal at end-of-life of components and materials, shall be made available for treatment facilities. Manufacturers shall provide information on how to install, use and maintain the circulator in order to minimise its impact on the environment.

Product groups	Resource efficiency requirements	Information requirements targeting resource efficiency
Water pumps (European Commission 2012c)		Information relevant for disassembly, recycling or disposal at end-of-life
Domestic washing machines (European Commission 2010a)	Requirements on water consumption	Recommendations on the type of detergent suitable for the various washing temperatures.
Domestic dishwashers (European Commission 2010b)		Information on the standard cleaning cycle referred to as "standard programme" and shall specify that it is suitable to clean normally soiled tableware and that is the most efficient programme in terms of its combined energy and water consumption for that type of tableware. Information on the indicative programme time, energy and water consumption for the main cleaning programmes.
Vacuum cleaners (European Commission 2013b)	The hose, if any, shall be durable so that it is still usable after 40,000 oscillations under stain. The operational motor lifetime shall be greater than or equal to 500 hours.	Information relevant for non-destructive disassembly for maintenance purpose, in particular in relation to hose, suction, inlet, motor, casing and cable. Information relevant for dismantling, in particular in relation to the motor and any batteries, recycling, recover and disposal at end-of-life.
Domestic ovens, hobs and range hoods (European Commission 2014a)		Information relevant for non-destructive disassembly for maintenance purpose and information relevant for dismantling, in particular in relation to the motor, if applicable, and any batteries, recycling, recovery and disposal at end-of-life. Domestic ovens: Mass of the appliance
Voluntary agreements		
Imaging equipment (EuroVAprint 2012)	Duplex availability Duplex-printing is set as default Availability of N-up printing Design for recycling: Plastic parts>100 g shall be manually separable into recyclable plastic streams with commonly available tools. Products shall utilize commonly used fasteners for joining components, subassemblies, chassis and enclosures. Non-separable connections (e.g. glued, welded) between different materials shall be avoided unless they are technically or legally required. Product plastics shall be marked by material type (ISO 11469 referring ISO 1043, resin identification code, SPI,	Provide end users with information regarding resource efficiency when using imaging equipment. Information that recycled as well as virgin paper certified under environmental stewardship initiatives or carrying recognised ecolabels may be suitable. For electro photography printers: indication that these can print 64 gr/m2 paper and that this paper contain less raw materials per print. Description of the benefits of printing in duplex mode. Cartridge disposal and treatment. Signatories shall provide end users with information on suitable end-of-life management options for used cartridges. Information on product environmental characteristics. Information on the environmental performance of their product shall

Product groups	Resource efficiency requirements	Information requirements targeting resource efficiency
	DIN or country specific with exemptions). Cartridges: Any cartridge produced by or recommended by the OEM for use in the product shall not be designed to prevent its reuse and recycling. The machines shall not be designed to prevent the use of a non-OEM cartridge.	be available to customers. Information on inkjet and toner cartridge yield available to customers based on the measurement standards specified.

TABLE 3 OVERVIEW OF THE REQUIREMENTS TARGETING RESOURCE EFFICIENCY IN THE 21 ADOPTED IMPLEMENTING MEASURES AND THE TWO RECOGNISED VOLUNTARY AGREEMENTS. THE WORDING IN THE TABLE IS THE SAME OR VERY SIMILAR TO THE ONE FROM THE IMPLEMENTING MEASURES OR VOLUNTARY AGREEMENTS. THE VOLUNTARY AGREEMENT FOR COMPLEX SET TOP BOXES (VA STEERING COMMITTEE 2013) AND THE IMPLEMENTING MEASURES FOR SIMPLE SET-TOP BOXES (EUROPEAN COMMISSION 2009A), HOUSEHOLD TUMBLE DRIERS (EUROPEAN COMMISSION 2012E), DOMESTIC REFRIGERATORS (EUROPEAN COMMISSION 2009H), AIR CONDITIONERS AND COMFORT FANS (EUROPEAN COMMISSION 2012B), BATTERY CHARGERS AND EXTERNAL POWER SUPPLIES (EUROPEAN COMMISSION 2009D) AND STANDBY AND OFF MODE LOSSES (EUROPEAN COMMISSION 2008A) ARE OMITTED FROM THE TABLE BECAUSE THEY DID NOT INCLUDE REQUIREMENTS TARGETING RESOURCE EFFICIENCY.

4.1 Requirements Targeting Resource Efficiency in the Implementing Measures and the Voluntary Agreements

The review of the adopted implementing measures and recognised voluntary agreements showed that currently there are generic information requirements targeting resource efficiency in 15 implementing measures and one voluntary agreement, and specific requirements targeting resource efficiency in five implementing measures and one voluntary agreement. The following section presents a discussion of the generic and specific resource efficiency requirements.

4.1.1 Information requirements targeting resource efficiency

Information relevant for disassembly, recycling or disposal at end-of-life.

For many of the product categories, information should be provided on disassembly, recycling and/or disposal at end-of-life. For circulators in buildings, it is further specified that the information shall be made available for treatment facilities. The end user has to know how to correctly dispose the product at its end-of-life; because otherwise it may never enter a proper recycling system. The recyclers also have to know how to disassemble and recycle the products in the best possible way. However, with the highly automatic and destructive methods applied today, especially by the European recyclers (Gmünder 2007), it could be questioned if information on disassembly and recycling will be used during the recycling process. Typically, the recyclers in Denmark receive very mixed batches of electronic and electrical waste, and it is therefore usually not possible for them to look into manuals or internet pages to determine how to dispose each product in the best way (Halvarsson 2013). However, still this information can be important to ensure e.g. that hazardous components are removed and treated correctly. Though, if such information could be made more easily available, by embedding it in the product in e.g. a RFID, it may benefit the recyclers more. Furthermore, it could be specified in the Directive which type of information the recyclers may need. This could be done in close collaboration with the recyclers to ensure that the information is indeed relevant for their processes.

Easy disassembly

For vacuum cleaners and domestic ovens, hops and range hoods, it is specified that the information relevant for non-destructive disassembly for maintenance purposes should be provided. Furthermore, for lamps there are requirements to include maintenance instructions and disassembly instructions. This can help improve maintenance of the product and thereby also improve resource efficiency. A study has shown that some of the key obstacles for repair of fridges, dishwashers and washing machines were increasing difficulty to disassemble the product for repair (RREUSE unknown). Hence, setting generic information requirements for non-destructive disassembly for maintenance purposes seem to be highly relevant also for other product categories. Furthermore, these requirements could be supplemented by requirements for the producers to make repair and service manuals public. It may also be relevant to set specific requirements, and not just information requirement, to easy disassembly of the product for maintenance purposes. Then the information requirements on easy disassembly can work as a stepping-stone to set specific requirements to easy disassembly.

However, easy disassembly is not only relevant for maintenance purposes but can also be relevant for the end-of-life treatment. Despite the automatic and destructive processes applied today, the recyclers still have to remove certain component in accordance with the WEEE Directive. It is typically components that need special treatment such as batteries, and they therefore need to be removed before disassembled destructively. Hence, the Ecodesign Directive could support the requirements in the WEEE Directive ensuring that the design of the products also enables a suitable end-of-life treatment, which is not always the case today.

Durability

For PCs and servers, the producers should include information on the minimum number of loading cycles the battery in the notebook computer can withstand. Additionally, if the battery of the notebook computer cannot be replaced by a non-professional this should be informed on the packaging and be freely available on a website. This provides the end user with the information necessary to make an informed choice when selecting a computer. For lighting information requirements include information on e.g. lumen maintenance factor, survival factor and lifetime. Again this makes the customer capable of selecting the most durable lamp thereby potentially improving resource efficiency. Generally, durability could be relevant to regulate by setting specific requirements, because the lifetime of electrical and electronic products are decreasing significantly for certain product categories (Zonneveld 2014). Of course, we need to ensure that extended durability does not result in increased energy consumption in the use phase, if newer products have significantly better energy performance.

Hazardous substances

Information requirements on the content of hazardous substances, mercury and lead, were included for PCs and servers, televisions and lamps. This type of information can be important for the recycling facilities to avoid contamination of the materials when they are recycled. However, information on hazardous substances, and other information relevant for end-of-life, needs to be easily accessible for the recycling facilities. When the recycling facility receives perhaps 1.000 different products, it is not possible for them to look up this type of information on a webpages or in a user instruction for each product. Therefore, it may be more beneficial, if the information was embedded in the product in some sort of marking scheme. It is not only information on potentially hazardous substances in the product that could be relevant for the recycling facilities. Also information on e.g. precious metals or rare earths could be relevant to ensure a more optimal recovery of these materials.

The use phase

Information requirements to stipulate the most efficient washing programs in terms of energy and water consumption should also be included for dishwashers. Furthermore, for washing machines information should be provided to ensure that the best suitable detergents are chosen. For imaging equipment information should also be provided to inform the end user on resource efficient use of durables such as paper and cartridges.

4.1.2 Specific Requirements Targeting Resource Efficiency

In the implementing measures and voluntary agreements, specific requirements targeting resource efficiency were included in the three product categories covering lighting, vacuum cleaners, domestic washing machines and imaging equipment. For lighting it includes requirements for lamp survival factor, lumen maintenance and number of switching cycles before failure. For vacuum cleaners there are requirements to the durability of the hose and requirements for the operational motor lifetime. All requirements target a longer lifetime of the product. Moreover, in the implementing measure covering domestic washing machines there are requirements to the water consumption. The voluntary agreement for imaging equipment includes several requirements targeting resource efficiency. Firstly, it includes requirements targeting paper consumption such as the availability of N-up printing, the availability of duplex-printing and duplex-printing as default. Furthermore, the voluntary agreement sets requirements for design for recycling such as separability, the use of fasteners, non-separable connections and the marking of plastics. Requirements are also set to ensure that the product do not prevent the reuse and recycling of cartridges. In the implementing measure for computers, it was further specified that the coming revision should look into various resource efficiency aspects, such as durability, dismantlability, recyclability, standardised interfaces for rechargers, information requirements on critical raw materials and minimum number of loading cycled and battery replacement issues. Hence, it will be interesting to follow the revision of computers and see how many of these aspects will end as requirements in the new revision.

Not many specific requirements targeting resource efficiency were found in the adopted 23 implementing measures and 2 voluntary agreements. Hence, there seems to be a possibility for improvement and potentially still some low hanging fruits to be utilised. For many years now energy has been seen as the main focus in the implementing measures and voluntary agreements. However, with the lifespan of electronic and electrical products decreasing and continuing to decrease, there might be other issues that need our attention such as durability, reparability, reusability and recyclability.

4.2 Sub-conclusions

This review of the adopted implementing measures and voluntary agreements under the Ecodesign Directive showed that requirements targeting resource efficiency are included. However, the majority of these requirements are generic information requirements. Information requirements focusing on resource efficiency or end-of-life were found in 16 of the 23 implementing measures and voluntary agreements.

The information requirements targeted both the end-consumers and the recyclers of the end-of-life products. The end-consumers need to have the necessary information to dispose of the product correctly, so that it enters the correct waste streams. It is the outset for any recycling process. However, it is also important that the consumers have the possibility to select the product with the best durability or where it is possible to update the product or change the battery. When this type of information is available to the end-consumers, they can make an informed choice and push the market in a more resource efficient direction.

Some information requirements are also targeting the recyclers of the end-of-life products, including information on the correct disassembly and hazardous substances. These types of information can be of importance for the recyclers. However, this information needs to be easily accessible for the recyclers to be useful. Therefore, this type of information ought to be embedded in the product and not merely available on websites and/or user manuals.

Few specific requirements targeting resource efficiency were found in the implementing measures and voluntary agreements. Hence, this could be further unfolded in future revisions and new developments of implementing measures and voluntary agreements.

Based on the review of existing requirements, the following recommendations are made:

Recommendations

- Set more specific requirements to resource efficiency in addition to the generic information requirements. The specific requirements could be set based on previous information requirements.
- Keep setting information requirements on how the end-consumer can dispose the product correctly at its end-of-life.
- Keep setting information requirement targeting the recyclers on how to disassemble, recycle and dispose the product in the best way and make this information easy accessible for the recyclers.
- Set generic information requirements relevant for non-destructive disassembly for maintenance purpose for all relevant product categories and consider setting also specific requirements.
- Set as a requirement that repair and service manuals should be made public available.
- Increase the synergies between the WEEE Directive and the Ecodesign Directive. This could ensure that component, which according to WEEE Directive needs special treatment and therefore needs to be removed before destructive disassembly, can be removed easily.
- Include both generic information requirements and specific requirements targeting durability.
- Include information requirements on the content and location of hazardous substances, when relevant, and make this information easy accessible for the recyclers.
- Include information requirements on the content and location of critical raw materials to ensure proper recycling of these materials and make this information easy accessible for the recyclers.

5. Case Study of Imaging Equipment and Vacuum Cleaners

As the review of the existing resource efficiency requirements in the implementing measures and voluntary agreements has shown, resource efficiency requirements are already implemented to a certain extent. To gain a deeper understanding of how these requirements was set op, two case studies were made of vacuum cleaners and imaging equipment. These two product categories were chosen as they were identified as some of the most far reaching in terms of resource efficiency requirements. The purpose of this chapter is to identify what made it possible to include resource efficiency requirements for these two product groups?

5.1 Voluntary Agreement for Imaging Equipment

The Commission recognised the voluntary agreement on imaging equipment in February 2013 (EuroVAprint 2012). The voluntary agreement covers imaging equipment and applies to the following product categories; copiers, multifunction devices, printers and fax machines, but it is limited to the marking technologies; electrophotography (EP), inkjet (IJ) and high performance IJ and solid ink. Furthermore, the voluntary agreement is limited to household and office equipment with a maximum speed of 66 A images per minute for black and white standard printing and a maximum speed below 51 A4 pages per minute for colour standard printing. Sixteen signatories have signed the voluntary agreement, and it is estimated that they account for more than 90% of the European market for imaging equipment.

The objective of the voluntary agreement is to, "*continuously improve the environmental performance of the types of imaging equipment in scope of this agreement*"(EuroVAprint 2012, p. 4). Thereby, the scope of the voluntary agreement is broader than other voluntary agreements, which have mainly focus on energy. The broader scope is also reflected in the requirements that cover aspects such as energy consumption, consumables (paper and cartridges) and design for recycling (see table 4). The voluntary agreement is managed by EuroVAprint, which is an association grouping all major manufactures of imaging equipment in Europe. The voluntary agreement expired in April 2014. However, a new version has been drafted by the industry, but the Commission has not yet approved it. Therefore, there is currently no valid voluntary agreement on imaging equipment (EuroVAprint 2014). The voluntary agreement expired because it follows Energy Star, and Energy Star for imaging equipment was revised to version 2.0 January 2014.

	January 2012
Energy	90% or more of the products placed on the EU market by the Signatories shall comply with the specifications of Energy Star v.1.1. (Energy consumption requirements and default delay time).
Paper	Duplex availability (depending on monochrome print speed) Duplex-printing is set as default when printing from the computer. Availability of N-up printing.
Cartridges	Shall not be designed to prevent its reuse and recycling. The machine shall not be designed to prevent the use of non-OEM cartridges.
Design for recycling	Plastic parts > 100g shall be manually separable into recyclable plastic streams with commonly available tools. Products shall utilize commonly used fasteners for joining components, subassemblies, chassis and enclosures. Non-separable connections (e.g. glues, welded) between different materials shall be avoided unless they are technically or legally required. Product plastics (>25 g or surface area > 50 cm^2) shall be marked by material type (ISO 11469 referring ISO1043).
Information requirements	Environmental information for end-users in relation to use and end-of-life. Resource- and energy-efficiency Information regards resource efficiency when using imaging equipment (energy, paper use, duplex mode, ect.) Cartridge disposal and treatment Information on product environmental characteristics

TABLE 4: ECODESIGN REQUIREMENTS IN THE VOLUNTARY AGREEMENT ON IMAGING EQUIPMENT (EUROVAPRINT 2012)

The voluntary agreement on imaging equipment follows to a large extent the framework laid down in the guideline on self-regulation measures (European Commission 2013e). The Signatories have set in place an independent inspector that reports once a year, whether the Signatories comply with the voluntary agreement. The inspector assesses compliance based on data provided by the Signatories. Furthermore, an auditing function will also be established. So far, the Signatories have paid for the independent inspector, but the Commission wants this to be changed. In the future, the European Commission wants to carry the expenses in accordance with the draft guidelines on self-regulation measures (EuroVAprint 2014).

5.1.1 The process of setting the requirements

The preparatory study was finalised in November 2007 and the first consultation forum was held in October 2009. The impact assessment in the preparatory study (Fraunhofer IZM and PE Europe 2007) suggested that energy efficiency and efficient use of materials were the main topics of product improvement. However, these conclusions depended on the type of product considered. The preparatory study identified the main areas for improvements to be:

- Energy Efficiency (power consumption and power management in the use phase).
- Resource efficiency (power electronics and bulk plastics in the manufacturing phase).
- Consumables efficiency (Paper utilization, toner and ink yield).
- Specific emissions (ozone and micro dust as health risks) (Fraunhofer IZM 2007, p. 5).

It was suggested that the focus should first be on energy requirements. The study recommended that the US Energy Star tier 1 criteria were used as the outset for energy requirements. In the second stage, requirements on resource efficiency, network standby and emissions should be included in addition to the energy requirement.

Figure 3 provides an overview of the process before the voluntary agreement was recognised. In February 2010, the first draft voluntary agreement (version 2.5) was presented. This was followed by a stakeholder Consultations Forum, which provided further input to the voluntary agreement. This subsequently resulted in a new draft of the voluntary agreements (version 3.5). The main changes from version 2.5 to version 3.5 were that the number of products that should comply with the requirements was significantly increased from 60% and 80% to 90%. Furthermore, requirements to the availability of N-up printing and design for recycling requirements were included. The information requirements and the requirements to cartridges were also altered. The design requirements regarding the cartridges had been strongly debated by the OMEs and the independent cartridges re-manufactures due to their inherent conflict of interest (ETIRA 2009).

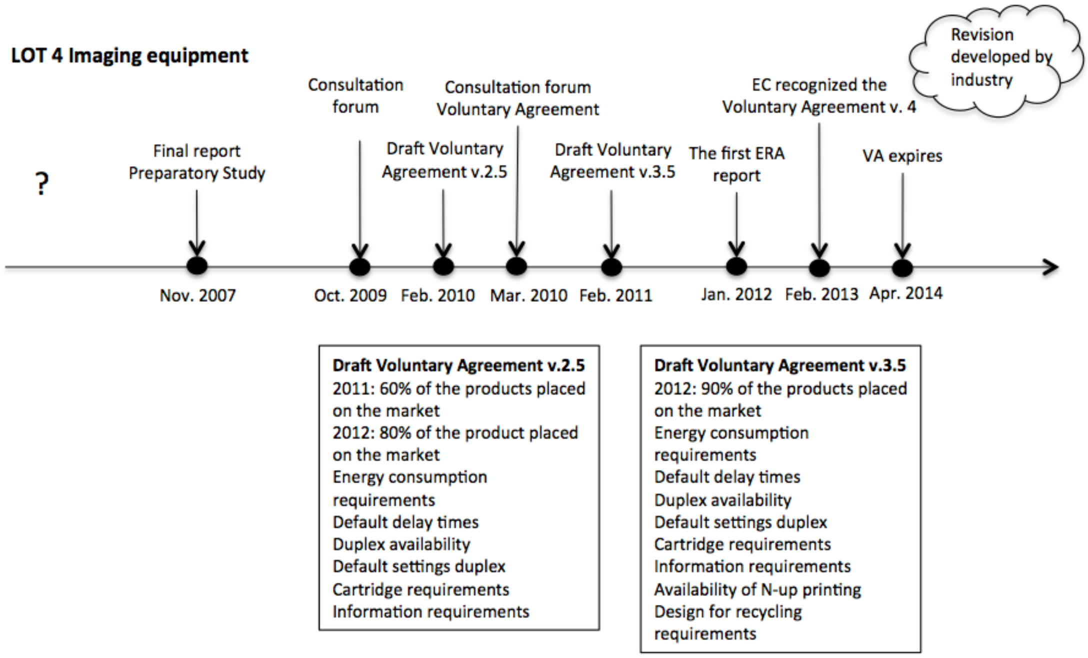

FIGURE 3 OVERVIEW OF THE PROCESS FOR DEVELOPING THE VOLUNTARY AGREEMENT FOR IMAGING EQUIPMENT (EUROVAPRINT 2010, EUROVAPRINT 2012, ECEEE 2013).

Additional requirements addressing resource efficiency and the efficient use of consumables, such as design for recycling and the availability of N-up printing, were introduced after the second consultation forum. According to a representative from the voluntary agreement, this broader focus on environmental impacts came after pressure from the stakeholders (EuroVAprint 2014). In the outset, EuroVAprint focused on energy and additional requirements in line with the Energy Star (EuroVAprint 2014). This was also the recommendation in the preparatory study, to firstly focus on energy and secondly on resource efficiency, consumables efficiency and specific emissions (AEA Energy & Environment 2009). However, the scope of the first voluntary agreement was broadened after pressure from the stakeholders involved. Furthermore, the requirements targeting resource efficiency were suggested in 2011 simultaneous with the publication of the flagship and roadmap on resource efficiency. Hence, the requirements were suggested at a time, where resource efficiency was put on the political agenda, and the Ecodesign Directive was identified as one of the instruments that could improve resource efficiency.

5.1.2 What made it possible to set the resource efficiency requirements?

The basis for setting the resource efficiency requirements in the voluntary agreement was that resource efficiency was identified as an area for improvement along with energy efficiency in the use phase in the preparatory study. In order for resource efficiency to be included in the preparatory study, it needs to be part of the methodology for making the preparatory study (MEErP). Hence, this emphasised the importance of resource efficiency being included in MEErP. Therefore, studies as the one on including material efficiency into MEErP are important. However, the fact that resource efficiency was identified in the preparatory study as an area for improvement was not the sole reason for the inclusion of resource efficiency requirement in the first version of the voluntary agreement. As mentioned, the recommendation in the preparatory study was firstly to focus on energy and then to include additional requirements on network standby, emissions and resource efficiency. So what made it possible to implement resource efficiency in the first voluntary agreement?

Firstly, the voluntary agreement was finalised concurrent with the publication of the flagship and roadmap on resource efficiency. Hence, resource efficiency was on the political agenda. Secondly, the implementation of requirements targeting broader environmental impact was also a consequence of pressure from the stakeholders involved in the process. As expressed by one of the representatives from EuroVAprint, "*What we have witnessed is a series of requests, which came from the institutional side, the European Commission - DG Energy. At least they were channelled through the European Commission, but they came from civil society in general and stakeholders in the wider sense EPAs, ministries, consumer and environmental groups. They all have a seat at the Consultation Forum for Ecodesign, as you know. We were at the time in the drafting phase, and we were under a lot of pressure from these stakeholder groups. Specifically, the European Consumers and Environmental NGOs...but my impression is that originally we were supposed to focus solely on Energy Star and energy consumption, but then it got broader"* (EuroVAprint 2014). Hence, the initial idea was to focus on energy. However, after pressure from the stakeholders involved in the Consultation Forum, the types of requirements were broadened. The industry was perhaps also more inclined to satisfy the stakeholders, because if they did not satisfy the stakeholders and the Commission, they would be facing regulation. As expressed by a representative from EuroVAprint, *"but in the voluntary agreement my feeling is that because it is a voluntary agreement in order to somehow make the voluntary agreement to be more appealing to member states and NGOs, we had to accept more things than we would have had in an implementing measure"* (EuroVAprint 2014). Hence, the fact that the industry was keen on avoiding regulation, in the form of implementing measures, inclined them to go a bit further in the types of requirements they would accept. This conclusion should not be interpreted as if voluntary agreements are always preferable to implementing measures in widening the scope of the requirements included.

Finally, what made it possible to include resource efficiency requirements was also that the voluntary agreement could build on existing initiatives. For instance, the requirements for default delay time and the requirement for duplex availability derived from the Energy Star version 1.1., and many additional requirements were based on ecolabels covering imaging equipment such as the US initiative the Electronic Environmental Assessment Tool (EPEAT) and the Blue Angel. As expressed by the representatives from the voluntary agreement, *"We did not have the EU ecolabel criteria at the time, so what we used at the time was EPEAT, which is the US standard, which a lot of companies use…but we also had discussions with other standard bodies, e.g. Blue angel, which is the German developed standard. It is also an inspiration for a lot of the new features (design for recycling criteria)"* (EuroVAprint 2014). Hence, the voluntary agreement builds on existing schemes and test measures that are already adopted by parts of the industry.

5.2 Implementing Measure for Vacuum Cleaner

The implementing measure for vacuum cleaners was adopted in July 2013. The requirements entered into force September 2014 and are further tightened in September 2017. In the implementing measure, requirements are set to energy consumption in the use phase, dust pick up, dust reemission, noise and durability (see table 5). The requirements for durability enter into force in September 2017. However, before the requirements enter into force, the Commission shall review the durability requirements (before September 2016). This review should be made, because the durability requirements were introduced very late in the process.

	September 2014	September 2017
Annual energy consumption	62.0 kWh/ year	43.0 kWh/ year
Rated input power	1,600 W	900 W
Dust pick up on carpet	0.70	0.75
Dust pick up on hard floor	0.95	0.98
Dust re-emissions		1 %
Sound power level		80 dB(A)
Hose durability		40,000 oscillations under strain
Motor durability		<500 hours
Information requirements	Technical documentation, booklet of instructions and free access websites of manufacturers, their authorised representatives, or importers shall contain the following elements: • Any information required to be published in respect of the vacuum cleaner under any delegated acts adopted under Directive 2010/30/EU of the European Parliament and the Council. • Short title or reference to the measurement and calculation methods used to establish compliance with the above requirements. • For hard floor vacuum cleaners mention that they are not suitable for use on carpet with the delivered nozzle. • For carpet vacuum cleaners, mention that they are not suitable for use on hard floors with the delivered nozzle. • For appliances that are enabled to function also for other purposes than vacuum cleaning, the electric input power relevant to vacuum cleaning if this is lower than the rated input power of the appliance. • As which of the following three groups the vacuum cleaner should be tested: general purpose, hard wood or carpet. The technical documentation and a part for professionals of the free access websites of manufacturers, their authorised representatives, or importers shall contain the following elements: • Information relevant for non-destructive disassembly for maintenance purpose, in particular in relation to the hose, suction, inlet, motor, casing and cable. • Information relevant for dismantling, in particular in relation to the motor and any batteries, recycling, recovery and disposal at end-of-life.	

TABLE 5: ECODESIGN REQUIREMENTS FOR VACUUM CLEANERS (EUROPEAN COMMISSION 2013B).

5.2.1 The process of setting the requirements:

Vacuum cleaners were covered in the transitional period before the working plan for 2009-2011 was adopted. Vacuum cleaners are covered by LOT17. The process of developing the implementing measure was quite long. As seen in figure 4, the preparatory study began in November 2007, and the final regulation was published in July 2013.

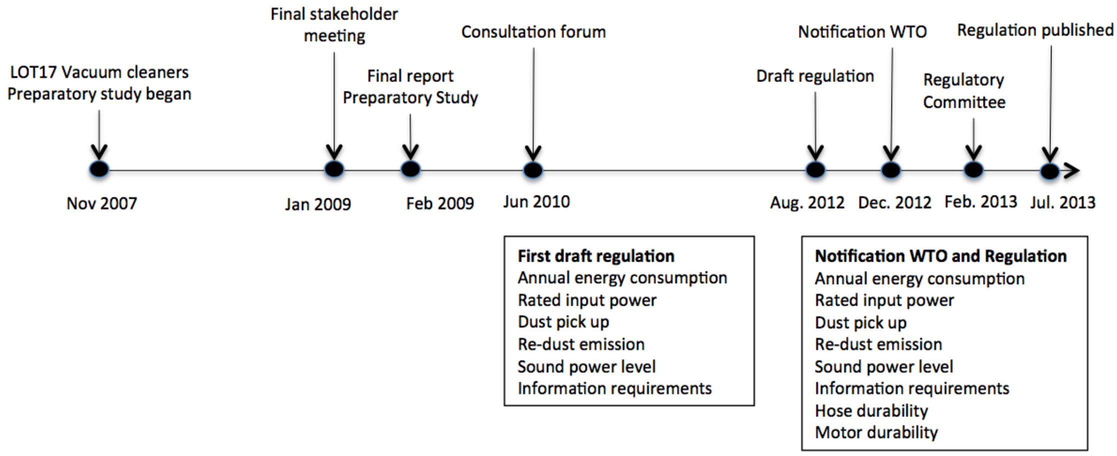

FIGURE 4: OVERVIEW OF THE PROCESS OF DEVELOPING THE IMPLEMENTING MEASURES FOR VACUUM CLEANERS (ECEEE 2014, AEA ENERGY & ENVIRONMENT 2009, EUROPEAN COMMISSION 2012F, EUROPEAN COMMISSION 2012H).

In the preparatory study for vacuum cleaners (AEA Energy & Environment 2009), energy in the use phase was emphasised as an important impact category. This was because the life cycle assessment (figure 5) showed that this phase had the largest impact, and partly because the rated input power of vacuum cleaner had increased since the 1960s (figure 6). The raise in rated input power is due to the general perception that cleaning performances improves with increasing input power, which is not necessarily true. Therefore, energy consumption was in focus in the requirements proposed in the preparatory study, which included suggestions for requirements on:

- Capped maximum power consumption
- Time based further reduction in maximum power consumption
- Standby maximum power consumption
- Maximum noise level
- Energy labelling scheme with information on cleaning performance for carpet and hard floor. (AEA Energy & Environment 2009, p. 94-95)

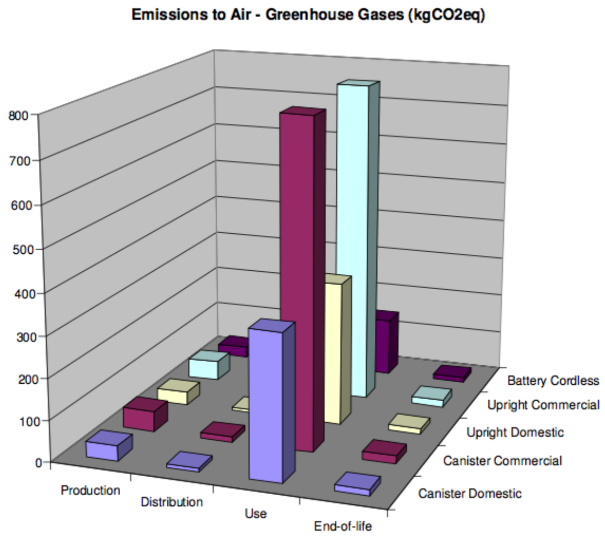

FIGURE 5: LIFE CYCLE ASSESSMENT OF VACUUM CLEANERS (AEA ENERGY & ENVIRONMENT 2009).

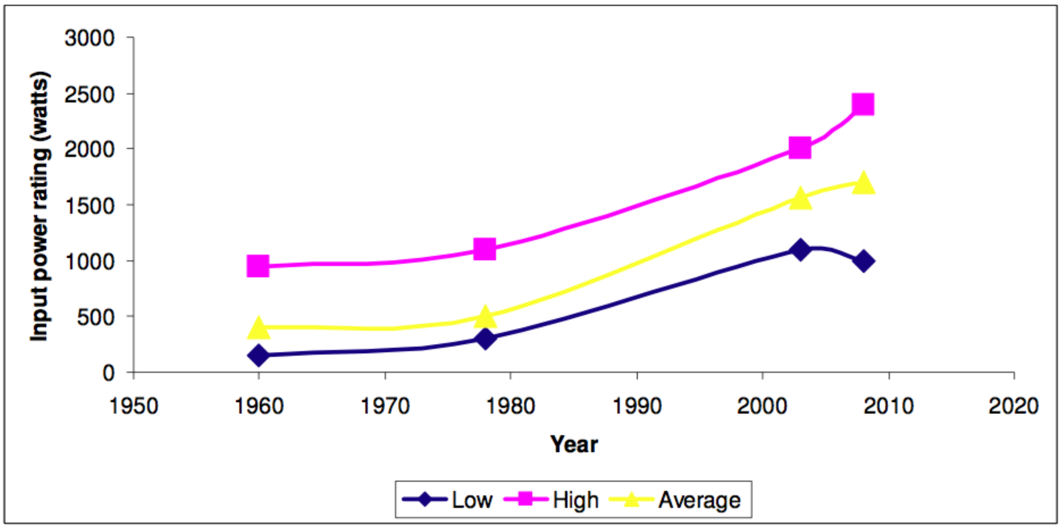

FIGURE 6: THE DEVELOPMENT IN INPUT RATING POWER (AEA ENERGY & ENVIRONMENT 2009)

In addition to the requirements proposed, one of the conclusions of the preparatory was that, *"the issue of product durability should be considered after the proposed measure have been put into place and older less efficient vacuum cleaners have disappeared from the working EU stock"* (AEA Energy & Environment 2009, p. 102). Hence, product durability was in focus in the preparatory study, but not emphasised as one of the requirements to be implemented first.

According to the Policy Officer currently in charge of the implementing measure for vacuum cleaners the process of setting the energy requirements were complex and long, *"The measurement of how to calculate the energy use of a vacuum cleaner is not so obvious, because you will have to relate it to the actual user behaviour. That was a difficult discussion, so I suspect that it is one of the reasons why at that stage nothing particular were proposed on durability"* (Deurwaarder 2014). Hence, setting the energy requirements turned out to be quite a complex process, because of disagreements on how to measure energy consumption. It is also supported by the fact that it took almost two years from the consultation forum was held to the draft regulation was proposed (figure 4). This may also be why durability requirements were not introduced in the first draft of the implementing measures. The durability requirements were not introduced until the requirements had been discussed internally in the Commission (Deurwaarder 2014). Hence, the durability requirements were not included until in the draft of the implementing measure that was used to notify WTO. The regulatory committee then approved the implementing measure given that the measurement and test methods for the durability requirements should be further examined, because they were not included in the stakeholder Consultation Forum (Deurwaarder 2014). Furthermore, according to a stakeholder involved in the process, the durability requirements were introduced by DG Environment, *"So they were about to finalise the ecodesign and the energy labelling process, and now it is 1.5 years ago. It was getting to a close and suddenly in the last minute DG Environment with David Magnotti, desk officer, started talking this about durability requirements for the engine and for the hose and there was one more that was scraped"* (Edsjö 2014). Furthermore, according to Ferenc Pekar from DG Environment, it was DG Environment that was pushing for requirements on durability (Pekar 2014).

Various reasons exist for the late introduction of the durability requirements. Firstly, durability was identified in the preparatory study as something that could be approached at a later stage. Secondly, resource efficiency was on the political agenda during the later years of the process, so the policy officers might have had a larger focus on resource efficiency at this stage of the process. Finally, the lengthy and complex process might also be why, the durability requirements were introduced so late in the process.

5.2.2 What made it possible to include the durability requirements for vacuum cleaners?

Vacuum cleaners are a good case example in terms of adopting resource efficiency requirements. However, on other aspects it is perhaps not as good an example. Firstly, the process of setting the requirements was quite lengthy. Secondly, the durability requirements were introduced quite late in the process, and therefore they were not included in the Stakeholder Consultation Forum. Still, there are relevant lessons to learn from this case study, on what made it possible to set these requirements?

The fact that durability was emphasised in the preparatory study laid the basis for including requirements in the implementing measure. As expressed by the policy officer currently involved, *"What is relevant for vacuum cleaners is that the preparatory study already identified that there was an issue of durability with vacuum cleaner"* (Deurwaarder 2014). As mentioned earlier, for resource efficiency to be part of and in focus in the preparatory study, it needs to be approached in MEErP. This has been attempted in the study about implementing material efficiency into MEErP and the EcoReport tool. However, as the review of this study also suggested, the alterations and changes made in MEErP and the EcoReport tool are minor. Therefore, they alone will probably not ensure the implementation of resource efficiency requirements into the Ecodesign Directive.

Durability was not proposed in the preparatory study as one of the first impact categories to set requirements to nor were the durability requirements included in the first version of the implementing measures. The reason why the durability requirements ended up in the final version of the implementing measures anyway might be that resource efficiency had come on the political agenda with the publication of the flagship and roadmap to resource efficiency. Hence, DG Environment might have seen a possibility to push the resource efficiency agenda in the case of vacuum cleaners.

A policy officer from DG Environment indicated that they (DG Environment) played an important role in getting the durability requirements included in the implementing measure, *"We have been pushing for the inclusion of durability requirements on the hose and the electric motor that was finally accepted…"* (Pekar 2014). Moreover, an industry stakeholder (Edsjö 2014) emphasised the fact that the implementing measure was developed simultaneously with the Energy Labelling also had a positive impact for the implementation of the durability requirements. Because some of the industry stakeholders were interested in getting the Energy Label and in exchange were willing to accept the durability requirements in the implementing measure, *"We thought it would be damaging if they scraped the energy labelling because of the ecodesign, it was a risk as we saw it"* (Edsjö 2014). Hence, the fact that part of the industry was interested in getting the Energy Label, made them more inclined to accept the implementation of durability requirements in the implementing measure.

Finally, it was possible to include the requirement, because there already existed an industry standard for the durability of the motor and for the hose. As expressed by the policy officer, *"it was possible (to set the requirements) because there are in fact measurement methods"* (Deurwaarder 2014). These standards are important to ensure that the requirements can be measured and verified, and that they thereby are enforceable. However, because the durability requirements were introduced so late in the process there will be an additional study to examine, if the measurement methods are actually the right ones.

5.3 Sub-conclusion

The two case studies have shown that in both cases, resource efficiency was regarded as a significant impact category in the preparatory study. Therefore, it might seem as an obvious consequence that these are included as requirements. However, in both cases, the preparatory studies suggested that resource efficiency was something to regulate at a later stage after the adoption of energy requirements. Hence, it was considered secondary to the energy requirements. However, in both cases it ended up as requirements in the final version of the voluntary agreement and implementing measure. In other words, it was not only because resource efficiency was included in the preparatory study that resource efficiency requirements were adopted.

The studies also indicated that the resource efficiency requirements were implemented late in the process after pressure from internal and/or external stakeholders. Hence, pressure from these stakeholders was crucial for implementing the resource efficiency requirements. In both cases, the possibility to convince the industry by different means made it possible to include the requirements. In the voluntary agreement for imaging equipment, it was possible to convince the industry to expand the scope of the agreement, because if they did not accept the voluntary agreement they would be facing regulation. This speaks in favour of voluntary agreements as a platform, where it is easier to include broader environmental parameters, because the industry is interested in avoiding regulation. However, this has not been the case for all voluntary agreements. An example is the voluntary agreement for complex set top boxes, which only includes energy requirements. In the case of vacuum cleaners, parts of the industry were keen on attaining the EU Energy Labelling, and therefore in fear of this falling apart accepted the durability requirements.

In both cases, the requirements were included after resource efficiency had come on the political agenda through the publication of the flagship and roadmap on resource efficiency. Hence, the fact that resource efficiency had come on the political agenda played a role in getting the resource efficiency requirements implemented. The two studies also revealed that the existence of measurement and test standards and ecolabelling schemes were important for the implementation of resource efficiency requirements. It needs to be measurable requirements that can be enforced and monitored when the products are put on the market, which leads us to one of the challenges in connection with the resource efficiency agenda, namely that some resource efficiency requirements can be hard to measure and thereby enforce. Table 6 provides an overview of the main findings in the two case studies.

Imaging equipment	Vacuum cleaners
Resource efficiency was identified as significant in the preparatory study	Durability included in the preparatory study and considered significant
Schemes (Energy Star, EPEAT and Ecolabels) existed already covering resource efficiency requirements	Measurement standard existed on durability of the motor and the hose
Pressure from stakeholders	Pressure from DG Environment
A wish from the industry to avoid regulation in the form of implementing measures	Willingness from parts of the industry
Resource efficiency on the political agenda	

TABLE 6 IMPORTANT ASPECTS FOR THE INTRODUCTION OF RESOURCE EFFICIENCY REQUIREMENTS IN THE TWO CASE: THE IMPLEMENTING MEASURE FOR VACUUM CLEANERS AND THE VOLUNTARY AGREEMENT FOR IMAGING EQUIPMENT.

Recommendations:

- Ensure that resource efficiency parameters are included in the preparatory study through changes in MEErP.
- Maintain pressure from the stakeholders and the Commission to include resource efficiency.
- Maintain political attention on resource efficiency.
- Focus on developing measurement standards, test standards and verification measures for resource efficiency.
- Increase collaboration and knowledge sharing between the Ecodesign Directive and the voluntary schemes, such as Energy Star EPEAT and the Ecolabels.

6. Barriers and Drivers for the Resource Efficiency Agenda under the Ecodesign Directive

Based on interviews with stakeholders from DG Environment, DG Energy, NGOs, consultancies and the industry, the following chapter will discuss the drivers and barriers for implementing resource efficiency in the Ecodesign Directive. Some of these have also been discussed in chapter 5. This is not a full account for all drivers and barriers, but the views of the different stakeholders involved in the processes.

6.1 Drivers

6.1.1 On the political agenda

A main driver of resource efficiency in relation to the Ecodesign Directive is that resource efficiency is on the political agenda, and the Directive is a strong policy instrument to implement this agenda. Hence, resource efficiency is included in the European 2020 strategy (European Commission 2010c) as one of the flagship initiatives (European Commission 2011c) and further specified in the European roadmap for resource efficiency (European Commission 2011e). As expressed by one of the policy officers, *"...resource efficiency is a flagship policy for the EU and has been identified as one of the areas where the EU should do more. So that is an important driver"* (Nuij 2014). The increasing attention to resource efficiency from 2011 and forward might also be a reason for the late introduction of resource efficiency requirements in the case of vacuum cleaners and imaging equipment. The political focus on resource efficiency and the Ecodesign Directive is also evident in the projects initiated by the Commission such as the one conducted by Joint Research Centre *on the implementation of resource efficiency into the Ecodesign Directive* and the project on *implementing material efficiency into MEErP and the EcoReport Tool*.

6.1.2 Resource efficiency is within the scope of the Ecodesign Directive

Resource efficiency aspects are also included as part of the ecodesign parameters that need to be considered for products if they are found significant. This includes aspects such as possibilities for reuse, recycling and recovery of energy, weight and volume of the product, use of materials issued from recycling activities, consumption of resource through the life cycle, hazardous substances, consumables, ease for reuse and recycling, incorporation of used components, avoidance of technical solution detrimental to reuse and recycling of components and whole appliances, extension of lifetime, amounts of waste generated (European Union 2009b, p. 23-24). Hence, as this long list indicates, there is in the ecodesign framework Directive the possibility to set requirements targeting resource efficiency. As expressed by one of the policy officers, *"Resource efficiency and broader environmental impacts are listed as issues that we should look at and so that is what we do for each product that we pick up. If these are found to be significant, we will address them in our measures"* (Nuij 2014). However, it requires that resource efficiency is identified in the preparatory study as having a significant improvement potential, which was the case for both vacuum cleaners and imaging equipment. Furthermore, this again requires that resource efficiency be recognised in MEErP as mentioned previously.

6.1.3 Pressure from the stakeholders and technical documentation

The two case studies and the interviews with stakeholders indicated that pressure from stakeholders such as NGOs and DG Environment was important for the implementation of resource efficiency requirements in the implementing measures for vacuum cleaners and the voluntary agreements for imaging equipment. Furthermore, many of the resource efficiency requirements were introduced after inputs from the external or internal stakeholders. Especially, DG Environment emphasises their role in driving the resource efficiency agenda, *"we will like to continue and provide more input to the whole process, so that these resource efficiency criteria are really taken serious in the preparatory study as mush as possible and later on included in the implementing measures. That is our main objective, and we are working along this line providing financing to the scientific studies by JRC and other consultants. So that we have the scientific evidence to prove that this is workable and will achieve a lot of environmental savings"* (Pekar 2014). Hence, pressure from internal and external stakeholders is key in driving the resource efficiency agenda along with the necessary technical documentation to support the arguments.

6.2 Barriers

6.2.1 The Institutionalisation of the Ecodesign Directive

A possible barrier, identified by a stakeholder, was what can be termed *the institutionalisation of the Ecodesign Directive*. So far the development of the implementing measures for the various product groups has been the responsibility of DG Energy (consumer products) or DG Enterprise (business to business products). DG Environment has been involved, but they have not been responsible for a product category. As expressed by the stakeholder, *"The second thing, which is a bit less traditional and which is important, is the fact that the ecodesign and the energy label are clearly focused on energy. It means that all the people working with this are mostly interested in energy and in energy in the use stage and the level of awareness of this community about the possibility and the needs, the opportunities to grasp the potential link to material efficiency, I would say, it is growing but it is not yet there"* (Arditi 2014).

The focus on energy is also a consequence of the scope of the Ecodesign Directive, which firstly focused on energy using products and then after the revision on energy related products. Therefore, DG Energy and DG Enterprise had the responsibility. The energy focus in DG Energy is further emphasised by a stakeholder from DG Energy, *"…from our perspective these directives are focused on energy efficiency although other environmental impacts are fully considered. This is also where the focus lay for most of the member states when voting on an implementing measure for ecodesign…"* (Nuij 2014). However, as energy efficiency of the product groups covered by implementing measures improves, other impact categories, including resource efficiency, will become relatively more important. For this to happen, the focus of those responsible for the Directive needs to change. DG Environment is an institution with a broader view on environmental aspects and with the competences to support the resource efficiency agenda. However, as Arditi also indicated above the focus is beginning to shift towards additional environmental requirements.

6.2.2 Measurement standards and approaches and market surveillance

Another barrier is that measurement methods, test methods and standards for resource efficiency are not yet as mature as those for energy. This is a key challenge, as the market surveillance authorities need to be able to verify the requirements. As expressed by a policy officer from DG Energy, *"Market surveillance is a key issue, and Member States want to make sure the adopted requirements can be checked, and can be checked within reasonable cost"* (Nuij 2014). Market surveillance is the responsibility of the Member States. Therefore, the Member States will of course be concerned with the verification of the product compliance and the related expenses. However, as the review of the resource efficiency criteria in the ecolabels will show in the next chapter, the ecolabels have already included many resource efficiency criteria. These criteria also need to be verified. Therefore, learning from the ecolabels on verification and market surveillance could potentially be transferred from the ecolabels to future requirements under the Ecodesign Directive. However, it will require further studies to examine how the ecolabels verifies these criteria.

6.2.3 The costs and benefits for the consumers

Another potential barrier in the relation to resource efficiency requirements is that the consumers might not have the same incentive to buy resource efficient products, as they had to buy energy efficient product, where the consumers would have a direct benefit by saving money on the energy bill. Hence, the drivers are different for the end-consumers, when it comes to resource efficiency compared to energy, as there are not always direct benefits for the consumers (Edsjö 2014). This also implies that the producers do not have the same incentive to make resource efficient products, as they had to make energy efficient product. This will be the case, when resource efficiency is understood as material efficiency, recycling and closing material loops. However, there will be cases where resource efficiency can be a competitive advantage for the producers. When resource efficiency is understood as durability, easy-to-repair, modular design, upgradeability, etc., it has direct consumer benefits and is at the same time a mean for the manufacturers to differentiate their products from their competitors.

6.2.4 The role of industry

Finally, some resource efficiency requirements might not always be in the interest of the manufactures. One of these requirements might be durability, where increased product lifetime potentially could reduce the manufactures sales. As expressed by one of the policy officers from DG Energy in the case of washing machines, "*Again then we will face resistance from manufacturers, in a saturated market as that of washing machines, of course they are interested in having products that breaks down after three or four years, and then the consumers are forced to buy new ones. So that will be a hard fight again I think. We did the same with vacuum cleaners*" (Pekar 2014), and it was further emphasised by a policy officer from DG Environment, *"yes definitely, there are quite some difficulties and barriers we will have to overcome. Of course first of all it is the industry's opposition, because obviously it is quite difficult. It is not in their direct interest for example to promote the recyclability and the reusability and the same goes for durability"* (Pekar 2014). However, it should also be emphasised that there are resource efficiency parameters, where it is a direct benefit for the producer to be more resource efficient, such as material consumption in the production; and it can be a competitive differentiation strategy to make the products easy to repair and up-grade, especially for manufacturers of high priced quality products.

6.3 Sub-conclusion

As the review of the stakeholders' different viewpoints has shown, there are drivers for resource efficiency to be further implemented in the Ecodesign Directive. Firstly and most importantly, resource efficiency is within the framework of the Ecodesign Directive. Hence, it is possible to include resource efficiency requirements within the scope of the Ecodesign Directive. Secondly, there is a political willingness and attention on resource efficiency. Finally, the stakeholders involved, especially NGOs and DG Environment, press for additional resource efficiency requirements in the implementing measures and voluntary agreements.

However, as the review has also showed, many barriers exist regarding the implementation of resource efficiency into the Ecodesign Directive. Firstly, there is the institutionalisation of the Ecodesign Directive. Hence, DG Energy and DG Enterprise have the main responsibility for the implementing measures and voluntary agreements, and they have traditionally had their main focus on energy. The energy focus is of course also a result of the characteristics of the product groups included in the Directive; first energy using and then energy related products. However, it may also be a result of the institutions responsible having a focus on energy and competences within that field. To sole this, one solution could be that DG Environment plays a bigger role in developing and updating future implementing measures and voluntary agreements. Secondly, measurement methods, testing methods and verification methods for some resource efficiency parameters are not fully developed, and therefore market surveillance may be challenging. Finally, opposition from parts of the industry could be expected for certain resource efficiency requirements such as durability requirements, because it may compromise sales.

Recommendations:

- Continue to have resource efficiency on the political agenda
- The stakeholders need to push for resource efficiency requirements
- The necessary technical documentation to support resource efficiency requirements needs to be developed
- Measurement-, test- and verification methods for resource efficiency criteria need to be developed further
- DG Environment's role in driving the resource efficiency agenda should be further strengthened
- DG Energy and DG Enterprise should also have a stronger focus on resource efficiency (progressing but with room for improvement)
- The current division of the product categories between DG Enterprise and DG Energy could be reconsidered and DG Environment could play a bigger role

7. Criteria for Resource Efficiency in the Nordic Ecolabel, EU Ecolabel, EU Green Public Procurement and EPEAT

As the previous chapter has documented, the existence of schemes already targeting resource efficiency such as standards and ecolabels played a significant role in setting ecodesign requirements in the case of imaging equipment and vacuum cleaners. Therefore, the following chapter will explore this subject further. In this chapter, the types of resource efficiency requirements will be examined that already exist in four voluntary instruments: the EU ecolabel, the Nordic Swan, EU green public procurement and EPEAT (table 7), and how and if these requirements could be transferred to the Ecodesign Directive. This chapter is based on a study by Dalhammer et al. (2014), but the discussion of the different criteria are further elaborated and there is only focus on energy-related products.

	PCs and servers	Imaging equipment	Windows
Nordic Ecolabel	▯ (Nordic Ecolabelling 2009)	▯ (Nordic Ecolabelling 2007)	▯ (Nordic Ecolabelling 2008))
EU Ecolabel	▯ (European Commission 2011f)	▯ (European Commission 2012f)	✗
EU GPP Guidelines	▯ (European Commission 2012g)	▯ (European Commission 2014b)	Old version used a new under development

TABLE 7: OVERVIEW OF THE VOLUNTARY INSTRUMENTS AND PRODUCT GROUPS INCLUDED IN THE REVIEW.

The voluntary criteria of these three products were analysed with the aim of spotting resource efficiency criteria. In table 8, the resource efficiency parameters covered in the voluntary instruments for these three products are presented. The review merely focuses on resource efficiency requirements other than energy and therefore this review is not a full account of the criteria in the four instruments.

Resource efficiency parameter	PCs and servers	Imaging equipment	Windows
Declaration of reusability, recyclability and recoverability (RRR) ratio			
Threshold of reusability, recyclability and recoverability (RRR) ratio	NE, EPEAT	EPEAT	
Easy disassembly (improve options for recycling and repair)	NE, EU E, EPEAT, GPP	NE, EU E, GPP, EPEAT	NE
Declaration of recycled content	EPEAT	EU E	
Threshold of recycled content	EU U, GPP, EPEAT	EU E, NE, GPP, EPEAT	NE, GPP
Hazardous substances (in lights, plastic parts and coatings, surface treatment, batteries)	NE, EU E, GPP, EPEAT	NE, EU E, GPP, EPEAT	NE, GPP
Bill of Materials (BoM)		NE, EPEAT	NE
Identification of plastic components	NE, EPEAT, GPP	NE	NE, GPP
Contamination of plastics	NE, EU E, EPEAT		
Mono-material	NE, EPEAT, GPP	NE	
Sustainable wood			NE, GPP
Efficient use of materials during use phase (paper and ink)		NE, EU E, GPP	
Durability (Extended warranty, upgradability and repair, spare parts, modularity)	NE, EU E, GPP, EPEAT	NE, EU E, GPP, EPEAT	NE, GPP
Waste from manufacturing			NE
Take-back Reuse, recycling and recovery systems	NE, EPEAT	NE, EU E	NE, GPP
Packaging	EU E, GPP	EU E, NE	NE
Information Requirements related to resource efficiency	NE, EU E	EU E, NE, GPP	NE

TABLE 8: AN OVERVIEW OF THE RESOURCE EFFICIENCY CRITERIA FOUND IN THE FOUR SCHEMES NORDIC ECOLABELLING (NE), EUROPEAN ECOLABEL (EU E), EUROPEAN GREEN PUBLIC PROCUREMENT (GPP) GUIDELINES AND EPEAT FOR THE TREE PRODUCT GROUPS PCS AND SERVERS, IMAGING EQUIPMENT AND WINDOWS

7.1 Resource Efficiency Criteria in the Nordic Ecolabel, the EU Ecolabel, EU Green Public Procurement and EPEAT and the Transferability of these Requirements to the Ecodesign Directive

The following section includes a description and discussion of the existing resource efficiency criteria in the four voluntary instruments for the three product categories. Furthermore, the section includes a discussion of whether or not these criteria can be transferred to the Ecodesign Directive. Energy requirements are excluded from the review as the focus is on resource efficiency requirements other than energy.

When discussing transferability to the Ecodesign Directive, then the ecolabels and the Ecodesign Directive are two distinct instruments with different purposes. The Ecodesign Directive is a mandatory instrument setting minimum requirements to energy-related products entering the European market, whereas the ecolabels are voluntary instruments targeting the environmentally best performing products on the market. Therefore, the level of ambition in the two instruments is not the same, but having this in mind, it is possible to use the learning from the ecolabels in future resource efficiency requirements in the Ecodesign Directive.

When considering including resource efficiency requirements in an implementing measures, article 15 in the framework Directive for setting ecodesign requirements (European Union 2009b) is important. Article 15 specifies which criteria the requirements in the implementing measures should meet to be considered as ecodesign requirements (see figure 7). Furthermore, article 15 specifies that, *"Specific ecodesign requirements shall be introduced for selected environmental aspects, which have a significant environmental impact"* (European Union 2009b, p. 21). This was also evident in the two case studies of vacuum cleaners and imaging equipment, where resource efficiency requirements were found significant in the preparatory study. Finally, it should be possible for market surveillance authorities to verify, if the products comply with the requirements in the implementing measures. If these criteria are fulfilled, it should be possible to set resource efficiency requirements in the implementing measures or voluntary agreements. However, these need to be evaluated for each product group, as these criteria will be highly depended on the product group in question. This review will focus on if the requirements can be verified and if the environmental aspect selected for a requirement has a significant impact.

Article 15, paragraph 5

Implementing measures shall meet all the following criteria:

(a) there shall be no significant negative impact on the functionality of the product, from the perspective of the user;

(b) health, safety and the environmental shall not be adversely affected;

(c) there shall be no significant negative impact on consumers in particular as regards the affordability and the life cycle cost of the product;

(d) there shall be no significant negative impact on industry's competitiveness;

(e) in principle, the setting of an ecodesign requirement shall not have the consequences of imposing proprietary technology on manufactures; and

(f) no excessive administrative burden shall be imposed on manufactures. (European Union 2009a, p. 20)

FIGURE 7: CRITERIA THE REQUIREMENTS (IMPLEMENTING MEASURES) SHOULD COMPLY WITH BE CONSIDERED.

7.1.1 Declaration and Threshold of Reusability, Recyclability and Recoverability ratio

Neither of the ecolabels include requirements for declaration of reusability, recyclability and recoverability (RRR) ratios. The Nordic Ecolabel and EPEAT set criteria for the threshold of material recovery for computers. They require that 90 % of the weight of plastics and metals in the enclosure of the computer can be recovered. Energy recovery is excluded from these ecolabel criteria, as it is considered the least resource efficient option. It is worth noting that the criteria are set for the recyclability of the materials in the enclosure and not the recyclability of the entire product. The recyclability of the product is more complex than the recyclability of the materials. The recyclability of the product also depends on how the different components and materials are assembled, whereas the recyclability of the materials only depends on the inherent properties of the materials. EPEAT gold also sets a threshold of 90 % reusability and/or recyclability requirement for imaging equipment. Here reusability and recyclability are combined.

Both declaration and threshold requirements to RRR ratio could be transferred to the implementing measures and voluntary agreements of the Ecodesign Directive, if a common methodology could be developed on how to calculate the RRR ratio for products and materials. Thereby, it would also be possible to verify these requirements based on technical information provided by the producers. Declaration requirements to RRR could be implemented first providing knowledge on the issue, which then later could be used to set meaningful threshold requirements. Furthermore, future requirements to RRR ratio should be made according to the waste hierarchy, hence prioritising reuse before recycling and recycling before recovery.

However, setting requirements for the RRR ratio of the material or the product will not ensure that the materials or products are in fact reused, recycled or recovered. It merely says something about the potential of the materials or products to be reused, recycled or recovered. The actual reuse, recycling or recovering will depend on the infrastructure for collection and treatment and the technologies available. Therefore, it might be difficult to assess the actual improvement potential.

7.1.2 Disassembly

The Nordic Ecolabel, the EU Ecolabel and EPEAT set criteria for design for easy disassembly for both computers and imaging equipment, whereas EU GPP Guideline only sets criteria for design for easy disassembly for imaging equipment. The EPEAT criteria are very generic whereas the Nordic Ecolabel, the EU Ecolabel and EU GPP Guideline set more detailed criteria emphasising that it should be easy for qualified or professionally trained personnel to dismantle the products with tools usually available. The criteria regarding disassembly are targeted increased recyclability of the materials but also to improve options for reuse and prolonged durability of the products. The EU Ecolabel encourages the use of screws and snap-fixes especially for parts containing hazardous substances. The EU ecolabel also emphasizes that value components, like circuit boards and other components containing precious metals in the computers, should be easy to remove manually. Furthermore, EPEAT restricts the use of glued and moulded metals. These are examples of requirements aimed at improving the recyclability of the products by both enabling easy disassembly and also reducing contamination of the materials in the product. Disassembly is not really addressed for windows. The Nordic Ecolabel criteria for windows and exterior doors set one criterion targeting disassembly, namely that it must be possible to separate glazing from metals and plastic for recycling.

Requirements targeting easy or manual disassembly could be possible categories to transfer to the Ecodesign Directive. The requirements for easy or manual disassembly could be verified, by performing disassembly test or the producers could provide a video of the dismantling of the product, which is how the requirements are verified in some of the ecolabels. Easy or manual disassembly can help improve reparability and upgradability of the product improving the durability of the product. According to Masanet et al. (2002), manual disassembly in the waste treatment process of electrical and electronic equipment is increasingly being replaced by automatic or destructive disassembly in many developed countries. Therefore, it could be questioned if requirements for easy or manual disassembly will improve the recyclability and recoverability of electrical and electronic equipment if they are fed into an automatic or destructive disassembly system. However, manual disassembly is still performed when economically feasible or when regulation requires it e.g. the WEEE Directive. Therefore, it might still be a relevant category, especially in relation to value components or components that contain hazardous substances. Furthermore, requirements targeting easy or manual disassembly might also improve automatic or destructive disassembly. However, this is an aspect that should be further examined. The waste treatment industry is also continuously developing new technologies. Therefore, it is not possible based on the finding of this study to assess whether or not requirements for manual disassembly will improve the recyclability and recoverability of electrical and electronic equipment in the future. However, requirements targeting automatic or destructive disassembly could be considered in addition to the requirements targeting manual disassembly.

7.1.3 Declaration and Threshold of Recycled Content

The EU Ecolabel and EPEAT set criteria for the use of recycled plastics for both computers and imaging equipment. The EU Ecolabel and EU GPP Guideline set a threshold requirement of not less than 10 % recycled plastics for both product categories. The most ambitious example of requirements to the recycled content is found in EPEAT for imaging equipment, where a minimum of 25 % post-consumer recycled plastics is required. The Nordic Ecolabel sets a cautious criterion for imaging equipment, where one part > 25 g must contain reused or recycled plastic. However, there is no threshold to the content. In the next revision of the Nordic Ecolabel for computers, a requirement has been suggested that the computer should be made of recycled plastics. In addition to requirements for the content of recycled plastics, EPEAT also requires *a minimum content of biobased plastics* in imaging equipment. The Nordic Ecolabel for windows sets threshold criteria for the content of recycled material. It requires that 30 % of non-renewable materials should be recycled materials for windows. Furthermore, the EU GPP Guideline for windows states that extra point can be awarded to products in proportion with their recycled content.

Criteria for the declaration and threshold of recycled plastic, recycled materials and bio-based plastics were found in the voluntary instruments. Setting criteria for the threshold of recycled materials can help create a market for these materials. However, before transferring these requirements to the Ecodesign Directive, it is important to assess if the manufacturers of recycled materials can handle the increases in demand that a requirement would create. Again a possibility could be to begin by setting declaration requirements and then tightening them continuously by setting threshold requirements. A challenge when setting criteria for recycled materials is that currently there are no reliable technologies for an analytical assessment of the recycled content in the products (Ardente et al. 2011a). It implies that verification can be challenging and dependent on supplier declarations. The environmental benefits of using recycled materials will depend on the type of material.

7.1.4 Hazardous Substances

The EU GPP guidelines, the Ecolabels and EPEAT for computers and imaging equipment include an elaborated list of criteria for hazardous substances. The instruments mix information requirements, threshold requirements and exclusion of certain substances. The requirements are both general requirements for the entire product and requirements for specific materials and components such as plastic, batteries and backlight. Many of the criteria in the Nordic Ecolabel, the EU Ecolabel, and GGP guidelines are listed according to the REACH Regulation's risk phrases, but for most criteria a list of exemptions exists. In the EU Ecolabel criteria for imaging equipment, one of these exemptions take into consideration the use of recycled materials by setting less strict requirements to the content of hazardous substances in recycled materials. Thereby, the stricter requirement to hazardous substances does not eliminate the possibility to include recycled materials in the product, which is of importance if a market for recycled materials should be developed. Requirements to the content of mercury or exclusion of intentionally added mercury in backlights and displays are included in EPEAT, the Nordic Ecolabel and the EU Ecolabel for computer and EU GPP guideline for imaging equipment. The RoHS Directive, with a maximum concentration value of 0.1 %, already restricts Mercury; however, exemptions are made concerning various types of lamps. The voluntary instruments remove the exemptions and thus strengthen the requirement in the RoHS Directive.

Criteria on hazardous substances are also included in the Nordic Ecolabelling and EU GPP Guideline for windows. A list of general criteria on hazardous substances is included prohibiting certain chemicals in the windows; the release or leaching of certain chemicals from the product under normal use condition; and certain chemicals in packaging. Further, chemical products (paint, adhesive, sealants, putty, etc.) in the finished window must satisfy certain requirements. The Nordic Ecolabel sets criteria for chemical substances in plastics. However, the Nordic Ecolabel differentiates between virgin and recycled plastic and thereby again does not hinder the use of recycled plastic in labelled products. Furthermore, the use of mercury asbestos is restricted in plastics by the Nordic Ecolabel, and lead is restricted in plastic by EU GPP Guideline. The EU GPP Guideline also sets restrictions to the use of chemicals in e.g. paint, adhesive, sealants, and putty. Furthermore, pressure impregnation is not permitted and the use of nano-materials should be documented.

The criteria for hazardous substances in the Nordic Ecolabel, the EU Ecolabel, and the EU GGP guidelines are first and foremost in place to avoid the exposure of humans and the environment to hazardous substances. However, it will also have trade-off to the end-of-life phase and could theoretically provide better opportunities to recycle the materials, when setting stricter requirements to hazardous substances.

An important issue to consider before including requirements to hazardous substances is whether chemical requirements should be included in the Ecodesign Directive, or if chemicals should solely be regulated through the RoHS Directive and the REACH Regulation. Hence, instead of including requirements for chemicals in the Ecodesign Directive, an expansion of the RoHS Directive could be proposed. A study has already been conducted on the subject matter (Gross et al. 2008), and inspiration for a future expansion of the RoHS Directive could be found here. The environmental improvement potential and the ability to verify the requirement will depend on the specific substance.

7.1.5 Bill of Materials

Bill of Materials (BOM) is defined in Ardente et al. (2011c) as a, "*document that synthesizes a detail of the product's composition*" (Ardente et al. 2011c, p. 13). In the voluntary instruments, no full BOM requirements exist for computers, imaging equipment or windows. However, an interesting criterion in the Nordic Ecolabel for windows is the product description criterion stating that the materials and chemical products of which the window comprises should be specified including a percentage weight. There are no BOM requirements in EPEAT, but a requirement to an inventory of intentionally added chemicals related to the category hazardous substances.

BOM is identified in scientific literature (Ardente et al. 2011c) as an important source of information: to conduct life cycle assessments, to measure the product's recyclability, recoverability and the recycled content and to identify priority resources and hazardous substances in the product, which should be taken into consideration in the end-of-life phase. Hence, BOM can be seen as a premise for many other requirements to improve a product's resource efficiency. Ardente et al. (2011c) makes a more detailed identification of elements considered critical and important to include in a BOM. It includes materials typology, employed masses, connections among different materials and placement of the components in the assembly/ disassembly process, and content of hazardous or other substance that negatively affect RRR (Ardente et al. 2011c, p. 22). Furthermore, it is proposed that BOM includes a disassembly scheme and a disassembly report. Ardente et al. (2011c) also suggest that priority resource should be identified and listed in BOM to ensure their reuse or recycling.

The information proposed by Ardente et al. (2011c) to be included in a BoM is much broader than the information requirement currently found in the Nordic Ecolabel for windows. However, it is a first step to set criteria for BOM for products, and it could interesting to examine further how these criteria have been implemented and verified for ecolabelled windows. Within the Nordic Ecolabel of computers, it has been suggested to include requirements to the use of rare metals (Nordic Ecolabelling 2009). However, due to the complexity of the supply chain of electronic and electrical equipment, this is an issue that is complex to approach (epeat 2013) especially for small producers, as they might not have the ability to force these requirements on to their larger suppliers. An issue that might prove difficult in relation to BoM is the protection of property rights and the industry might oppose such requirement. Hence, it would require the setup of a system that can ensure the companies property rights.

7.1.6 Identification of Plastic Components

The Nordic Ecolabel includes criteria for the identification of plastic components for all three product groups. For windows, computers and imaging equipment the Nordic Ecolabel (and EU GPP Guideline for windows and computers) require that plastic parts above 50 g./25 g. must be visibly labelled for recycling according to ISO 11469 (Generic identification and marking of plastics products). The standard provides a system of uniform marking of products and parts of plastics. The marking is intended to help identify different plastic types and parts to ensure correct handling during waste recovery or disposal. It implies that plastic parts are labelled with an identification marking allowing for the visual identification of polymer types implying that the making can only be read manually.

Visual marking of plastics parts according to certain ISO standards might be quite easy to verify visually by market surveillance authorities when dismantling the product. However, the environmental improvement potential could be questioned. The study by Masanet et al. (2002) has also assessed how ISO 11469 is actually being applied during the waste handling and treatment. The study showed that when the plastic parts were manually sorted, the use of ISO labels were in fact an effective strategy for improving the recyclability of plastic parts, but the study also indicated that up to 20 % of the ISO labels were incorrect. For automatic sorting systems, the ISO labels had no effect as these systems sort according to the plastic's mechanical, optical and electrostatic properties. Hence, the effectiveness and thereby the environmental improvement potential of visual marking of plastic according to ISO 11469 will depend on the sorting systems. Therefore, before setting criteria for visual marking of plastics in the Ecodesign Directive or prolonging the criteria for marking of plastic in the voluntary instruments, it is recommended to further examine to what extent the waste is manually sorted for the product group in question, and how the future waste treatment of the product might look like. Furthermore, alternative marking methods should be examined, which could be apply in e.g. automatic sorting systems.

7.1.7 Contamination of Materials

The Nordic Ecolabel, EU Ecolabel and EPEAT set requirements for computers regarding contamination of materials. The Nordic Ecolabel requires that large plastic parts (above 25 grams) must not be painted or metallized and that chlorine based plastics must not be contained in the enclosure and chassis. The EU Ecolabel requires that plastic parts shall not contain a chlorine content greater than 50% by weight. EPEAT requires that larger plastic parts shall be free from PVC, and that paints or coatings not compatible with recycling should be eliminated. It might be possible to transfer the requirements regarding contamination of materials to the implementing measures and the voluntary agreements under the Ecodesign Directive. Requirements regarding contamination of materials are relevant for the recyclability, as the potential for recycling is reduced if incompatible materials are combined after disassembly, especially limiting of paints was documented in the study by Masanet et al. (2002) to be an effective strategy to improve the recyclability of plastic. Hence, there seem to be an environmental improvement potential. Furthermore, depending on the specific requirement, it might in many cases also be something that could be verified visually. However, some of the requirements are also target hazardous substances, such as PVC, and again it is a question of whether chemicals should merely be regulated in the RoHS Directive and the REACH Regulation or if they should also be included in the implementing measures and voluntary agreements under the Ecodesign Directive.

7.1.8 Mono-Materials

In terms of mono-materials, the Nordic Ecolabel for both computers and imaging equipment sets requirements to the use of compatible plastic types, and that the enclosure should use a maximum of two types of polymers that are separable (also a EU GPP award criterion for computers). EPEAT for computers similarly requires a reduced number of plastics (epeat 2014). Using compatible or a reduced number of plastics can improve the recyclability of e.g. thermoplastics, as a mixture of different polymers or a contamination of the plastic fractions can significantly decrease the plastics properties and thereby the use of the recycled materials (Beigbeder et al. 2013). Hence, including requirements in the Ecodesign Directive on compatible or a reduced numbers of polymers or plastics could potentially improve the recycling of plastics. However, if this potential will be utilized will strongly depend on the recycling system that the products enter into. Therefore, setting these types of requirements should be supplemented with a dialogue with the stakeholders from the recycling industry to ensure the effectiveness of these types of requirements.

7.1.9 Sustainable Sourcing of Wood

The sustainable sourcing of wood covers, as the name also indicates, more than resource efficiency. However, there is an interface between sustainable sourcing of wood and resource efficiency. An example is that extended use of reused wood would contribute to reduced deforestation. Criteria on sustainable sourcing of wood only apply to windows. The main focus of the criteria is targeting sustainable wood and wood coming from legal sources. The Nordic Ecolabel for windows sets threshold requirements for the amount of wood deriving from certified forests. The EU GPP Guideline for windows sets a threshold requirement of 70 % to the use of wood from certified forest and requirements, which ensure that the wood derives from forests managed in a sustainable way. This criterion targeting sustainable materials and more specifically sustainable wood is quite product specific and linked to the fact that windows can be comprised partly by wood.

Setting requirements for sustainable sources of wood in the Ecodesign Directive will only be relevant for a small number of energy-related product categories. However, windows, for which there is currently being made a preparatory study, could be a relevant product category. A risk of setting this type of mandatory requirement on sustainable sourcing of wood could be that the supply could not follow the demand, and that the producers might be depending on a small numbers of suppliers. This should be examined before setting the requirements. More generally, sustainable sourcing of materials could be relevant for other product groups setting requirement to e.g. conflict minerals in the Ecodesign Directive.

7.1.10 Efficient Use of Materials During the Use Phase

Efficient use of resources during the use phase, other than energy, is included for the imaging equipment targeting the consumables: paper and ink. The Ecolabels and EU GPP guideline address this differently, but all schemes set requirements to the capability of duplex printing and printing of two or more sides on one paper. Furthermore, EPEAT, EU Ecolabel and EU GPP Guideline set requirements to duplex printing as default.

Energy consumption in the use phase is an aspect, which has been widely covered by existing implementing measures and voluntary agreements under the Ecodesign Directive, but it is also relevant to target other resources. An example is as mentioned the Nordic and EU Ecolabel criteria for imaging equipment, where a more efficient use of paper and ink cartridges is promoted. These types of requirements are already included in the voluntary agreement for imaging equipment under the Ecodesign Directive (duplex availability, default duplex setting, and information requirements targeting resource efficiency of e.g. paper) (EuroVAprint 2012). However, the category is also highly relevant for other product groups. An example of requirements within this category could be to set a requirement to an automatic detergent dosing system for washing machines avoiding over-dosage and overconsumption of detergents.

7.1.11 Durability

Various criteria were found in the voluntary instruments targeting durability. The criteria can be divided into the following categories: direct criteria on durability of the product, extended warranty, upgradability and repair, spare parts and modularity. The categories are closely interlinked, and therefore they are all dealt with within the overall category durability. All criteria strive to extend the lifetime of the product thereby preventing electronic waste. Durability is also related to the previous category disassembly, where criteria targeting easy disassembly for repair and upgradability were included.

Criteria on durability are set to imaging equipment in both the Nordic Ecolabel and the EU Ecolabel but differently. The durability requirements in the EU Ecolabel are aimed at the cartridge and the reusability of this, whereas the Nordic Ecolabel requirements are aimed at quality assurance and maintenance of the entire product. The durability criteria for windows strive to hinder early wear of the products.

Extended warranty was included in the EPEAT criteria for computers for three years or as a service arrangement. The EU Ecolabel for imaging equipment included an extended warranty for five years and finally the Nordic Ecolabel for windows included a 10-year warranty for parts of the windows (thermo panels and wood rot). The length of the warranty will of course be product specific as evident in the criteria examined. Further, it is also strongly related to the availability of spare parts.

Criteria for upgradability and repair were only found for computers and imaging equipment. However, this type of criteria could also be relevant for windows like for instance upgradability to a higher energy class. Upgradability as a means to increase durability was found in Nordic e

Ecolabel, EPEAT and EU GPP Guideline and covers general criteria on upgradability with common tools and more specific criteria such as easy expansion of the computer's memory and replacement of computer's batteries.

Both the EU Ecolabel, the Nordic Ecolabel and EPEAT require that spare parts and components for repair are available for 5, 5 and 3 years, respectively. Determining how long spare parts should be available can be a challenge. On one hand components should be available to enable repair, but on the other hand the risk is that a too large inventory of components will be out-dated and never utilized. This is counterproductive from both an economic and a resource efficiency point of view, and it needs to be considered when setting future requirements for spare part availability.

Modular design and easy disassembly enable upgrading and repair and are thus prerequisites for lifetime extension. Modular design is only required in the ecolabels (EU Ecolabel, Nordic Ecolabel and EPEAT) for computers, and it is linked to upgradability and repair requirements. For computers there are specific requirements for upgradability with common tools and/or consumer instructions in all ecolabels and this may reflect the rapid technological development of computers, which spurs high replacement rates. Upgradability can potentially reduce the frequency of replacement. Also for imaging equipment the EU Ecolabel and EPEAT set requirements to reparability and upgradability.

The voluntary instruments included general criteria on durability, warranty, upgradability and repair, spare parts and modularity to ensure upgradability and repair. All these requirements could possibility be verified by market surveillance authorities. Improved durability is part of waste prevention and thereby improvement of resource efficiency, and it should be included as possible resource efficiency requirements in the Ecodesign Directive. Durability is also including as a topic in the work carried out by Joint Research Centre (Ardente, Mathieux & Forner 2012). Furthermore, an interesting study was also made by RREUSE (RREUSE unknown), where they looked into reparability of domestic washing machines, dishwashers and fridges. The study identifies the main obstacles to the repair of these product categories and there is an overlap to the criteria found in the ecolabels. The study identifies the main obstacles as: (1) rapid changes of product design, (2) difficulties in assess to spare parts, (3) increasing lack of access to repair and service manuals, software and hardware for reuse and repair centres and (4) increasing difficulty to disassemble product for repair (RREUSE unknown, p. 3-4). Hence, there seems to be an improvement potential for at least these product categories. However, it is important to ensure that prolonging the lifetime of the product is the environmentally best solution in a life cycle perspective, e.g. that possible environmental benefits are not evened out by increased energy consumption of the older product compared to a new more energy efficient product. Additionally, increasing the durability of products might decrease sales of new products in a saturated market. Hence, if including these types of requirements the Ecodesign Directive unwillingness from the industry might be expected from some manufacturers, while the producers with high quality products can have a competitive advantage due to such requirements.

7.1.12 Waste from Manufacturing

The Nordic Ecolabel for windows and exterior doors sets criteria for improving resource efficiency during manufacturing. The Nordic Ecolabel for windows and exterior doors sets some overall criteria for the separability of the waste fractions from the production and the handling of hazardous waste. Furthermore, it sets criteria for the handling of the individual materials at end-of-life. The individual criteria apply to the entire production process in the factory where the ecolabelled products are manufactured and they also apply to subcontractors' production of insulation units, casement and frames (Nordic Ecolabelling 2008). By including requirements to the manufacturing, the labels expand the scope from a product focus towards a production focus. The Ecodesign Directive, as the name states, mainly sets requirements to the design of the product, however targeting the environmental performance of the entire product life cycle. Therefore, design requirements to the product that might improve the manufacturing process would be highly relevant. However, as many electronic products are produced outside Europe, it might be difficult to enforce these criteria.

7.1.13 Take-Back Schemes

The Nordic Ecolabel for computers and windows includes a criterion that national legislation, regulation or agreements within the sector regarding recycling systems should be followed. The Nordic Ecolabel for windows further sets a criterion to have a system in place that ensures collection for recycling of plastic windows. It is not known why only plastic windows are targeted in this criterion. The Nordic and EU Ecolabel for imaging equipment set criteria to a take-back system or return system for toner, ink modules and containers. Furthermore, the Nordic Ecolabel for imaging equipment requires that a system is set up for consumables to ensure their reuse or recovery. EPEAT requires provision of a product take-back service for computers.

Getting the used products into the reuse or recycling system is key for reuse, recycling and recovery of the products, components and materials. Therefore, take-back schemes are important means to reduce the environmental impacts from electronic and electrical equipment. However, take-back system and reuse, recycling and recovering are partly covered by the WEEE Directive, and setting criteria in the Ecodesign Directive on take-back systems and reuse, recycle and recovery systems might create an overlap to the WEEE Directive. Hence, it should be discussed if such an overlap is advisable. However, for consumables or products that are not covered by the WEEE Directive or other legislation, it could be a good possibility.

7.1.14 Packaging

The EU Ecolabel sets criteria that the packaging of computers and imaging equipment should be made of recycled or biodegradable material, more specifically cardboard boxes must consist of 80 % recycled material, and 75 % of the materials in plastic bags must be recycled, biodegradable or compostable.

Transferring these types of requirements to the Ecodesign Directive might again create an overlap to the European Directive on packaging and packaging waste (Europa 2011). Hence it can be questioned if the Ecodesign Directive is the right place to incorporate requirements for packaging as the Directive on packaging and packaging waste already aims to limit the production of packaging waste by promoting recycling, reuse and recovery (Europa 2011).

7.1.15 Information Requirements Related to Resource Efficiency

The Nordic Ecolabel includes criteria for all three product groups regarding consumer information that is intended to help improve resource efficiency. The EU Ecolabel has this type of criteria for both imaging equipment and computers. Criteria on consumer information include: recommended maintenance, cleaning and refurbishment that could help prolong the lifetime of the product. Furthermore, the Nordic Ecolabel and the EU Ecolabel include criteria on what should be done with the product by it's end-of-life, and the EU Ecolabels also include an indication of the expected life time of the product.

In the effort of improving resource efficiency, the consumers are important actors. The consumer is crucial in improving resource efficiency during the use phase such as printing double-sided, maintaining the windows to extend their life span, and upgrading their existing products instead of buying new ones. They are also important actors in a products end-of-life, as they shall ensure correct disposal of the products, which is a precondition for proper waste collection, reuse and recycling. Therefore, requirements on consumer information on resource efficiency are important requirements to include in the Ecodesign Directive. Furthermore, consumer information is also an issue emphasised in the Framework Ecodesign Directive. Information requirements are easy for market surveillance authorizes to verify, as they can be verified by looking through the documentation provided by the producers. Information requirements targeting resource efficiency are already widely applied in the currently adopted implementing measures and voluntary agreements as documented in chapter 4.

7.2 Sub conclusion

When setting requirements in the Ecodesign Directive, many aspects need to be considered and the requirements will vary depending on the product group. The possible requirements found in the ecolabelling schemes could work as inspiration for future requirements in the Implementing Measure and the voluntary agreements. However, it needs to be assessed for each product category and back up with further studies. Table 9 provides an overview of the requirements proposed and inputs from the discussions in this chapter. Additional and relevant resource efficiency requirements most likely exist. These are merely the requirements identified based on a review of the ecolabels, EPEAT and EU GPP Guidelines for the selected product categories.

Possible requirements		Environmental improvement potential	Verifiable	Additional Comment
Declaration and threshold of Reusability, Recyclability and Recoverability ratio		Difficult to document as it will only indicate the potential RRR ratio and not the actual	If a common methodology is developed to calculate RRR ratio	First declaration requirements could set followed later by threshold requirements
Disassembly	Easy disassembly for a qualified or professional with tools usually available.	Improve the reparability and upgradability of the product. Might improve recycling and recovery of the materials however it will depend on the waste treatment system	Could be verified by disassembly test or a video of the dismantling of the product	Disassembly requirements targeting automatic or destructive treatment system could be examined Easy disassembly or removal of contaminated components could be considered
	Screws and snap-fixer			
	Restricts the use of glued and moulded parts			
	Easy to remove value components like e.g. circuit boards			
Declaration and threshold of recycled content		Depending on the material the impact from reused or recycled materials can be significantly lower than virgin materials. Helps create a market for reuse or recycled materials	Not possible or very difficult to verify	
Hazardous substance		Will depend on the substance.	Will depend on the substance.	Overlap to the RoHS Directive and the REACH Regulation.
BoM	Full/ detailed	Of importance for setting other resource efficiency requirements	Will depend on the requirements	The property rights of companies might provide a challenge
	Priority metals / rare earth elements	Could potentially increase the recyclability and recoverability of priority metals and rare earths		

Possible requirements		Environmental improvement potential	Verifiable	Additional Comment
	Hazardous substances	Could help the recycles to remove components containing hazardous substances		Overlap to the RoHS Directive, REACH Directive but focus more on in formation
Identification of plastic components		Will depend on the waste treatment system (manual/ automatic).	Possible – visual verification	Examine alternative marking methods
Contamination of materials	Avoid painted, metalized and coating	Indications that it could have a positive effect for the recycling and recovering of materials.	Depending on the requirement, it could be verified visually	Linked with the RoHS Directive and REACH Regulation.
Mono-materials	Reduced number or compatible polymers/plastics	Could improve the recycled plastics properties and thereby reuse / recycling potential.		The improvement potential will strongly depend on the waste treatment system.
Sustainable wood sourcing		Could potential reduce deforestation	Verified in the ecolabels through different certification schemes.	Other materials could be considered such as conflict minerals. Need to ensure that there supply can follow the demand.
Efficient use of materials during the use phase	Depending on product group	Verifiability will depend on the type of requirement proposed	Energy consumption in the use phase is already included in all existing implementing measures and voluntary agreements.	Efficient use of materials during the use phase
Durability requirements	Extended warranty Upgradability Repair Spare parts Modularity	Extending product lifetime and thereby waste prevention	Can be verified	Increased durability of the product might reduce sales of new products in a saturated market.
Waste from manufacturing		Potentially large environmental improvement potential depending on the product.	Might be difficult to enforce if produced outside Europe	
Packaging	Recycled materials Bio-materials Bio-degradable materials	Could promote recycled materials, bio-materials and bio-degradable materials.		Overlap to the EU Packaging Directive
Information requirements		The end-consumers are important actors to ensure the durability, reuse, recycling and recovery of the products, components and materials.	Easy to verify by looking though the information materials provided by the manufacturer	Are already largely implemented in existing IM and VAs

TABLE 9: OVERVIEW OF THE RESOURCE EFFICIENCY CRITERIA IN THE FOUR POLICY INSTRUMENTS AND MAIN DISCUSSION POINTS.

8. Conclusion

Resource efficiency is currently high on the European Political Agenda, and the Ecodesign Directive has been identified as one of the policy instruments that should help drive this agenda. Two project have been launched Joints Research Centre's project *Integration of resource efficiency and waste management criteria in the implementing measures under Ecodesign Directive* and BIO Intelligence Service's project on the implementation of material efficiency in Methodology for the Ecodesign of Energy-related Products (MEErP). Changes in MEErP are important for the implementation of material efficiency and resource efficiency requirements in the Ecodesign Directive. However, the project has only lead to minor changes to MEErP and will not alone be able to ensure the implementation of material efficiency. Hence, to ensure the implementation of material efficiency and resource efficiency further action is needed.

The review of the adopted implementing measures and voluntary agreements showed that resource efficiency is targeted in the implementing measures and voluntary agreements, but the majority of these are generic information requirements. Information requirements focusing on resource efficiency were found in 16 of the 23 implementing measures and voluntary agreements under the Ecodesign Directive. However, specific requirements were only included for six product categories, three lighting products, vacuum cleaners, imaging equipment and household washing machines. When it comes to specific resource efficiency requirements, the uptake could be improved in future revisions and when developing new implementing measures and voluntary agreements.

In the two case studies of the implementing measures for vacuum cleaners and the voluntary agreement for imaging equipment, it was examined why it was possible to include more elaborated resource efficiency requirements for these product categories. The study revealed that for both product categories, resource efficiency was regarded as a significant impact category. Therefore, resource efficiency was targeted in the requirements. However, the study also revealed that some requirements were implemented late in the process after pressure from internal and/or external stakeholders. In both cases, it was possible to convince the industry that they should accept the resource efficiency requirements by different means. In the voluntary agreement for imaging equipment, the industry wanted to avoid regulation in the form of implementing measures and was therefore more inclined to accept the resource efficiency requirements. In the implementing measure for vacuum cleaners, part of the industry was interested in getting the EU Energy label. However, the two initiatives, the Ecodesign Directive and the Energy labels, were linked. So, if they did not accept the requirements in the implementing measures, they would not get the EU Energy label. This made them more inclined to accept the durability requirements. Finally, the studies indicated that the existence of measurement and test standards and ecolabelling schemes with resource efficiency requirements were important to be able to set and enforce resource requirements.

Some *barriers* have to be overcome for resource efficiency to become actual requirements in the implementing measures or voluntary agreements. In the study, the following barriers were identified through interviews with stakeholders involved in the Ecodesign process:

- The Ecodesign Directive is embedded mainly within DG Energy and DG Enterprise. This is a potential barrier, since especially DG Energy has focus on energy and has competences within this field. However, this is slowly changing.

- The calculation, measurement and test standards for resource efficiency requirements are not fully matured for all types of requirements. This might be a challenge in terms of market surveillance.
- Some of the resource efficient requirements may not provide the same obvious benefits for the consumer compared to an energy efficient product. Hence, the manufactures have difficulties in applying resource efficiency to differentiate their products. However, this is not the case for resource efficiency requirements such as durability and reparability where there is an obvious benefit for the consumer.
- Opposition from parts of the industry could be expected especially when targeting requirements such as durability, as it might have a negative impact on their business if not combined with new business models. However, some of the producers may see resource efficiency requirement as a good opportunity; especially, producers of high-end products, because it may remove some of their competitors' products.

However, there are also *drivers* which help push for the implementation of resource efficiency requirements into the implementing measures and voluntary agreements. These drivers are that:

- Resource efficiency aspects are already part of the ecodesign framework Directive, and included in a few implementing measures.
- Resource efficiency and circular economy is currently high on the political agenda.
- Pressure from the internal and/or external stakeholders.

To answer how and which future resource efficiency requirements could be implemented in the implementing measures and voluntary agreements a review of resource efficiency requirements in the four voluntary instruments the Nordic Ecolabel, the EU ecolabel, EU GPP Guidelines and EPEAT was made. The review revealed that resource efficiency requirements are already widely applied in the voluntary instruments covering energy related products. The instruments included criteria covering:

- Threshold of RRR ratio
- Disassembly
- Declaration and threshold of recycled content
- Bill of materials
- Identification of plastic components
- Contamination of materials
- Mono-materials
- Sustainable wood sourcing
- Efficient use of materials during the use phase
- Durability requirements
- Waste from manufacturing
- Packaging
- Information requirements

It should be acknowledged that other resource efficiency requirements exist in addition to the ones identified in this review. The inspiration for future requirements in the implementing measures and voluntary agreements under the Ecodesign Directive could be found within these voluntary instruments. However, their transferability will depend on the product category. Therefore, an individual evaluation is needed to examine if the requirement is suitable for the product, and that it can fulfil the criteria given in article 15 of the ecodesign framework Directive.

APPENDIX 1: REVIEW OF JOINT RESEARCH CENTRE'S WORK ON RESOURCE EFFICIENCY IN THE ECODESIGN DIRECTIVE

8.1 Deliverable 1: Review of resource efficiency and end-of-life requirements

8.1.1 Survey of the current legislation

JRC's first report begins with a review and analysis of the existing European legislation, which already to some extent has implemented requirements to resource efficiency and waste management.

8.1.2 The Directive on the End-of Life Vehicles (ELV) and the related legislation

The Directive establishes measures with the purpose of preventing waste from vehicles and to ensure the reuse, recycling and other forms of recovery of end-of-life vehicles and their components. The Directive is one of the first examples of the implementation of ecodesign principles in European legislation. The Directive is part of Directive 70/156 Whole Vehicle Type Approval (WVTA). This Directive establishes the framework for the requirements, which a vehicle should comply with to be allowed access to the European market.

The Directive sets requirements to reuse and recovery of the vehicle:

- "The reuse and recovery shall be increased to minimum 85 % by an average weight per vehicle and year"(Ardente et al. 2011a, p. 12)
- "The reuse and recycling shall be increased to a minimum of 80 % by an average weight per vehicle and year" (Ardente et al. 2011a, p. 12)

The calculations of reuse, recycling and recovery are based on ISP 22628 Calculation methods for recoverability and reusability. Furthermore, the Directive sets requirements to the minimum information that should be supplied in the information document.

The Directive sets requirements in the design phase that should push the manufactures towards environmentally better performing products. This is a clear link to ecodesign. Although the Directive solely sets requirements to vehicles there are some general suggestions, which can be transferred to other products, including:

- "the recyclability/ recoverability of products is assessed by means of specific "rates" that represent the mass fraction in percentage that is potential recyclable or recoverable"
- "the starting point for the analysis is the material breakdown."
- "the assessment of recyclability/recoverability is demanded to the manufacture that has anyway, to provide sufficient additional information to support their assumptions.
- "a competent body is responsible for verifying the truthfulness of the manufacturer's assertions and to validate the provided information and the calculation of the rates" (Ardente et al. 2011a, p. 20)

A conceptual flow diagram is presented for the assessment and verification of recyclability/ recoverability potentials of products, see figure 8.

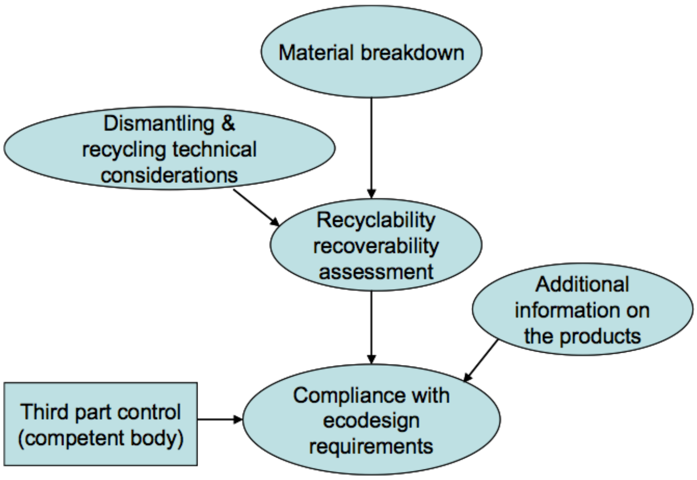

FIGURE 8: CONCEPTUAL FLOW DIAGRAM FOR THE ASSESSMENT AND VERIFICATION OF RECYCLABILITY/ RECOVERABILITY POTENTIALS OF PRODUCTS (ARDENTE ET AL. 2011A, P. 21)

Calculation methods for recoverability and reusability (ISO 22628)

The ISO 22628 establishes how to calculate recyclability and recoverability rates. The calculations are conducted in four steps (1) pre-treatment, (2) dismantling, (3) metal separation and (4) non-metallic residue treatment. The equations are presented in figure 9:

1) $$\text{Recyclability rate } (R_{cyc}) = \frac{m_p + m_D + m_M + m_{Tr}}{m_V} \cdot 100$$

2) $$\text{Recoverability rate } (R_{cov}) = \frac{m_p + m_D + m_M + m_{Tr} + m_{Te}}{m_V} \cdot 100$$

FIGURE 9: CALCULATION OF RECYCLABILITY RATE AND RECOVERABILITY RATE FOR VEHICLES. MV IS THE VEHICLE MASS, MP IS THE MASS OF MATERIALS TAKEN INTO ACCOUNT AT THE PRE-TREATMENT STEP, MD IS THE MASS OF MATERIALS TAKEN INTO ACCOUNT AT THE DISMANTLING STEP, MM IS THE MASS OF METALS TAKEN INTO ACCOUNT AT THE METAL SEPARATION STEP, MTR IS THE MASS OF MATERIALS TAKEN INTO ACCOUNT AT THE NON-METALLIC RESIDUE TREATMENT STEP AND WHICH CAN BE CONSIDERED AS RECYCLABLE, MTE IS THE MASS OF MATERIALS TAKEN INTO ACCOUNT AT THE NON-METALLIC RESIDUE TREATMENT STEP AND WHICH CAN BE CONSIDERED FOR ENERGY RECOVERY.

The Restriction of Hazardous Substances (RoHS) Directive and the EU Regulation on the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH)

The RoHS Directive restricts the use of certain hazardous substances in electrical and electronic equipment. The main purpose of the Directive is to protect human health and to ensure an environmentally sound recovery and disposal of waste electrical and electronic equipment. The RoHS Directive bans the use of: lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyles (PBB) or polybrominated diphenyl ethers (PBDE) with certain exemptions. The member states are themselves responsible for ensuring compliance to the RoHS Directive. When the report was written, the RoHS Directive was under revision.

The purpose of the REACH Regulation is to enhance the protection of the environment and human health by earlier and better identification of the intrinsic properties of chemicals. The regulation places a greater responsibility on the industry to manage these risks. Therefore, manufactures and importers are obliged to collect information on the properties of the chemicals they apply. This should ensure safe handling of the chemicals and that the chemicals are registered in a database. Furthermore, the Regulation also requires progressive substitution of the most dangerous chemicals when suitable alternatives exist.

There are several potential interactions between the REACH regulation and the RoHS Directive. Therefore, a proposal for the recast of the RoHS Directive is that the introduction of new substance in the RoHS Directive should be in line with the REACH methodology. Furthermore, environmental conscious design should also consider the environmental risk of hazardous substances and the negative impact it might have on the product's recycling.

Possible requirements on the use of hazardous substances could be introduced in the Ecodesign Directive's implementing measures as well as environmental labelling schemes such requirements could be:

- "Declaration by the manufacturer of the content of hazardous substances into the product (or some specific components)"
- "Threshold limits on the use of the hazardous substances into the product (or into some specific components)"
- "Labelling/ marking of components containing hazardous substances, in order to simply/improve their identification of the EoL"
- "Accessibility and easy disassembly of components containing hazardous substances."(Ardente et al. 2011a, p. 28-29)

When these requirements are implemented, it is important to take the entire life cycle of the product into consideration.

The Waste Directive (European Directive 2008/98/EC)
The main purpose of the Directive is to lay, *"down measures to protect the environment and human health by preventing or reducing the adverse impacts of the generation and management of waste and by reducing overall impacts of resource use and improving the efficiency of such use"* (European Commission 2008b). The Directive is based on two key principles polluter pays principle and the waste hierarchy. The polluter pays principle implies that the original waste producer or current or previous waste holders are responsible for the costs of waste management. The waste hierarchy establishes a priority order of the best environmental option in waste legislation and policy. Where prevention is above reuse and reuse is above recycling and so on. The waste hierarchy is illustrated in figure 10.

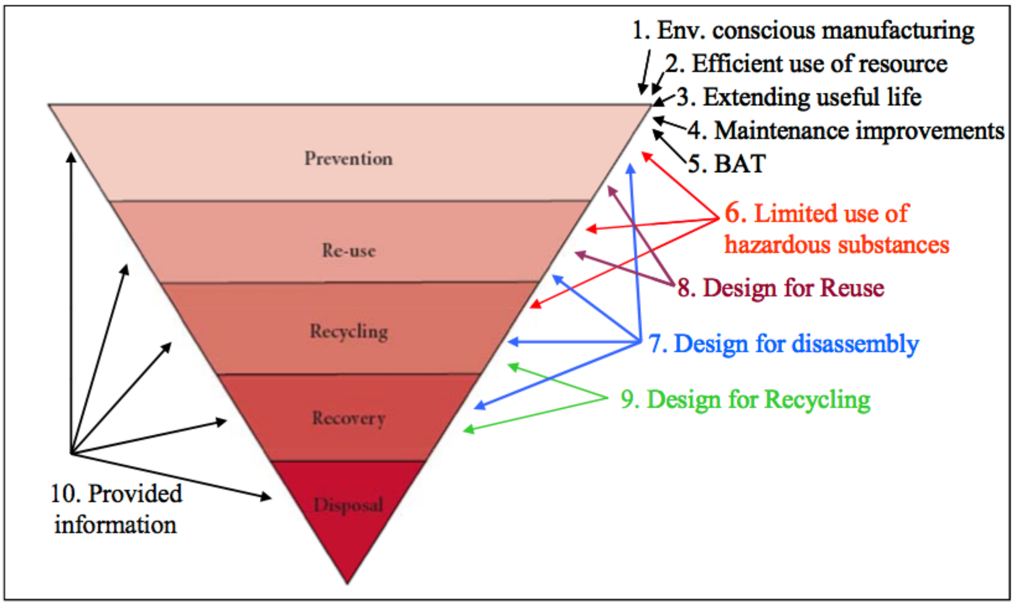

FIGURE 10: THE WASTE HIERARCHY AND ITS LINKS TO THE ECODESIGN STRATEGIES (ARDENTE ET AL. 2011A, P. 32).

Environmental conscious design should take the product's end-of-life into consideration in order to minimize the production of waste. It also goes for ecodesign policies. In figure 10, different ecodesign strategies are linked to the waste hierarchy, these strategies include:

1. Adoption of environmental conscious manufacturing
2. Efficient use of resources
3. Improving the expected product's lifetime and lifetime performance
4. Maintenance improvement
5. The adoption of best available technology (BAT) can be a key issue to improve the manufacturing of the product and to improve the performance of products over their lifetime.
6. Limited use of hazardous substances
7. Design for disassembly
8. Design for reuse
9. Design for recovery/ recycling
10. Availability of information for stakeholders

The Directive on the Waste Electrical and Electronic Equipment (WEEE)

The purpose of the WEEE Directive is, "the prevention of waste electrical and electronic equipment (WEEE), and in addition, the reuse, recycling and other forms of recovery of such wastes so as to reduce the disposal of waste" (European Union 2009a). Furthermore, the Directive places the responsibility on the producer or third parties acting on their behalf of setting-up a system. The system should provide for the treatment of WEEE applying the best treatment, recovery and recycling techniques. Additionally, the distributors is responsible for that the WEEE can be returned back to the distributor for free. Thereby, it is also an application of the producer responsibility principle. Placing the responsibility of WEEE on the producers should help create an incentive for them to design product with an improved end-of-life.

The Directive sets up minimum recycling and recovery targets of WEEE for various product categories. The targets are presented in figure 11. Moreover, the Directive sets up a list of minimums treatments.

Product category	Reuse/Recycling rate	Recovery rate
❖ Large household appliances ❖ Automatic dispensers	75%	80%
❖ IT and telecommunications equipment ❖ Consumer equipment	65%	75%
❖ Small household appliances ❖ Lighting equipment ❖ Electrical and electronic tools (with the exception of large-scale stationary industrial tools) ❖ Toys, leisure and sports equipment ❖ Monitoring and control instruments	50%	70%
❖ Gas discharge lamps	80%	

FIGURE 11: MINIMUM RECYCLING AND RECOVERY TARGETS OF THE WEEE DIRECTIVE (ARDENTE ET AL. 2011A)

During the writing of the first JCR report, the Directive was under revision, the main proposed changes were:

- "to set a 65 % WEEE collection rate, defined in function of the average amount of EEE placed on the market in the two preceding years"
- "to set minimum inspection requirements for Member States to strengthen the enforcement of the WEEE Directive"
- "to include the re-use of whole appliances into the recycling target and set a new target for medical devices"
- "to harmonize producer registration and reduce unnecessary administrative burden" (Ardente et al. 2011a, p. 36)

Prevention is, however, also one of the main objectives of the WEEE Directive *"Member States shall encourage the design and production of electrical and electronic equipment which take into account and facilitate dismantling and recovery, in particulate the reuse and recycling of WEEE, their components and materials"* (European Union 2009a), this provides a link to ecodesign.

Ecodesign Directive and Implementing Measures

This section includes a preliminary review of the implementing measures already adopted, at the time the study was published. The implementing measures already adopted were: simple set-box, domestic lighting, tertiary sector lighting, ext. power supplies, circulator, electric motors, refrigerator, televisions, dishwasher and washing machines. The review of the implementing measures showed that requirements on recyclability, recoverability and reusability, use of recycled materials and limitation of the use of priority resource were not present. However, some requirements on hazardous substances were included. Furthermore, the implementing measures included general requirements to consumer information that should be provided by the producer. An overview of these requirements is presented in figure 12.

Products	Simple set-box	Domestic lighting	Tertiary sector lighting	Ext. power supplies	Circulator	Electr. Motors	Refrigerator	Television	Dishwash.	Wash. Machine
General Information about technical characteristics	✗	✓	✓	✗	✗	✓	✗	✗	✓	✓
Information about consumptions and efficiency	✓	✓	✓	✗	✓	✗	✗	✓	✓	✓
Information about optimal use	✗	✓	✓	✗	✓	✓	✓	✗	✓	✓
Information on lifetime and operational life; decay of performances or failures, etc	✗	✓	✓	✗	✗	✗	✗	✗	✗	✗
Information about disassembly, recycling, disposal	✗	✗	✗	✗	✓	✓	✗	✗	✗	✗
Content of hazardous substances	✗	✓	✓	✗	✗	✗	✗	✓	✗	✗
Benchmark for the *BAT*	✗	✗	✗	✗	✓	✗	✗	✗	✓	✓

✓ Information to be provided ✗ Information not significant

FIGURE 12: REQUIREMENTS IN THE IMPLEMENTING MEASURES ON INFORMATION THAT SHOULD BE PROVIDED TO THE CONSUMERS (ARDENTE ET AL. 2011A, P. 39)

EU Ecolabel and Ecodesign: two complementary schemes

The Ecodesign Directive and the European Ecolabel are to complement each other. Where the Ecodesign Directive sets minimum requirements for products and the European Ecolabel represents the environmentally best products on the market. Both tools are thereby helping to drive (European Ecolabel) and push (Ecodesign Directive) the market towards more sustainable production and consumption. It is, therefore, important that the two tools are developed together and in harmony. Moreover, the criteria should be continually tightened.

The report covers a review of the criteria for Recyclability / reusability / recoverability, recycled content, priority resources and hazardous substances already found in the European Ecolabel for the product groups: desktops, laptops, washing machines, heat pumps, refrigerators, televisions, light bulbs and vacuum cleaners.

The main conclusion is that there already in the European Ecolabel criteria are several criteria covering resource efficiency, such as:

- "obligation for some manufacturer to take back for free the product for refurbishment or recycling"
- "use of compatible polymers to enhance recyclability"
- "possibility to separate labels and metal parts from plastic components"
- "design for disassembly"
- "information to be provided about product recycling"
- "recyclability requirements about plastic and metals"
- "restrictions on hazardous materials and substances".
- "criteria about the recycled content are partially inserted, concerning only some packaging" (Ardente et al. 2011a, p. 41-42)

However, no criteria were found regarding priority resources.

8.1.3 Recyclability, reusability and recoverability (RRR)

This part of the report includes a review and discussion of various definitions of recyclability, reusability, recoverability and other related concepts in legislation, international standards and technical guidance documents and scientific publications.

The main conclusions are:

- A clarification of product recyclability, reusability, recoverability and related concepts due to the broad range of definitions in use is needed.
- The methods to calculate recyclability, reusability and recoverability have to be as simple as possible to be used for different product categories. Many of the existing methods are complex and product specific.
- Furthermore, three key issues have been identified significantly affecting recyclability, recoverability and reusability of products: *"1) the physical/ chemical properties of the materials, 2) the product's disassembly issues and 3) the potential contamination of materials in a product"* (Ardente et al. 2011a, p. 82).

Regarding the technical characteristics of the product:

- Identify the potentially valuable and/ or re-usable parts
- Prefer, when possible materials and components that are technically and economically viable for recycling.
- Identify the parts containing hazardous substances and preparations and the location of such parts.
- Define special handling and disposal precautions
- Provide additional information about the product's end-of-life (Ardente et al. 2011a, p. 82)

Regarding material contamination:

- Limited the number of different materials (especially polymers) used in the product
- Check the compatibility of materials for recycling, avoiding when possible, combinations of non-compatible materials.
- Use labels and other identification marks compatible with the labelled product or component. (Ardente et al. 2011a, p. 82)

Regarding disassembly:

- Grant an easy access, separability and disassemblability of materials and components.
- Disassembly down to the module level should be generally possible using commonly available tools and performed by normal technicians.
- The number and variety of welds, glued joints and connections should be reduced.
- It is necessary to grant an easy and safe separation of parts containing hazardous substances and preparations. (Ardente et al. 2011a, p 82)

These three aspects along with more information on the products in terms of bill of materials, disassembly plans and the assessment of available and viable technologies for waste treatment and recycling will be in focus in the following steps of the project, when defining methods for calculating recyclability, reusability and recoverability.

8.1.4 Recycled content of products

Typically, the recycle content of a product is defined as "*the faction in weight of a product that is made of recycled materials* " (Ardente et al. 2011a, p. 83). In other words, the recycled content is a percentage of the recovered secondary mass relative to the total mass. In table 10, a number of definitions are provided. There is often made a distinction between pre-consumer and post-consumer recycled materials. Where pre-consumer materials are materials recovered from the manufacturing process and post-consumer recycled materials are recovered after the product's use.

Table 3.1. Definitions of recycled content

Definition	Reference
Proportion, by mass, of recycled material in a product or packaging.	[ISO 14021, 1999]
Percentage by weight of recyclate in a material or product	[ASTM D7209, 2006]
Percentage by weight of recycled material in a product	[EN 15343, 2007]
A percentage number calculated by dividing the weight of recycled material of the type of material being measured, divided by the full weight of the material in the part or product. For example, if filler materials or additives are used in recycled plastics, the calculation of the recycled plastic content shall be made by dividing the weight of the recycled plastic in the part by the full weight of the plastic material, including additives and fillers, in the part or product. Additives or fillers shall not be considered recycled plastic, except in the case where the additives or fillers are derived from a recycled plastic feedstock	[IEEE, 2009].

TABLE 10: DEFINITIONS OF RECYCLED CONTENT (ARDENTE ET AL. 2011A, P. 83)

However, there is no reliable method to physically or chemically test the proportion of recycled material in the product. Therefore, it must be calculated on the basis of data provided by the manufacturer and supplier. Definitions or calculations of the proportion of recycled material are found in the following standards and regulations:

- CEN standard
- ISO 14021 Self-declared environmental claims
- The American society for testing materials (ASTM) standard guide for validating the recycled content in packaging.
- The Institute of Electrical and Electronics Engineers (IEEE) standard about the recycled content in its standards for the environmental assessment of Electronic products.
- US EPA guideline
- The Federal Trade Commission of USA guidelines on the use of environmental market claims.

8.1.5 Limitation of the use of priority resources

The EU is highly dependent on imports of strategic raw materials, but market disportions are incresingly affecting the market for these materials. Therefore, JRC's work also includes a review of resource depletion indicators. They focus on increasing resource efficiency and replacement of raw materials and to promote recycling and use of recycled materials in the EU.

There are various definitions and identifications of which materials are considered as priority materials. United Nations Environment Programme (UNEP) has identified the following critical materials: indium, germanium, tantalum , platinum group, tellurium, cobalt, lithium , gallium and rare earths.

The hierarchy of critical materials can also be made in relation to the three parameters (Figure 13) increasing need (1), security (2) and limitations of recyclability (3). Critical materials are those in the overlapping region: indium, gallium, tellurium (within 5 years), rare earth elements, lithium, tantalum, platinum metal group (within 10 years) , germanium and cobalt (over 40 years).

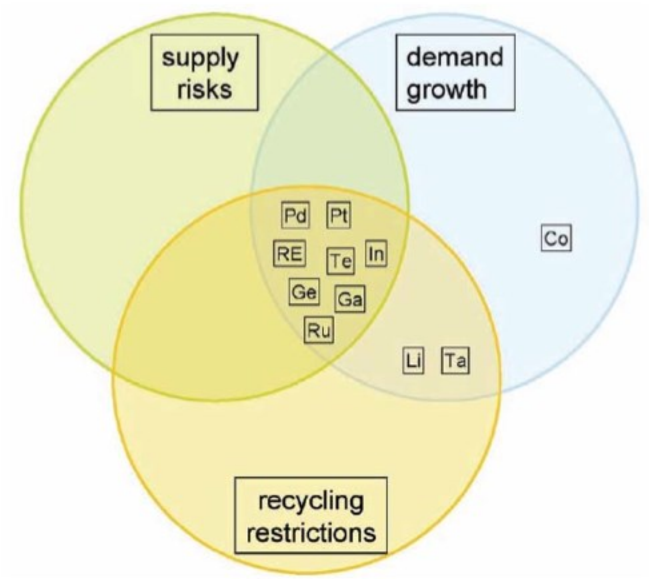

FIGURE 13: PRIORITIZATION OF CRITICAL METALS (BUCHERT, SCHÜLER & BLEHER 2009)

The EU also has on-going research on defining critical raw materials. Their work has analysed the criticality of materials according to three indexes: economic importance, supply risk and environmental risk.

Resource depletion is not a well-defined concept. However, methods for the assessment of resource depletion can be group into the following categories:

- "Those based on energy or mass"
- "Those based on the relations among use and deposits"
- "Those based on future consequences of resource extraction"
- "Those based on exergy consumption or entropy production" (Ardente et al. 2011a, p. 97)

There are no indications that resource depletion will become a problem within a considerable future. However, increased environmental impact for using low degradable ores is becoming an issue. It is, however, the perception of the authors that they have *"....a fairly optimistic view on the human ability to cope with resource depletion..."*(Ardente et al. 2011a, p. 98)

8.1.6 Hazardous substances

Main potentially hazardous substances to be regulated:

- Beryllium
- PVC
- Bisphenol-A
- Tetrabromobisphenol-A
- Antimony trioxide
- Hexabromocyclododecane (HBCDD)
- Medium-chained chlorinated paraffins (MCCCP)
- Short-chained chlorinated paraffins (SCCPs)
- Bis (2-ethylexyl) phthalate (DEHP)
- Butyl benzyl phyhalate (BBP)
- Dibutyphthalate (DBP)
- Nonylphenol

Hazardous substances can also contribute to improved performance of a product. Therefore, the assessment of a hazardous substance should always be based on a life cycle approach.

8.2 Deliverable 2: In-depth analysis of the measurement and verification approaches, identification of the possible gaps and recommendations

8.2.1 Bill of Materials (BOM): basis for the calculations:

Bill of Materials (BOM) is identified as one of the important data sources and a precondition for the measurement of the product's recyclability/ recoverability and the recycled content in the design phase. A procedure for drafting a BOM is presented, and it includes the following steps:

1. Determine the components, assemblies and sub-assemblies that enter in the manufacturing of the product.
2. Obtain information about the material composition and mass of each component as well as its content of hazardous and other adverse materials/compounds from the suppliers. This complete list of all the components will form the basis for the BOM.
3. Define/ identify a procedure for the product's disassembly at the end-of-life, with attention to the assembly elements. Assemblies that cannot be further disassembled manually and therefore need to be shredded should be identified.
4. The time for manual disassembly of each component should be measured or estimated.
5. Each component or assembly should be numbered with an identifying code taking into consideration the position in the disassembly scheme.
6. The information on each component should be provided in a datasheet including information on material typology, the mass and the information in point 1-5.

8.2.2 A method for the measurement of recyclability, reusability and recoverability ratio

In this chapter, a general method for the measurement and verification of recyclability, reusability and recoverability is presented.

Firstly, definitions of reuse, recycling and recoverability are proposed. They are:

- Reuse is the process when a product or its component is use for the same purpose after its first use including reuse of a product after refurbishment.
- Recycling is the reprocessing of waste materials for its original purpose or for other purposes excluding energy recovery.
- Recovery is any of the applicable operation provided in Annex II B of Directive 2006/12/EC of the European Parliament and the Council of 5 April 2006 on waste.

When determining the reusability, recyclability and recoverability ratio, three aspects are identified as crucial in the study: product disassemblability, material contamination and material degradation. It should be mentioned, that the RRR ratio merely represents a potential for reuse, recycling and recovery of the materials, components and products, and it does not say anything about the actual reuse, recycling or recovery.

Calculation of the reuse ratio:

The following two figures show the calculation methods proposed in the JCR report for the reusability ratio and the potential reused masse. As figure 14 shows, the reusability ratio is merely the percentage in mass of the product that is potentially reusable. However, it gets more complicated when the reusable mass are to be calculated. As the formula shows in figure 15, the reusable mass depends on the mass of the product or component that is suitable for reuse, the disassembly index and the materials degradation index for reusability.

'Reusability Ratio' (***R_{Reuse}***) [%]: it is the percentage (in mass) of the product that is potentially reusable. It is calculated as:

$$\textbf{\textit{Formula 1}} \quad R_{\text{Reuse}} = \frac{\sum_i \sum_k m_{reuse_{i,k}}}{m_{tot}} \cdot 100$$

- m_{tot} = total mass of the product [kg];
- $m_{reuse,i\ k}$ = potentially reusable mass of the k^{th} material of the i^{th} component [kg].

FIGURE 14: CALCULATION OF REUSABILITY RATIO (ARDENTE ET AL. 2011C, P. 40)

$$\textbf{\textit{Formula 6}} \quad m_{reuse_{i,k}} = m_{i,k} \cdot D_{i,k} \cdot M_{D_{i,k}}$$

- $m_{reuse,i,k}$ = potential reusable mass of the k^{th} material of the i^{th} component [kg]
- $m_{i,k}$ = mass of the k^{th} material of the i^{th} component, which is suitable for reuse [kg]
- $D_{i,k}$ = disassembly index of the k^{th} material of the i^{th} component [%]
- $M_{D,i,k}$ = material degradation index for reusability of the k^{th} material of the i^{th} component [%]

FIGURE 15: CALCULATION OF POTENTIAL REUSABLE MASS (ARDENTE ET AL. 2011C, P. 43)

Calculation of recycling ratio

The following two figures (16 and 17) show the calculation method proposed in the JCR report for the recyclability ratio and the potential recycled masse. As figure 16 shows, the recyclability ratio is calculated as a percentage in mass of the product that is recyclable. However, the recyclable mass is more difficult to calculate and depends on the mass of the materials that are suitable for recycling, the disassembly index, the contamination index for recyclability and the material degradation index for recyclability.

'Recyclability Ratio' ($R_{Recycle}$) [%]: it is the percentage (in mass) of the product that is potentially recyclable. It is calculated as:

$$\textbf{Formula 2} \quad R_{Recycle} = \frac{\sum_i \sum_k m_{recycle_{i,k}}}{m_{tot}} \cdot 100$$

- m_{tot} = total mass of the product [kg];
- $m_{recycle,i,k}$ = potentially recyclable mass of the kth material of the ith component [kg].

FIGURE 16: CALCULATION OF THE RECYCLABILITY RATIO (ARDENTE ET AL. 2011C, P. 40)

$$\textbf{Formula 7} \quad m_{recycle_{i,k}} = m_{k,i} \cdot D_{i,k} \cdot C_{1_{i,k}} \cdot M_{R_{i,k}}$$

- $m_{recycle,i,k}$ = potential recyclable mass of the kth material of the ith component [kg]
- $m_{i,k}$ = mass of the kth material of the ith component, which is suitable for recycling [kg]
- $D_{i,k}$ = disassembly index of the kth material of the ith component [%]
- $C_{1,i,k}$ = contamination index for recyclability of the kth material of the ith component [%]
- $M_{R,i,k}$ = material degradation index for recyclability of the kth material of the ith component [%]

FIGURE 17: CALCULATION OF THE POTENTIAL RECYCLABLE MASS (ARDENTE ET AL. 2011C, P. 43).

Calculation of the recovery ratio:

The recovery ratio is defined as the percentage that is recoverable either as recyclable or recoverable as energy by incineration. The recyclable mass can be calculated according to figure 18 and the recyclable mass can be calculated according to figure 19. The recoverable energy will depend on the mass of the materials that has en energy content suitable for recovery, the disassembly index and the contamination index for energy recoverability.

'**Recoverability Ratio**' ($R_{Recovery}$) [%]: it is the percentage (in mass) of the product that is potentially recoverable. It is calculated as:

Formula 4 $$R_{\text{Recovery}} = \frac{\sum_i \sum_k (m_{recycle_{i,k}} + m_{E-recovery_{i,k}})}{m_{tot}} \cdot 100$$

- m_{tot} = total mass of the product [kg];
- $m_{recycle,i,k}$ = mass of the k^{th} material of the i^{th} component potentially recyclable [kg];
- $m_{E\text{-recovery}, i,k}$ = mass of the k^{th} material of the i^{th} component that has an energy content potentially recoverable by incineration [kg].

As sub-definition it can be assumed that:

Formula 5 $$m_{\text{recovery}_{i,k}} = (m_{recycle_{i,k}} + m_{E-recovery_{i,k}})$$

- $m_{recovery, i,k}$ = mass of the k^{th} material of the i^{th} component that can be recovered.

Note: IF: $(m_{recycle\,i,k} + m_{recovery\,i,k}) > m_{i,k} \Rightarrow$ THEN: $(m_{recycle\,i,k} + m_{recovery\,i,k}) = m_{i,k}$;

ELSE: $m_{\text{recovery}_{i,k}} = (m_{recycle_{i,k}} + m_{E-recovery_{i,k}})$

FIGURE 18: CALCULATION OF THE POTENTIAL RECOVERY RATIO (ARDENTE ET AL. 2011C, P. 41)

Formula 8 $$m_{E-recovery_{i,k}} = m_{i,k} \cdot D_{i,k} \cdot C_{2_{i,k}}$$

- $m_{E\text{-recovery},i,k}$ = potential energetically recoverable mass of the k^{th} material of the i^{th} component [kg]
- $m_{i,k}$ = mass of the k^{th} material of the i^{th} component, which has an energy content suitable for recovery [kg]
- $D_{i,k}$ = disassembly index of the k^{th} material of the i^{th} component [%]
- $C_{2,i,k}$ = contamination index for energy recoverability of the k^{th} material of the i^{th} component [%]

FIGURE 19: CALCULATION OF POTENTIAL ENERGETICALLY RECOVERABLE MASS (ARDENTE ET AL. 2011C, P. 43)

8.2.3 A method to assess priority resources

This section focuses on RRR and the potential benefits related to the reuse, recycling and recovery of materials as a key issue for their prioritisation.

A method for calculating the benefits of using secondary materials compare to primary is proposed. This is call differential impact. Differential impact is defined as the difference between the impact to produce one unit of primary material and the impact to produce the same quantity from recycled scraps. The bigger the difference is, the higher the environmental benefits of recycling are. The differential impact can also have a negative value, implying that the impact from recycling is larger than the impact from producing new materials. Hence, the differential impact and the percentage differential impact can be use to measure the potential environmental benefits achievable by material recycling. Based on existing LCA data, the differential impact (δ) and the percentage differential impact (Δ) are calculated for a list of materials, see figure 20. Two life cycle impact categories are used: the primary energy consumption (PEC) and the global warming potential (GWP). It should be mentioned, that there are some limitations in the data used to make the calculations.

	Primary production		Secondary production		δ_{PEC}	Δ_{PEC}	δ_{GWP}	Δ_{GWP}
	[MJ/kg]	[$kg_{CO2eq.}$/kg]	[MJ/kg]	[$kg_{CO2eq.}$/kg]	[MJ/kg]	[%]	[$kg_{CO2eq.}$/kg]	[%]
Magnesium	284.0	42.0	11.40	1.7	272.60	*96.0%*	40.30	*96.0%*
Aluminum	173.09	9.67	7.68	0.5	165.40	*95.6%*	9.17	*94.8%*
Nickel	404.0	24.80	27.70	n.a.	376.30	*93.1%*	-	-
PE-HD	70.84	1.92	8.65	0.6	62.19	*87.8%*	1.31	*68.0%*
PS	82.04	4.49	14.45	1.0	67.59	*82.4%*	3.54	*78.7%*
Zinc	49.28	3.17	9.0	0.5	40.28	*81.7%*	2.69	*84.9%*
PET	76.49	3.40	14.08	1.0	62.41	*81.6%*	2.44	*71.8%*
Copper	33.0	3.20	6.30	0.4	26.70	*80.9%*	2.76	*86.3%*
Platinum	218,500	n.a.	43,700	n.a.	174,800	*80.0%*	-	-
PE-LD	72.17	2.10	15.0	0.9	57.17	*79.2%*	1.20	*57.3%*
Paper	62.76	0.97	14.27	0.5	48.49	*77.3%*	0.46	*46.9%*
Brass	80.0	4.39	20.0	1.1	60.0	*75.0%*	3.29	*74.9%*
Stainless steel	80.0	5.32	20.50	1.6	59.50	*74.4%*	3.72	*69.9%*
PP	86.64	2.33	24.90	1.1	61.74	*71.3%*	1.22	*52.4%*
Steel	34.25	2.98	11.0	0.8	23.25	*67.9%*	2.16	*72.4%*
Titanium	430.0	n.a.	140.0	n.a.	290.0	*67.4%*	-	-
Cardboard	30.38	0.68	10.09	0.6	20.29	*66.8%*	0.12	*17.5%*
Lead	26.94	1.78	10.0	0.5	16.94	*62.9%*	1.25	*70.2%*
Tin	33.30	3.20	14.20	1.3	19.10	*57.4%*	1.90	*59.4%*
Cadmium	70.0	n.a.	38.0	n.a.	32.0	*45.7%*	-	-
Glass	12.68	0.77	n.a.	0.53	-	-	0.24	*31.1%*

n.a. Data not available

FIGURE 20: DIFFERENTIAL IMPACT INDICES CALCULATED FOR VARIOUS MATERIALS (ARDENTE ET AL. 2011C, P. 89)

Subsequently, methods for calculating reusability, recyclability and recoverability benefits ratios are proposed. These can be used to prioritise between reusability, recyclability and recoverability. However, it should be mentioned that it is a general recommendation to follow the waste hierarchy.

The reusability benefit ratio

Figure 21 provides the formula for calculating the reusability benefit ratio, which is defined as the ratio between the environmental benefits of the potential reuse of the product or part of the product and the maximum benefits that is potentially achievable by full product reuse. The maximum benefits are defined as the impacts that the manufacturing would cause if only primary materials were used. Hence, $I_{i,k}$ is defined as the impact related to the primary production of the materials in the components and $m_{i,k}$ is the mass of the materials in the components. The potential benefits of reuse of the product are calculated based on the disassembly index for reuse for the materials of the components, the materials degradation index for reusability of the materials of the components, the mass of the materials in the components which is suitable for reuse and the impact related to the primary production of the materials in the components.

'Reusability Benefit Ratio' (***R**eusability,Benefit*) [%]: it is the ratio between the environmental benefits related to the potential reuse of the product (of its parts), with the maximum benefits that is potentially achievable by the full product reuse. It is calculated as:

Formula 27 $$Reusabiliy_{Benefit} = \frac{\text{Reuse}_{\text{Benefit}}}{\text{Reuse}_{\text{Benefit,Max}}} \cdot 100$$

Where:

$$\text{Reuse}_{\text{Benefit}} = \sum_{i} \sum_{i} D_{i,k} \cdot M_{Di,k} \cdot m_{i,k} \cdot I_{\text{i,k}}$$

$$\text{Reuse}_{\text{Benefit,Max}} = \sum_{i} \sum_{i} m_{i,k} \cdot I_{\text{i,k}}$$

- $\text{Reuse}_{\text{Benefit}}$ = Environmental benefit related to the potential reuse of the product [unit];
- $\text{Reuse}_{\text{Benefit,Max}}$ = Maximum potential environmental benefit related to the reuse of the product [unit];
- All the used symbols are those already introduced in Chapter 2.5 and Chapter 3.4.3.

FIGURE 21: CALCULATION OF THE REUSABILITY BENEFIT RATIO (ARDENTE ET AL. 2011C, P.99)

The recyclability benefit ratio

The recyclability benefit ratio is defined as the ratio between the environmental benefits related to the potential recycling of the product or part of the product and the maximum benefits that is potentially achievable by recycling, figure 22. The maximum benefit that is achievable by recycling is calculated by multiplying the mass of the materials in the components with the percentage differential impact of the materials. The potential environmental benefits of recycling the product or its parts are calculated by multiplying the disassembly index of the materials in the components, the contamination index for recycling of the materials of the components, the material degradation index for recyclability of the materials and the components, the mass of the materials of the components which is suitable for recycling and the percentage differential impact of the materials.

'**Recyclability Benefit Ratio**' (***R**ecyclability,Benefit*) [%]: it is the ratio between the environmental benefits related to the potential recycling of the product (or its parts), with the maximum benefits that is potentially achievable by recycling. It is calculated as:

$$\textbf{\textit{Formula 28}} \quad Recyclability_{Benefit} = \frac{\text{Recycle}_{\text{Benefit}}}{\text{Recycle}_{\text{Benefit,Max}}} \cdot 100$$

Where:

$$\text{Recycle}_{\text{Benefit}} = \sum_i \sum_k D_{i,k} \cdot C_{1_{i,k}} \cdot M_{Ri,k} \cdot m_{i,k} \cdot \delta_{\text{i,k,I}}$$

$$\text{Recycle}_{\text{Benefits, Max}} = \sum_i \sum_k m_{i,k} \cdot \delta_{\text{i,k,I}}$$

- $\text{Recycle}_{\text{Benefit}}$ = Environmental benefit related to the potential recycling of the product [unit];
- $\text{Recycle}_{\text{Benefits, Max}}$ = is the 'maximum' potential benefits related to the recycling of the product;
- All the used symbols are those already introduced in Chapter 2.5 and Chapter 3.4.2.

FIGURE 22: CALCULATION OF RECYCLABILITY BENEFIT RATIO (ARDENTE ET AL. 2011C, P. 100).

The energy recoverability benefit ratio

The energy recoverability benefit ratio is calculated as the ratio between the environmental benefits related to the potential energy recovery of the product or its parts by incineration and the maximum benefits that is potentially achievable by incineration. The calculations are presented in figure 23. $HV_{k,i}$ is the heating value of the material in MJ/kg, $m_{k,i}$ is the mass of the k^{th} materials and the i^{th} component potentially recoverable in kg, η is the energy conversion factor, 3.6 is a conversion factor from MJ to kWh, $D_{i,k}$ is the disassembly index of the k^{th} materials of the i^{th} component in % and $C_{2,i,k}$ is the contamination index for energy recoverability of the k^{th} materials of the i^{th} component in %.

'Energy Recoverability Benefit Ratio' (***ERecoverability$_{Benefit}$***) [%]: it is the ratio between the environmental benefits related to the potential energy recovery of the product (or its parts) by incineration, with the maximum benefits that is potentially achievable by incineration. It is calculated as:

Formula 29
$$ERecoverability_{\text{Benefit}} = \frac{ER_{Benefit}}{ER_{Benefit,Max}} \cdot 100$$

Where:

$$\text{ER}_{\text{Benefits}} = \eta \cdot I \cdot \sum_i \sum_i D_{i,k} \cdot C_{2_{i,k}} \cdot m_{i,k} \cdot \frac{\text{HV}_{\text{i,k}}}{3.6}$$

$$\text{ER}_{\text{Benefits, Max}} = \eta \cdot I \cdot \sum_i \sum_i m_{i,k} \cdot \frac{\text{HV}_{\text{i,k}}}{3.6}$$

- $\text{ER}_{\text{Benefit}}$ = Potential environmental benefit related to the potential energy recovery of the product [unit];
- $\text{ER}_{\text{Benefit,Max}}$ = Potential maximum potential environmental benefit related to the energy recovery of the product [unit];
- All the other symbols are those already introduced in Chapter 2.5 and Chapter 3.4.1.

FIGURE 23: CALCULATION METHOD OF ENERGY RECOVERABILITY BENEFIT RATIO (ARDENTE ET AL. 2011C, P. 101).

8.2.4 A method for the measurement of the recycled content

This part of the report defines a methodology for measuring the recycled content of a product. The recycled content of a product is a physical characteristic and will remain constant. However, it is not possible to measure or test the recycled content of a product directly. Therefore, it is necessary to depend on supply-chain information when calculating the recycled content of a product or material, such as self-declaration supported by technical documentation.

A methodology is introduced for estimating the recycled content of materials and products. The recycled content is calculated as *"the ratio of the scraps used to manufacture the component, divided by the total mass of the component itself"* (Ardente et al. 2011c, p. 120). If more materials are used to produce the component, the recycled content is calculated as a weighted mean of the recycled content of each material. When calculating the recycled content, a distinction should be made between pre-consumed and post-consumed recycled content and the focus should mainly be on post-consumed recycling.

Potential ecodesign requirements could be set for the recycled content of a product or specific materials or components could be target. These types of requirements could help boost the recycling of targeted materials thereby increasing the demand for recycled materials. This could be done especially for materials with a low value after recycling.

8.2.5 Case study of hard disk

The methodologies described in the previous sections are applied in a case study of hard disks. The case study strived to:

- Illustrate the calculations of the indices for reusability, recyclability, and recoverability and recycled content along with an assessment of the use of priority resources.
- To estimate the potential for reuse, recycling and recovery of hard disks.
- To estimate the potential benefits of reuse, recycling and recovery of hard disks.
- To identify some critical components of the products that could be target for potential design requirements. (Ardente et al. 2011c, p. 121)

The case study of hard disk showed that:

- BOM is critical to being able to calculate the additional parameters.
- The reusability, recyclability and recoverability benefits ratios are desirable to pure reusability, recyclability and recoverability ratio. The benefits rations are more representative, because the do not just look at the mass but also included the burdens from the production and recycling. However, before setting requirements to RRR ratio or RRR benefit ratio, it is important to do a life cycle check to avoid shifting burdens from one phase to another and potentially end-up with an even larger environmental impact.
- Requirements for post-consumer recycled content should be set for specific materials such as priority materials, materials with a high environmental impact or materials which recycling needs to be fostered.
- Verification should include self-declarations from the manufacturer supported by technical documentation.

8.2.6 Assessment at the design stage of use of hazardous substances into products

The RoHS Directive and the Reach Regulation already regulate requirements to hazardous substances. When considering setting ecodesign requirements targeting hazardous substances, it is important to keep in mind that the restriction of certain substances could potentially worsen the overall environmental life cycle performance. Therefore, the restriction of hazardous substances should be assessed in a life cycle perspective. Furthermore, requirements to hazardous substances have to be evaluated case by case for each product and technology. To take these aspects into account, a methodology for the assessment of the use of hazardous substances is proposed. The methodology includes the following four steps:

1. Identify the base-case. Firstly, it is necessary to identify the product to examine and the hazardous substance, which should be assessed.
2. Alternatives, an alternative product is identified that does not contain the hazardous substance which should be assessed. The alternative product should have the same functionality as the base case.
3. Life Cycle Assessment (LCA), then a life cycle assessment is performed of the base-case and the alternatives.
4. Comparison, the base-case and the alternatives are compared based on the results of the life cycle assessment.

After the introduction of the methodology, the methodology is applied assessing the use of mercury in compact fluorescent lamps. The base-case, the compact fluorescent lamp is compared with halogen lamp and LED lamp. The results of the LCAs showed that overall, despite the use of mercury, the compact fluorescent lamps had a lower impact than halogen. However, LED had an even lower environmental impact than compact fluorescent lamps.

8.2.7 Ecodesign requirements for products

In this chapter ecodesign requirements for products are introduced. The requirements should however be considered as prototypes. In figure 24, the requirements are gathered in three main groups: descriptive requirements, declarative requirements and threshold requirements. It is recommended to avoid requirements on the overall recycled content of the product, as such requirements merge information on different materials and risk causing confusion. Requirements targeting hazardous substances could include requirements such as:

- Disassembly of key components containing hazardous substances.
- Declaration of hazardous substances in the product or key components.
- A maximum on the content of hazardous substances in the products or key components. (Ardente et al. 2011c, p. 180)

n°	**Potential Requirements** *Description*	**Descriptive Requirement**	**Declarative/ Demonstrative Requirement**	**Threshold Requirement**
1	Declaration of the 'Reusability Benefit Ratio' (or the Reusability Ratio)		X	
2	Declaration of the 'Recyclability Benefit Ratio' (or the 'Recyclability Ratio')		X	
3	Declaration of the 'Energy Recoverability Benefit Ratio' (or the 'Energy Recoverability Ratio')		X	
4	Threshold of the Reusability Benefit Ratio (or the Reusability Ratio)			X
5	Threshold of the Recyclability Benefit Ratio (or the 'Recyclability Ratio')			X
6	Threshold of the Energy Recoverability Benefit Ratio (or the 'Energy Recoverability Ratio')			X
7	Manual disassembly of key components	X	X	
8	Declaration of the recycled content of plastics.		X	
9	Threshold of the recycled content of plastics.			X
10	Manual disassembly of components containing hazardous substances	X	X	
11	Content of hazardous substances into key components	X		
12	Limit of hazardous substances into plastics			X
13	BOM	X		
14	Identification of plastic components	X		
15	Contamination of plastics			X
16	'Monomaterial'			X
17	Compatibility of labels with recycling.			X

FIGURE 24: OVERVIEW OF POTENTIAL RESOURCE EFFICIENCY REQUIREMENTS (ARDENTE ET AL. 2011C, P. 172).

8.3 Deliverable 3: Contribution to Impact assessment

In deliverable 3 (Ardente, Mathieux 2012b), the potential requirements from deliverable two are applied and discussed in the case of hard disk drives. The potential requirements include recyclability, reusability and recoverability, recycled content, use of priority resources and hazardous substances. Figure 25 provides a detailed overview of the potential requirements examined.

n°	Requirements	Description	n°	Requirements	Description
1	Declaration of the Reusability Ratio (or teh Reusability Benefit Ratio)	The manufacturer has to declare the value of the Reusability Benefit Ratio of the product.	10	Manual disassembly of components containing hazardous substances	Components containing hazardous substances shall be easily and safely removable
2	Declaration of the Recyclability Ratio (or the Recyclability Benefit Ratio)	The manufacturer has to declare the value of the Recyclability Benefit Ratio of the product.	11	Content of hazardous substances into key components	Manufacturer has to declare the content of hazardous substances (regulated and unregulated) contained in the component.
3	Declaration of the Energy Recoverability Ratio (or the Energy Recoverability Benefit Ratio)	The manufacturer has to declare the value of the Energy Recoverability Benefit Ratio of the product.	12	Limit of hazardous substances	Target components heavier than X [g] shall not contain more than Y% by mass of substances that are classified with the following risk phrases: R45, R46, R60, R61, R50/53, R51/53 as defined in Council Directive 67/548/EEC
4	Threshold of the Reusability Ratio (or teh Reusability Benefit Ratio)	The product shall have a minimum Reusability Benefit Ratio of X%.	13	BOM	Manufacturers have to compile the BOM of the product and to make it available on request to surveillance authority
5	Threshold of the Recyclability Ratio (or the Recyclability Benefit Ratio)	The product shall have a minimum Recyclability Benefit Ratio of X%.	14	Identification of plastic components	Plastic components with a mass higher than X [g] shall be marked with a material code in accordance with the identification and marking requirements of ISO 11469:2000.
6	Threshold of the Energy Recoverability Ratio (or the Energy Recoverability Benefit Ratio)	The product shall have a minimum Energy Recoverability Benefit Ratio of X%.	15	Contamination of Plastics	Plastic enclosures shall not contain moulded-in or glued-on metal inserts unless these are easy to remove by one person alone with commonly available tools
7	Manual disassembly of the key components	Key components of the product shall be easily accessible to professionally trained recyclers in order to facilitate their removal.	16	'Mono-material'	Only one plastic material type shall be used in each plastic enclosure part with a mass higher than X [g]
8	Declaration of the recycled content of plastics.	Manufacturers have to declare the 'post-consumer' recycled content of plastic components.	17	Compatibility of labels with recycling.	Labels, inks, glues, adhesives and paints with a mass higher that X% of the component shall be compatible with the recycling, or they shall be easily removable without leaving residues that could interfere with the reuse/recycle/recovery
9	Threshold of the recycled content of plastics.	The product shall have at least X% of post-consumer recycled plastic content (measured as percentage of the overall mass of plastics components).			

FIGURE 25: OVERVIEW OF THE POTENTIAL REQUIREMENTS (ARDENTE, MATHIEUX 2012B, P. 30).

The report is structured as a preliminary impact assessment, but it is not a full impact assessment. The life cycle assessment has been used to assess the relevance of the ecodesign requirements proposed. The main conclusion of the life cycle assessments was that for the majority of the impact categories, the use phase is the most important. The exception was abiotic depletion potential where the manufacturing phase was the largest. Furthermore, the manufacturing of the printed circuit board was identified as the main contributor to the impact categories: abiotic depletion potential, freshwater eco-toxicity and terrestric eco-toxicity. The manufacturing of the aluminium components was identified as the main contributor to the impact categories global warming, acidification, photochemical ozone creation and human toxicity.

Hence, in the case of the hard disk drives, the printed circuit board was a key component along with the aluminium components. Furthermore, the analysis showed that even though the mass of gold might be small in the printed circuit board, it was still relevant in terms of environmental impact. Therefore, a selective separation of components containing key materials, such as the printed circuit board, could deliver considerable benefits in the end-of-life treatment of the hard disk drive and an improvement of the product's performance in general.

However, some of the requirements suggested (in figure 25) proved to be irrelevant in the case of hard disk drives. This included:

- Indices requirements based on mass fraction because they did not take into consideration the recycling of key components.
- Reusability requirements could potentially affect the product's energy performance or hinder technological development.
- To be able to set requirements to the recyclability benefit ratio, a more robust calculation methodology and comprehensive data on the environmental impact of products are needed.
- As the content of recoverable energy from the hard disk drive was low, requirements for energy recoverability were not relevant.
- A requirement to recycled plastic was not relevant in the case of hard disk drives because of the low plastic content. However, it could be relevant for other product categories.
- Requirements to hazardous substances were again not relevant due to the low content in the hard disk drives.

8.4 Deliverable 4: Analysis of Durability

Extending the useful lifetime of products is intuitively resource efficient as it reduces the materials used for production and the generated amounts of waste. In this report (Ardente, Mathieux & Forner 2012), JRC investigates whether increased durability is in fact likely to generate environmental benefits when the entire lifecycle of the product is considered. More specifically, JRC proposes and tests a method for such an assessment and identifies potential product policy criteria for durability. This includes how durability of products can be measured and verified, which technical barriers there may possibly be, and how beneficial the improvement of durability of products can be.

8.4.1 Durability in scientific literature

How is durability defined? JRC reviews scientific literature to identify this along with potential methods for the assessment of the durability of products. Two different approaches are identified. The first is the classic civil engineering approach, which deals with models to forecast the expected duration of products e.g. based on resistance to loads and failure models. The second is a more comprehensive approach that involves technical, environmental and social issues in the evaluation of the sustainability of products and the role of durability. The key issues for durability depend on which of these two approaches is used.

For the first approach, the key issues are:

- Resistance of the product and its materials to wear and degradation e.g. due to physical and chemical factors and stresses.
- Resistance to loads and improper uses by consumers.
- Probability of failure of some key components.

For the second sustainability approach, the key issues are:

- Ease of access, cleaning, repairing, substitution of components.

- Low costs for maintenance and repair.
- Adaptability to technical innovation e.g. upgradability and modularity.
- Analysis of social factors influencing durability e.g. fashion and planned obsolescence.
- Consumer awareness

This differentiation between the two approaches is however not strict.

The methods for estimating the lifetime are for the first approach generally based on statistical and stochastic methods, and direct/indirect assessment (by testing or calculation).

8.4.2 Definition of a method for the environmental assessment of durability

There has not been established a simple standard method to carry out an environmental assessment of increased durability of products. JRC therefore defines a method suitable for energy related products. The aims of this method are (1) to estimate the life cycle environmental benefits of extending the operating life of the considered product by a given additional time-span, (2) to assess the relevance of such environmental benefits compared to the product's life cycle impacts. The method is based on a comparison of different scenarios concerning the lengths of the useful life of the product and its potential substitution with better performing alternative products. The method does not take into account consumer behaviours. The method is presented in report 3.

8.4.3 Application of the method to a case study

JRC applies the theory to a case study of two washing machines. For both products there are environmental benefits by extending the operating time. However, the benefits depend on several parameters, including the selected environmental impact category, the length of the extension of the lifetime and the efficiency of the replacing product.

8.4.4 Identification of potential product policy criteria for the extension of the operating time of WMs

JRC focuses on the identification of product hotspots for extended lifetime or durability, i.e. the key components that are functionally critical for the product and that can influence the product's lifetime. The components, which are most likely to cause failure for washing machines, are motor, pump, drum and control board. At the same time these hotspots for durability are also the components responsible for the highest life cycle impacts for the washing machines.

JRC discusses potential product policy criteria aiming at achieving the extension of the products lifetime. These include: non-destructive disassemblability of key functional components (the hot spots), adoption of product specific standards on durability, introduction of extended warranties and guarantees for the product or some of its components and provision of information for users.

JRC highlights that the analysis is affected by come uncertainties related to assumptions on e.g. the use phase and uncertainties in setting some key parameters of the method including the impact related to the repair of the product and energy consumption of the potential replacement product.

They also apply a simplified index for the environmental assessment of durability in order to assess the potential benefits and drawbacks of extending the operating time of the analysed products. They assess the simplified index to be scientifically robust for the scope of the assessment.

JRC has not been able to estimate precisely by how much the identified criteria could prolong the lifetime of products, but the relationship is in the positive direction i.e. lifetime extension. They have not included consumer behaviour, but recognized that that is an important parameter influencing the durability of products and should thus be part of future research.

8.5 Deliverable 5: Application of the project's methods to three product groups

The purpose of this report is to test the methodologies listed in the previous reports for two case studies. Furthermore, the study identifies and assesses additional ecodesign requirements targeting resource efficiency, which could potentially be implemented in the Ecodesign Directive.

8.5.1 High level environmental assessment

The first chapter identifies the materials and product categories with the largest environmental impact. The study is in line with another study by JCR called Life-Cycle based monitoring Indicators.

Literature review on the environmental impact of products

Decoupling of economic growth and resource use is one of the possible actions to take to achieve a more sustainable management and use of resource. To monitor resource use and economic growth, a study identifying an indicator has been developed by Van der Voet et al. (2005). The indicator is call environmentally weighted material consumption (EMC). What the indicator does is that it multiplies the material flow with a factor that represents the environmental impact of the material. Based on this indicator, it is possible to show that:

- Construction materials use the largest amount of materials (concrete, stone and sand), but the impact from these materials is lower that for many of the other materials.
- The largest environmental impact is from the production of food.
- Fossil fuels also contribute to large impacts.
- Iron, steel and plastic also contribute with signification impacts whereas aluminium, zinc, nickel and lead contribute with much lower impact despite the fact that they are characterised by a high environmental impact.

It should be mentioned that there are a number of limitations to this model.

Environmental impact of products

A review was also made of the study carried out by JCR on the environmental impact of products (Tukker et al. 2006). Product with the largest environmental impact throughout their life cycled is identified based on input-output modelling and literature reviews. The study identified the following areas as those with the highest environmental impact: food and drink, private transport and housing. Furthermore, 20-30 % of the total environmental impact from private consumption was from food and drinks, 15-35 % of the total impact from private consumption was from passenger transport, 20-35 % of the impact from all products (for most impact categories) came from products related to housing such as buildings, furniture domestic appliances and energy for room and water heating. The main results are summarised in figure 26.

Product category	Energy	Land use	Resource Depletion	Water consumption	Eutrophication	Greenhouse gas	Phot. Smog	Acid.	Waste
Food and beverages	++	++	++ (energy related, biomass) ++ (non- energy related)	++	++	+(-)	+	++	+(+)
Clothing and footwear		+(-)	++ (energy and non-energy, mineral, biomass, synthetic) + (metal)	+	+(-)	+(-)	+(-)	+	+(-)
Construction – Residential dwellings	+(-)	++				+	+	+(-)	++
Water supply and misc.services related to dwellings				+(+) (toilet and sanitary use)					
Electricity, gas and other fuels									
Heating / Hot water	++		+(+) (energy related)			++	+(-)	+(+)	
Lighting	+(-) (important domestic and commercial)		+(-) (energy and non-energy)						
Furniture			+(-) (non- energy related, metals)		+(-)				+(-)
Household appliances	+(-)		+(-)			+(-)	+(-)	+(+)	
Food storage, preparation, dishwashing			+(-)				+(-)		
Maintenance clothes and textiles	+(-)		+(-) (energy and non-energy)						
House maintenance									
Audio, TV, computer, etc.			+(-) (non-energy)						
Office appliances (incl. paper use)	+(-) (energy use in offices, public administration etc…)		+(-) (organic, depends on product definition)						+(+) (paper products)
Personal vehicles	++		++ (energy and non-energy, metal, synthetic)			++	++	++	+(-)
Restaurants and hotels		+(-)		+(-)	+(-) ('holidays' and 'restaurant, pub')		+(-) ('holidays')	+(-) ('holidays' and 'restaurant, pub')	
Household packaging			+(-) (synthetic) - (depletion)					+(-)	++

++ : agreement on high relevance
+ : agreement on relevance, but not with the highest contributors

UNEP FIGURE 26: MAIN PRODUCT GROUPINGS AND ENVIRONMENTAL IMPACTS (ARDENTE, MATHIEUX 2012A, P. 16).

UNEP has conducted a study on resource efficiency and the impact of products (Hertwich et al. 2010). Part of the study has looked into the priority of materials and products, and a priority list of materials has been developed based on their impact (figure 27).

	Impact global production primary metals	Impact per kg primary metals
1	Iron	Palladium
2	Chromium	Rhodium
3	Aluminium	Platinum
4	Nickel	Gold
5	Copper	Mercury
6	Palladium	Uranium
7	Gold	Silver
8	Zinc	Indium
9	Uranium	Gallium
10	Silicon	Nickel

FIGURE 27: PRIORITY OF MATERIALS (ARDENTE, MATHIEUX 2012A).

Furthermore, the study underlines that academic literature does not agree on whether resource scarcity is a fundamental problem or something that could be solved by the market.

UNEP has, in their reports, also looked into sustainable use of resources. They have assessed that modern technologies are totally dependent on metal and minerals, especially iron, manganese, aluminium and lead. Hence, one of the key aspects UNEP focuses on is if society should be concerned about the long terms supply of these metal minerals. In this connection, it is important to look at both the natural stocks of metals and the anthropogenic stock, which are those metals already put into society. Because, recycling of metals can be a strategy to overcome resource scarcity. Therefore, UNEP has also looking into the recycling of metals.

High level analysis of the impacts of materials and products

This chapter includes a high level analysis of materials and products impacts. The main results are presented in figure 28. The figure shows the ranking of materials according to their impact.

Material	Ranking of materials according to their impacts (per unit of mass) for the following impact categories														
	Climate change	Acidification	Photochemical ozone	Ozone depletion	Respiratory effects	Aquatic eutrophication fresh water	Aquatic eutrophication marine water	Human toxicity	Freshwater Acquatic Ecotoxicity	Terrestric ecotoxicity	Abiotic Depletion - elements	Abiotic Depletion - fossil fuels	Water consumption	Agricultural land occupation	Urban land occupation
ABS	23	29	29	n.a.	30	18	28	46	41	34	35	20	25	n.a	n.a
Aluminium	13	17	19	12	19	32	19	17	29	19	31	16	29	n.a	n.a
Baryte	44	43	44	35	46	36	44	34	32	38	21	44	23	26	28
Bauxite	52	52	49	43	36	51	49	52	48	52	52	52	46	30	29
Bentonite	41	38	40	25	40	24	40	27	28	29	29	38	n.a	24	21
Borates	48	45	43	36	35	41	43	42	40	42	13	48	42	27	24
Cadmium	39	37	37	30	39	31	38	29	23	24	2	37	34	21	22
Chromium	10	13	14	9	14	9	12	12	11	6	14	9	10	12	13
Clays	53	53	53	44	53	53	53	53	53	53	53	53	50	31	31
Cobalt	14	16	12	17	13	17	9	14	16	16	20	13	12	10	9
Copper	24	8	11	20	10	22	11	9	9	7	10	30	19	13	7
EPS	26	30	30	n.a.	32	26	29	44	39	28	39	22	21	n.a	n.a
Feldspar	50	51	50	37	51	48	50	51	43	45	41	50	41	29	26
Fluorspar	45	42	45	34	44	33	46	32	27	30	32	45	38	25	27
Gallium	5	9	7	5	9	3	5	7	7	9	12	5	5	7	10
Gold	1	2	2	1	2	2	1	1	2	2	1	1	2	1	1
Graphite	51	49	52	42	49	47	52	47	42	44	42	51	44	28	30
Gypsum	46	50	51	39	52	46	51	39	52	50	22	46	47	n.a	n.a
HDPE	35	35	35	n.a.	37	44	35	49	22	48	49	25	36	n.a	n.a
Indium	6	5	5	7	6	7	6	4	8	4	6	6	6	5	6
Iron	29	32	32	21	33	27	31	22	25	40	43	42	n.a	n.a	n.a
LDPE / LLDPE	33	34	34	n.a.	34	40	33	48	45	46	40	27	33	n.a	n.a
Lead	36	19	28	28	22	38	36	30	35	31	9	35	37	n.a	n.a
Limestone	38	48	47	41	50	42	47	35	49	36	50	41	43	n.a	n.a
Lithium	11	15	15	10	15	15	15	13	14	14	19	10	8	11	16
Magnesium	8	25	18	15	21	10	16	18	18	17	28	15	13	6	17
Manganese	30	23	24	29	25	39	24	24	33	27	30	29	27	n.a	n.a
Mercury	7	7	8	6	8	14	8	10	4	1	7	7	14	17	12
Molybdenum	12	12	9	18	7	11	7	8	10	10	8	11	9	9	5
Nickel	19	3	6	16	4	19	21	15	6	15	17	19	15	15	14
PA	16	22	20	n.a.	24	8	14	37	26	33	33	12	11	n.a	n.a
PC	18	24	22	n.a.	26	12	23	38	30	21	26	18	28	n.a	n.a
Perlite	37	40	38	23	41	35	37	32	31	37	36	36	35	22	23
PET	27	28	27	n.a.	28	50	26	40	37	25	46	24	30	n.a	n.a
Phosphate	49	47	48	40	48	52	48	45	50	47	37	49	45	n.a	n.a
Platinum (PGM)	2	1	1	2	1	1	2	2	1	3	3	2	1	2	2
Potash	32	33	33	24	29	29	32	25	20	22	27	34	26	20	19
PP	34	36	36	n.a.	38	21	34	50	46	49	47	26	32	n.a	n.a
PS	21	25	26	n.a.	27	25	25	43	38	26	38	17	20	n.a	n.a
PUR	22	26	25	32	23	13	22	23	21	23	22	21	16	23	25
Rare Earth	9	11	10	8	11	6	10	6	12	12	16	8	7	8	11
Salt	47	44	42	38	45	49	41	41	51	51	25	47	48	n.a	n.a
Selenium	31	14	23	11	16	23	27	16	17	18	18	32	18	16	18
Silica-sand	43	46	46	31	47	45	45	36	47	43	51	43	40	n.a	n.a
Silicon	15	21	16	13	20	37	17	26	34	32	34	28	31	n.a	n.a
Silver	3	4	3	3	3	5	3	3	3	5	4	3	4	4	3
Sulphur	40	39	41	33	43	34	42	28	36	35	45	33	49	n.a	n.a
Talc	42	41	39	27	42	43	39	33	44	41	48	39	39	n.a	n.a
Tantalum	4	6	4	4	5	4	4	5	5	8	11	4	3	3	4
Tellurium	17	10	13	19	12	20	13	11	13	11	5	14	17	14	8
Tin	28	31	31	22	32	28	30	21	24	39	44	40	n.a	n.a	n.a
Titanium	20	20	21	14	18	16	20	20	15	20	24	23	22	19	20
Zinc	25	18	17	26	17	30	18	19	19	13	15	31	24	18	15

Ranking:

	1 - 10
	11 - 20
	21 - 30
	31 - 40
	over 40
n.a.	not available

FIGURE 28: RANKING OF MATERIALS ACCORDING TO THEIR IMPACT (ARDENTE, MATHIEUX 2012A, P. 36).

8.5.2 Selection of the case-studies

In this chapter, suitable product groups are selected that should form the basis of the study. A list of criteria are identified that should be used as the basis for the selection. It includes:

- Criterion 1: Relevance within the ecodesign policies
- Criterion 2: Relevance to potential requirements on reusability, recyclability and recoverability.
- Criterion 3: Relevance to potential requirements on recycled content.
- Criterion 4: Relevance to potential requirements on priority materials.
- Criterion 5: Relevance to potential requirements on the content of hazardous substances.
- Criterion 6: Relevance to potential requirements on durability.
- Criterion 7: Data availability
- Criterion 8: The modelling complexity (Ardente, Mathieux 2012a)

Based on the requirements, a shortlist of product groups was developed see figure 29. Based on the analysis of the possible product categories, three were selected: washing machines, televisions and imaging equipment.

Criteria		Product group						
		Imaging and sound & imaging equipments	Dishwasher / Washing machines	Televisions	Vacuum cleaners	Laundry driers	Computers & monitors	Air-conditioning and ventilation systems
A.1	Relevance to policies	Included in the WP 2009-11.	IM developed	IM developed	Product group covered during the transitional period	IM close to be published	Product group covered during the transitional period	Included in the WP 2009-2011
B.2	Relevance for "RRR" Req.	Disassembly of recyclable/reusable components relevant. Reuse of components detected.	Disassembly of recyclable/reusable components relevant. Reuse of components detected.	Disassembly of recyclable/reusable components relevant. Reuse of components detected.	Disassembly of recyclable/reusable components relevant. Reuse of components possible	Disassembly of recyclable/reusable components relevant. Reuse of components detected.	Disassembly of recyclable/reusable components relevant. Reuse of components detected.	Mostly constituted by recyclable materials. Disassembly at EoL potentially relevant. No evidence for reuse.
B.3	Relevance for "recycled content" Req.	Plastics represent a significant portion of product mass (even up to 40-50%)	Plastics represent about 15% of product's mass. Small amounts of glass	Plastics and glass detected (their amount depends on the considered technology)	Product mainly made by various plastics (over 50% in mass).	Plastics (mainly PP and ABS) around 20% in mass.	Plastics can represent a significant portion of product mass (40-50%)	Plastics (mainly PP) account for about 15%.
B.4	Relevance for "use of priority materials" Req.	Several priority materials detected, including critical raw materials and various high impact materials.	Large amount of steels. Presence of copper	Use of critical raw materials and high impact materials detected.	No priority materials detected.	Relevant amount of steels. Low amount of copper. Relevant materials into electronics (5% in mass)	Several priority materials detected, including critical raw materials and various high impact materials.	Some relevant materials into electronic components and compressors
B.5	Relevance for "use of hazardous substances" Req.	Potetial hazardous substances into plastics and electronics	Potetial hazardous substances into plastics and electronics	Potetial hazardous substances into plastics and electronics	Potetial hazardous substances into plastics	Potetial hazardous substances into plastics and electronics	Potetial hazardous substances into plastics and electronics	Potetial hazardous substances into plastics and electronics
B.6	Relevance for "durability" Req.	Life-time of products not long. Products often discarded due to technological development. Product upgrade possible	Product with a generally long useful life; design for maintenance can sensibly affect performance	Potential life-length very variable. Design for maintenance relevant	Potential life-length very variable. Design for maintenance potentially relevant	Product with a generally long useful life; design for maintenance can affect performance	Life-time of products not long. Products often discarded due to technological development. Product upgrade possible	Product with a long useful life; design for maintenance can sensibly affect performance
C.7	Data availability	Preparatory study available. Few data on disassembly (some available in the literature e.g. printers)	Preparatory study available. No data on disassembly. Possible cooperation with manufacturer	Preparatory study available. No dat on disassembly. Possible cooperation with manufacturers	Preparatory study available (some LCA published).Few data available on disassembly	Preparatory study available. Few data available on disassembly	Preparatory study available. Some studies in the literature. No data on disassembly.	Preparatory study available. Few LCA publication on the sector. No data on disassembly.
C.8	Computational complexity	Complex product group (several components) with various technologies	Products generally complex (several components).	Potential complex for number of components and technologies	No particular difficulties foreseen.	Products generally complex (several components).	Very complex products (computer + monitors)	Complexity of data required and their modeling

Legend
- Suitable for the criterion
- Potentially suitable for the criterion
- Not suitable for the criterion

FIGURE 29: SHORTLIST OF THE PRODUCT GROUPS FOR THE CASE STUDIES SELECTION (ARDENTE, MATHIEUX 2012A, P. 53).

8.5.3 Analysis of ecodesign requirements

The following chapter provides a review of the existing requirements targeting resource efficiency in the EU ecolabels and in scientific literature. The overview is used to develop an updated overview of typologies of resource efficiency requirements.

Ecodesign requirements in the EU ecolabel

A review of ecodesign requirements in the EU ecolabels for energy-related and non-energy-related product groups is provided in figure 30 to 33.

	Product group	Criteria Date	Criteria about: Reusability	Recyclability	Recoverability	Recycled content	Use of priority resources	Use of hazardous substances	Durability
ERP	Personal Computers Portable Computers	9/6/2011 6/6/2011	Design for disassembly: "The manufacturer shall demonstrate that the personal computer/monitor can be easily dismantled by professionally trained personnel using the tools usually available to them, for the purpose of undertaking repairs and replacements of worn out parts, upgrading older or obsolete parts, and separating parts and materials, ultimately for recycling or reuse.			The external plastic case of the system unit, monitor and keyboard shall have a post-consumer recycled content of not less than 10 % by mass. Criteria on recycled content into packaging	circuit boards, and/or other precious metal-containing components, shall be easily removable using manual separation	Exclusion of dangerous substances in the product (mercury and other hazardous substances)	Design for Disassembly; User reparability (instruction for the users for basic repairs); spare parts are available for at least five years from the selling, Lifetime extension (upgradability)
	Televisions	12/3/2009	-	Manufacturer shall demonstrate that the television can be easily dismantled [...] for the purpose of: undertaking repairs and replacements of worn-out parts, upgrading older or obsolete parts, and separating parts and materials, ultimately for recycling.		-	-	Data on the nature and amount of hazardous substances in the television shall be gathered in accordance with Directive 2006/121/EC	Life-time extension (extended warranty for 2 years and availability of spare parts for 7 years)
			-	Plastic parts shall be of one polymer or be of compatible polymers for recycling and have the relevant ISO11469 marking if greater than 25 g in mass		-	-	Criteria based on lists of restricted substances (including some regulated ones), and/or restriction of use of substances with some risk phrases.	-
	Light bulbs	6/6/2011	-	-	-	Criteria on the recycled content of packaging	-	Restricted use of mercury and other hazardous substances	Criteria on minimum lifetime and lumen maintenance factor. Criteria on minimum number of switch on/off cycles.
	Heat pumps	9/11/2007	-	-	-	-	-	Criteria based on lists of restricted substances (including some regulated ones), and/or restriction of use of substances with some risk phrases. Criteria about the impacts of refrigerants	Information for the maintenance and availability of spare parts
	Lubricants	24/06/2011	-	-	-	-	-	Restrictions on the use of several hazardous substances; tests on the toxicity of the substances	-

FIGURE 30: ECODESIGN REQUIREMENTS IN THE EU ECOLABEL FOR ENERGY RELATED PRODUCTS (ARDENTE, MATHIEUX 2012A, P. 58).

	Product group	Criteria Date	Criteria about						
			Reusability	Recyclability	Recoverability	Recycled content	Use of priority resources	Use of hazardous substances	Durability
non-Energy Related Products (non-ERP)	All purpose cleaners Hand dishwashing detergents Laundry detergents	28/06/2011 24/06/2011 28/04/2011	partially considered the reusability of the packaging by the 'weight utility ratio' (WUR)	identification (marking) of different parts of the packaging for recycling,	-	information of recycled content of packaging (that enters in the calculation of WUR)	-	Criteria based on lists of restricted substances (including some regulated ones), and/or restriction of use of substances with some risk phrases.	-
	Dishwashing detergents	28/04/2011	-	identification (marking) of different parts of the packaging for recycling,	-	Cardboard packaging (minimum 80% recycled)	-	Criteria based on lists of restricted substances (including some regulated ones), and/or restriction of use of substances with some risk phrases.	-
	Soaps, shampoos and hair conditioners	21/06/2007	Partially considered the reusability by the weight/Content Relationship (WCR)	identification (marking) of different parts of the packaging for recycling,	-	Recycled content of packaging enters in the calculation of WUR	-	Criteria based on lists of restricted substances (including some regulated ones), and/or restriction of use of substances with some risk phrases.	-
	textile products	9/07/2009	-	-	-	Criteria on the use of recycled fibres	amount of antimony in the polyester fibres shall not exceed 260 ppm.	Criteria based on lists of restricted substances (including some regulated ones), and/or restriction of use of substances with some risk phrases.	-
	Footwear	9/07/2009	-	-	-	recycled content of packaging: cardboard (100% recycled); plastics (75% recycled or biodegradable)	-	Criteria based on lists of restricted substances (including some regulated ones), and/or restriction of use of substances with some risk phrases.	Criteria on Flex resistance, Tear strength, Abrasion resistance and Sole adhesion, for various parts of the footwear (measure according to EN standards)
	Indoor and outdoor paints and varnishes	13/08/2008	-	-	-	-	-	Criteria based on lists of restricted substances (including some regulated ones), and/or restriction of use of substances with some risk phrases.	Criteria on Resistance to water, Wet scrub resistance and abrasion (measured according to EN and ISO standards)

FIGURE 31: ECODESIGN REQUIREMENTS IN THE EU ECOLABEL FOR NON-ENERGY-RELATED PRODUCTS (ARDENTE, MATHIEUX 2012A, P. 59).

	Product group	Criteria Date	Criteria about: Reusability	Recyclability	Recoverability	Recycled content	Use of priority resources	Use of hazardous substances	Durability
non-Energy Related Products (non-ERP)	Wooden floor coverings	26/11/2006	Packaging should be made by easily recyclable material, or materials taken from renewable resources, or materials intended to be reusable.			Recycled wood accounted in the calculation of energy consumption of the floor coverings	cork, bamboo and virgin wood must originate from forests that are managed according to sustainable forest management.	Criteria based on lists of restricted substances (including some regulated ones), and/or restriction of use of substances with some risk phrases.	Information to be provided (recommendations for the use and maintenance of the product)
	Textile floor coverings	30/11/2009	-	-	-	Information for the use of recycled fibres	The amount of antimony in the polyester fibres shall not exceed 260 ppm.	Criteria based on lists of restricted substances (including some regulated ones), and/or restriction of use of substances with some risk phrases.	Information to be provided (recommendations for the use and maintenance of the product)
	Hard floor coverings	9/7/2009	Paperboard used for the packaging should be designed for reuse or be made out of 70 % recycled materials	-	-	(see criteria for reusability)	Limitation of the use of certain soils (as classified according to the European Soil Bureau's indications)	Criteria based on lists of restricted substances (including some regulated ones), and/or restriction of use of substances with some risk phrases.	recommendations for the use and maintenance of the product.
	Wooden furniture	30/09/2009	Information on how to handle the EoL of the product	The product must be easily recyclable. Information on how to handle the EoL of the product	Information on how to handle the EoL of the product	Criteria pushing for use of recycled wood	Restriction of use of certain woods	Criteria based on lists of restricted substances (including some regulated ones), and/or restriction of use of substances with some risk phrases.	Adoption of EN durability standards; criteria on the maintenance including availability of spare parts for 5 years
	Soil improvers Growing media	3/11/2006 15/12/2006	-	-	-	Soil improvers produced by recycled organic waste	Product does not contain peat; restriction on the use of minerals coming from protected areas.	Criteria based on lists of restricted substances (including some regulated ones), and/or restriction of use of substances with some risk phrases.	-
	Mattresses	9/07/2009	-	Packaging made by recyclable materials; plastic packaging shall be marked	-	-	Limitation of the concentration of various substances (e.g. Sb < 0.5ppm; Cu < 2 ppm)	-	Lifetime of the mattresses (calculated according to EN standard)
	Copying and graphic paper	7/6/2011	-	Information to promote recycling of paper	-	The use of recycled paper accounted in the calculation of energy use; - Information on the recycled content of paper to be provided	Restriction of use of certain woods	Criteria based on lists of restricted substances (including some regulated ones), and/or restriction of use of substances with some risk phrases.	-
	Tissue paper	9/7/2009	-	-	-	The use of recycled paper accounted in the calculation of energy use; - Information on the recycled content of paper to be provided	Restriction of use of certain woods	Criteria based on lists of restricted substances (including some regulated ones), and/or restriction of use of substances with some risk phrases.	-

FIGURE 32: ECODESIGN REQUIREMENTS IN THE EU ECOLABELS FOR NON-ENERGY-RELATED PRODUCTS (ARDENTE, MATHIEUX 2012A, P. 60)

Product group	Date	Draft criteria about: Reusability	Recyclability	Recoverability	Recycled content	Use of priority resources	Use of hazardous substances	Durability
Imaging equipment	draft criteria (June 2012)	The manufacturer shall demonstrate that the imaging device can be easily dismantled […] for repairs and replacements of worn-out parts, upgrading older or obsolete parts, and separating parts and materials, ultimately for recycling or reuse. The applicant shall complete the "checklist for recyclable design"; The products must accept remanufactured toner and/or ink cartridges; The applicant shall offer a take-back system for the return of toner/ink modules and toner/ink containers			Plastic parts larger than 25g shall have in total a recycled and/or reused content of not less than 10 % by mass. The total post-consumer recycled content and the reused content of the external plastic parts shall be declared	-	Criteria based on lists of restricted substances (including some regulated ones), and/or restriction of use of substances with some risk phrases.	The applicant shall ensure guarantee for repair or replacement of minimum five years; availability of spare parts
					cardboard packaging at least 80 % recycled material	-	Restricted use of mercury in lamps.	
Water tap	draft criteria (May 2012)	-	Packaging shall be easy to separate and recyclable	-	cardboard packaging at least 80 % recycled material	-	criteria on Ni-Cr coating	Reparability and availability of spare parts; warranty for 5 years
toilets and urinals	draft criteria (May 2012)	-	Plastic materials shall be marked correctly to ensure they are recovered, recycled or disposed of in the correct manner during the end-of-life phase.		-	-	-	Reparability and availability of spare parts; warranty for 5 years
Central Heating system	draft criteria (November 2011)	Promotion of reuse, recycling and generally sound end-of-life management (draft)			-	-	Criteria based on lists of restricted substances (including some regulated ones), and/or restriction of use of substances with some risk phrases.	Product quality/usability and lifetime extension (draft)
Office Building	draft criteria (April 2012)	At least 80% in weight of the waste generated at the construction phase and the end of the service life of the building shall be prepared for being re-used, recycling and other material recovery, including backfilling operations. A waste management plan shall be developed by the constructor, applied during the construction phase and proposed for the demolition phase.			At least 50% in cost of the construction components installed in the building will be formed by products and materials containing at least 30% of recycled, reused and /or recovered materials	Use of low impacts construction materials and restriction in the use of some materials (e.g. wood)	Criteria based on lists of restricted substances (including some regulated ones), and/or restriction of use of substances with some risk phrases.	The building shall be supplied with relevant user information for maintenance
Newsprints	final draft criteria (2012)	-	-	-	At least the 70 % (w/w) on the total amount of fibbers used for newsprint paper shall be recovered fibres.	-	Criteria based on lists of restricted substances (including some regulated ones), and/or restriction of use of substances with some risk phrases.	-

FIGURE 33: RESOURCE EFFICIENCY REQUIREMENTS IN THE EU ECOLABELS FOR ENERGY-RELATED AND NON-ENERGY-RELATED PRODUCTS (ARDENTE, MATHIEUX 2012A, P. 61)

Ecodesign requirements in scientific literature

In addition to the review of the requirements in the EU ecolabel, a review was made of resource efficiency requirements in scientific literature, the main results are presented in figure 34. Based on the review, dematerialization and design for disassembly were included as two possible strategies to improve resource efficiency.

Typologies of criteria for the ecodesign of products	References
Design for material recycling and part reuse	
Use materials with higher recyclability	[Dowie, 1995; Mathieux, 2002; Mathieux et al, 2008; Dewulf et al. 2001; TU Wien, 2008; EcoDEEE 2008]
For large polymer parts that are addressed to manual dismantling before recycling, and if a cooperation with recycler is set-up, choose among: ABS, HIPS, PP, P/E, PP+EPDM, PP-GF, PC, ABS-PC, PA, PA-6, HDPE, SAN. Otherwise prefer: PP, P/E, PP-GF, PP-EPDM; HIPS; ABS.	[Mathieux, 2002; Mathieux et al., 2008]
Avoid sticks and metal inserts on plastic parts	[Dowie, 1995; EcoDEEE 2008]
Minimise number of different types of materials (including additives for polymers and alloys for metals)	[Dowie, 1995; Graedel, 1996; Johansson, 1997; Froelich et al., 2007]
mark plastic and metal parts according to ISO standards	
Think of re-use of parts	[Zwolinski et al., 2006]
Avoid coating (e.g. painting, varnish) on metallic parts	[EcoDEEE, 2008]
Avoid coating (metal, plastic film, painting, textile, film, etc.) on plastics parts	[Graedel, 1996]
Recycled content	
Use recycled materials	[Dowie, 1995; ENSAM, 2002]
Separability of components	
If different types of polymers have to be closely associated, prefer types of plastics that could be easy separated after shredding	[Renault, 1994]
For materials that are not separable, prefer types of polymers or of metals that are compatible	[Renault, 1994; Castro et al., 2005; Froelich et al., 2007]
Design for disassembly	
Minimise number of fasteners	
Think of fasteners that can be broken instead of dismantled	[Dowie, 1995; Johansson, 1997]
Minimise number of parts	
Design metallic parts and assemblies so that the liberation of pure material particles during shredding is facilitated	[Froelich, 2007; Castro et al., 2005]
Prefer fasteners easy to remove	[Dowie, 1995; Graedel, 1996]
Make sure that fasteners that will have to be unlocked are easy accessible / visible	[Haoues et al., 2007; Dowie, 1995]
Focus on a limited number of parts whose characteristics (mass, material, position, etc.) bring good recyclability performances	[Renault, 2001]
Electronic components and other critical parts should be put in the same location.	[EcoDEEE, 2008]
Make design modular	[Dowie, 1995; Graedel, 1996; Johansson, 1997]
Make high value parts easy accessible	[Dowie, 1995; Johansson, 1997]
Think of Active Disassembly techniques (fasteners activated by external triggers)	[Duflou et al, 2006, Chiodo et al, 1998 ; Hislop et Hill, 2011]
Marking of parts for sorting (e.g. labels, marking, colour, smart barcodes, tracers, magnetic dust, etc.)	[EcoDEEE, 2008; Bezati et al., 2011; Hislop et Hill, 2011]
Pollutants	
Reduce the number / the weight of pollutants	[Graedel, 1996]
Make pollutant (battery, fluids, some PCB, etc.) easy accessible and clearly marked	[Dowie, 1995, Graedel, 1996; Johansson, 1997; Eco'DEEE 2008]
Durability	
Promote longer life for products (through product quality, reparability, etc.) especially for products with most significant impact out of use phase	[Lagerstedt et Luttrop, 2006]
Think of reparability of product	[Zwolinski, 2006; TU Wien, 2008; Lagerstedt et Luttrop, 2006]
Think of over dimensioning some parts so that it is possible to machine them during remanufacturing process.	[TU Wien, 2008]
Information	
Think of filling-in a "recycling profile" (or end-of-life treatment manual) for the product to be communicated to treatment facilities	[Rose, 2000; Mathieux et al, 2001; Dewulf, 2001; EU, 2012; TU Wien 2008]
Dematerialisation	
Minimise weight of the product	[EcoDEEE, 2008]

FIGURE 34: SCIENTIFIC LITERATURE REVIEW OF GUIDELINES FOR DESIGN FOR RECOVERY OF PRODUCTS (ARDENTE, MATHIEUX 2012A, P. 63)

Based on the analysis of the resource efficiency requirements in the EU Ecolabels and in scientific literature, an updated overview of typologies of ecodesign requirements was developed see figure 35.

Typology of Ecodesign requirement		Parameter potentially influenced by the requirement:				
Typology	Sub-typology	RRR	Use of priority resources	Recycled content	Use of haz. Subst.	Durability
Declaration of indices (RRR rates, , RRR benefits rates, Recycled content, Recycled content benefit)	General indices	X	X	X		
	Indices restricted to some specific material (e.g. RRR rates or Recycled content restricted to plastics, CRM, etc.)	X	X	X		
Threshold of indices (RRR rates, RRR benefits rates, Recycled content, Recycled content benefit)	General indices	X	X	X		
	Indices restricted to some specific material (e.g. RRR rates or Recycled content restricted to plastics, CRM, etc.)	X	X	X		
Design for recycling	Use of compatible materials (or forbid the jointly use of materials that are not compatible for recycling)	X				
	Use of materials more recyclable	X	X			
	Reduce number of contaminants (labels, glue, solders, etc.)	X				X
Design for disassemblability / dismantlability	Time based index (e.g. dismantling of a component)	X	X	X	X	
	Mass / Time based index	X	X	X	X	
	Non destructive disassembly (for repair/substitution)					X
	Reduction / simplification of fastening (e.g. reduction of number and typologies)	X	X		X	X
Availability of spare parts						X
Warranty						X
Indices for durability	According to standardized measurement of performances (when available)					X
Dematerialization	Reduction of the weight of materials	X	X			X
	Design of components for optimal use of materials	X	X			X
Declaration of substances	BOM of product or parts (at different level of detail)	X	X		X	
	Relevant substances (e.g. CRM to be recycled)	X	X		X	
	Pollutants (e.g. flame retardants), which interfere with EoL treatments	X	X		X	
Threshold of substances	Relevant substances (e.g. CRM to be recycled)	X	X		X	
	Pollutants (e.g. flame retardants), which interfere with EoL treatments	X	X		X	
Marking / labelling / tracing	Easy identification of recyclable materials / parts	X	X	X	X	
	Identification of pollutants	X	X	X	X	
	Use of innovative technologies for the automatic sorting systems (tracing substances, magnetic powders, etc.)	X	X		X	
Provision of information		X	X	X	X	X

FIGURE 35: OVERVIEW OF THE TYPOLOGIES OF ECODESIGN REQUIREMENTS (ARDENTE, MATHIEUX 2012A, P. 67).

8.5.4 Identification of potentially relevant ecodesign requirements

A method was proposed for the identification of potentially relevant ecodesign requirements. It includes the following steps:

- Selection and characterization of the product.
- Application of the methods (definitions of EoL scenarios and calculations and assessments).
- Identification of product's resource efficiency hot spots (identification of key components, identification of looses for RRR indices, identification of hot sports).
- Identification of potentially relevant requirements at the product level.
- Assessment of requirements at the product group level.

The methodology is then applied on the three case studies.

8.5.5 Case study: Imaging equipment

In the case study of imaging equipment, an Ink-Jet multi functional device was identified as the relevant product to examine. Imaging equipment contains a considerable amount of plastic. Therefore, it is evaluated that imaging equipment could be used as the base case to analyse the use of recycled plastic. Different scenarios have been examined including different percentages of recycled plastic in the manufacturing of the product. Furthermore, different eco-profiles for recycled plastic have been applied.

The analysis showed that with a recycled content of plastic of 10 %, it was possible to get a 3.5 % reduction of the global energy requirement. With an introduction of 30 % recycled content, it was possible to gain a 10 % reduction of the global energy requirements. Hence, including recycled plastic in the case of Ink-Jet multi functional devices could provide an environmental improvement. Therefore, a potential ecodesign requirement was proposed for recycled content see figure 36.

Potential Requirement: Recycled content of plastics for Imaging Equipment

Ink Jet – Multi Function Devices should have at least 10% of Recycled Content of post-consumer plastics (calculated according to the provided method).

Verification:

Manufacturer shall provide a declaration to this effect, together with appropriate supporting documentation, including:

- documented practises that assure the traceability of the product and its constituting materials and components (according to the standard EN 15343 [CEN15343, 2007]);
- records of the amount and types of recycled materials used in the product for the previous four consecutive quarters preceding the declaration.
- declarations from each supplier of post-consumers recycled materials (or of components embodying post-consumers recycled materials).;
- records that demonstrate an active business relationship with each supplier of recycled post-consumers materials.

FIGURE 36: POTENTIAL RESOURCE EFFICIENCY REQUIREMENT FOR INK-JET MULTI FUNCTIONAL DEVICES (ARDENTE, MATHIEUX 2012A, P. 87).

However, a potentially problematic issue is that currently it is not possible to measure and verify the recycled content in a product. Furthermore, before setting these types of requirements, it is important to make a market analysis to ensure that the manufactures have access to sufficient recycled plastics.

8.5.6 Case study: Washing Machines

In the case study of the washing machines, the focus was on the calculation of RRR ratios, RRR benefit ratios and assessing the use of hazardous substances. In total two household washing machines were analysed.

A life cycle assessments and calculations of RRR ratios and RRR benefits ratios were made in order to identify product parts that were of relevance for the impact categories and where improve recycling could provide benefits. This information was combined with the ecodesign typologies identified earlier (figure 35) and three requirements were suggested for the washing machines. The potential requirements were:

- Improvement of the disassemblability of the PCB
- Improvement of the disassemblability of the LCD screens
- Improvement of the disassemblability of the motor to recover copper, steel and neodymium (Ardente, Mathieux 2012a, p. 121)

Furthermore, additional requirements have been proposed:

- Provision of information on PCB and motors
- Declaration and/ or threshold of RRR and RRR benefit rates
- Improvement of the product durability (Ardente, Mathieux 2012a, p. 121)|

Improvement of the disassembly of PCBs

The results of the life cycle assessment for the two washing machines showed that PCBs are responsible for relevant life cycle impacts of the product. For some impact categories, such as abiotic resource depletion, the PCB accounted for 50% to 80 % of the impacts. Furthermore, the analysis of the recycling rates showed that large fractions of copper and precious metals are lost during the waste treatment process. The end-of-life scenarios of the washing machines also showed that PCMs are not systematically disassembled manually but are shredded resulting in loos of materials. Based on a dialogue with the recycles, it was estimated that easier disassembly could potentially stipulate manual disassembly of PCBs and improve the recycling rates. Therefore, the resource efficiency requirement presented in figure 37 was proposed.

Potential Requirement: Design for Disassembly of the Printed Circuit Board

Printed Circuit Board larger than $10cm^2$ shall be designed in a way that it requires less than 40 seconds[103] to be extracted[104] by professionally trained personnel using the tools usually available to them.

Verification:

Manufacturer shall provide free of charge technical information for disassembly (websites and on demand of recyclers) and provide (to the market surveillance authority on request) a declaration to this effect, together with appropriate supporting documentation, including:

- Disassembly report (including the schemes of where the printed circuit board is installed in the product, details of the component fastening system, disassembly procedures, tools needed for disassembly)
- The disassembly report should include the time (in seconds) needed for disassembly and the disassembly steps undertook during the testing of the disassembly.

FIGURE 37: POTENTIAL REQUIREMENTS FOR DISASSEMBLY OF PCBS (ARDENTE, MATHIEUX 2012A, P. 122).

The main environmental benefits of such requirements could be to increase the amount of PCBs manually disassembled with larger recovery of the materials in the PCBs as a consequence. Furthermore, the environmental impact of the PCB could be decreased if the recycling ratios were increased.

Improved disassembly of the LCD screens

According to the analysis, the amounts of electronics in washing machines are increasing; this includes the introduction of LCD screens in washing machines. Washing machines with LCD screens are not in the waste streams yet. However, according to the interviewed recyclers, the LCD screens need to be removed before the shredding process to avoid contamination of the recycled materials. Therefore, potential requirement to the manual disassembly is proposed in figure 38.

Potential Requirement: Design for Disassembly of the electronic parts with LCD screens

Electronic parts of the WM with LCD screen shall be designed in a way that these can be extracted[111] in less than 30 seconds[112] by professionally trained personnel using the tools usually available to them.

Verification:

Manufacturer shall provide free of charge technical information for disassembly (on website and on demand of recyclers) and provide (to the market surveillance authority on request) a declaration to this effect, together with appropriate supporting documentation, including:

- Disassembly report (including the schemes on where the LCD screen/s and annexed printed circuit board/s are installed in the product, details of the component fastening system, disassembly procedures, tools needed for disassembly)
- The disassembly report should include the time (in seconds) needed for disassembly and the disassembly steps undertook during the testing of the disassembly.

FIGURE 38: POTENTIAL REQUIREMENT FOR DISASSEMBLY OF LCD SCREENS (ARDENTE, MATHIEUX 2012A, P. 125).

Improved disassembly of the motor

The motor in the washing machine is a key contributor to the overall environmental impact of the washing machine mainly due to the large amounts of copper. The motor in washing machines is sometime manually separated, if the time consumption is not too high. Otherwise, it is shredded together with the rest of the washing machine. It is proved that shredding of the motor can result in difficulties during the next treatment processes, where the metals are separated and result in larger loses of materials. Furthermore, separating the motor before shredding could reduce contamination amongst metals. Copper and steel can be separated after shedding. However, there are other elements that cannot such as rare earths. Therefore, separating the motor from the rest of the washing machine before shredding could increase the potential for recovering other elements. For these reasons, a potential requirement on disassembly of the motor is proposed in figure 39.

Potential Requirement: Design for Disassembly of the WM's motors

Motors of WM shall be designed in a way that its extraction[114] requires less than 50 seconds[115] by professionally trained personnel using the tools usually available to them.

Verification:

Manufacturer shall provide free of charge technical information for disassembly (on the manufacturer's website and on demand of recyclers) and provide (to the market surveillance authority on request) a declaration to this effect, together with appropriate supporting documentation, including:

- Disassembly report (including the schemes on where the motor and where is installed in the product, details of the component fastening system, disassembly procedures, tools needed for disassembly)
- The disassembly report should include the time (in seconds) needed for disassembly and the disassembly steps undertook during the testing of the disassembly.

FIGURE 39: POTENTIAL REQUIREMENT FOR DISASSEMBLY OF THE WASHING MACHINES MOTOR(ARDENTE, MATHIEUX 2012A, P. 127).

In addition to these three requirements, the following requirements are proposed:

- Declaration of the content of rare earths in the motor of the washing machine.
- Declaration of the recyclability benefit ratio for the impact category X.

8.5.7 Case study: LCD TV

The case study of LCD TV applies the methods for calculating RRR ratio and RRR benefit ratio along with an assessment of the use of hazardous substances. Based on the results of the assessment, the following hotspots were identified:

Backlight fluorescent lamps are relevant due to their content of hazardous substances and critical rare materials.

- LCD screens are relevant due to they content of critical rare materials.
- Plastic parts are relevant because they comprise 50 % of the mass and contribute to 2% to 5 % on the impact for certain impact categories.
- Lamps and LCDs are relevant because they are rich in critical and rare materials.
- Parts from polymers are relevant, because if plastics were sorted manually it would result in a higher recyclability. When, plastics are sorted mechanical, it is not possible to separate PMMA and plastics with flame-retardants.

Based on the hotspots the following potential requirements were identified:

- Improve disassemblability of key parts including PCBs, lamps, LCD screens, PMMA board.
- Declaration of the content of indium in LCD
- Improved marking of large plastic parts
- Threshold of the recyclability rate for plastics

8.6 Deliverable 6: Refined Methods and Guidance Documents for the Calculation of Indices Concerning Reusability / Recyclability / Recoverability, Recycled Content, Use of Priority Resources, Use of Hazardous substances, Durability.

The last report includes a revision of the methods and guides provided in the first three reports from 2011. Furthermore, it includes a method for the environmental assessment of the durability of products.

8.6.1 Revision for the method for Reusability, recyclability and recoverability ratio

The calculation method for RRR ratio has been fundamentally revised. The purpose of the revision has partly been to harmonise the method with the method proposed by the International Electrotechnical Commission in IEC/TR 62635. However, some alterations to the IEC&TR 62635 methodology are also proposed. The method proposed is now:

- For each product an end-of-life scenario is defined summarising the treatment each part will undergo. More specifically, the product is divided into subparts: reusable parts, parts for selective treatment, parts for selective recycling, parts difficult to process and other parts (Ardente, Mathieux 2012b, p. 6).
- Then the recycling and recovery rates for each part and each scenario are identified.
- Finally, the RRR rate is calculated.

8.6.2 Revision of the method for the calculation of the use of priority resources

Then a revision was made of the method for calculating the use of priority resources. The revision is in line with the prioritisation performed in the previous report, and uses the potential environmental impacts or benefits related to the potential reuse, recycling and recovery of the product. As in the previous report, a RRR benefit rate is developed based on the RRR rate and combined with life cycle data on the production of the product, the production of the materials, the impacts from recycling and the production of secondary material and the disposal and the transport during all life cycle phases. (Ardente, Mathieux 2012b, p. 7)

8.6.3 Revision of the method for the calculation of the recycled content

The revision of the method for calculating the recycled content does not differ largely from the methods proposed earlier. However, the method has be standardised and consolidated with existing methods such as the ISO 14021. Furthermore, there is focus on developing a robust procedure to verify the requirements, which is one of the weaknesses of the requirements. Additionally, a new index for recycled content benefit is introduced.

8.6.4 Revision of the method for the use of hazardous substances

The revision of the method for the use of hazardous substances has been quite fare reaching. The review has focus on reducing the risk of using hazardous substances. The new steps for the procedure are as follows:

- Definition of a set of substances to be considered
- Identification of components embodying the considered substances
- Identification of treatments for the end-of-life of the component and potential risk
- Identification of key components (Ardente, Mathieux 2012b, p. 9)

8.6.5 Method for the assessment of durability of products

Durability was not part of the first analysis of possible resource efficiency requirements. Therefore, it is not a revision of the method but an introduction of the method. The method is based on a literature review. When increasing the durability of a product, it is possible to reduce the impact from the manufacturing and disposal of the product. However, you might end up with a higher impact in the use phase if newer products are more efficient. Therefore, when assessing the durability of the product, it is important to consider the entire life cycle of the product.

Overall the assessment of a product’s durability is based on a comparison of two scenarios.

The base case scenario, here it is assumed that the product (A) is replaced after its average operating time (T) by a new product (B). In the durability scenario, it is assumed that the operating time of the product is extended from the average operating time to an extended operating time (X), and then first after this additional operating time the product is substituted by a new product.

Then, the environmental impact category for the assessment should be select. It is important to acknowledge that the results may differ depending on the impact categories. Hence, for some impact categories, it might be better to increase the products durability. However, for others it might result in a larger impact. The extension of the operating time should be estimated based on expert judgement. It is recommended to make a sensitivity analysis of the operating time as it may vary. Finally, formulas are proposed for a comprehensive calculation and a simplified calculation of the assessment of the product's durability.

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The Ecodesign Directive is one of the policy instruments that can play an important role in the change towards increased resource efficiency in Europe. The objective of this study has been to examine how resource efficiency requirements can be further integrated into implementing measures and voluntary agreements under the Ecodesign Directive. An overview is given of to what extent this has been the case in the existing implementing measures and voluntary agreements; and a detailed study is made of the two most ambitious cases: the voluntary agreement on imaging equipment and the implementing measure on vacuum cleaners. Finally, a review was made of existing resource efficiency requirements in four voluntary instruments: the Nordic Ecolabel, the EU ecolabel, EU Green Public Procurement (GPP) Guidelines and Electronic Product Environmental Assessment Tool (EPEAT) for imaging equipment, computers and windows.

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