Synergies between ecodesign related regulations for household refrigerating appliances

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Abstract

There are a number of product related environmental policy instruments in the EU that are based on life cycle thinking and ecodesign. They are put forth for achieving sustainability targets and improving environmental performance of groups of products. For the effective implementation of the regulations it is important to identify and analyze synergies and limitations of already existing policy framework.

In this project the focus is split between voluntary (Ecolabelling, voluntary agreements) and mandatory measures (ErP, WEEE, RoHS and REACH Directives). The study is carried out by means of using a case study of domestic refrigerating appliances.

The case of household refrigerating appliances does not have serious deviations. However, it is relevant to observe general constrains and limitations appeared during policy implementation. This example represent coherent structure, but it has a lack of voluntary measures for market stimulations and implementing measures set quite ambitious targets to be achieved in the coming years.

This project also recommends possible suggestions for improving of the current policy framework and of environmental performance of products.

Preface

The Master thesis was made during the fourth and last semester of the Master Program in Environmental Management & Sustainability Science and JEMES at Aalborg University in spring 2012 by Veronika Kozlova.

This report is composed of 8 chapters; the references to literature are given in Author-Date Style, referred to Harvard method. All references are listed at the end of the report.

I would like to thank all the people without support and help of which this thesis would not have been possible. In particular, at first I would like to thank my supervisors Arne Remmen and Kasper Dirckinck-Holmfeld for their helpful comments, thoughtful tutoring, and their help in finding useful materials.

I also would like to thank the team of environmental consultancy BIO Intelligent Service, where I have done my internship, for the opportunity to receive professional experience; and in particular Adrian Tan, for providing me with wise guidance and sharing invaluable knowledge.

I would like to thank as well my classmates both from the JEMES program and from Aalborg Master Program for the friendly atmosphere, exchange of ideas and productive discussions. I am delighted to have had opportunity of studying with so bright individuals.

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1. Introduction

1.1. EU sustainability strategy

Environmental problems and sustainable development issues like resource efficiency, reduction of greenhouse gases emissions, waste, and recycling are actively discussed in Europe and worldwide. Various strategies are developed to mitigate environmental impacts and comply with international protocols, agreements and regulations.

European Union introduces initiatives for improvement of environmental and energy performances of Member States. In December 2008 the European Union (EU) adopted a plan on climate change mitigation, with the so-called “20-20-20” target (European Commission, Climate Action, 2012), which is a part of an ambitious EU strategy on sustainable growth and jobs. This plan covers objectives related to innovation, education, social and climate/energy spheres to be reached by 2020 year. Following goals in terms of sustainable development are put forth:

- 20% reduction of GHG emissions from 1990 levels
  There has been also a proposal of raising the target for greenhouse emissions up to 30% in case of other developed countries commit to proportional emission reductions. The analysis of such an option as regards of benefits, cost and ways of achieving has been done by the Commission but the agreement between countries has not been found yet.
- 20% of primary energy use reduction compared with projected levels, to be achieved by improving energy efficiency
  According to the COM(2006) 545 final report if the saving objective of 20% reduction in primary energy is met, apart from 400 Mtoe decrease in primary energy consumption and 860Mt CO2 emissions reduction (EC, 2006a), it will result also in avoiding the construction of about 1000 coal power units or half a million wind turbines (EC, 2008a).
- 20% of overall increase in renewable energy sources
  The types of green energy sources differ among Member States (MS). This results in fluctuations of the goal percentage value depending on a MS. However 10% of biofuel’s use in transport is a binding requirement for each Member State (EC, 2008b). The renewable energies target connotes not only with mitigation of climate change but also with dependence on fossil fuels. There is a forecast of increase of imported gas from 57% to 84% and imported oil from 82% to 93% which can affect ETS (emission trading scheme) allowances or increase risk of so-called carbon leakage[1]. Hence, increase of renewable energy sources share is crucial to avoid such situation (EC, 2007, p.3).

Reduction of GHG emissions and increase of renewable energy sources are set as mandatory requirements for the EU, whereas primary energy consumption reduction is not defined as a mandatory objective. Nevertheless, impair of primary energy consumption together with GHG emissions are very important targets because of their influence on energy efficiency improvement.

Therefore, ambitious plan for implementing energy efficient technologies for achieving the EU “20-20-20” objective is essential. According to COM(2008) 772 final there are five pillars to the EU's specific energy efficiency policy that can be mentioned (EC, 2008a):

[1] Carbon leakage is a tendency of moving industries with CO2 emission production from a country with a strict payment system to a country with less strict one.

1. the general policy framework and the actions taken under the European Energy Efficiency Action Plan;
2. the National Energy Efficiency Action Plans based on the framework Directive on Energy Services;
3. the legal framework for the most important consumption sector: buildings[2] and energy consuming products;
4. policy instruments such as targeted financing, provision of information and networks like the Covenant of Mayors and Sustainable Energy Europe;
5. international collaboration on energy efficiency.

These are the options EU should base on for achieving sustainability goals. Energy efficiency legislation is one of the most influential instruments. In this regards European Commission has introduced several key Directives such as Ecodesign Directive 2009/125/EC for energy-related products, Energy Labeling Directive 2010/30/EU and Energy Performance of Buildings Directive which enhance the role of energy efficiency and strengthen legislation. New sustainable strategies, concepts and approaches are being developed for implementing policy instruments on the resource efficiency and mitigation of harmful environmental impacts. Life Cycle Thinking (LCT) concept can be considered one of those. This approach allows identifying opportunities that exist to minimize environmental impacts at various stages of products' life, starting from extracting of materials to the end-of-use and disposal, and to evaluate harmful impacts within economical, social and environmental dimensions. LCT is able to incorporate environmental issues throughout the life cycle of products and services into corporate concept.

1.2. Sustainable Consumption and Production

Currently European Commission is implementing Sustainable Consumption and Production (SCP) Action Plan (EC, 2008c).It proposes series of actions to contribute to the improvement of environmental performances. One of Policy Areas covered under EU's SCP action plan is Integrated Product Policy. IPP is EU initiative framework which bases on life cycle thinking and aims at impairing environmental impacts of products throughout their life cycle. It combines a set of tools for implementing sustainable strategies such as ecodesign, life cycle assessment and others. It was introduced in February 2001 in a Green Paper (EC, 2001), after the study on IPP provided by independent consultancy for EC DGXII in March 1998 (Ernst&Young, 1998).

IPP focuses both on supply and consumer sides. It aims at "greening" production phases as well as on the way customers purchase, use and dispose goods. It includes tools for the market change towards sustainable production and consumption.
The main principles of IPP are following:

- Life-cycle thinking approach
- Market orientation
- Stakeholders involvement

IPP establishes framework that applies to various groups of products, identifies most environmentally damaging ones, and provides strategies and initiatives for preventing and mitigation of their harmful impacts.

IPP has a whole variety of measures - both voluntary and mandatory - that can be used to achieve this objective. These include measures such as economic instruments, substance bans, voluntary

[2] Other important consumption sectors like meat production or transportation are covered in the specific regulations

agreements, environmental labeling as well as ecodesign approach. This system of measures looks at a product from resources extraction, design, manufacture, distribution, use, end-of-life and disposal phases and provide measures to improve environmental performance at every individual stage.

Main policy instruments that are used under Integrated Product Policy, as follows:

- Voluntary agreements
- Environmental Management and Audit System (EMAS)
- Green Public Procurement
- Eco-labeling
- Energy labeling
- Legislation

Policy instruments mentioned above help implement life cycle thinking, and one of the main tools they use is ecodesign. Generally, ecodesign can be perceived as "ecological design", i.e. creating (designing) a product which is environmentally-friendly and "green", however, there is no single definition. According to the European Commission (EC) definition *"ecodesign means the integration of environmental aspects into product design with the aim of improving the environmental performance of the product throughout its whole life cycle"* (EC, 2005).

Mandatory legislation under IPP related to ecodesign is following:

- Ecodesign Directive on energy-related products (ErP) 2009/125/EC i (revised version of Ecodesign Directive on energy-using products 2005/32/EC)
- Energy Labelling Directive 2010/30/EU
- Waste Electrical and Electronic Equipment Directive (WEEE) 2002/95/EC
- Registration, Evaluation, Authorization and Restriction of Chemical substances Directive (REACH) EC 1907/2006
- Restrictions on Hazardous Substances Directive (RoHS) 2011/65/EC

All of the directives use ecodesign to address life cycle of a product. ErP, WEEE and RoHS Directives cover particularly electrical/energy-using/energy-related products throughout their life cycle and help improve their environmental performance. On the Members States and EU level voluntary labeling based on ecodesign can exist, for example, EU Ecolabel, Nordic Swan, die Blau Engel etc. It is important to use a mixture of regulatory and voluntary measures. This combination of regulations is crucial for strengthening resource efficiency and sustainable consumption and production EU's strategy by stimulation manufactures and the market.

By referring to life cycle of a product these policy instruments intersect each other, see Figure 1. Likewise, RoHS and WEEE directives supplement each other, RoHS limits amount of hazardous substances used in the manufacturing phase which later are going to be addressed by WEEE directive in the end-of-life phase. ErP directive looks at the product within whole life-cycle, taking into account raw materials concentrations and waste recycling rates but with a focus shift towards the use phase. Additionally, Energy Labelling Directive 2010/30/EC can be supplementary measure to the Ecodesign Directive. It aims at market stimulation and encouraging consumers to buy sustainable products.

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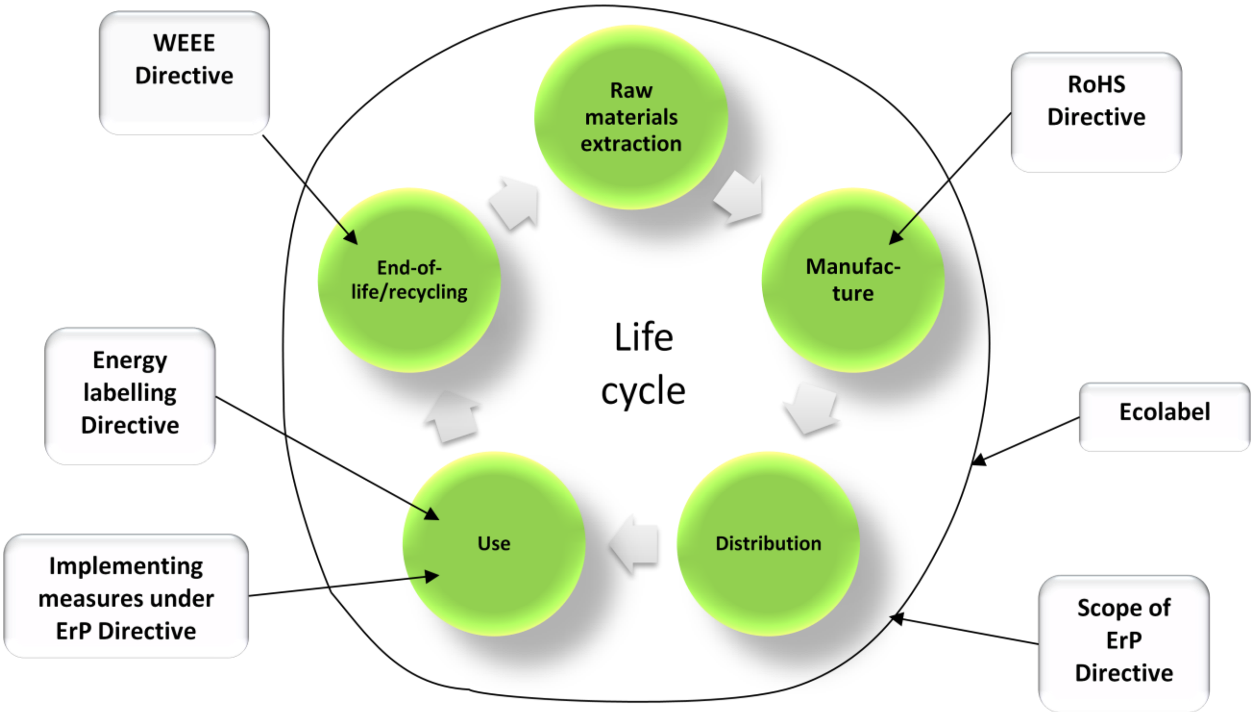

Figure 1: Life cycle of the product and directives related to it

As it can be seen from the figure above focus of the major policy instruments under IPP is various. Scope of the ErP Directive and Ecolabel cover the whole life process of a product and, thus, addressing related to it possible environmental and economic impacts. Nevertheless, Implementing Measures under ErP Directive have a clear focus on the use phase. WEEE Directive focuses on the end-of-life stage, setting requirements for collection and utilization of electric and electronic wastes. RoHS sets limits on the hazardous substances in the electric and electronic equipment in the manufacturing phase.

1.3. Problem field

As seen above sustainable consumption and production is an important issue on the EU's agenda. Resource efficiencies strategies give an opportunity for economical, social and environmental growth. They are the key element in achieving EU targets in reduction of energy consumption, GHG emissions and increasing share of renewable sources.

EU has set Sustainable Consumption and Production Action Plan to achieve desired goals. One of the important policy area under this framework is policy instruments related to Integrated Product Policy. It is an approach based on life cycle thinking which exams environmental performance of products, and seeks possibilities for an improvement in a cost-effective way. IPP approach aims at assessing harmful impacts throughout the life cycle, and recommends measures for their mitigation. Those measures shall be implemented at the "front-of-the-pipe" meaning that ecodesign is one of the main tools to be used under Integrated Product Policy.

Policy measures related to ecodesign are a good instrument to encourage sustainable development. However, as it was mentioned in the section 1.1 there are some constrains and limitations that can take place. For instance, Ecodesign Directive for energy related products evaluates product during its life, but it has a visible focus towards use-stage, whereas stages like end-of-life, manufacturing and distribution are poorly addressed.. Also other ecodesign related directives like WEEE or RoHS have a focus on particular life cycle stage: end-of-life and manufacturing, consequently.

For the time being there have been several studies carried out to discover actual issues related to collaboration between ecodesign related regulations. For instance, the research by Aalborg University on the Washing Machines (DG ENER Lot 14)(Aalborg University, 2012) has showed that ecolabel for domestic washing machines does not push the market to eco-innovation towards best performing products as it I supposed to do. On the contrary, Implementing Measures for Ecodesign Directive, which phase out worst performing products, set the strictest requirements. Furthermore, study on washing machines revealed that ecodesign related regulations have sometimes deviation from life cycle thinking approach, lack of collaboration between the policy instruments, different time limits for regulations and as an outcome discrepancy in required measures. Also research on the TV (DG ENER Lot 5) (Andersen & Remmen, 2011) has showed that the pulling force for that product group is not legislation but consumer's demand and technology push. The study investigated that TVs on the market could comply with Implementing Measures, as well as a big part of appliance could provide high environmental performance and obtain ecolabel to have a privilege in the market competition. This research described "rebound effect" when energy efficiency of a single appliance is decreased, the amount of TVs sold on the market rises significantly and, hence, energy consumption in total is not decreasing as it is projected. However, example of these product groups represents deviant cases since they obtain some problematic issues (Flyvbjerg, 2006).

In this project I will assess what kind of synergies, limitations between mandatory and voluntary measures can take place in the product group of domestic refrigerating appliances (DG ENER Lot 13).The purpose of choosing refrigerating appliances is to describe an example the outcomes of which can be applied for other product groups, because this product group can be defined as a critical case. According to Flybjerg terminology the purpose of a critical case is to *"achieve information that permits logical deductions of the type"* (Flyvbjerg, 2006). The product group of refrigerating appliances does not have any visible deviation neither in the process of preparatory studies, nor in the implementing measures itself[3]. Therefore, since critical case follows the most or least likely definition, the rule *"If this is (not) valid for this case, then it applies to all (no) cases" can be used* (Flyvbjerg, 2006). In the case of household refrigerating appliances, it can imply that improvements of synergies between ecodesign regulations can be applied for other product groups as well.

1.4. Research question

Based on the problem field/description, I formulate research question as follows:

"What are the synergies between ecodesign related regulations throughout life cycle of household refrigerating appliances and are there possibilities for improvements?"

[3] Elaborated explanation is given in the section 2

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2. Methodology

2.1. The case-study of refrigerating appliances

According to Flyvbjerg a case-study can be classified as extreme/deviant case, the maximum variation case, the critical case and the paradigmatic case. The aim of considering a critical is to reveal general problems, applied to other group of products. In this report I am using as a case study domestic refrigerating appliances. As it was mentioned in the problem field, this product group can serve as a critical example.

Domestic refrigerating appliances can be defined as a critical case for several reasons. Firstly, Implementing Measures for them have been published quite recently, in 2010, and with no delays. Implementing Measures were introduced quite fast after preparatory study had been finished. This means the product group does not have much controversial opinions, like boilers study (DG ENER Lot 1), which has been significantly delayed, or much of inconsistencies between the requirements as product group of domestic washing machines (DG ENER Lot 14). In such respect refrigerating appliances can represent average situation in relation to Ecodesign regulations. Secondly, refrigerating appliances are a good example because they have a clear pattern of use, they operate irrespective of a consumer, there are always on. Thirdly, domestic refrigerating appliances have simply energy consumption calculation, hence, no polemic discussion took place. Therefore, manufactures affect the most energy efficiency of a product by presenting more or less effective appliances.

2.2. Internship

Crucial part of the research, material collection and work on the project has been carried out during my internship at the French environmental consulting firm "BIO Intelligent Service", where I have been as an intern from September 2011 to April 2012. This consultancy provided me with various studies related to the thesis topic as well as with personal consultations offering company's specific point of view, definitely this working experience could be seen as the most influential to the whole report.

During my stay in BIOIS I was working in Sustainable Policy Department, Sustainable consumption and production unit. I was involved into the various project projects relevant for this thesis. Resource efficiency in a food cycle that aims at creating general sustainability criteria for food focusing on environmental impacts of food products and following a life cycle approach:

- Biomass boilers in the EU that aims at demonstration of cost efficient small scale biomass boilers with low emissions and their future perspectives in European market under the FP7 Cooperation Work Programme.
- RoHS project which aims at supporting impact assessment with regards to scope changes for RoHS II Directive, estimate needs of further scope amendments and provide background data.
- Preparatory study for on local and central heating appliances DG ENER Lot 20&21 for European Commission in the context of Ecodesign Directive. The aim of preparatory studies is to provide complete market and technical overview on the heating appliances and to propose future minimum energy requirements.

The work on the ecodesign projects influenced the most my choice of the topic for the thesis. It inspired me with the ideas and gave me valuable insight knowledge of the subject.

2.3. Desktop research

Desktop research involves the summary, collection and synthesis of existing research rather than primary research, where data is collected from, for example, research subjects or experiments (Sunny Crouch, 2003). It is a general survey of the documents and positions in the relevant field; published articles and internal materials analysis. Analyzing documents can be for structuring concepts, ideas, and categorizations.

3. Theories

My thesis project has a practical research problem. The theories presented explain the ecodesign approach in general and introduce possible way of improvements of the current ecodesign related regulations collaboration.

3.1. Life cycle thinking and ecodesign

Applied to product design, production processes and a decision-making, life cycle thinking is an essential concept for implementing sustainable development "the objectives of which are prevention of pollution and reducing environmental impacts at the source and to reduce resource use and emissions in the different life cycle" (Kørnøv, L., Thrane, M., Remmen, A. & Lund, 2007, p.198).

Table 1: Different management levels and examples of strategies, systems, and tools related to Life Cycle Thinking concept

Management level	Social Dimension	Environmental dimension	Economical dimension
Objective		Sustainability	
Concept		Life cycle thinking	
Strategies		Life cycle management	
	CSR	Pollution prevention	Product- and supply chain management
Systems	OHSAS	POEMS	TQM, ERQM, IPD
Tools	Work place assessment	Cleaner production, LCA, EcoDesign	EMA, LCC

Table is a adopted from Kørnøv*et al* 2007

Explanations: OHSAS – standard for occupational H&S, EMS – Environmental Management System, POEMS – Product Oriented Environmental Management System, TQM – Total Quality Management, EFQM – European Foundation for Quality Management, IPD – Integrated Product Development, LCA – Life Cycle Assessment, EMA – Environmental Management Accounting, LCC – Life Cycle Cost

The tools mentioned in the Table 1 are, in principle, well-described and have established guidelines. However there is no single definition of Ecodesign, it became recognizable after series of publications like UNEP manual in 1997: "EcoDesign: A promising approach to sustainable production and consumption" and a book by Ursula Tischner "How to do eco-design" in 2002. Ecodesign is built upon pollution prevention principle, hence, it replaces traditional "end-of-pipe" approach and focuses on managing potential environmental impacts at the product designing level.

Ecodesign provides guidelines on how to improve a product. The design phase is crucial in this case because the solution and measures for product-related environmental issues are addressed at the beginning, at the design phase. The idea is that negative environmental impacts can be mitigated by improving product design. Implementing of ecodesign can be done on different levels: small or big enterprise/industry or regulatory approach on state and international levels, hence, ecodesign can be classified by as:

- Ecodesign as an enterprise's policy for eco-improvements

Designing a sustainable product that integrates environmental, social and economical concerns is a nowadays tendency in a company's strategy (Ecodesign - The Competitive Advantage 2010). Product innovation by addressing impacts at the product development stage results in cost efficiency and mitigation of harmful impacts. The necessary skills in order to create such appliance are good knowledge base of a life cycle perspective for a product (raw, materials, manufacture, distribution, use, end-of-life and disposal of a product) as well as knowledge of working with product development, thereby it complies engineering design as well as concepts of functionality and user friendly interface. It is important that ecodesign concepts are integrated into the company's business strategy taking into account product specific features, organization culture and structure.

Accodring to Brezet and Van Hemel (1997) ecodesign can be represented as following strategy wheel, see Figure 2. It describes options for development of Ecodesign strategy in companies, which are:

1. New concept development
2. Selection of low-impact materials
3. Reduction of materials usage
4. Optimization of production techniques
5. Optimization of distribution system
6. Reduction of impact during use
7. Optimization of initial lifetime
8. Optimization of end-of-life system.

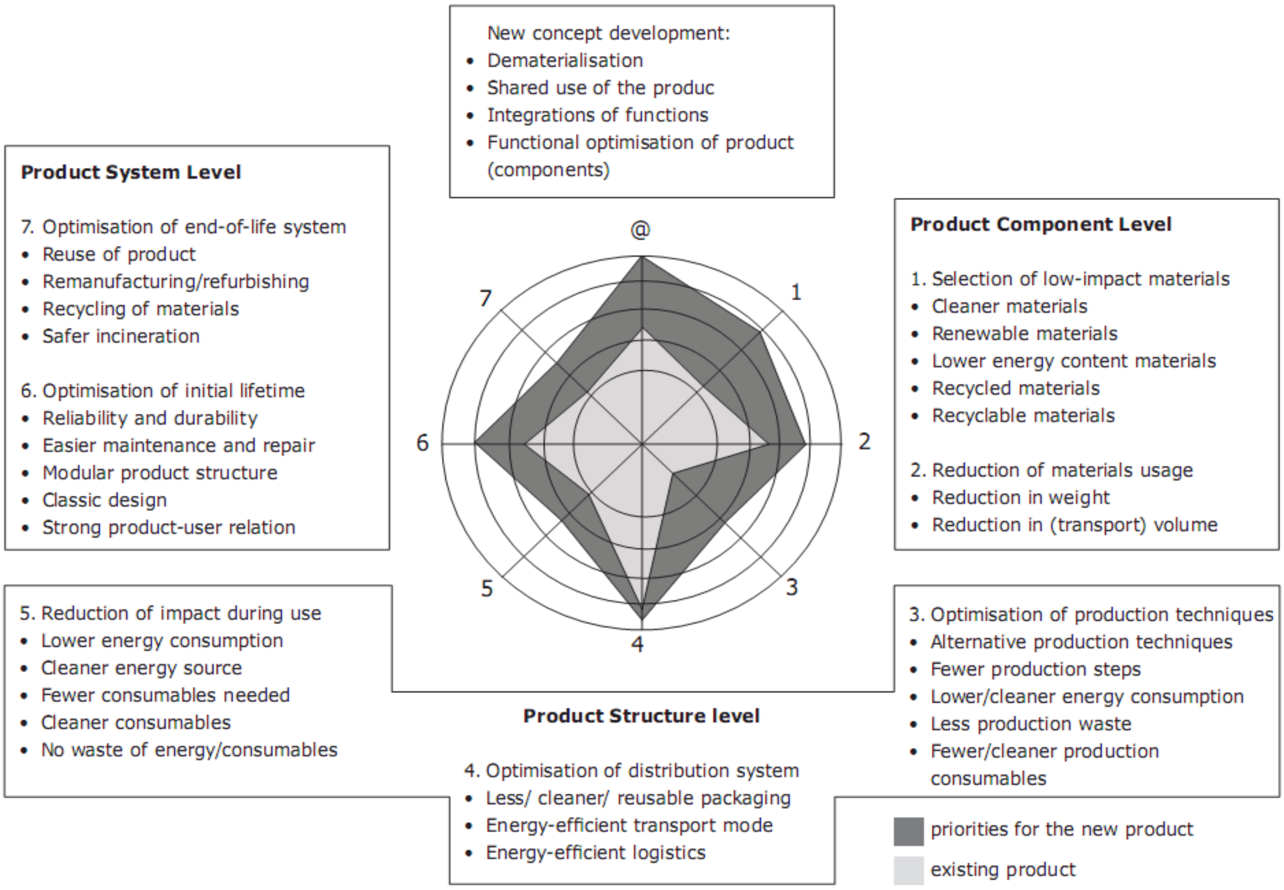

Figure 2: The EcoDesign strategy wheel (Brezet and Van Hemel, 1997)**.**

Ecodesign strategies are divided by product component (materials used), structure (process organization) and systems (recycling processes, optimization of lifetime) levels. Priorities for a strategy use as regards new product have a greater importance since it is crucial to include ecodesign features at product creating process. However, optimization of a distribution system has equal importance for the existing and new product; it deals with organization of efficient transportation and logistics as well as reusable and recycling packaging.

- Ecodesign as a regulatory approach on state/international level

Different legislative strategies exist around the world for promoting ecodesign. Likewise, USA applies Design for the Environment Program (DfE), which aims at the reduction of amount of materials with significant environmental impacts, waste management and improving energy efficiency strategies, however the main focus of this program is a restriction of hazardous chemicals (United States Environmental Protection Agency (US EPA), 2012).

- **Cradle-to-cradle theory**

Another interesting theory to mention is cradle-to-cradle theory. It is base on life cycle approach and in considers product during all the life stages. However, this approach goes further and it aims at moving from cradle-to-grave approach to cradle-to-cradle one.

This theory was proposed by William McDonough and Michael Braungart in 2002. The main idea is about changing common way of reduce reuse recycle methods towards the system of "lifecycle development". The authors propose to switch from downcycling to upcycling principle where products in their end of life stage are considered as biological or technical nutrients depending on the type of a system.

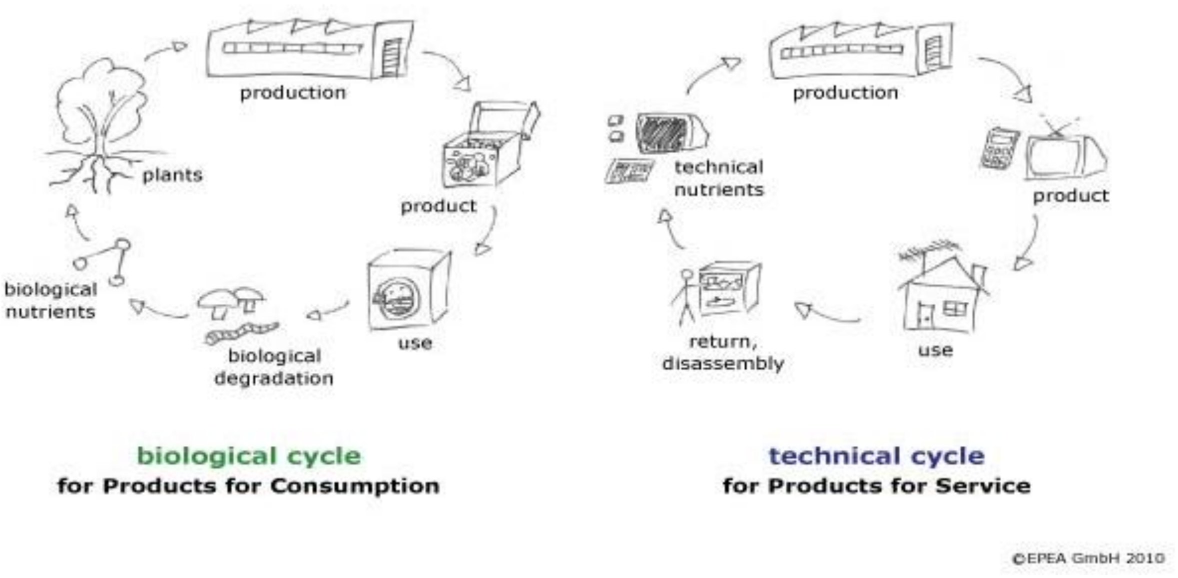

Figure 3: Biological and technical cycles in relation to cradle-to-cradle theory (EPEA, 2011)

In Figure 3 the schemes of biological and technical metabolisms are presented. In biological cycle nutrients are those organisms which can enter environment once again to form a basis for new resources (for example, biodegradable products us as compost). In the technical cycle the main idea is that material's flow is a closed-loop cycle and technological nutrients are kept in a closed system remaining at the same quality level.

There are three general principles of cradle to cradle theory (Braungart, M. & McDonough, 2002):

1. Waste equals food

After one organism dies and becomes waste it automatically transforms into the food for another. Likewise, tree leaves becomes falling break down and become compost and nutrients for other organisms.

2. Use current solar income

Industrial revolution was driven by energy reservoirs of the past like fossil fuels. Nowadays there is a possibility of using less harmful, renewable sources like solar energy/ wind energy or biomass.

3. Celebrate diversity

Natural systems are diverse and different; and this is the basement for their development and growth. The same approach of variety should be used in relation to product manufacturing. The concentration on only one parameter can cause imbalance and instability.

Cradle to cradle proposes products with continued lifetime, whether lifetime of a products with cradle to grave approach ends in a landfill or in a downcycling process to another product (plastic bottle to plastic flees for example).

McDonough and Braungart promote the idea the every product can be designed in a way that after the end of life it can be upcycled to another new product. For example, the book “Cradle-to-cradle” itself is 100% recyclable. It is printed on synthetic paper and considered to be a technical nutrient for other books or plastic paper.

The authors cultivate the idea of eco-effectiveness instead of eco-efficiency. Cradle to cradle approach takes as example natural principles and leaving the concept of product being less bad towards being good and eco-effective (Bram van der Grinten, 2008).

Discovering of actual benefits that product can bring like cleaning air or producing energy.

4. Policy instruments

4.1. ErP

The Ecodesign directive history goes back 1992, when the first regulation on energy efficiency was published for hot-water boilers (EC, 1992). It set efficiency requirements which were aiming at improving boilers performance and facilitating series production by that giving a fundament for creating current ecodesign directive.

In 2003 the proposal for the Directive "On establishing a framework for the setting of Eco-design requirements for Energy-Using Products and amending Council Directive 92/42/EEC" putting forward ecodesign requirements was published by the Commission. The proposal's goal was to introduce the eco-design framework, scope and present basic working principles with the overall aims of environmental protection by improving general environmental performance, developing strong EU market with free movement of EuP within the EU and high competitiveness of the EU products by taking into account interests of consumers and manufactures.

All that provided background so that in August 2005 the Ecodesign Directive for Energy-using Products (EC, 2005) was adopted by European Parliament and it became a national law in Member States by August 2007. However, later the Ecodesign Directive was revised In 2009 (EC, 2009), extending its scope to Energy-related products (ErP) including also products such as insulation, windows, doors, which do not consume energy directly but are able to make significant impact on energy consumption.

The Ecodesign Directive provides a framework for establishing mandatory, ecological, coherent and integrated EU-wide rules which set compulsory ecodesign requirements for energy related products (ErPs) for improving the environmental performance of products (European Commission, 2000).

The primary aim of the Directive is to mitigate negative environmental impacts through reduction of products energy consumption, emissions, water consumption, providing sustainable waste management and recyclability. In its turn manufactures are supposed to do those improvement modifications at the design stage of the products where over 80% (Tuschner, 2000) of all product-related environmental impacts are determined (EC, 2006b).

The Ecodesign Directive defines a framework but does not include any binding requirements itself. The mandatory obligations for industries are adopted through special requirements, so called "Implementing Measures", which are set for every product group separately. They include minimum limit values and calculations for energy, water consumption, waste generation depending on the product group.

The scope of the Directive is broad since it covers in principle all products that use, produce, transfer, measure or depend on energy, as well as products that may affect energy consumption such as water-using devices, detergents etc. There around 40 product groups in the scope of the Directive (Lots) and ten lots are covered now having their Implementing Measures in place. Not every kind of energy related product can be considered under the Directive. To determine whether particular group of product shall be in the scope there are certain criteria according to which ErP should be evaluated (EC, 2009):

- Significant volume of product sales and trade on the market
  More 200,000 units a year with respect to the most recent data
- Significant environmental impact
- Significant improvement potential

Minimum obligations that come from Implementing Measures suppose to contain following:

- Specific requirements that present numerical targets which must be achieved before placing product on the market.
- Generic requirements that do not set numerical targets but comprise guiding requirements to the manufacture in relation to the materials used or to the end used in relation to best practices of product maintenance and use for minimizing environmental impacts.

For the evaluation of eligible Energy-related Products the European Commission has published methodology (MEEuP) which sets requirements for carrying out the assessment[4].

The outcomes of the Directive should be reduction of energy consumption and mitigation of environmental impacts from manufactures by minimum environmental impacts requirements set in Implementing Measures. The Ecodesign Directive does not aim at putting high eco-standards as ecolabeling schemes do but at phasing out worst performing products from the market, see Figure 4. Thus, in practice, the introduction minimum requirement may result in banning all non-compliant products from EU market. For example this was the case for the incandescent lamps (Cool Products, 2009).

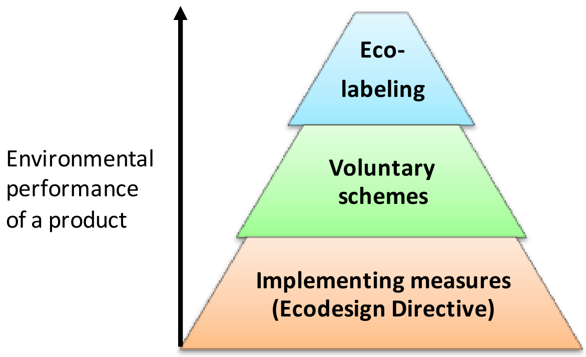

Figure 4: Hierarchy of the Ecodesign Measures

Also often at the same time as Implementing Measures take place Energy Labelling is introduced. Energy Labelling is described under Directive 2010/30/EU. First energy labelling classification with regard to household refrigerating appliances was published in 1994 under 92/75/EC Directive, later it was amended by Directive 2010/30/EU. The objective of energy labelling is to classify appliances in accordance with their energy performances into classes from A to G, where G is the least efficient; also it provides additional parameters as noise, capacity depending on the appliance. According to the Figure 5 provided by the EC Implementing Measures suppose to be the starting point for the energy labeling classification. Also figure below shows that Energy Labelling together with Ecodesign Directive enhance the amount of high efficient unit sold. Energy efficiency ranking is an effective instrument for stimulation of the market and together with Ecodesign Directive it forms broader framework for bringing additional savings.

[4] December 2011, the new methodology for energy-related products has been published (MEErP).

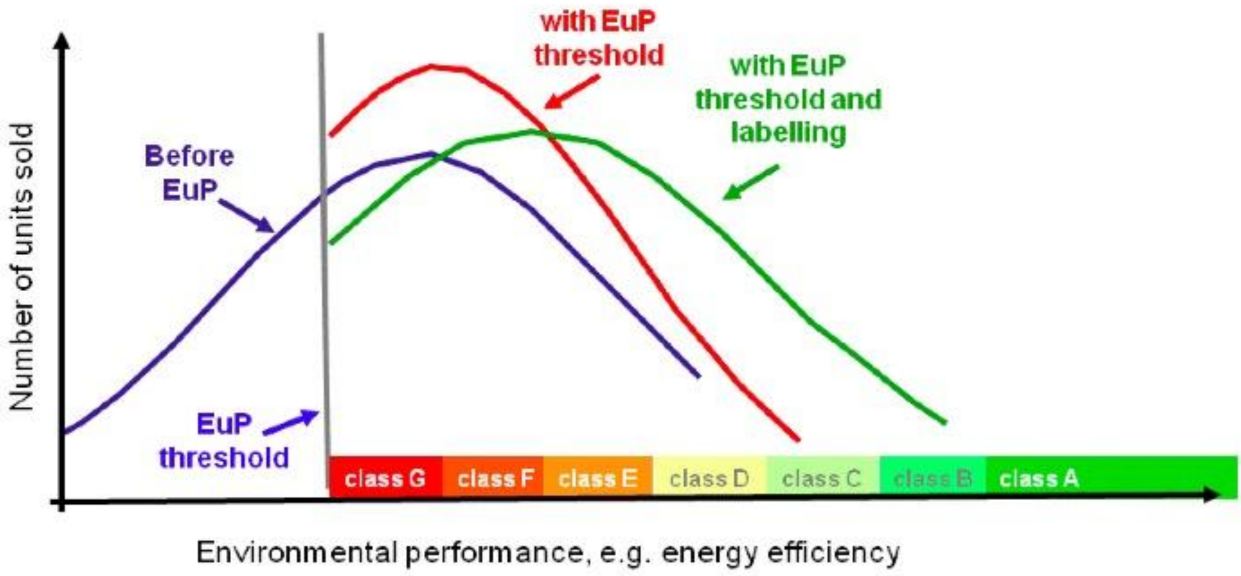

Figure 5: Concept of implementation EuP Directive together with energy labelling (DG Energy, 2011)

4.2. WEEE

WEEE Directive 2002/96/EC on Waste electrical and electronic equipment came into force on 13 February 2003 introducing essential targets for EEE waste within the European Union, and setting deadline of transporting them into Member States' regulations by 13 August 2004, with achieving a minimum rate of 4 kilograms per capita per year recovered for recycling by 2009. Since that the Directive has had couple of minor revisions, the last one in March 2008 when WEEE Directive 2008/34/EU was published introducing amendments to the previous WEEE Directive.

According to the Article 1 Directive 2002/96/EC aims at prevention of e-waste and promoting such measures as recycling, waste recovery and reuse, as well as improvement of environmental performance of all actors involved in the life cycle of electrical and electrical products.

Electronic waste rate in 2005 was 9.1 mln tones with a forecast of reaching 12.3 mln[5] tones by 2020. Still only approximately a one third of waste electrical and electronic equipment (33%) is treated according to the legislation, the 13% goes to landfills and 54% potentially to sub-standard treatment inside or outside the EU. However, Illegal waste trade to non-EU countries is still widespread.

The WEEE Directive objective is to limit growth of e-waste by have proper waste treatment schemes. In order to achieve those targets Members States should apply appropriate measures to increase amount of separate WEEE collection, important factor to achieve that is to ensure that high levels of e-waste collection that come from private households.

WEEE Directive promotes collection and recycling of hazardous substances in electrical and electronic equipment by creating schemes when e-waste are being returned after the end of the use-phase. It also states that heavy metals such as lead, mercury, cadmium, and hexavalent chromium and flame retardants such as polybrominated biphenyls (PBB) or polybrominated diphenyl ethers (PBDE) to be substituted by safer alternatives (European Commission, 2012).

WEEE directive covers 10 product categories such as:

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[5] Proposal for a Directive Of The European Parliament and of the Council on Waste Electrical And Electronic Equipment (WEEE) (recast) , December 2008

1. Large household appliances: refrigerators, washers, stoves, air conditioners
2. Small household appliances: vacuum cleaners, hair dryers, coffee makers, irons
3. Computing & communications equipment: computers, printers, copiers, phones
4. Consumer electronics: TVs, DVD players, stereos, video cameras
5. Lighting: lamps, lighting fixtures, light bulbs
6. Power tools: drills, saws, nail guns, sprayers, lathes, trimmers, blowers
7. Toys and sports equipment: videogames, electric trains, treadmills
8. Medical devices
9. Monitoring and control instruments including industrial monitoring and control instruments
10. Automatic dispensers: vending machines, ATM machines

Each category has its own treatment according to the Article 6 of the Directive, for instance, category 1 and 10 products should have increased rate of the recovery by 80% on a product level and by 75% on a component level.

The new recast of the Directive is currently in the process of revising and adopting. It proposes the 65% rate of WEEE collection based on the average equipment placed on the market in the each two coming years. The proposed collection should be reached every year from 2016(European Commission, 2008). In 2012 the proposed collection rate should be reviewed in terms of setting possible targets for cooling and freezing equipment separately, based on the presented report.

Also as the reuse and recycling target should be increased by 5% and include reusing whole appliances. Additionally, it's important to promote encouraging measures for increasing waste electrical and electronic equipment collection from private households by financing appropriate collection facilities: monitoring and inspection rules through comitology.

4.3. RoHS

RoHS - Restrictions on Hazardous Substances Directive, RoHS I 2002/95/EC Directive came into force on 23rd February 2003, it introduced compulsory limits for hazardous substances used in electrical and electronic equipment (EEE), according to Article 9 of this Directive Member States should have been brought *"into force the laws, regulations and administrative provisions necessary to comply with this Directive before 13 August 2004"* (European Commission, 2003).

In December 2008 a proposal for the recast COM (2008) 809 final was introduce, and the recast of RoHS I with substantial changes has been launched and on 21 June 2011. RoHS II Directive 2011/65/EU came into force, though a number of scope changes in the final recast have not been assessed yet. According to Article 25 RoHS Directive 2011/65/EU Member States "shall adopt and publish, by 2 January 2013, the laws, regulations and administrative provisions necessary to comply with this Directive" (EC, 2011). Also RoHS II states according to Article 24 that by 22 July 2013 the appropriate needs of amendments to the existing directive should be examined and the report should be presented to the European Parliament and by 22 July 2011 general review of the Directive should be presented to the Parliament with a possible legislative proposal.

- **Generally the Directive establishing minimum requirements to the following hazardous substances, according to the Annex II of the Directive 2011/65/EU:**

1. Lead (Pb): < 1000 ppm
   Lead is usually used in wiring for electronic connection, in CRT screens, batteries (in this case batteries are out of the scope since they are covered by a separate directive)
2. Mercury (Hg): < 1000 ppm

Mercury is commonly used to conduct electricity, measure temperature and pressure, very common in fluorescent lamps that provide backlighting in LCDs.

3. Cadmium (Cd): < 100 ppm
   Cadmium is used in rechargeable NiCd-batteries, fluorescent layer (CRT screens), photocopying-machines (printer drums)
4. Hexavalent Chromium: (Cr VI) < 1000 ppm
   Chromium VI is usually used in data tapes, floppy disks
5. Polybrominated Biphenyls (PBB): < 1000 ppm
6. Polybrominated Diphenyl Ethers (PBDE): < 1000 ppm
   PBB and PBDE are common flame retardant used in coatings.

The maximum concentrations are tolerated by weight in homogeneous materials, and are 1000ppm (0.1%) for 5 substances and 100ppm (0.01%) for Cadmium. This implies that the values apply to any single substance of a product or component that could be separated mechanically.

For instance, if the amount of flame retardant of the product case is more than 1000 ppm it means that the entire product would not comply with the Directive requirements.

Everything that can be identified as a homogeneous material must meet the limit. So if it turns out that the case was made of plastic with 2,300 ppm (0.23%) PBB used as a flame retardant, then the entire radio would fail the requirements of the directive.

- **The following product categories are covered by the RoHS Directive according to the Annex I:**

1. Large household appliances: refrigerators, washers, stoves, air conditioners
2. Small household appliances: vacuum cleaners, hair dryers, coffee makers, irons
3. Computing & communications equipment: computers, printers, copiers, phones
4. Consumer electronics: TVs, DVD players, stereos, video cameras
5. Lighting: lamps, lighting fixtures, light bulbs
6. Power tools: drills, saws, nail guns, sprayers, lathes, trimmers, blowers
7. Toys and sports equipment: videogames, electric trains, treadmills
8. Medical devices
9. Monitoring and control instruments including industrial monitoring and control instruments
10. Automatic dispensers: vending machines, ATM machines
11. Other EEE not covered by any of the categories above.

Notably, that in the first RoHS 2002/95/EC Directive product categories 8 and 9 (medical devices and monitoring and control instruments) were excluded, but after the recast and publishing RoHS 2011/65/EU those categories have been included in the scope.

However not every electrical and electronic equipment fall under the RoHS Directive. According to the Article 2 of the Directive, the equipment which has military or space purposes, used in the planes or in large scale fixed installations or can be replaced just by the same kind of specifically designed equipment can be exempted from the RoHS requirements.

4.4. REACH

REACH is directive on Registration, Evaluation, Authorisation and Restriction of Chemical substances (EC, 2006c), which entered into force on 1 June 2007. It was an important step in EU's chemical legislation and it took seven years for it to pass.

According to REACH manufactures are obliged to provide information of chemical substances and their properties used in the production and register substances if their amount is equal to one tonne or more per year with European Chemical Agency (ECHA). The Agency, based in Helsinki, has its database where manufactures and consumers can find information on hazardous substances.

4.5. Ecolabelling

Ecolabel is a type of voluntary schemes, it can be applied on a country or a Union level, and it is a main trigger for promoting best performing products on the market. It is a measure of product sustainability level and it is created for simplifying distinguishing more environmentally friendly products from the less ones. The criteria chosen can be all kind of environmental parameters such as energy, water consumption, noise, waste/recycling rates etc. Ecolabel certification aims at boosting best products on the market. Usually ecolabels are based on a commonly accepted benchmark for a given product group, but of course they can vary depending on the MS. The typical ecolabel representatives are EU Ecolabel, Nordic Swan, Blue Angel etc.

4.6. Voluntary measures

Voluntary agreements it is an initiative signed by association and/or industry representatives which sets certain criteria for given group of products. They introduce more than “business as usual”, they add a value to a product.

For instance, CECED (European Committee of Domestic Equipment Manufactures) signed a commitment between manufacturers of refrigerators, freezers and their combinations (2002-2010). This commitment foresees a monitoring and reporting action on energy performance of these appliances.

5. Synergies between policy options in relation to household refrigerating appliances

Ecodesign Directive is one of the central policy options in IPP since it is a mandatory legislation with a scope that covers all life cycle stages, whereas other mandatory directives like WEEE or RoHS supplement particular life cycle stages with specific parameters. As a case study I consider product group of domestic refrigeration (DG ENER Lot 13), Implementing Measures for which has been published in 2009. As it was mentioned in the section 1.3 of the current report this product group can be considered as a critical example and does not have particular deviations as the case of washing machines (DG ENER Lot 14), TVs (DG ENER Lot 5) or obstacles during preparatory study as boilers product group (DG ENER Lot 1), thus it is able to reveal what kind of downsides can be typical for all kind of product groups and what are the potential improvements.

Table 1Table 2 below represents the list of regulations to be considered in this chapter in relation to domestic refrigerating appliances.

Table 2: List of the regulations related to household refrigerating appliances

Regulation name	Latest regulation related to household refrigerating appliances	Mandatory	Voluntary
Ecodesign Directive 2005/32/EC	COMMISSION REGULATION (EC) No 643/2009 from July 2009	x	
Energy Labelling 2010/30/EU	COMMISSION DELEGATED REGULATION (EU) No 1060/2010 from September 2010	x	
WEEE Directive 2002/96/EC	Directive 2002/96/EC	x	
RoHS Directive 2011/65/EU	Directive 2011/65/EU	x	
REACH	REGULATION (EC) No 1907/2006		x
EU ecolabel	Decision 2004/669/EC		x
Nordic Swan ecolabel	Nordic Ecolabel version 5.3 (29 May 2008 – 31 October 2013)		x
CECED Voluntary Agreement	CECED VA (2002-2010)		x

5.1. Refrigerating appliances

According to the EN ISO 15502:2005 refrigerating appliances are defined as:"*factory-assembled insulated cabinet with one or more compartments and of suitable volume and equipment for household use, cooled by natural convection or a frost-free system whereby the cooling is obtained by one or more energy-consuming means".*

Refrigerating can be divided into two groups by working principle:

- Compressor type

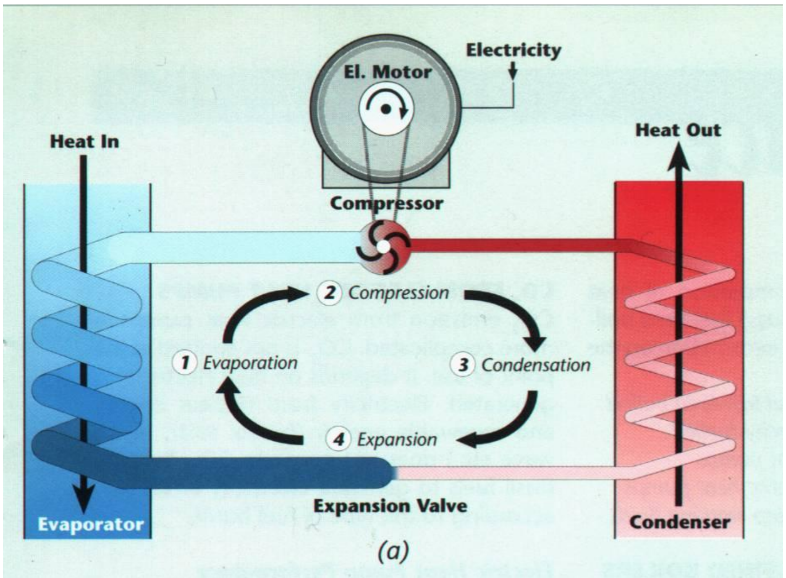

Figure 6: Single stage vapor compression refrigeration (Ammonia absorption refrigeration, 2012)

The principle is following: refrigerant flows through the compressor and compressor raises the pressure of the refrigerant this way increasing its temperature and pushing it through the system. Then refrigerant vapor goes to the condenser where it is transferred into a liquid, giving off heat. After that liquid passes through the expansion valve which causes an abrupt pressure reduction, this result in flash evaporation of a part of a liquid and also in lowering the temperature. After that cooled liquid and vapor are transferred to the evaporator. A fan blows the warm air through the coil or tubes of evaporator, thus liquid part evaporates, and at same moment circulating air is cooled. The evaporator is a device to absorb and remove heat of the circulating refrigerant, the vaporized refrigerant then transferred back to the compressor.

- Absorption type

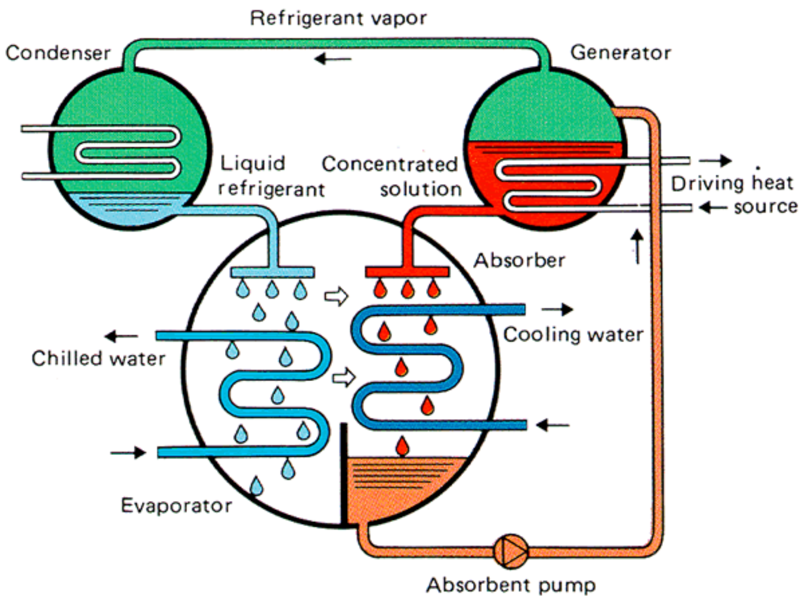

Figure 7: Absorption type of refrigerating appliance (The Architectual Engineering Companion, 2012)

The principle is following: the lithium bromide solution (the absorbent) in the generator receives heat from the driving heating source and boils, so water (the refrigerant) is evaporated. Then vapor is supplied to the condenser, where water vapor is transferred into a liquid by releasing heat to the water cooling loop. The cooled water goes to the evaporator, where it boils under low pressure at the low temperature and it takes heat from the cooling loop by chiller/fan coil circuit. The remaining concentrated solution from the generator passes through mortar exchanger /hydraulic seal to the absorber, after solution is sprayed and it absorbs vapor from evaporator. The resulting solution of water and lithium bromide is pumped back to the generator through the absorbent pump. In this process lithium bromide does not boil and, thus, water is easily separated by adding heat. The resultant water vapor goes into the condenser, the absorbent solution returns to the absorber, and the process repeats.

The principle of absorption refrigerator is similar to electric vapor compression systems, while the last one use an electric compressor, absorption type use cooling substitutes: a generator and absorber, called a thermal compressor (generator, absorber, pump and heat exchanger) (Gas-fired air conditioning equipment 2012).

5.1.1. Market trends

Nowadays compression type of refrigerating appliances is by far the most common used in household and industries. According to EUROSTAT in 2005 compression type sales were more than 7mln units, whether absorption type were around 700 000-800 000 units which is almost 10 times less (ISIS, 2007a, p.132). This may be due to the efficiency of the appliances: compressor type of appliance is more efficient than absorption type. However, absorption type has other advantages such as noiseless. Dut to the fact that they can operate on water or ammonia (refrigerant) they avoid the use of motor driven compressor and have low environmental impacts.

According to the Task 2 report of the Preparatory study for refrigerating appliances the total stock of refrigerators and freezers in 2005 was 160mln units and 80mln units consequently (ISIS, 2007a). In the Figure 8 it can be seen that refrigerators market has increased significantly and nowadays almost totally saturated, since every family has at least one refrigerator. Freezers have a bit lower ownership rate according to the same preparatory study for the Ecodesign Directive. On the Figure 9 the significant growth can be observed, nowadays the share of freezers is above 50%.

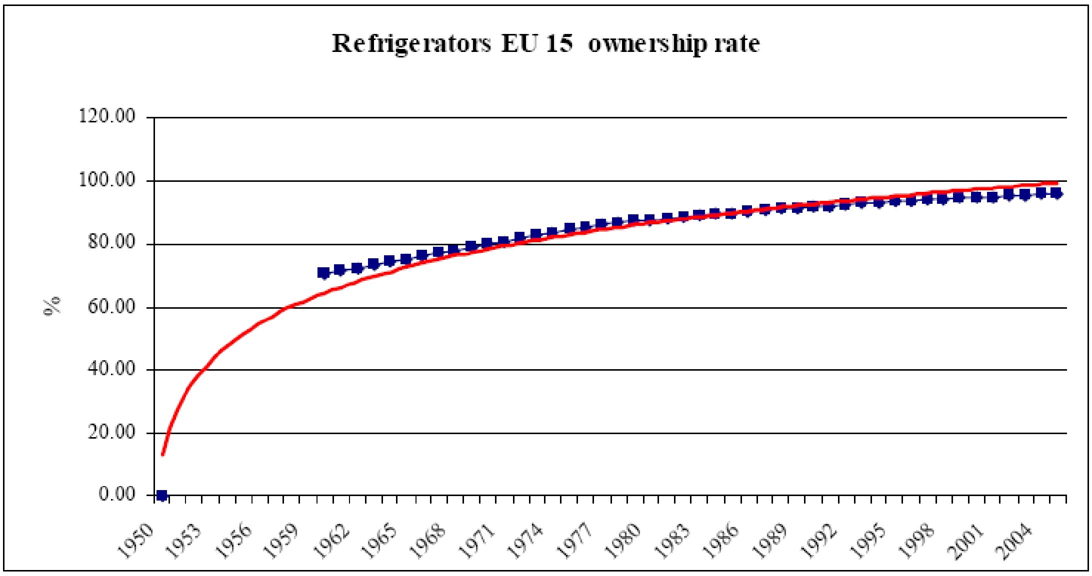

Figure 8: Ownership of refrigerators

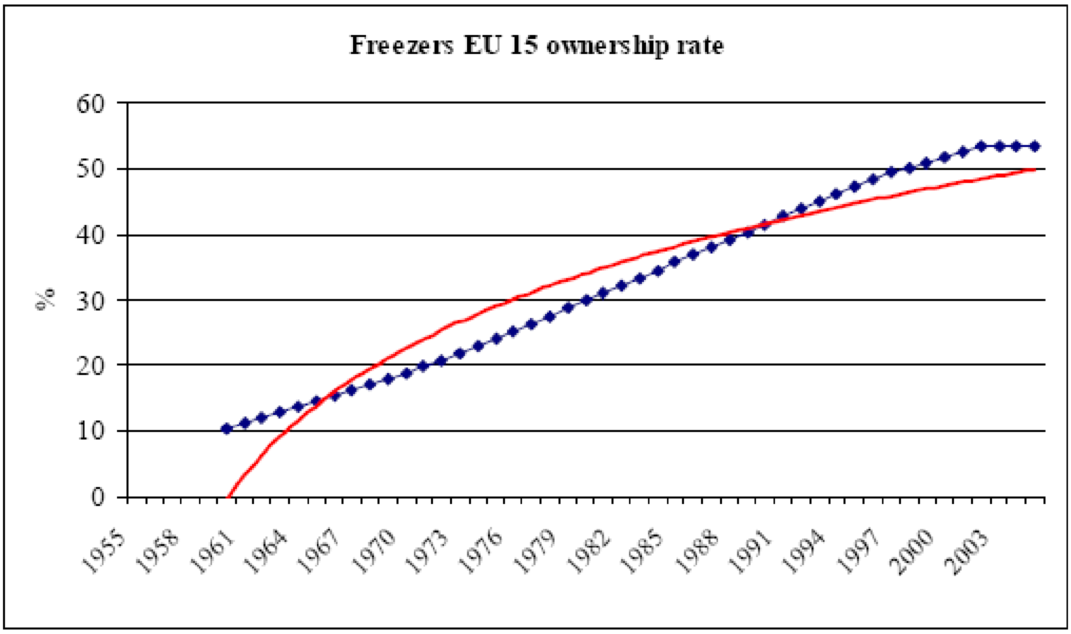

Figure 9: Ownership rate of freezers

5.1.2. Classification

According to EN ISO 15502:2005 refrigerating appliances can be categorized as follows:

- Refrigerator – appliance which is intended for food preservation, fresh food storage
- Refrigerator-freezer – appliance which has at least one compartment for food preservation and at least one for freezing of fresh food with different freezing capacities (one, two or three star storage conditions)
- Frozen-food storage cabinet – appliance with at least one compartment for the storage of frozen food
- Food freezer – appliance with at least one compartment for freezing foodstuffs under the temperature down to – 18°C.

- Build-in category – fixed refrigerating appliances, installed in a cabinet, wall or similar location.

In the Energy Labelling Directive 94/2/EC first time 10 categories of refrigerating appliances were specified, later this specification was used in the Directive 96/57/EC on energy efficiency requirements for domestic refrigeration and in the amended Energy Labelling Directive 2003/66/EC.

The new version of Energy Labelling Directive under Commission Regulation 1060/2010 as well the Implementing Measures from 2009 under the ErP Directive use the updated classification, see Table 3. They cover "*electric mains-operated household refrigerating appliances with a storage volume up to 1500 liters*" (EC, 2009, article 1) means a refrigerating appliance intended for the preservation of foodstuffs with at least one compartment suitable for the storage of fresh food and/or beverages, including wine.

Table 3: Categories of refrigerating appliances

Category	Energy Labelling Directive 94/2/EC, 2003/66/EC; Directive 96/57/EC	Energy Labelling Directive 1060/2010; Commission Regulation 643/2009
Category 1	Household refrigerators, without low temperature (T) compartments	Refrigerator with one or more fresh-food storage compartments
Category 2	Household refrigerator/chillers, with compartment(s) at 5 °C and/or 10 °C	Refrigerator-cellar, cellar and wine storage appliances
Category 3	Household refrigerators, with no-star low T compartments (< 0 °C or ice box)	Refrigerator-chiller and Refrigerator with a 0-star compartment
Category 4	Household refrigerators, with low T compartments (*) (i.e. ≤ -6 °C)	Refrigerator with a one-star compartment
Category 5	Household refrigerators, with low T compartments (**) (i.e. ≤ -12 °C)	Refrigerator with a two-star compartment
Category 6	Household refrigerators, with low T compartments (***) (i.e. ≤ -18°C)	Refrigerator with a three-star compartment
Category 7	Household refrigerator/freezers, with low T compartments *(***) (i.e. ≤ -18 °C and a freezing capacity of 10Kg/100 litre in 24h)	Refrigerator-freezer
Category 8	Household food freezers, upright	Upright freezer
Category 9	Household food freezers, chest	Chest freezer
Category 10	Household refrigerators and freezers with more than two doors, or other appliances not covered above.	Multi-use and other refrigerating appliances

The main changes that have been done are related to the Category 2 and Category 3. In the previous directives Category 2 was covering "refrigerators/chillers with compartments at 5°C and/or 10°C", however this was leading to some misunderstanding. An appliance with a chiller compartment at +10°C nominal temperature can be classified not as Category 2 but as Category 10, where determined temperature can be adjusted by manufacture. Also Category 3 has been amended by moving refrigerators-chiller in it from Category 2. Additionally, absorption-type of refrigerating appliances is explicitly included in the scope of the last directives to avoid misunderstanding from the stakeholders. Absorption type of refrigerating appliances is referred to the Categories 1 to 3.

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According to the Figure 10 the biggest share on the market among refrigerating appliances have Categories 1, 7, 8 and 9, and it was increasing from 1995 to 2005 years (ISIS, 2007, p.185), right after energy labelling was put in place in 1994. This can represent the influence of ranking refrigerating appliances into energy efficiency classes by their performance.

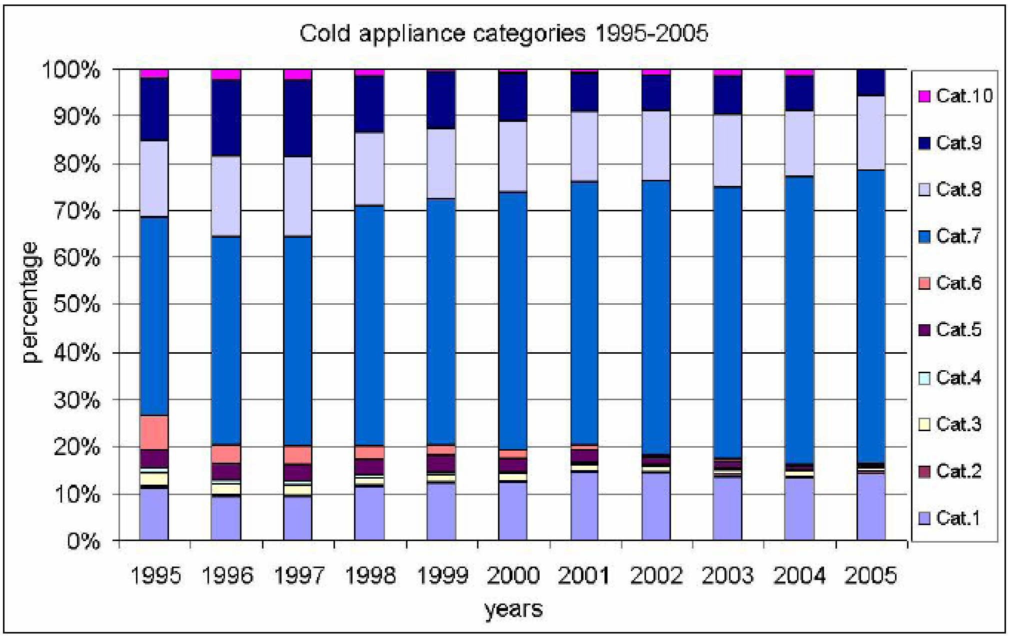

Figure 10: Cold appliance categories share in percentage (1995-2005)

In the following chapter I would like to consider mandatory and voluntary measures for refrigerating appliances related to Ecodesign and synergies between them as regards each life cycle stage. The main mandatory and voluntary regulations to include are: Ecodesign Directive, WEEE, RoHS, REACH, EU ecolabel, Nordic Swan ecolabel and CECED certification.

However, EU Ecolabel and CECED voluntary agreement are no longer valid for the refrigerating equipment. The Commission Decision of 6 April 2004 establishing revised ecological criteria for the award of the Community eco-label to refrigerators and amending Decision 2000/40/EC was valid from 1 May 2004 until 31 May 2007, but no revised version of it is yet published. However, Ecolabels such as Nordic Swan are mainly based on the EU flower requirements[6]. CECED voluntary commitment on reducing energy consumption of household refrigerators, freezers and their Combinations was published in 2002 and set targets for 2002-2010 years. The key elements of those agreements are going to be mentioned.

5.2. Life cycle stages

5.2.1. Material extraction/Manufacturing phase

The relation of policy options to the household refrigerating appliances at the material extraction and manufacturing phase is described below as per each regulation:

- RoHS

According to the RoHS Directive following substances shall not be used in electrical and electronic equipment: lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls (brominated

[6] The latest version of Nordic Ecolabel 5.3 is valid until 31 October 2013.

flame re-tardants), polybrominated diphenyl ethers (brominated flame retardants). No specific requirements for household refrigerating equipment are set under RoHS Directive.

- REACH

Refrigerating appliances have to follow general REACH requirements which oblige manufactures to have responsibility of reporting the use of chemicals, but no specific requirements in relation to refrigerators or freezers are put forth.

- EU ecolabel

EU ecolabel regulation in relation to the material acquisition and production phase sets specific requirement on the refrigerants in the refrigerating circuit and foaming agents. Parameters as Ozone Depletion Potential (OZP) and Global Warming Potential (GWP) are used, where one shall be equal to zero and other at least less than 15 consequently. Apart from exclusion of PBB and PBDB flame retardants by RoHS directive, there is a restriction on contain in plastic parts of chloroparaffin flame retardants with 10-13 carbon atoms and chlorine content > 50% by weight. Additionally, plastic parts more than 50 gram should have a marker, and more than 25 grams shall not include any substances that may be harmful according to Directive 67/548/EEC.

- Nordic Swan

Nordic Swan ecolabel gives the same requirements as EU ecolabel under the Commission Decision of 6 April 2004 establishing revised ecological criteria to refrigerators.

From the description above we can see that material extraction is highlighted in specifically related directives like RoHS and REACH; or ecolabels which are supposed to address best performing products. On the other hand, implementing measures under ErP Directive and CECED's voluntary agreement which are supposed to cover each life cycle stage does not set any particular requirement on the materials used.

5.2.2. Distribution phase

This life cycle stage might have significant environmental impacts due products and materials transportation; however, it is not addressed by any of the policy instruments.

5.2.3. Use phase

On the opposite of the distribution phase use phase is addressed by the most of the considered regulations. The main parameter used to assess efficiency of energy consumption is EEI (Energy Efficiency Index), which is calculated as follows:

$$EEI = \frac{AE_C}{SAE_C} \times 100$$

— *AEC (*Annual Energy Consumption) of the household refrigerating appliance equals:

$AE_c = E_{24h} \times 365$

where:

— E_{24h} is the energy consumption of the household refrigerating appliance in kWh/24h and rounded to three decimal places.

— *SAEC* (Standard Annual Energy Consumption) of the household refrigerating appliance equals:

$SAE_c = V_{eq} \times M + N + CH$

where:

— *CH* is equal to 50 kWh/year for household refrigerating appliances with a chill compartment with a storage volume of at least 15 litres;

— the *M* and *N* values are constants which are set per each category.

— V_{eq} is the equivalent volume of the household refrigerating appliance and equals:

$$V_{eq} = \left[\sum_{c=1}^{c=n} V_c \cdot \frac{25 - T_c}{20} \cdot FF \right] \cdot CC \cdot BI$$

— *n* is the number of compartments

— V_c is the storage volume of the compartment(s)

— T_c is the nominal temperature of the compartment(s)

— FF_c, *CC* and *BI* are volume, climate and building correction factors

This calculation version has been published recently, It was adjusted between implementing measures and energy labelling when introducing Commission Regulation 649/2009 under ErP Directive 2005/32/EC and Commission Regulation 1060/2010 under Energy Labelling Directive 2010/30/EU. Nevertheless, some important points have not been addressed still. For example, the climate correction (CC) factor implies only rooms with ambient temperature above 10 °C, and rooms with lower temperature are not taken into account.

- ErP Directive

Use stage of the life cycle is the central focus in the requirements of ErP Directive and Energy Labelling for refrigerating appliances. The Implementing Measures for household refrigerating appliances were published in July, 2009, while the Preparatory study for this product group was conducted through 2007-2008 years, these requirements replaced previous Directive 96/57/EC on energy efficiency requirements for household electric refrigerators, freezers and combination of thereof, from September 1996. Implementing Measures set requirement separately for absorption and compression type of refrigerating appliances due to significant difference in working principle and, hence, energy efficiency. The targets to achieve of the new Directive are EEI of 42% for compression type and EEI of 110% for absorption type of refrigerating appliances by 2014. The absorption type appliances has a lower limits since they consume more energy due to their working principle, however they are noiseless.

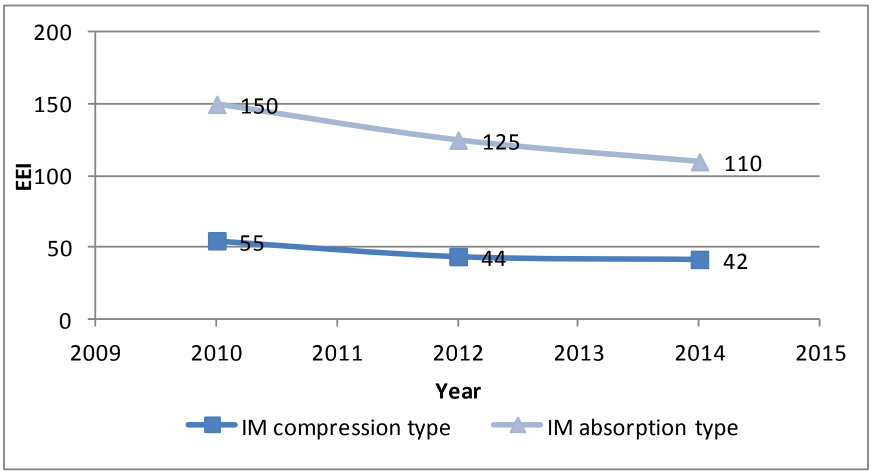

Figure 11: IM for the next years

Apart from MEPS Implementing Measures also provide recommendations and instructions for responsible and energy efficient use of the device.

- Energy labelling

One year after implementing measures energy labeling has been introduced in September 2010. Amended energy labelling ranking under Commission Regulation 1060/2010 proposes scheme of dividing energy consumption of refrigerating appliances into 10 classes from G to A +++, where G is the least efficient and is equal of EEI more than 150 and A+++ is the most efficient with EEI of less than 22 the summary figure of all measures can be seen at Figure 13. Current Energy labeling directive has replaced previous Directive 2003/66/EC of July 2003, the main amendment was adding new class of energy A+++.

Energy labeling scheme appeared to be very successful instrument in term of market stimulation, according to the Preparatory study of Lot 13, from the start of energy ranking 1994 the share of A and higher marked appliances has increased from less that 5% in 1995 to more than 80% in 2005, see Figure 12 (ISIS, 2007, p.191).

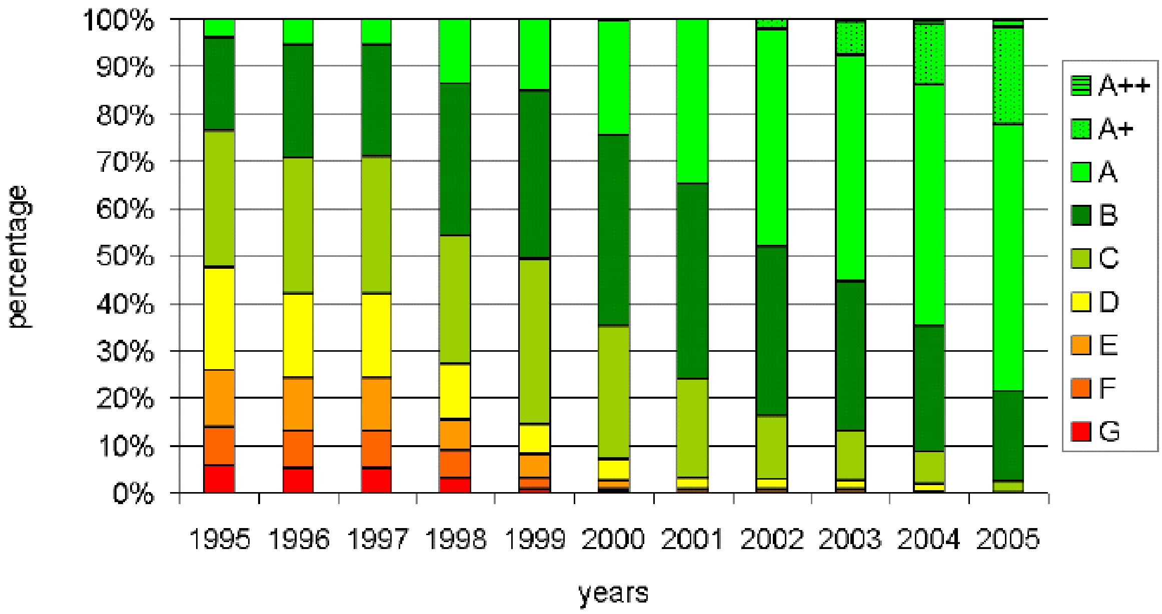

Figure 12: Distribution of energy classes between all categories

- Nordic Swan

Nordic ecolabel provides requirements referring to the Energy Labelling regulation by putting a limit of A+ energy label in order to comply with Nordic Swan. Apart from energy performance, Nordic ecolabel provides requirements for noise emissions. According to it airborne noise from the appliance, counted as sound power, shall not exceed 40 dB(A), but it is not applied to category 9.

The availability of compatible replacement parts and service shall be guaranteed for 10 years from the time that production ceases.

- CECED and EU ecolabel

As it was mentioned before requirements coming from voluntary agreement made by CECED and EU ecolabel are no longer applied since there were set till 2010 and 2007 years consequently, and have not been prolonged yet. However, it is interesting to see the required targets. Thereby, EU ecolabel had a stronger limits setting a value of 42/44 EEI within time period 2004-2007 years, and CECED had introduced required EEI of 75% by 2004 and 52% by 2006 years.

5.2.4. End-of-life phase

- WEEE

Refrigerating appliances have to follow common requirements set by WEEE Directive which are described in the section 4.2. They belong to category 1 of WEEE classification and have to reach waste collection target of 65% of the average weight by 2019. Also according to WEEE product should be easy to reuse and recycle, thus joints parts shall be accessible, product should be easy to disassemble.

- Nordic Swan

According to the Nordic Swan requirements product should be align with WEEE directive, which is described above.

Additionally, cardboard packaging shall consist of at least 80% recycled material, and all packaging materials should be easily separated and divided into individual elements to facilitate recycling process.

- EU ecolabel

It sets requirements for manufactures to offer free of charge recycling of the product and replacements of its components. Also manufacture shall provide a disassembly report reassuring that appliance is easily dismantled, details are accessible and all hazardous and incompatible materials are separable.

From the overview above it can be seen that as in the material extraction phase the specifically oriented WEEE Directive and Ecolabels cover end-of-life phase and ErP Directive and Voluntary Agreement but CECED does not set any peculiar requirements.

6. Comparison and discussion

The Table 4 summarizes all the requirements related to the refrigerating equipment in relation to the most important life cycle stages of a product. The overall picture of the policy options for the refrigerating appliances appears to be coherent and, as expected, no extreme conditions were discovered. Thereby, domestic refrigeration is serving as a critical example.

However, there are some interesting issues to note. The general observation appeared in this study among all policy instruments is scope limitation and focus shift in the considered regulations. For example, mandatory WEEE, RoHS and REACH Directives concentrates specifically on one life cycle stage (manufacturing or end-of-life). ErP Directive scope theoretically covers the whole life cycle, however implementing measures covers just use stage. Only voluntary ecolabels address the whole life cycle of refrigerating appliances.

Table 4: comparison between all policy options as regards every life cycle stage

Phase	Manufacturing	Distri-bution	Use	End of life
ErP Directive			EEI 2010 < 55 EEI 2010 < 150 EEI 2012 < 44 EEI 2012 < 125 EEI 2014 < 42 EEI 2014 < 110	
Energy labeling			EEI classification from A+++ to G class with consequent ranges: (<22; 22-33; 33-44; 44-55; 55-75; 75-95; 95-110; 110-125; >125)	
RoHS	Restriction of the use of lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls and polybrominated diphenyl			
WEEE				Reach waste collection target of 65% of the average weight by 2019.
REACH	Put obligations on manufactures for the reporting on hazardous substances			
Nordic Swan	For refrigerating circuit and foaming agents: ODP =0 and GWP <15. Chloroparaffin flame retardants with 10-13 carbon atoms and chlorine content > 50% by weight should be restricted. Plastic parts > 50 gram should have a marker, and > 25 grams shall not include any substances that may be harmful according to Directive 67/548/EEC.		EEI < 42/44 Noise levels <40 dB(A)	

EU Ecolabel	For refrigerating circuit and foaming agents: ODP =0 and GWP <15. Chloroparaffin flame retardants with 10-13 carbon atoms and chlorine content > 50% by weight shoud be restricted. Plastic parts > 50 gram should have a marker, and > 25 grams shall not include any substances that may be harmful according to Directive 67/548/EEC.	EEI < 42/44 Noise levels <40 dB(A)
VA CECED		EEI 2004 < 75 EEI 2006 < 52

According to the research, use phase is described by the most of considered regulations. Hence, it seems relevant comparing energy performances set by different policy instruments. The Figure 13 shows the comparison between different legislation requirements related to the energy consumption. Generally, compared to other product groups refrigerating appliances seem to have quite coherent set of energy requirements and labelling criteria. For example, there are no significant changes in energy ranking system since the first energy labelling directive for refrigerating appliances entered into force in 1994. The differences that have been done are:

- Lowering the limits for classes C, D, E, F, G.
- Lowering limit for A++
- Addition of extra energy class A+++

Concerning implementing measures one of the main remarks is that requirements for compression type and absorption type are very different. Probably it does not seem to be dramatic from the point of minimum energy efficiency requirements because it is logical to have different requirements for appliances that have different working principle. But when it is seen in a big picture under the energy labelling scheme perspective, absorption type of refrigerators seem to be “outsiders”, they have the lowest energy ranking and it is not feasible for them to obtain ecolabel like Nordic Swan, for example. As it was displayed in the Figure 5 energy labelling is a strong driving force on the market, and if appliance does not have high energy label it has very poor competitiveness on the market. Indeed, absorption type of refrigerating appliances is less efficient than compression type, but it has other advantages like noiseless or low environmental impact, which are not taken into account in the parameters set under implementing measures.

It can be seen that Implementing Measures have quite ambitious plan setting future target for compression type of refrigerating appliances equal to A+ energy label by 2012 and 2014 years, at the same moment Nordic Swan has A+ labeling criteria and it is valid till 2013. Thus by 2013, the worst performing product on the market (compression type) will be labeled with A+ energy label, which also equivalent to Nordic Swan ecolabel. This goes in contrast with a general approach of voluntary and mandatory measures where voluntary measures should set higher targets for market stimulation (see Figure 5). . Therefore, it is very important to update all the legislation constantly so the parameters will not overlap and right parameters will be put forth.

	A+++	A++	A+	A	B	C	D	E	F	G
Energy Label										
1994&2003	-	<30*	<42*	<55	<75	<90	<100	<110	<125	>125
2010	<22	<33	<42/44**	<55	<75	<95	<110	<125	<150	>150
IM (absorption type)								2014 (110)	2012 (125)	2010 (150)
IM (compression type)			2012 (44)/ 2014 (42)**	2010 (55)						
Nordic Swan (October 2013)			<A+							
EU Ecolabel (2004-2007)			<A+							
CECED VA (2002-2010)				2006 (52)	2004 (75)					

*Energy Labelling Directive 2003/66/EC

**tier until 30 June 2012/after 1 July 2014

Figure 13: Comparison between different policy instruments in relation to the use-phase

EU ecolabel criteria and CECED's voluntary agreement are no longer valid, though they were putting quite ambitious targets. Thus, on average, now there are mandatory regulations that push the market from the worst performing product, but there few voluntary regulations that pull the market towards best performing products.

It also seems relevant to see how the current minimum energy requirements apply on the market and to investigate if current requirement are actually ambitious not only in theory but in practice. I have chosen four major categories of refrigerating appliances to consider: refrigerators (Category 1), refrigerators/freezers (Category 7), upright freezers (Category 8), chest freezers (Category 9). For comparison of energy performance four different models (per category) were taken from five manufactures.

Figure 14 and Figure 15 represent EEI of major brands models per category. The research has showed that from the 18 models considered 14 comply with EEI 2012 tier (78%), and 4 must be taken out of the market. As for the EEI of 2014 year only 6 models (33%) are able to fulfill the requirements. This means that manufactures of refrigerating appliances should start improving their product already now in order them to stay on the market. The list of the parameters and models used can be seen in the Annex section.

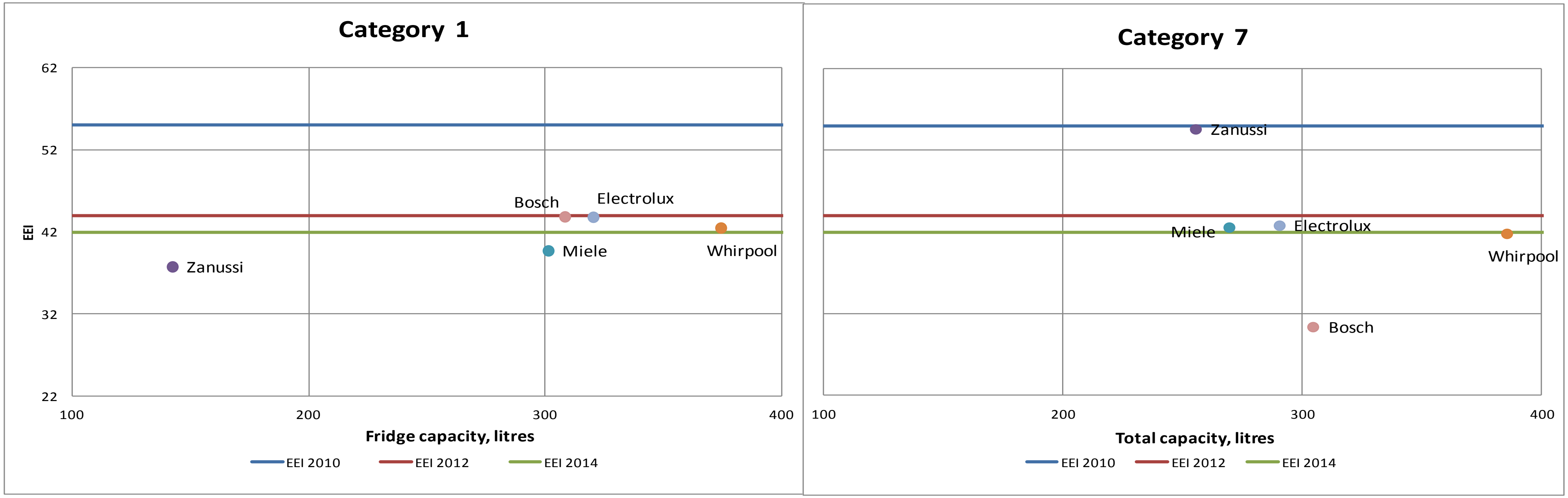

Figure 14: Category 1 and Category 7

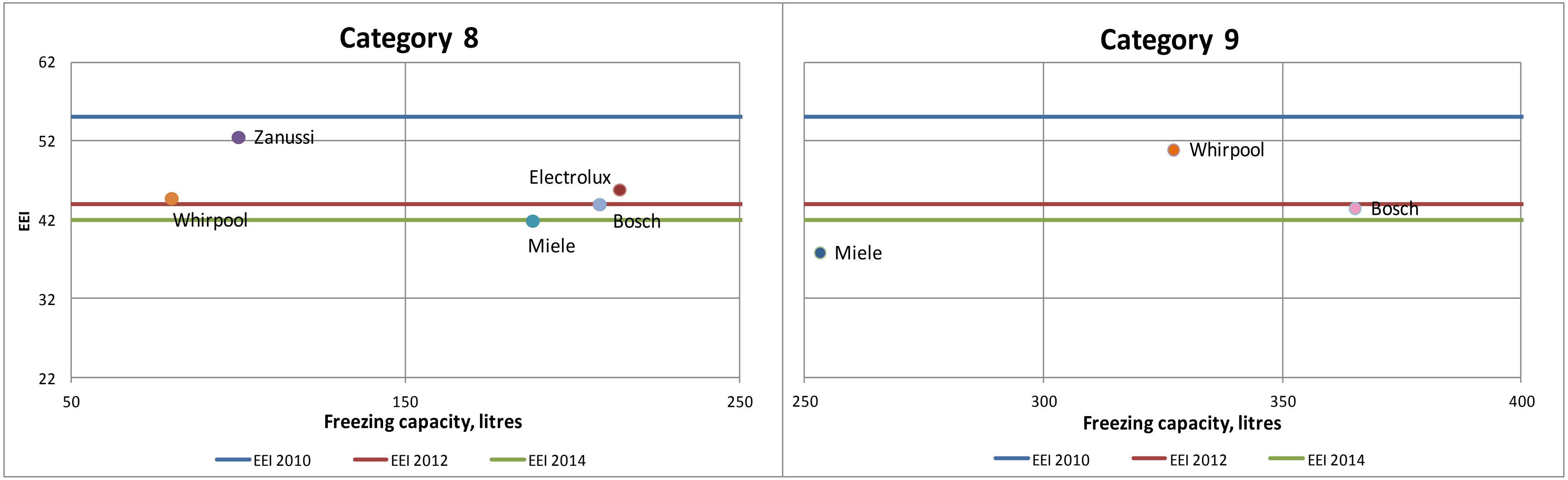

Figure 15: Category 8 and Category 9

7. Conclusions

My project is aimed at discovering synergies between different ecodesign related directives throughout lifecycle of domestic refrigerating appliances. These regulations are a part of European strategy on Sustainable Consumption and Production, and they play significant role in achieving European "20-20-20" targets and fostering sustainable development.

As a result of my research, I have got an overview of mandatory and voluntary regulations for refrigerating appliances with a focus on ecodesign and life cycle thinking. These regulations are supposed to cover the whole life cycle of a product and address environmental impacts at the design phase.

Being a part of a common framework the regulations are implied to supplement and collaborate with each other. However, there are still some constrains and limitations. The main comment is that there is a focus change from life cycle perspective to a particular life cycle stage. For instance, design and end-of-life phases are addressed just by specific directives like RoHS, WEEE or REACH and no specific requirements are provided by ErP Directive or voluntary measures.

According to the research use phase is described by the most of considered regulations and the main parameter described is energy performance. The important observation is that voluntary and mandatory requirements sometimes overlap, putting forth equal requirements, which shall not be the case in order to have market stimulations.

Also there are particularities in collaboration between the directives for refrigerating appliances concerning different types of refrigerators. For example, implementing measures are set for different types of refrigerating appliances separately (absorption type and compression type), however ecolabels (e.g. Nordic Swan) provide criteria with no distinction per type. This results in that is that absorption type is not able to obtain ecolabel. Additionally, Implementing Measures under Ecodesign Directive have ambitions EEI targets. According to the market research around 78% of appliances of compression type from the four main categories are comply with 2012 tier, and only 33% are able to fulfill energy requirements of 2014, which means manufactures shall apply new technologies to align with mandatory requirements.

It can be concluded that policy instruments for refrigerating appliances have a coherent structure. However, they also obtain certain constrains in terms of classification of refrigerating appliances and collaboration between policy options. For that several possible improvements are proposed in the following chapter as supplementary measures.

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8. Perspectives and possible improvements

According to the findings of the current report the main improvements can be divided into two categories: specific and general. Specific improvements are those applied to refrigerating appliances only, and general improvements can be applied to all product groups since refrigerating appliances defined as critical product group (Flybjerg, 2006). Summary of the possible improvement options can be seen in Table 5.

Table 5: Possible specific and general improvements

Issue to address	Improvement
Specific to refrigerating appliances	
Categories classification	Consider low room temperature conditions (below +10°C) Define temperature range of 0-star compartment
Ecolabel	Introduce ecolabel for absorption type of refrigerating appliances
General to all product groups	
Collaboration between regulations	Update mandatory and voluntary regulations in time
Life cycle	Equal distribution of regulations between life cycle phases Striving for cradle to cradle approach

Specific comments concern mainly categories classification and calculation of which has been described in section 5. Likewise, calculation methodology should take into consideration low temperature condition rooms. Temperature range of 0-star compartment shall be defined in order to avoid misunderstandings.

The absorption type of refrigerating appliances could be described in more details as well. This type of appliances has a little share on the market and smaller energy efficiency compared to compression type of appliances, due to a specific working principle. However they are noiseless and can be used for a certain purposes where noise is a main criterion. According to current ecodesign related regulations only compression type of refrigerators can obtain ecolabel (Nordic Swan), because they can achieve required level of energy efficiency. But at the same time among absorption type of appliances there are best performing and efficient for its class products. Thus, probably ecolabelling could be done for absorption type separately, taking into account its specific features.

The main general constrain that was found during the current research relate to collaboration between regulations and ways of addressing life cycle of a product. It is important so the measures proposed by mandatory and voluntary policy instruments would not overlap and follow the principle where mandatory regulations push the market and voluntary pull it to the best performing products. Hence, there are should be a regular revision of the whole set of policy instruments. To avoid mismatches between regulations, ecolabels and voluntary agreements should be opportunely updated.

Yet another common constrain found during this research and that can appear in other product groups, is poorly addressed life cycle stages but the use phase. For instance, the end of life phase is described just by WEEE Directive, which in practice sets requirements only for waste collection. However, cradle to cradle theory can be applied to fix this issue. As it was presented in the section 3.1 cradle to cradle theory main idea is eco-effectiveness. In this manner the solution for addressing all life cycle stages can be introducing mandatory and voluntary regulation with requirement of achieving by certain year closed cycle where waste becomes nutrients for a new product.

For example, in relation to the ErP Directive it can be presented by means of Tiers. Likewise, one of tiers can represent the target of achieving cradle to cradle principle by particular year. The upside of doing so is that automatically manufacturing and end of life phases are going to be covered, however the downside of this innovation can be long time period consumed.

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Annex

Table 6: List and status of product groups under ErP directive

LOT	PRODUCT GROUP	STATUS
Heating & cooling equipment		
Lot 1 and Lot 2 (DG ENER)	Boilers and water heaters	Ecodesign & Energy Label measures have been discussed since 2008. Consultation will take place in February 2012
Lot 11(DG ENER)	Circulators for boilers	Implementing measures adopted in 2009
Lot 10 (DG ENER)	Domestic air-conditioners and ventilation	Implementing measures and energy labeling adopted in 2011 and published in March 2012
Lot 15 (DG ENER)	Solid fuel burners	Preparatory study completed
Lot 20 (DG ENER)	Local room heating	On-going preparatory study (final stakeholder meeting organised in April 2012)
Lot 21 (DG ENER)	Central heating using hot air	On-going preparatory study (final stakeholder meeting organised in April 2012)
Household appliances:		
Lot 13 (DG ENER)	Domestic fridges & freezers	Implementing measures and energy labeling adopted in 2009 & 2010
Lot 14 (DG ENER)	Domestic washing machines	Implementing measures and energy labeling adopted in 2010
Lot 14 (DG ENER)	Domestic dishwashers	Implementing measures and energy labeling adopted in 2010
Lot 16 (DG ENER)	Domestic tumble driers	Ecodesign & energy label in final stage.
Lot 17 (DG ENER)	Vacuum cleaners	Ecodesign & Energy label under discussion
Lot 22 and Lot 23 (DG ENER)	Ovens, hobs and grills	Preparatory study completed. Consultation forum in April 2012
Lot 25 (DG ENER)	Coffee machines	First working document issued and discussed in December 2011
Electronics:		
Lot 2 and Lot 3 (DG ENER)	PCs & monitors	Discussed since 2009
Lot 4 (DG ENER)	Printers & copiers	Voluntary agreement proposed by the industry in 2009 but not yet endorsed by the European Commission
Lot 5 (DG ENER)	Televisions	Implementing measures and energy labeling adopted in 2009 & 2010
Lot 6 and 26 (DG ENER)	Standby losses	Implementing measures adopted on simple standby and off modes adopted in 2008
Lot 7 and Lot 27 (DG ENER)	Power supplies	Implementing measures on power supplies adopted in 2009
Lot 18 (DG ENER)	Set top boxes	Implementing measures for simple set top boxes adopted in 2009
Lot E3 (DG ENTR)	Sound & image products (DVD, projectors, game consoles)	Preparatory study completed
Lighting:		
Lot 8 and Lot 9 (DG ENER)	Office and street (tertiary) lighting	Implementing measures adopted in 2009, amended in 2010
Lot 19-1 (DG ENER)	Domestic non-directional lamps	Implementing measures phasing out incandescent lightbulbs adopted in 2009
Lot 19-2 (DG ENER)	Domestic directional lamps	Ecodesign working document for halogens and LEDs and revised Energy label for lamps discussed in July

		2011. Consultation in February 2012.
Commercial & industrial equipment:		
Lot 11 and Lot 30 (DG ENER)	Electric motors	Implementing measures on standard motors adopted in 2009
Lot 11, Lot 28 and Lot 29 (DG ENER)	Water pumps	Ecodesign regulation in discussion for standard pumps. Preparatory studies launched on pumps for waste water, swimming pools, fountains and aquariums in March 2012.
Lot 11 (DG ENER)	Non-residential fans	Implementing measures published in April 2011
Lot 12 (DG ENER)	Commercial and professional refrigeration	Ecodesign regulation for supermarket fridges discussed once but on hold. Working document for vending machines expected in 2012
Lot 24 (DG ENER)	Professional washing machines & driers	Preparatory study completed
Lot 2 (DG ENTR)	Electric transformers	Preparatory study completed. First consultation planned in April 2012.
Lot 4 (DG ENTR)	Industrial & laboratory furnaces	Preparatory study completed
Lot 5 (DG ENTR)	Machines tools	On-going preparatory study and voluntary agreement proposed by the industry
Lot 6 (DG ENTR)	Tertiary air-conditioning & ventilation	On-going preparatory study

Table 7: Category 1 – refrigerators

Brand	Model	EEI	AEC	V fridge	Veq
Miele	12421 SD	40	145	301	301
Zanussi	ZRG310W	38	105	142	142
Whirpool	WMN1866A+DFCW	42	153	374	494
Electrolux	ERC33430X	44	140	320	320
Bosch	KIR38A55GB	44	149	308	407

Table 8: Category 7 – refrigerators/freezers

Brand	Model	EEI	AEC	V fridge	V freezer	Veq
Miele	KT 12510 S	43	257	217	52	386
Zanussi	ZBB6266	55	389	164	91	526
Whirpool	WBC 3546 A+NFCXL	42	343	246	139	665
Elextrolux	ERN29600	43	310	214	76	541
Bosch	KGE36AW30	30	223	215	89	489

Table 9: Category 8 – upright freezers,

Brand	Model	EEI	AEC	V freezer	Veq
Miele	FN 12421 S	42	277	188	640
Zanussi	ZFT710FW	53	246	100	284
Whirpool	AFB 901	45	201	80	248
Electrolux	EUP23901X	44	307	208	708
Bosch	GIN38A55GB	46	325	214	729

Table 10: Category 9 – chest freezers

Brand	Model	EEI	AEC	V freezer	Veq
Miele	GT 5242 S	38	237	253	718
Whirpool	WH 3200 UK	51	369	327	928
Bosch	GTM38A00GB	44	318	365	942