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Potential Ecodesign Directive Contributions to Resource-Efficient Innovations

A Case Study on the Electric Motor Product Group Expansion and Rare Earth Element Use in Permanent Magnet Motors

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Abstract

This study looks at potential contributions of the Ecodesign Directive 2009/125/EC to eco-innovations addressing resource efficiency improvements of energy-related products. This aim is secondary to the prime objective of the Directive, the increase in energy efficiency of energy-related products. By conducting ten in-depth interviews, the study investigates whether and in what form the Directive, which is to address 31 product groups, can contribute to innovations, potentially with resource efficiency improvements, referred to as eco-innovations. The analysis reveals the success of the Directive in cutting off the worst performing products from the market, highlights the Energy label as a stronger driver for innovation and discusses the current limitations of the Directive regarding the implementation of resource efficiency objectives. Recognizing that many issues are product-specific, the study is narrowed down to focus on electric motors, which account for high energy consumption in industry and demonstrate significant ecodesign improvement potential. The extension of the Directive electric motor group to possibly comprise permanent magnet motors is related to whether it could foster innovations capable of achieving resource efficiency improvements of rare earth elements. These materials, classified as critical in the EU, are able to achieve high energy densities in permanent magnets and can contribute to developing motors with higher energy efficiency classes. The case study uses a selection of innovation drivers integrated in Geels' (2002) multi-level perspective for technological transitions to evaluate their influence on permanent magnet motor developments. Perceptions of permanent magnet motor manufacturer participants of the first preparatory study meeting are gathered through questionnaires for this purpose and interviews with material experts complement the case study. With regulatory standards being one of the most relevant innovation drivers, and the option to request design for recycling, the potential of the Directive to contribute to rare earth element resource efficiency improvements is indicated.

Keywords: Ecodesign Directive, Innovation, Resource Efficiency, Rare Earth Elements, Permanent Magnet Motors.

Executive Summary

The use of resources is essential to European economic growth and the wellbeing of its citizens. Acknowledging the environmental challenges resulting from human activities and in order to pursue more sustainable development, it is imperative that resources are used more carefully. "A Resource Efficient Europe", one of seven flagship initiatives of the Europe 2020 Strategy, provides a framework for policies which attempt to support the transition towards a resource-efficient and low carbon economy. (European Commission [EC], 2011a) Several resources have been classified as critical, amongst others rare earth elements (REE), which are used in many sustainable technologies. (EC, 2010) It is recognized that European competitiveness and innovations in the high-tech industry are dependent on these materials. Several policy options can facilitate their diligent use, including the EU product-oriented environmental policy, which aims to achieve resource efficiency through addressing the entire product life cycle. This concept is also taken up in the Integrated Product Policy which recognizes the need for more coordination among product policy instruments. Multiple instruments work towards increasing resource efficiency in the product life cycle, whereby most of them address a specific phase. Among the mandatory instruments, the Ecodesign Directive by itself has an integrated life cycle perspective although its main objective is limited to increasing the energy efficiency in energy-related products. These products consume not only a significant share of energy but also a considerable amount of resources within the EU. (Official Journal of the European Union, 2005) Against a background of needing to increase resource efficiency through such means as product innovations, the Directive appears to be an instrument that has the potential to contribute to this objective by way of product design improvements.

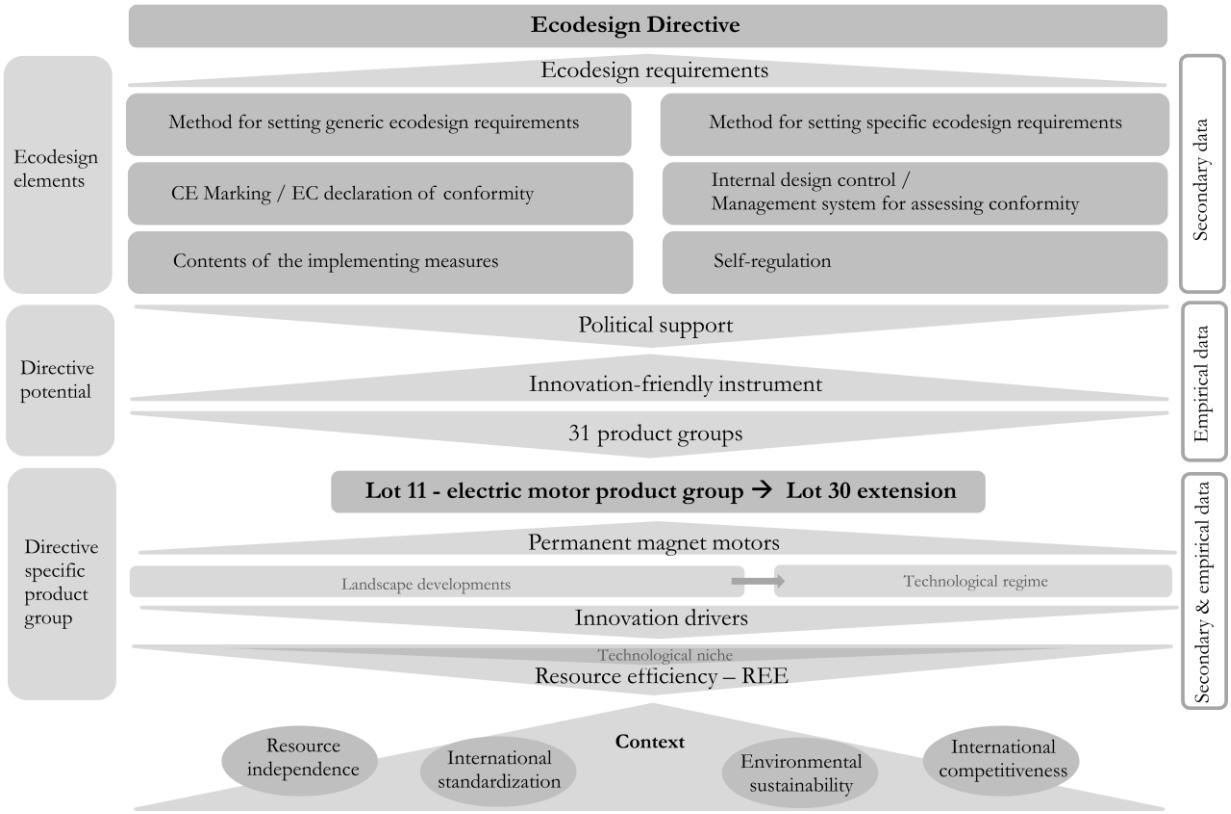
The overall aim of the thesis is to understand whether and to what extent the Ecodesign Directive has the potential to contribute to innovations focusing on an increase in resource efficiency, otherwise known as eco-innovations. In addition, addressing the specific product group of electric motors, light is shed on the potential effect of a Directive product group extension to permanent magnet (PM) motors, on eco-innovations and the resource-efficient use of rare earth elements in them. The main research question that guides this study is: *How may the Ecodesign Directive contribute to promoting eco-innovations?* Two sub questions support the research of the case study: a) *Which of the selected drivers for innovation are perceived to be most influential?* and b) *To which extent could a PM motor regulation influence company eco-innovation activities, specifically resource efficiency of REE in PM motor design?*

Method

Semi-structured interviews with representatives of national contact points for the implementation of the Directive, as well as of the European Environmental Bureau, a non-governmental organisation, and of the EC Directorate-General for the Environment were conducted to obtain data regarding the perceptions as to the Directive innovation potential. The collected empirical data was analyzed according to the degree of associated *political support and innovation-friendliness*, two selected *innovation drivers* developed by Martin Jänicke. The case study relied on questionnaires, which were designed with a further selection of innovation drivers and filled in by representatives of permanent magnet motor producers. Obtained data was analyzed qualitatively according to these innovation drivers, namely *export intensity, price volatility, uncertainty, rule set and anticipation* developed by Knut Blind, Martin Jänicke, Jan Van den Ende and René Kemp which were integrated into the *multi-level perspective on technological transitions* by Frank W. Geels. This perspective

was to add to the comprehensiveness of the case study by its use of three hierarchical levels: landscape developments, technological regimes and technological niches. Landscape developments refer to the external context which outlines the interaction of all actors. The seven wider technology-external factors by which it is described in its original, are aggregated into three innovation indicators: export intensity, price volatility and uncertainty. Also the seven key dimensions of the technological regime, the level which creates stability and directs innovations towards gradual improvements, are summarized, with a focus on policy, into rule set and anticipation of regulation. The technological niches are characterized by providing space for learning environments which are supportive for the development of radical innovations.

Three in-depth, semi-structured interviews with material experts, one representative from a European PM manufacturer and two representatives from academia, all of whom will collaborate in the REEgain project, to be described later, complemented the data collection for the case study.



Simplified analytical framework

The proposed analytical framework, which is presented here in a simplified version, illustrates the overall structure and sequence followed in the analysis of this work.

Key findings

The Ecodesign Directive in general is a well accepted policy instrument among industry representatives and politicians, partly due to the technology-oriented measures with which it works, facilitating political agreement. The less commonly accepted aspects of the Directive relate to the perception of the importance and methodological development for non-energy related aspects including resource efficiency, which are to some extent a result of the doubts regarding how these aspects are addressed best. A conflict with the EC Directorate-General (DG) for

Enterprise and Industry and the EC DG for Energy management of the Directive is noted with a view to the distinct objectives the representatives of these Directorates pursue which appears to leave limited scope for non-energy related environmental issues. Addressing the Ecodesign Directive openness to participation of a wide range of stakeholders in the process for the elaboration of binding product group specific implementing measures, the limitations are perceived in the knowledge and circulation of information, resource asymmetry, and limited or no national representation of some member states in consultations.

Even if the Directive potential to contribute to eco-innovations and resource efficiency improvements in energy-related products according to a life-cycle perspective is being widely recognized, to-date its success is noted in the removal of the worst performing products from the market. Amongst the aspects which could support the Directive in lifting the market to improved product life cycles and resource efficiency, the most important is raised as a commitment to elaborating ambitious long-term standards, which address functionality rather than technology, are oriented towards best available technology and underpinned by a re-definition of the legislative least life cycle cost requirement to account for technological progress and partially address the rebound effects. The recommended European top runner policy concept, which reflects certain aspects of the Japanese Top Runner Program, is outlined as supportive framework to attend to and facilitate the stipulated adjustments.

The analysis of the Directive for its innovation friendliness is achieved through the application of four selected innovation drivers by Jänicke (2008). In terms of the *economic incentives* indicator, the results reveal that NGOs address resource efficiency within the energy efficiency debate, presenting resources as embedded energy and thereby adding an economic incentive. The product declaration of conformity, visible as CE marking, is indicated as a further economic motivation as it protects against products from outside the EU market with poor energy efficiency performance. Evaluations of the Directive *acting in combination with other policy instruments*, reveal its alignment with the EU Energy label, and a weaker link with the EU Ecolabel and green public procurement. A recommendation for the establishment of greater coherence between the Directive and WEEE, RoHS and REACH starts with the drafting of a common set of criteria for the instruments which address the same criteria, jointly with the same evaluation methodology and a close to simultaneous review of each instrument's criteria. A combination with an escalation process, under which a higher threshold is to be reached under each instrument, is perceived to benefit this approach. The Directive performs well on *strategic planning and goal formulation*, with the anticipation of new standards being facilitated and the elaboration of implementing measures, being its goals. It is noted that eco-innovations could be promoted by ensuring that non-energy related environmental aspects are addressed in the preparatory study. Adopted implementing measures are not perceived to be stringent enough and more continuous market surveillance for real time data is recommended. With a view to the Directive supporting *innovation as a process* which considers different phases of innovation, it is remarked that the ecodesign requirements are set in tiers which are to represent industry's design cycle. The Directive inbuilt life cycle perspective adds to its innovation potential and the understanding of significance in environmental aspects as improvement potential could further advance it. The Directive contribution towards a resource efficiency improvement is perceived to be dependent on available, accepted indicators with the critical material indicator introduced in the MEErP representing a first step. The easiest option to increase resource efficiency through the Directive is seen in horizontal measures requiring a certain concentration of a specific material through ecodesign. Supply chain certification is raised as another option, with practicability, namely the available data for a certain requirement being the limitation. Other options include the total cost of ownership method, being already applied to the product group of transformers, and EoL efficiency, which aims at defining the optimal EoL

treatment of a material by comparing the costs of different EoL treatment options with the cost of the virgin material.

Realizing that many of the revealed issues are context specific, a *case study* is conducted to investigate their validity on the product group of *electric motors*. In particular it explores the anticipated effect of a potential Directive scope *extension to PM motors* on the development of and innovations in PM motors and especially their technological transition towards more *resource efficiency in REE*. The case study builds on Geels'(2002) *multi-level perspective on technological transitions* which is adapted by selecting innovation drivers provided by Blind, Jänicke, Van den Ende and Kemp, integrated into the landscape development and technological regime levels. Questionnaire replies of two PM motor manufacturers are analyzed according to these drivers. At the level of *landscape developments*, and with specific reference to the innovation driver *export intensity*, and of Blind (2012), who argues that export-oriented businesses need to be successful in innovation as serving customers from abroad results in a broader array of demand-side requirements, it is observed that exports, ranked by the permanent magnet motor manufacturers in the range between 30 and 60 per cent of their overall business, are of importance for both manufacturers, a good precondition for the further analysis. *Price volatility*, an innovation driving force suggested by Jänicke (2008), is strengthened as both manufacturers rank fluctuating prices of REE as a high impact factor for innovation activities. The impact of *uncertainty*, which is defined as insecurity about environmental pressures and requirements, on innovations is less clear with one manufacturer evaluating it of high importance and the other of medium importance.

At the level of the *socio-technical regime*, rankings indicate the high importance of *regulatory standards* on innovation. Design rules, derived from engineering practices and regulatory standards, and production practices influence innovations as well, even if they are solely of medium importance. The ranking of the Ecodesign Directive contribution to *resource efficiency aspects*, namely eco-innovations, a reduction in the material intensity of REE in PM motors and the adherence to a life-cycle perspective in PM motor design, illustrate on average a medium influence which can be seen in the light of the generic interview responses pointing to the Directive full potential not having been exploited yet. The *anticipated extension of the electric motor product group regulation* to PM motors and its influence on PM motor innovation activities appears to be of less importance to manufacturers than the price development of the magnets containing REE and market demand. It is noted that an inclusion of new EU energy efficiency ratings would accelerate innovations.

At the level of *technological niches* for PM motor development, respondents indicate the potential in terms of the energy efficiency level which can be attained by PM motors and it is expected that their market share will increase with further commercialisation, resulting in increased supply, and a price decrease. Against the background of increased demand for REE, global supply imbalances and unavailable post consumer recycling options for REE, their substitution in the magnets is being investigated. It comes with a performance loss. Thus, increasing the recyclability of PMs is of interest. With to-date inexistent methods for post consumer rare earth element recycling, one technological niche is constituted by the Siemens led motor recycling project which investigates options for the extraction of REE from electric motors. Also the Danish REEgain project represents a technological niche, as various representatives from industry and academia collaborate to investigate both different processing options for rare earth ores and the recycling of REE. Another niche, which could potentially result from either of this projects, is perceived to be in radical novelties, which could take the form of a redesign of PMs both to improve on the resource efficiency of the REE by concentrating them in the magnet to facilitate their recycling and to allow for their easy removal from a motor and reuse in a new one. Another potential radical novelty would be the exploration of energy-efficient ways for post-consumer recycling of REE from PM.

Research contributions

The research adds the dimension of eco-innovations to existing analyses of the Directive. It contributes to the existing literature by evaluating the Directive potential to foster innovations which can also enable resource efficiency improvements. In this regard, it examines the preconditions for eco-innovations and provides suggestions for achieving more coherence between the Ecodesign Directive and policy instruments with which it shares common criteria. It highlights approaches for measuring non-energy-related aspects, provides recommendations as to the approaches which could be pursued by means of the Directive and ranks the options, through the perceptions of the stakeholders interviewed, regarding their easiness in implementation through the instrument.

The added value by the adapted multi-level perspective by Geels (2002) in the case study relates to its provision of a further theoretical rationale, namely the influence of innovations on technological transitions. The case study confirms the validity of price volatility and regulatory standards as innovation drivers, in addition to highlighting the influence of customer demand and new EU energy efficiency levels on innovations in PM motors. Another case study contribution lies in its demonstration of the importance of increasing PM recyclability, against the dual background of PM motors potential to achieve high energy efficiency levels and REE supply risk.

The semi-structured interviews with the material experts allowed for available legal standards, which are able to address REE resource efficiency aspects in PM motors, and could be fostered through the Ecodesign Directive regulation, to be seen through "a practical feasibility lens". This view permitted a ranking of the standards and revealed an emphasis on design for recycling of motors. This focus was pointed out with a view to facilitating the access to the PM in the disassembly, as it appears to be the comparably easiest to be implemented approach to-date. With potential technological innovations leading to an economically feasible post-consumer recycling of REE, challenges and priorities on the path to setting up a recycling scheme, in case a decision in favour of implementing European REE recycling was taken, are also addressed.

Recommendations and reflections

The transferable results of this study are seen in recommendations provided, departing from an Ecodesign Directive perspective, for achieving more coherence among policy instruments with similar objectives in the area of resource efficiency. Against this basis, eco-innovations could be fostered by the use of escalation processes applied to the same set of criteria applied in several instruments whereby different thresholds are used to create incentives for manufacturers to distinguish themselves through their compliance with one policy instrument as opposed to another with possible lower requirements on a certain criterion.

With a view to increasing the resource efficiency in PM motors and encouraging eco-innovations in PM motor design, an inclusion of this motor technology into the existing motor regulation under the Ecodesign Directive is recommended. The rationale is threefold: First, this study reiterated the strong role of regulation, which could potentially even foster innovations if motor energy efficiency requirements were to be further tightened; second, the role of REE PM in achieving higher energy efficiency levels is acknowledged and so is the criticality of these materials, which leads to the incentive in working on using them more efficiently, despite ongoing exploration and mining activities which are expected to counteract supply-bottlenecks. Therefore, and third, it is being recommended, that the legal standards able to facilitate resource efficiency improvements, especially the design for recycling, are enforced with a view to best-available-technology, as part of the motor regulation.

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Abbreviations

3 R-s	Reusability, Recyclability, Recoverability
BAT	Best Available Technology
BOM	Bill of Materials
DG ENER	(EC) Directorate-General for Energy
DG ENTR	(EC) Directorate-General for Enterprise and Industry
EC	European Commission
EEA	European Economic Area, or European Environment Agency
EMDS	Electric Motor Driven System
EoL	End-of-Life
ErP	Energy-related Product
EU	European Union
EuP	Energy-using Product
GDP	Gross Domestic Product
GPP	Green Public Procurement
IM	Implementing Measures
IPP	Integrated Product Policy
ISO	International Organisation for Standardization
KETs	Key Enabling Technologies
kW	Kilowatt
LC(s)	Life Cycle(s)
LCA	Life Cycle Assessment
LLCC	Least Life Cycle Costs
MEEuP	Methodology for the Ecodesign of Energy-using Products
MEErP	Methodology for the Ecodesign of Energy-related Products
MLP	Multi-Level Perspective
ppm	parts-per-million
PM	Permanent Magnet
RE	Resource Efficiency
REE	Rare Earth Elements
REACH	Registration, Evaluation and Authorisation of CHemicals
RoHS	Restriction on the use of Hazardous Substances
SCP	Sustainable Consumption and Production
SIP	Sustainable Industrial Policy
TT	Technological transitions
TWh	Terawatt hours
W	Watt
WEEE	Waste Electrical and Electronic Equipment

1 Introduction

1.1 Background

European economic growth and the wellbeing of its citizens is based on the use of resources. Against the background of increasing pressures, such as global population growth and consumption patterns exceeding sustainable levels, exercised on the ecosystem and the services it provides, resource use needs to be handled with more diligence. (EC, 2011a)

Within the European Union (EU) each person accounts for a material consumption of 16 tonnes per year out of which 6 tonnes are wasted with three tonnes of it being land filled. (EC, 2011a) The prevailing paradigm of our economic system disregards the need for full cost pricing and thereby undervalues our common pool resources. (Carter, 2007) To continue consumption at current patterns, we would need, as derived from the ecological footprint indicator measuring global capita hectare use, more than two planet earths by 2050. (EC, 2011a and Rees and Wackernagel, 1996)

A four to tenfold increase in material efficiency is required by 2050 according to estimates by the World Business Council for Sustainable Development (2010). Resource trend scientists call for a factor five improvement fostered by strong innovations, whereby solely 20 per cent of current material use per unit of production will be used in 2050. (EC, 2011a, b)

The shift of our economy and society towards increased resource efficiency (RE) requires a supportive policy framework which creates incentives, such as rewards for innovation and RE, and aims at integrating existing policies to form a coherent approach towards decoupling economic growth from resource use. This objective will be supported by initiatives addressing the reduction in greenhouse gas emissions to halt global warming and climate change. (EC, 2011a)

One of the seven flagship initiatives of the Europe 2020 Strategy, which emphasizes a "smart, sustainable and inclusive growth", is "A Resource Efficient Europe", supported by a roadmap. It outlines both interrelations between policies and establishes a framework for policies which are to assist the move towards a resource-efficient and low-carbon economy within the global efforts to facilitate a transition towards a green economy. (EC, 2011a, b)

Benefits of a RE increase are, from a micro-economic perspective, linked to improved business profitability and competitiveness as a result of enhanced innovation. On a macro scale, the advantages are linked to job creation, the support of economic recovery while reducing resource use and thereby contributing to securing their supply in the European region. (EC, 2011a, b)

1.1.1 Resource efficiency and critical raw materials

Resource efficiency is pursued to diminish the negative environmental, economic and social impacts caused by a certain resource use. (Hirschnitz-Garbers et al., 2012) It is increasingly gaining importance and the EU has investigated global supply imbalances and the associated risk for the EU economy as a result of production concentration in a few countries. Applying the indicators supply risk and environmental risk, whereby the former summarizes political-economic stability of the producer country, the level of production, the substitution potential and the recycling rate, and the latter assesses the risks of more stringent environmental regulation being put in place in countries with current low environmental protection, rare earths have been listed, along with 13 other raw materials, as critical at EU level. (EC, 2010 and EC, 2012a) Rare earths, also known as rare earth elements (REE), comprise 15 specialty metals in the lanthanide series of the periodic table, which share unique physical, chemical and light-emitting properties. With scandium and

yttrium, which have similar chemical properties, also being added, the REE count 17 elements. REE are used in a multitude of applications, primarily in hi-tech industry products, consumer electronics and sustainable technologies, including in motors.

1.1.2 EU environmental product policy

Several different policy options for addressing critical materials are available. They include but are not limited to obtaining improved access to the extraction of primary resources, the aim to create a level playing field in trade and investment, and to promote recycling, the substitution of critical materials and to increase material efficiency, the latter three of which have potential for direct applicability to product policy. (EC, 2010) "Product-related initiatives are potentially effective instruments to change prevailing consumption patterns. (...) Increasingly globalised product chains and international trade mean that EU product-oriented RE initiatives could have a double benefit - reducing global impacts of Europe's consumption and, through standard setting and leading by example, stimulating a global market for resource-efficient goods and products." (EEA, 2011, p. 27, and EC, 2001)

The EU product-oriented environmental policy is key to achieving RE improvements as it is to target the entire life cycle of a product from raw material extraction over manufacture, transport and use to disposal. From a political perspective, considering the likelihood for achieving a consensus amongst a critical mass, it appears that products constitute a good basis for discussion. (Dalhammar, 2012) Besides their interface between producers and consumers, they are control points for environmental impacts attached to all life cycle phases. (Dalhammar, 2007a)

1.1.3 Integrated Product Policy

Coordinated product policy had been discussed over a longer time period until in 2001, the European Commission (EC, 2001) instigated a Green Paper on Integrated Product Policy (IPP), followed by an EC (2003) communication on IPP. The concept, featuring, as per the EC Communication (2003, p.5) five key principles, namely "life-cycle thinking; working with the market; stakeholder involvement; continuous improvement [of products]; and a variety of policy instruments", was seen as a measure to reduce the life cycle impact of products from cradle to grave, in other words, from raw material extraction and production to disposal and to incorporate multiple instruments with the aim of achieving more eco-friendly products through co-operation with stakeholders. An illustration is provided in figure 1-1. (EC, 2001 and Dalhammar, 2007)

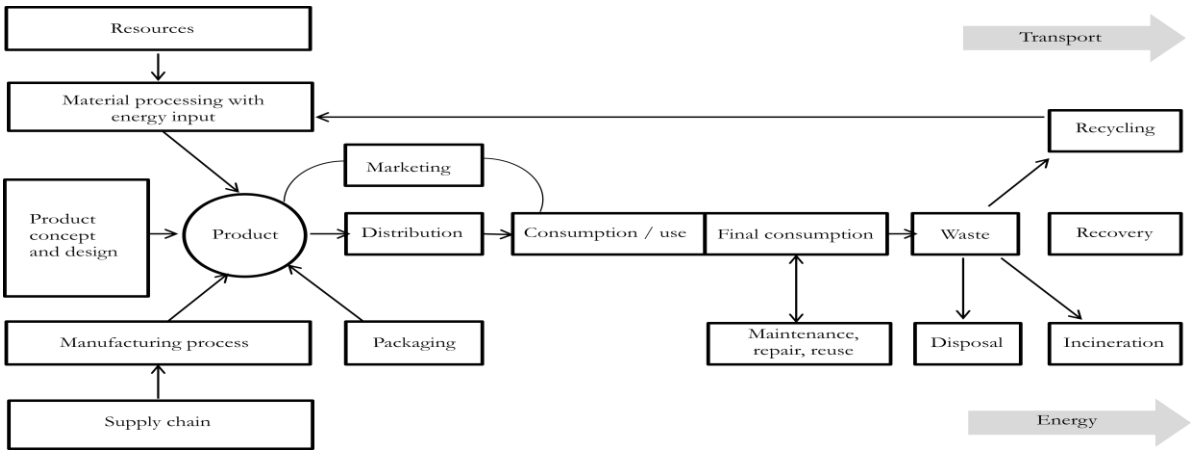


Figure 1-1. Schematic life cycle of a product

Source: adopted from EC, 2011

The Green Paper recognizes that the key actors in the process towards more eco-friendly products are businesses and consumers since design, where environmental characteristics are defined, and purchasing decisions account for the largest share in environmental impacts of products. It elaborates also on the need for a product-related environmental policy to extend to all businesses within the internal market of the EU, stipulating the global dimension of trade and the EU market influence on international environmental standards triggering positive harmonization efforts, a so-called "trading-up"(Selin and VanDeveer, 2006), in other non-EU markets exporting products to the EU. The "trading-up" in non-EU markets refers to a tightening of non-EU product standards to meet the EU required standards in order to enable product exports to the EU market, which results in more products of equal standards also outside the EU and in a further step triggers product improvements, innovation and competition. (EC, 2001)

In essence, the IPP Green paper and communication recommend a mix of voluntary and mandatory instruments of an administrative, economic and informative nature, including differentiated taxation of products, GPP, environmental labelling, several approaches to support the further application of life cycle assessment (LCA) and eco-design in industry, as well as standardisation such as through the implementation of environmental management systems. (EC, 2001) Both IPP papers advocate the facilitation role of public authorities as compared to direct intervention and outline the purpose of policy to be in the elaboration of objectives along with the design of incentives and means for the stakeholders to attain the stipulated objectives. Over time experience has shown, however, that voluntary commitments and the role of facilitation by public authorities have their limitations. The communication on IPP thus expands the scope from energy-using products (EuPs) to Energy-related (ErPs) of the Ecodesign Directive. As Dalhammar (2007b, p. 110) points out "there is a need for more regulatory standard-setting in environmental product policy, because a) there is a need to speed up the increased supply of and demand for greener products, and b) only relying on economic and informative instruments will probably not be very effective as their current application limits the effectiveness." Dalhammar (2007b, p. 111) further stipulates that mandatory product standards seem to be "the most powerful drivers for inducing eco-design practices in industry."

1.1.4 Product-oriented resource efficiency instruments

A significant share of natural resource and energy consumption within the EU is attributable to ErPs. Also, the environmental impact within product categories varies notably despite comparable functional qualities. With the aim of pursuing sustainable growth within Europe and attaining a global shift towards a green economy, promoting the continuous improvement of ErP with significant negative environmental impacts and a high improvement potential at feasible costs is desirable. (Official Journal of the European Union, 2005)

With raising awareness of the importance of a system thinking approach (Meadows, 2008) and the need to incorporate a life cycle (LC) perspective into policy-making, several product-oriented instruments have been put into place within the EU policy framework to facilitate higher resource efficiency rates in various phases of the life cycle. Figure 1-2 provides an illustration of the instruments attached to electrical and electronic products and their relevance to specific LC phases.

The production phase of a product has been extended to comprise design in the figure, acknowledging the influence over the RE and performance of the product over its entire life time. Of most relevance in this phase is the Directive 2002/95/EC on the restriction of the use of certain hazardous substances (RoHS) in electrical and electronic equipment. It aims at limiting the use of six toxic substances including four heavy metals, namely lead, mercury, cadmium and hexavalent chromium, and two chemicals, polybrominated biphenyls and polybrominated diphenyl

applying a maximum allowed concentration per weight measure. (Official Journal of the European Union, 2003a)

The Directive is accompanied by the Regulation on the registration, evaluation and authorization of chemicals (REACH) which seeks to improve chemical management and regulation by generating more comprehensive risk assessment data along with stricter controls of the most hazardous chemicals. According to Selin and VanDeveer (2006), the regulation constitutes one of the most complex environmental policies in European history as it eradicates the regulatory distinction between new and existing chemicals, replaces many existing chemical laws and requires approximately 30,000 existing substances to be registered between 2007 and 2018.

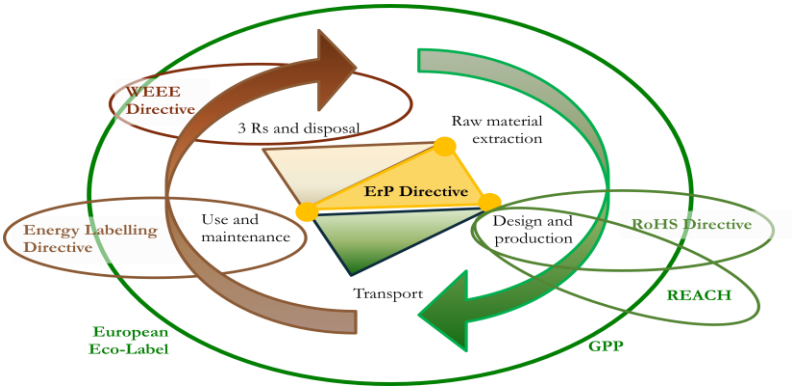


Figure 1-2. 'IPP instruments in a life cycle perspective'

Source: adapted from Remmen (2011)

In the use phase, one of the two EU labelling schemes, the EU Energy Label, and the Ecodesign Directive, both of which will be described in more detail later, are most relevant for electrical and electronic products.

The last phase of the product life cycle addresses the end-of-life (EoL) phase of the product which summarizes reusability, recyclability, and recoverability[1], in literature commonly summarized as "3-Rs", and disposal. The Directive on waste electrical and electronic equipment (WEEE) aims at achieving the European recycling and recovery of electrical and electronic equipment to diminish the quantity of e-waste for final disposal. It is designed with the principle of extended producer responsibility, which broadly summarizing, requires producers to take back WEEE and consumers to assume responsibility in returning all regulated electrical and electronic products to them. (Official Journal of the European Union, 2003b) The WEEE and RoHS Directive jointly address the design and end-of-life phase of products, whereby the RoHS Directive can be understood as a supplement to the WEEE. (Dalhammar, 2007 and Selin and VanDeveer, 2006)

Green public procurement (GPP) or sustainable public procurement, refers to the purchasing process and addresses procurement decisions taken by public institutions which are based on defined environmental criteria. This regulatory instrument has a model function in that it considerably influences product design due to its market potential: Public authorities have high purchasing power. On average, public procurement accounts for 12 per cent of EU gross domestic product. (EC, 2001 and Bundesministerium für Wirtschaft und Technologie und Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit [BMWi and BMU], 2011)

[1] The 3 Rs refer to the potential of a product to be reused, recycled and recovered, which needs to be harnessed.

The European Eco-Label, also commonly referred to as "the Flower" is a voluntary, informative instrument and a type I label according to the ISO 14000 environmental standard series[2], which implies that the best environmental performance of the product, measured by specified criteria, has been verified by an independent body. (EC ENV, 2012 and SIS, 2010) It attains to cover the entire life-cycle of a product.[3] Several other instruments should be mentioned including economic instruments targeted at products, product LCA; deposit-refund, and reuse and repair schemes.

1.1.5 The Ecodesign Directive

It is the Ecodesign Directive 2009/125/EC, which has potential to address all phases of the LC of a product, which provides the rationale for it being placed within the policy framework of Sustainable Consumption and Production (SCP) and the Sustainable Industrial Policy (SIP) Action Plan and the EU policy commitment to SIP by Europe 2020 and the two flagship initiatives on "sustainable growth", "Industrial Policy" and "A Resource Efficient Europe", shown in figure 1-3.

The Directive 2005/32/EC establishing a framework for the setting of ecodesign requirements for energy-using products and amending Council Directive 92/42/EEC and Directives 96/57/EC and 2000/55/EC of the European Parliament and of the Council, or commonly referred to as Ecodesign Directive, has been developed with a specific 'IPP focus'. It has been designed with the recognition that the ecodesign of products constitutes an essential element in the Community strategy on IPP. (Official Journal of the European Union, 2005)

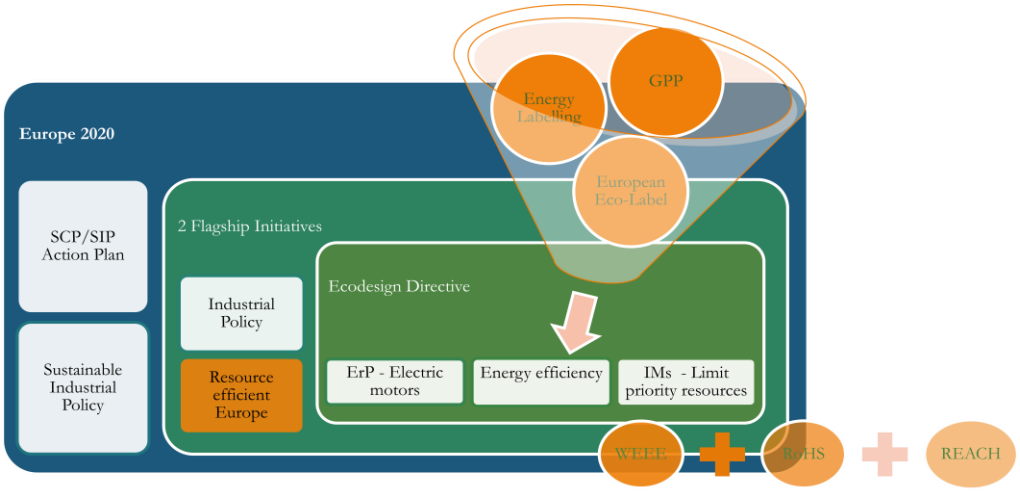


Figure 1-3. The Ecodesign Directive within the Europe 2020 Strategy

Source: own visualisation created on the base of EC, 2011a, b and EC, 2008c

As framework directive, it establishes the legal basis for putting detailed environmental standards in place contrary to setting directly binding objectives as a regulation would provide. The Directive supports the preventative approach and pursuing the objective of improving the environmental performance of products, the energy efficiency potential in particular, without impacting their functional qualities and thereby creates new chances for society, both for manufacturers who are

[2] The International Organization for Standardization (ISO), in its ISO 14000 series of environmental standards, specifically in the ISO 14020 group, provides standards for three types of eco-labelling schemes, whereby type I and III are verified by independent bodies with the difference that type III provides information on the environmental impact of the product in form of a report card and an environmental product declaration. (SIS, 2010)

[3] The EU Ecolabel also applies to the Blue Angel, the Austrian and Nordic Ecolabel. (Ecolabel-Products.eu, 2012)

challenged to experiment on innovative approaches and for consumers who are to experience new functional designs. (Official Journal of the European Union, 2005 and Dalhammar, 2007)

A total of 31 product groups have been identified as applicable for the Directive. Implementing measures (IM) for 12 product groups have been adopted and evaluated with the results highlighting the annual energy saving potential of the lot 11 product group electric motors at estimated 135 TWh by 2020. (EC, 2012) RE, despite being an additional objective, and referred to in the form of LC aligned ecodesign parameters of the Directive, appears to be an additional, even if not too obvious, additional objective alongside energy efficiency.

One of the product groups for which IM have been adopted, is lot 11 which addresses electric motors. The Regulation 640/2009 addresses the ecodesign requirements for this product group with its focus being restricted to induction motors.[4] Against the background of REE being defined as critical materials and needed, amongst others, in the production of permanent magnets (PM), which are used in other electric motor types, an inclusion of these motor types is perceived to be a contribution to the objectives of the Directive. In addition, PM motors appear to be more energy efficient and are expected to be more frequently applied in future applications.

With this realisation, a preparatory study on lot 30 which aims at identifying the potential for environmental improvement of products outside the scope of Regulation 640/2009 on electric motors is being undertaken at the moment and it is anticipated to include PM motors. (Official Journal of the European Union, 2009b and De Almeida et al., 2012a)

In their study for the EC Joint Research Centre (JRC), Ardente et al. (2011) investigated options for the integration of RE and waste management criteria in the IM under the Ecodesign Directive. They developed methodologies which could potentially be used to calculate and verify parameters including for the 3Rs, recycled content, use of priority resources and use of hazardous substances. With a view to the 3Rs, one index for each of the three parameters as well as combined indices have been developed. The indices for the 3Rs are based on mass fraction expressed in a percentage of the overall mass of the product. Regarding the priority use of resources, the study aimed at identifying resources with the largest environmental benefit when reused, recycled or recovered. A set of indices, the "RRR benefit indices" was developed which are derived from dividing the percentage of the potential environmental benefits as a result from reuse, recycling and recovery of the product by the maximum benefits achievable. Due to the restrictions inherent to measuring recycled content on the product, supply-chain information needs to be collected and the developed index joins information from the bill of material with additional data of the recycled content of each component and material. The assessment of the use of hazardous substances has been viewed as dependent on a LC perspective since these substances can also have an influence on the technical performance of a product. In general it has been suggested that the Ecodesign requirements could include declarative and threshold requirements correlated with the indices and other requirements including on the disassembly of key components. Technical product documentation could complement the requirement.

It is to be explored whether RE will be a topic discussed in the preparatory study meetings and if and to which extent industry responds in the drafting of the regulation on the ecodesign parameter laid out in the Directive. Of particular interest with a view to REE are the LC aligned ecodesign

[4] Electric motors are categorized into direct current (DC) and alternating current (AC) motors, whereby DC motors comprises permanent magnet motors and induction motors form part of the AC category. (De Almeida et al., 2008)

parameters "raw material selection and use" and "EoL" since they, if considered in the design process, would enable both for a careful consideration of REE use, if not a limitation of their use and for a design which could facilitate their reuse and recycling.

1.1.6 Eco-innovation and competitiveness

This design could result from eco-efficient or eco-innovations, which are understood as introductions of environment friendly technologies that also **increase resource productivity** (Jänicke, 2008), and thereby RE. According to Jänicke (2008), eco-innovation is an alternative concept to ecological modernisation. He stresses that modernisation forms part of the technological progress and recognizes that "the compulsion for innovation" can be put "at the service of the environment". (Jänicke, 2008, p. 558) To ensure a successful influence in the progress, "ecological-economic "win-win" solutions" need to be attained by stressing competition for innovation and cost reduction. (Jänicke, 2008, p. 558) The role of regulation in this regard has been highlighted earlier and the Ecodesign Directive has potential to contribute to this process.

1.2 Problem definition

The Ecodesign Directive has been drafted with an IPP influence, in as far as agreements are used as an alternative to regulation, and a preventative approach with the aim to improve specifically the energy efficiency performance of selected product groups. This objective puts an emphasis on the use phase of the selected product group. Nonetheless, and as described earlier, the Directive has potential to address the entire LC of a product and its latest methodology revision which included a critical material indicator illustrates a first attempt to extend its potential outreach. With a view to the LC approach, the Directive provides generic and specific ecodesign parameters which address the improvement potential of environmental aspects of a product throughout its LC. The Directive requires from the manufacturer to conduct a product model assessment throughout the product LC from which an ecological product profile is to be derived, if so stipulated in the adopted product group specific IM.[5] (Official Journal of the European Union, 2009a, Article 8, para. 1 and Annex I, Part 3 (1), Annex IV, 2 c) This profile outlines the input and output quantities during the product LC and serves, in combination with the benchmarks identified in the IM by the EC, as a scale in the evaluation of other product design options by the manufacturer. The EC further highlights the necessity to attain a rational balance between the environmental aspects, and the environmental aspects and other aspects such as product safety, functionality, performance and quality, as well as economic aspects. (Official Journal of the European Union, 2009a, Annex I, Part 3 (2)) The control of whether IM are adhered to remains with the manufacturer or its authorized representative.

From this outline of the requirements part of the Directive it is evident that several elements can potentially pose a challenge with a view to achieving a product LC approach: Even if specific ecodesign requirements address the improvement potential of a chosen environmental aspect of a product during its LC, it is initially to be decided and assessed by the manufacturer which ecodesign requirements will be considered in the future product. This autonomy might lead, on behalf of the manufacturer, to a decision in which the trade-off between environmental and other aspects results in the neglect of the environmental aspects. The consumption reduction of selected resources in certain LC phases of the products are addressed, *however, none* of the outlined ecodesign requirements in the Directive are accompanied by quantitative targets such as a percentage of recycled content of a certain material to be used in the production. An improvement

[5] As per article 15 (6) of the Directive, implementing measures can also state that ecodesign requirements are not needed for certain specified ecodesign parameters described in the Directive Annex I, Part 1. (Official Journal of the European Union, 2009a)

in RE would be preceded by innovations, namely eco-innovations. These aspects are of particular importance as the RE debate has come to the forefront of political discussions and the Europe 2020 Strategy also works towards an "Innovation Union", aiming at re-focussing research and development and innovation policy on energy and RE. (EC, 2012b) Of strategic political interest in the EU, besides achieving increased innovation, are the access to and the efficient use of available resources, especially of the as critical classified REE.

Against the background of a limited number of instruments which are politically acceptable to address product LC related issues, including resource efficiency, the Ecodesign Directive appears to have great potential. This promising outlook of the Directive as a tool for resource efficiency and its limitations needs to be assessed. It is understood that innovations with a resource efficiency focus, namely eco-innovations, will need to precede an improvement in resource efficiency and therefore the Directive potential to contribute to eco-innovations will need to be evaluated.

1.3 Aim and research question

The research aim is twofold. On one hand, the research aims at revealing the Ecodesign Directive's potential to trigger eco-innovations. On the other, it attempts to deepen the research by applying the findings to a specific product group by assessing the capability of the Directive to promote eco-innovations of critical REE in permanent magnet motors, if they were to be included in the extension of the product group. This is a particular relevant field of investigation as resources are crucial to the European economy, its competitiveness, and our lifestyles, and both are under-investigated and under-regulated. On the path to reaching the first element of the aim, the Directive is assessed against several criteria which have been found to trigger eco-innovations (Jänicke, 2007), namely:

- the political support towards the Directive which is measured by its acceptance as policy instrument, and its openness for the participation of a wide range of stakeholders, both of which are also innovation drivers, and second,
- its innovation-friendliness, examining its potential to:
  - provide economic incentives and act in combination with other policy instruments (and thereby foster an ErP LC perspective, which forms, besides the aim of market harmonization and increase in product energy efficiency, also the basis and rationale of the Directive)
  - support innovation as a process (namely to contribute to eco-innovations by creating appropriate structures and thereby increase resource efficiency of ErP),
  - work with strategic planning and goal formulation (elaborating requirements in line with industry's design cycle and working with IM).

The following research question has been drafted to support this endeavour:
How may the Ecodesign Directive contribute to promoting eco-innovations ?

In a next step, given that many of the presented issues are context-specific, the assessment is scoped down and related to the specific product group of electric motors in lot 11 and specifically, to its product group extension, lot 30. Electric motors were selected due to their high potential for energy efficiency savings, and thus, them presenting a prime target for ecodesign requirements. (Grundfos, 2008 and Official Journal of the European Union, 2009b) This second element of the work, presented as case study, sets out at complementing existing research by shedding light on the potential contribution of the Directive on eco-innovations addressing resource efficiency of rare earth elements in permanent magnet motors. The relevancy of this research element to

current economic and political discussions is demonstrated through increased efforts addressed towards this field including through an EC (2008) raw materials initiative[6], a report by the EC (2010) established ad-hoc working group on defining critical raw materials, which elaborated a list of 14 critical raw materials including REE (2012a), the EC (2011) resource-efficient Europe flagship initiative under the Europe 2020 Strategy, and an EEA (2011) investigation of policies and approaches for RE in EEA member and cooperating countries, to mention but a few efforts with high impact factors.

Detailed objectives which result from the work towards accomplishing this described element are:

- a critical review of the currently undertaken preparatory study of lot 30 which is to extend the scope of the Regulation 640/2009 adopted for electric motors to comprise PM motors,
- a review of the issues addressed in the preparatory study stakeholder meeting, and
- a capture of PM motor producers' perception regarding innovation drivers

The efforts undertaken to answer the research question will be supported by two sub-questions:

a. Which of the selected drivers for innovation are perceived to be most influential?
b. To which extent could a PM motor regulation influence company eco-innovation activities, specifically RE of REE in PM motor design?

1.4 Scope and limitations

The scope of this work is clearly limited by the two complementary aspects which build the focus: On one hand, an attempt is made to draw a general picture of the perceived political support of the Directive and its perceived potential contributions to eco-innovations, which are understood as innovations that enhance RE. On the other hand, the aim is to explore the potential of the Ecodesign Directive to increase RE through eco-innovations within the electric motor product group, and especially of potentially future Ecodesign Directive regulated PM motors which are produced from REE.

When addressing the general picture, also referred to as first element of the research aim, the scope extends to all product groups and encompasses both the political framework attached to the Directive, especially regarding the perceived political support amongst industry and politicians and options for stakeholder participation in the decision-making process, as well as to the eco-innovation friendliness of the Directive. With a view to the latter, specific aspects of the Directive, namely the LC perspective, RE and product innovation potential, the IM and ecodesign requirement stringency, are reviewed according to selected, established criteria from Jänicke (2008) which assess the innovation-friendliness of the policy instrument. They are partially also illustrated by examples from different product groups.

The case study which takes the form of an assessment of an anticipated Directive electric motor product group regulation extending to PM motors is limited to evaluating its potential contribution to eco-innovations enhancing the RE of REE in PM motors. The analytical framework applied to the case study data collection and analysis entails a multi-level perspective, in which the innovation-friendliness indicators are embedded. This part of the framework, specifically the technological-external factors determining the socio-technological landscape and the key dimensions of socio-technological regime, appear to be extending the scope of this paper to

[6] The EC raw materials initiative (2008) defined response levels at EC, member state and industry levels, the first level of which was a EC (2010) report on defining critical raw materials, and revealed the criticality of REE . Level nine and ten of the initiative specifically refer to an increase in resource efficiency and raw material substitution as well as the promotion of recycling and facilitation of secondary raw materials in the EU. (EC, 2008b)

geopolitical and social implications. However, it should serve the purpose of providing a more comprehensive picture of the setting in which the framework directive is embedded, rather than the detailed exploration of the global circumstances. It is therefore limited to embedded, selected innovation drivers, which will be described in sections 2.2.1 and 2.2.2.

Multiple factors influence eco-innovations and the data on possible contributions of the Ecodesign Directive to these innovations can only be obtained from the perceptions of people who are directly or indirectly involved in the process. Thus, the scope is limited to providing an analysis of the obtained observations and estimates rather than to establish an indisputable link between the Ecodesign Directive and its potential contributions to eco-innovations.

1.5 Intended audience

This work is addressed to researchers in the field of eco-innovation, policy makers and EU member state representatives specializing in resource efficiency and ecodesign and in particular to representatives of nongovernmental institutions which actively participate in the EC consultation processes, closely interact with researchers, EU national representatives and provide recommendations and support to the EC.

1.6 Disposition

In chapter two the analytical framework is described. This framework provides the basis for both the assessment of the Directive potential contributions to resource-efficient innovations, or eco-innovations, in chapter five and for the case study in chapter seven. In addition, the framework supports the discussion and conclusion in chapter eight and nine.

Chapter three elaborates on the Ecodesign Directive, its requirements, and related policy instruments with resource efficiency objectives. The chapter also comprises a summary of the recent conducted effectiveness and efficiency review of the Directive as well as an insight into the amendments made in the course of its methodology revision.

Regulation, efficiency standards and their relevance for competitiveness is discussed in chapter four, along with the Japanese Top Runner Program and the proposed EU top runner concept.

The core of this thesis is presented in chapter five: Empirical data is used to assess the Ecodesign Directive against its innovation potential based on political support and innovation-friendliness, two innovation drivers provided by Jänicke. The chapter also briefly assesses the interviewees' perceptions as to the Directive possibility to contribute to RE in its regulated product groups.

Chapter six focuses on electric motors, introduces the international motor efficiency standard, the EU electric motor regulation and the to-date ongoing preparatory study for the extension of the electric motor group to permanent magnet motors. It discusses trends in this product group and their efficiency level's dependence on REE.

Chapter seven presents the case study on the potential electric motor product group expansion to PM motors and uses an array of selected innovation indicators, embedded in the multi level perspective, to shed light on the Directive possibility to increase RE of REE in PM motors.

In chapter eight, the findings are discussed, and further thoughts and ideas are raised.

Chapter nine concludes, provides ideas for further research and discusses the applicability of this work within other contexts.

2 Methodology and Analytical Framework

For the purpose of attaining the stipulated two elements of the research aim and to answer the research question, an analytical framework, which encompasses the complexities attached to product eco-innovations, was needed. The selection of a framework for the collection and analysis of data was guided by several data sources, including Blind (2012), Carter (2007), Dalhammar (2007), Huber (2007), elaborating on the development and diffusion of technological environmental innovations, and the existing and commonly applied frameworks in the field of policy research, the evolutionary approach to technological development, ecological modernisation, technological regimes and evolution, amongst others, Rip and Kemp (1998), Jänicke (2008), Van den Ende and Kemp (1999), Nelson and Winter (1982), and Geels (2002). The chosen framework has been independently elaborated with specific building blocks from Blind (2012), Geels (2002) Jänicke (2008), and Van den Ende and Kemp (1999), for the two elements of the research and guide the data analysis.

Martin Jänicke is a professor for comparative politics at the Free University of Berlin (2011). In the Journal of Cleaner Production Volume 16, Jänicke (2008, p. 560) elaborates on "elements of a "smart" and innovation-friendly framework of environmental regulation", and outlines criteria which influence the innovation-friendliness of instruments, policy styles and actor configurations.

2.1 Political support and innovation-friendly instrument indicators

Two indicators, as depicted in table 2-1, were selected from Jänicke (2008) and support the general analysis of the Ecodesign Directive with a view to assessing its acceptance as policy instrument and its potential to generate innovations with a RE improvement.

Table 2-1.Indicators for the general assessment of the Ecodesign Directive

Indicators	Description
Political support	Eco-innovation requires political support from politicians and industry
Innovation-friendly instrument	Instruments are innovation-friendly if they: • provide economic incentives • act in combination • are based on strategic planning and goal formulation • support innovation as a process

Source: adapted from Jänicke, 2008.

According to Jänicke (2008, p. 558), "eco-innovations invariably require political support." Ashford et al. (1985), Hemmelskamp et al. (2000), Jacob et al. (2005) and Klemmer (1999), confirmed this stance in their work which targeted determinants of eco-innovations. Jänicke (2008, p. 558) further elaborates by indicating that generally, "(...) there is interplay between environmental policy-making and technological innovators: politicians in favour of technology-based (marketable) solutions co-operate with industrial innovators that seek regulatory support for their respective technologies." With a view to innovation-friendly instruments, Jänicke (2008, p. 560) points out that they have several characteristics in common which are specified in table 2.2.

The further expansion of this analysis to the second element of the research aim, the ex-ante assessment to which extent the Directive can contribute to eco-innovations in the product group of electric motors and specifically to PM motors, if they were to be included in the current electric motor product group regulation, is then supported by the multi-level perspective on technological

transitions framework by Geels (2002). It was published in the Research Policy Volume 31 in 1991. (Geels, 2002) Geels is a professor of system innovation at the University of Sussex in the United Kingdom. His inter-disciplinary work addresses the dynamics of socio-technical transitions with the aim of establishing interconnections between science and technology studies. Geels analyses and extends the multi-level framework on the dynamics of socio-technical change provided by Rip and Kemp (1996) and Kemp et al. (2001).

2.2 Multi-level perspective on technological transitions

Geels (2002) expands on the "technological regime" concept by Nelson and Winter (1982) and the co-evolution processes of new technologies, markets and user preferences addressed and further explored by Nelson (1994, 1995) and adds a multi-level perspective (MLP) to it. As illustrated in figure 2-1, the MLP on technological transitions (TT) works with three concepts or levels, a macro-level constituted by so-called landscape developments, a meso-level, specified as socio-technical regimes and a micro-level, formed by technological niches. The nested nature of the hierarchy, illustrated to the left, refers to the interlinks between the three concepts whereby the socio-technical regimes are rooted within landscapes and the technological niches within regimes. The lines in the illustration of the nested hierarchy between the various levels highlight the reliance of emerging niches on existing regimes and the overruling, corresponding landscape. In the following sections, the three levels and their roles within the MLP will be further explained.

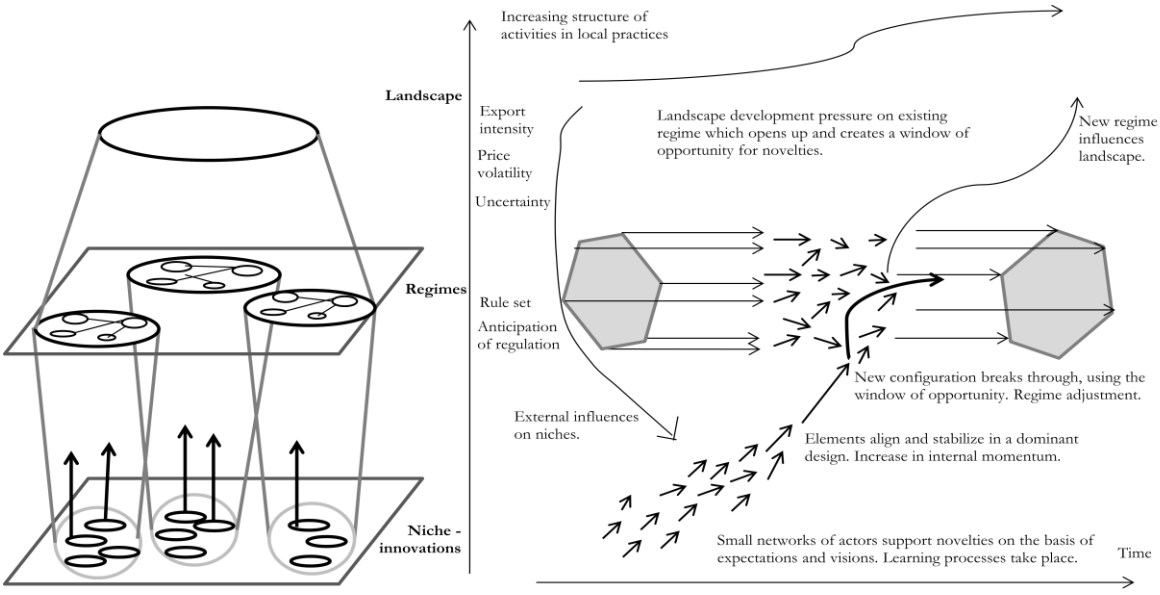


Figure 2-1. Nested hierarchy (left) and corresponding Multi-level perspective on transitions (right).

Source: adapted from Geels and Schot, 2007, who adapted it from Geels, 2002, p. 1263

2.2.1 Landscape developments

Landscape developments, whereby landscape is used as metaphor for the material context of society, is the concept attached to the macro-level of the MLP of TT. It provides for the external context which shapes the interaction of all actors. In its original, it represents seven wider technology-external factors including economic growth, broad political conditions, environmental problems, oil prices, emigration, wars, and cultural and normative values, all of which change slowly, and for which changes are harder to be achieved as compared to regimes. The landscape also provides rises for trajectories, which arise when e.g. a community of engineers searches in the same direction. The original technology-external factors have been aggregated to the innovation indicators derived from Blind (2011), Jänicke (2008), and Van den Ende and Kemp (1999),

specifically, export intensity, price volatility and uncertainty. The rationale for scaling down the number of factors and dimensions used is inherent to the aim of the revelatory case: it shall be specific and comprehensive in as far as a close-to-complete picture of the innovation factors which influence PM motor development the most and the potential contributions of the Directive to fostering eco-innovations is drawn. The first innovation driver, export intensity, was derived from Research Policy Volume 41, where Blind (2012, p. 397) quantitatively assesses OECD countries for their regulations' influence on innovations, works with the renowned Porter hypothesis on competition, and establishes through several regressions that "export intensity", defined as "serving customers from abroad, and the degree of openness of an economy, are positive for innovation". Knut Blind is an economist with specialisation in innovation economics and standardisation. (Fraunhofer Fokus, 2010) Jänicke (2008) supplies the price volatility and uncertainty innovation drivers.

Table 2-2.Selection of innovation indicators

Source	Selected innovation driving forces	Description	Geels (2002) MLP on TT
Blind (2012)	Export intensity	Serving customers from abroad increases the variety of requirements from the demand side and therefore export-intense company has to be successful in innovation.	Socio-technological landscape
Jänicke (2008)	Price volatility	Fluctuating prices of mineral sources impact eco-innovation.	
Jänicke (2008)	Uncertainty	Insecurity about environmental pressures and requirements influences eco-innovations.	
Van den Ende and Kemp (1999)	Rule set	Core, hard and transient rules influence the technological regime and eco-innovation.	Socio-technological regime
Jänicke (2008)	Anticipation of regulation	The potential for a company to anticipate regulation improves its possibility to predict markets/competitors and encourage timely eco-innovations.	

Source: adapted from Blind, 2012, Geels, 2002, Jänicke, 2008 and Van den Ende and Kemp, 1999.

2.2.2 Socio-technical regimes

On the meso-level, socio-technical regimes create stability and direct innovations towards incremental improvements along the trajectories. These regimes are shaped by cognitive routines (Nelson and Winter, 1982) of social groups and are translated into rules as part of a knowledge base, engineering practices, corporate governance structures, manufacturing processes and product characteristics. Policy makers, various societal groups, scientists and users, amongst others, affect the regimes. According to Geels (2002), seven key dimensions form a socio-technical regime: technology, user practices and application domains (markets), symbolic meaning of technology, infrastructure, industry structure, policy and techno-scientific knowledge. For the purpose of this work, the policy key dimension is of most interest and will be explored by applying two innovation indicators: rule set and the anticipation of regulation, as depicted in table 2-2. (Geels, 2002) Van den Ende and Kemp (1999, p. 837) have jointly researched historical technological transitions on the case of the computer regime and in that effort they focused on rules and their influence on innovations which can lead to changes in the technological regime. Jan van den Ende is a professor of technology and innovation at the Erasmus University of Rotterdam. His research focuses on the development process of new products and services in firms. (Rotterdam School of Management, 2012) Professor René Kemp research focus is on eco-innovation, environmental and innovation policy at Maastricht University. (Kemp, 2012)

2.2.3 Technological niches

Radical innovations rely on the existence of micro-level technological niches where innovations are insulated, almost as in "incubation rooms" according to Schot (1998), from the market selection employed in the socio-technical regime. These niches create enabling learning and are a supportive ground for the generation and development of radical innovations.[7] (Geels, 2002)

A critique on the MLP is provided in Appendix A. This paper refrains from providing a new framework for policy analysis in the field of technological change facilitated by eco-innovations. It rather uses elements of existing work to support the specific needs of this research. The theoretic nature of a framework indicates its purpose of providing an approximate representation of reality. With the Ecodesign Directive potential, in principle, to foster design changes that enhance RE and thereby lead to eco-innovations, the literature by Jänicke (2008) on ecological modernisation was considered most adequate for the provision of innovation indicators. Geels (2002) MLP on TT offered for an extension of the analysis to a more comprehensive picture beyond mere indicators.

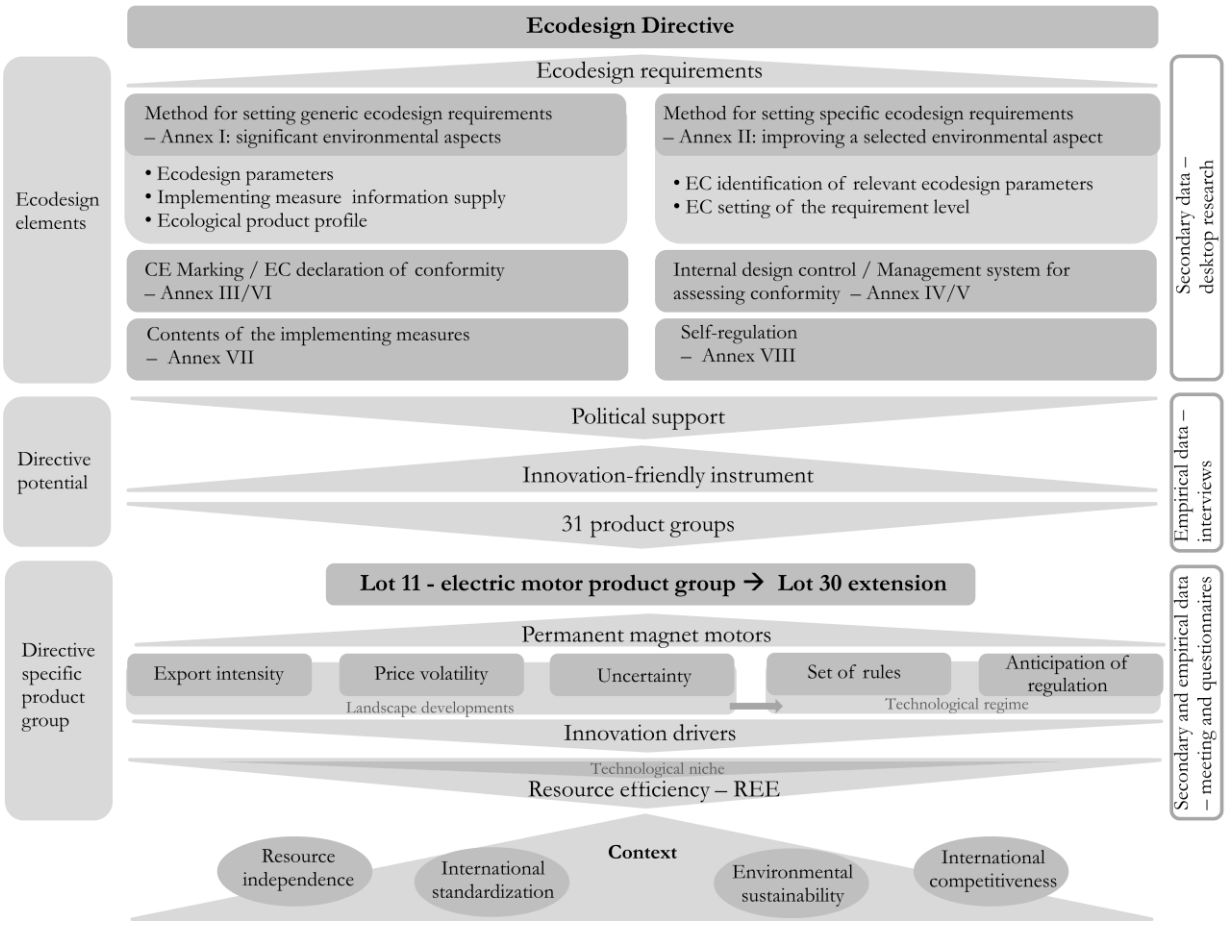


Figure 2-2. Analytical framework.

Source: own visualisation.

Figure 2-2 outlines the overall framework, in which the indicators and the MLP on TT are embedded. It guided the data collection and analysis of this paper and supported the investigations

[7] Jänicke (2008, p. 558) further elaborates on this point by indicating that "The ecological effectiveness of environmental innovation depends on its radicalness but also on the degree of its diffusion. Incremental innovations that remain restricted to niche markets, for instance will only have a limited effect".

in as far as it provides a clear, sequential structure for data collection and analysis. The "Ecodesign elements" block builds the pillar of this work, in which an outline of the main features of the Ecodesign Directive is to be provided. The elaboration of this part can be accomplished through a review of secondary data. The next step leads then to the generic analysis of the Ecodesign Directive contribution to eco-innovations which is guided by Jänicke's (2008) innovation indicators "political support" and "innovation-friendly instrument", and will be addressed in the block "Directive potential". It requires empirical data whereby the data collection focus is on investigating whether the Directive, with its 31 product groups, is a politically accepted and an innovation friendly instrument, also regarding RE improvements. The findings from this section are then to be expanded in their application to the specific product group of PM motors, the last block of this framework. A case study is to support this detailed investigation on PM motors.

2.3 Research Design

With a view to assessing the Ecodesign Directive potential to contribute to promoting eco-innovations, and the guiding research question, a qualitative approach was considered to be most suitable. This decision was based on description and theory development, being two of the different objectives of a qualitative approach, which also form the pillars of this work. (Flick, 2006)

Product design and eco-innovations are influenced by multiple internal and external drivers, and people who either participate in or are familiar with the process, are sought to be in the best position to assess the contribution of the Directive. Against this background, semi-structured interviews were considered best for data collection. Through interview guides, a red thread was to be followed in each interview ensuring, on one hand, that important topics inherent to both the Directive political support and innovation-friendliness were covered in each interview, while on the other, the semi-structuredness allowed for the further detailed investigation of specific aspects within the innovation-friendliness indicators, if any were raised by the respondent. While the interviews addressed the entirety of product groups it covers, it was considered to be beneficial for the research to focus on one product group in order to test preliminary findings and extend the depth of analysis. A case study on the anticipated regulation of PM motors and the Directive potential contribution to enhancing RE of PM motors was to attend to this purpose. The author participated in the first stakeholder meeting of the preparatory study for the extension of the electric motor product group and a questionnaire addressed to PM motor producers who attended the meeting was considered to yield most results. Specific interviews were found to be an additional route to complement the case study.

The research took an *inductive* approach aiming at elaborating recommendations from the findings obtained. The process was shaped by a degree of deduction, as, following the initial review of collected data on the Directive in its entirety and retrieved preliminary findings, additional data was collected for the case study to confirm them. (Bryman, 2004 and Sage Reference, 2012)

2.4 Data collection

The data collection was aligned with the analytical framework. The research relied on secondary data obtained through several databases including EBSCO host and its databases Academic Search Complete, Business Source Complete, Green File and the Public Affairs Index for social science aspects, SciVerse for the technical element, and the Lund University library catalogue "Summon".

Empirical data for the first element of the research aim was gathered in generic interviews which followed the interview inquiry stages outlined by Kvale and Brinkmann (2009), specified as thematizing, designing, interviewing, transcribing, analyzing, verifying and reporting. An interview guide, to be found in Appendix C, designed in line with the selected indicators political support and for an innovation-friendly instrument derived from Jänicke (2008) supported the interviews.

A total of ten interviews were conducted with eight respondents from different EU member states national contact points for the implementation of the Directive whereby the attempt was to obtain a good balance between small and large as well as early and comparatively new EU member states. One of the ten interviews was conducted with a representative of the European Environmental Bureau (EEB, 2012), a federation of more than 140 environmental citizens organisations representing civil society and consumer interests in the environmental field, and another interview was undertaken with a respondent of the EC DG on Environment. All interviews were conducted by Skype or telephone and the average duration was an hour. The list of interviewees can be found in Appendix B and selected, quality assured interview transcripts, in Appendix D.

Empirical data for the revelatory case was obtained from the first stakeholder meeting for the lot 30 EuP preparatory study in June 2012, where the author made contacts with representatives of industries which are regulated upon by the Directive and the specific motor regulation. Questionnaires were drafted in line with the selected key drivers for innovations of Blind (2012), Jänicke (2008) and Van den Ende and Kemp (1999). The identification of suitable respondents was key, as only a limited number of the stakeholder meeting representatives' companies have a core business in electric motor manufacturing and a product portfolio containing PM motors. To obtain clear data, the questionnaire was sent out only to representatives of PM motor producers and motor industry federations who participated in the preparatory study. Feedback from industry federation representatives suggested that the specificity of the questions limited the number of qualified respondents within the already small target group of PM motor manufacturers, also reflected in the limited response rate. Interviews with material experts from academia and industry were used to complement the case study. The transcripts are available in Appendix H. Several respondents requested anonymity and they are therefore mentioned as representatives of their respective organisation or institution.

Table 2-3 illustrates the work plan and the five milestones according to which the author worked.

Table 2-3. Thesis work plan and milestones

Task (and numbered milestones)	May		Jun				Jul				Aug				Sep		
Week	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37
1: Environmental policy and Ecodesign Directive review																	
2: Identify analytical framework																	
Identify interview partners																	
3: Conduct interviews																	
Analysis of the interview data																	
4: PM motor case study - Attendance of the 1st Preparatory study stakeholder meeting																	
Draft questionnaire, identify respondents and send it out																	
Analysis of questionnaire data																	
Conduct additional interviews and analyze the findings																	
5: Conclusion and discussion																	
Final review and submission																	
Milestones in the thesis process			1	2							3				4		5

Source: own data.

3 The Ecodesign Directive and its Ecodesign requirements

The Ecodesign Directive, being a framework directive, is considered to have the potential to lead to ambitious product regulations. It was adopted in 2005, as Directive 2005/32/EC, following intensive debates such as on its scope. (Official Journal of the European Union, 2005 and Dalhammar, 2007) Its main purpose is to supply ecodesign requirements for selected EuP groups in the form of implementing measures (IM) with the primary objective of achieving higher energy efficiency rates. A methodology for the Ecodesign of Energy-using Products (MEEuP) was developed and accompanied the adoption of the Directive which was to support the process of evaluating whether and to which degree numerous energy-using products meet the criteria attached to being suitable for the IM.

The IM as laid out in table 3-1 contain the criteria applying for EuP which are to be met, whereby measure 'c' is complemented with further specifications namely, where EC legislation is inexistent, market forces solely cannot achieve an improvement and broad inconsistency in environmental performance coupled with comparable functionality is apparent. (Official Journal of the European Union, 2009a, Art. 15 (2) a - c)

Table 3-1.Implementing measures

a	Significant volume of sales and trade > 200 000 units a year within the Community
b	Significant environmental impact within the Community
c	Significant potential for improvement in terms of its environmental impact without entailing excessive costs

Source: adapted from the Official Journal of the European Union, 2009a, Art. 15 (2) a - c.

The product groups which were prioritized for the elaboration and adoption of IM due to their high potential for cost-effective savings of greenhouse gas emissions, are heating and water heating equipment, electric motor systems, lighting in both the domestic and tertiary sectors, domestic appliances, office equipment in both the domestic and tertiary sectors, consumer electronics and heat ventilating air conditioning systems and a product group affected by stand-by losses for which separate IM are to be elaborated. (Official Journal of the European Union, 2009a)

In working plans, the product groups for which IM apply, are defined. (Official Journal of the European Union, 2009a, Art. 16 (1) para. 2) To date, 31 product groups, summarized in lots, have been identified, for which industry has not elaborated self-regulatory initiatives or voluntary agreements[8] as stipulated in the Directive. The EuP need to fulfil the stipulated IM to carry the EC declaration of conformity, which is to be made visible as CE marking on the product or its packaging, in order to be eligible for the European market. This declaration introduces an additional responsibility for the manufacturer who might import components for its products from outside the EU and needs to ensure that these, if covered by the Directive, also meet the IM. (Official Journal of the European Union, 2005)

Figure 3-1. CE Marking

Source: Official Journal of the European Union, 2009a

[8] The Ecodesign Directive acknowledges self-regulatory initiatives or voluntary agreements as alternatives to IM under the condition that specified criteria, which are described in Annex VIII of the Directive, are fulfilled. (Official Journal of the European Commission, 2009a, Art. 17)

In 2009, following an intense review of the effectiveness of the Directive and recognizing the need for the expansion of the product scope definition, the Directive 2005/32/EC was repealed and substituted by Directive 2009/125/EC. (Official Journal of the European Union, 2009a) The products covered under the scope of the new Ecodesign Directive are summarized as energy-related products (ErP), which refers to

" (...) any good that has an impact on energy consumption during use which is placed on the market and/or put into service, and includes parts intended to be incorporated into energy-related products covered by this Directive which are placed on the market and/or put into service as individual parts for end-users and of which the environmental performance can be assessed independently."(Art. 2 (1))

Figure 3-2 illustrates the differences in the scope of the former and the current Directive.

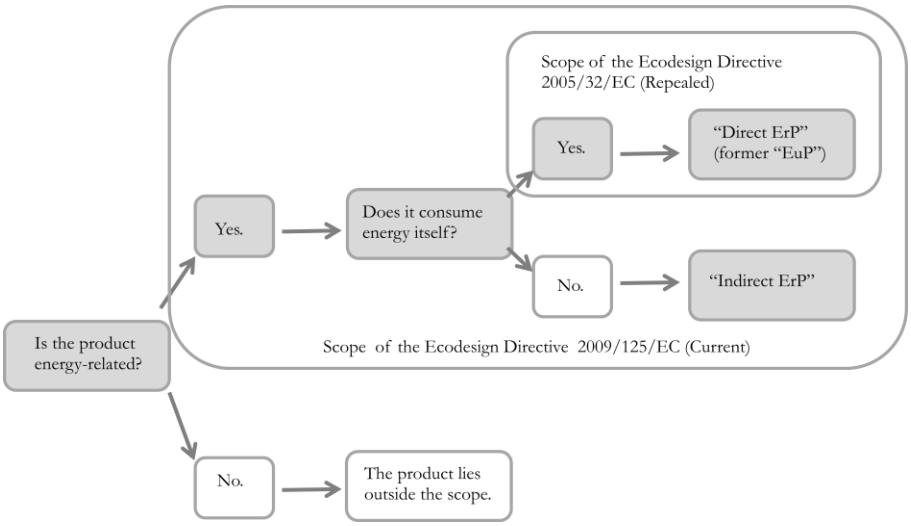


Figure 3-2. Explanation of the scope of the former and current Ecodesign Directive

Source: adopted from Van Elburg, Van der Voort, Van den Boorn, Kemna, and Li, 2011

"Direct ErP" refers to energy-related products which consume energy on their account directly during use such as electric appliances or self-propelling machinery. Usually these products are connected to a fuel source, the power grid, a battery or another energy supply. Some of these products strongly influence the energy impact of other direct ErP, for instance variable speed drives, which were covered as "EuP" under the former Ecodesign Directive. (Van Elburg et al., 2011) "Indirect ErP", such as thermal insulation, taps and showerheads, bearings, gears and filters indirectly affect the energy consumption of other ErPs without consuming energy themselves. Therefore, the improvement of their energy performance has potential to lead to energy savings within the larger energy system it is a part of. (Van Elburg et al., 2011) The new Directive has also been accompanied by the elaboration of a new methodology, applicable to energy-related products (MEErP) which will be addressed in section 3.6.

3.1 Procedure applied to the elaboration of implementing measures

The decision-making process related to the elaboration of a regulation for the specified product groups follows a procedures, which is outlined in figure 3-3 and is adhered to in DG Enterprise and Industry (DG ENTR) and in DG Energy (DG ENER), both of which manage the Directive. The first step in the process is the preparatory study which is prepared in a process during which numerous analyses and assessments are conducted with the inclusion of interested stakeholders to

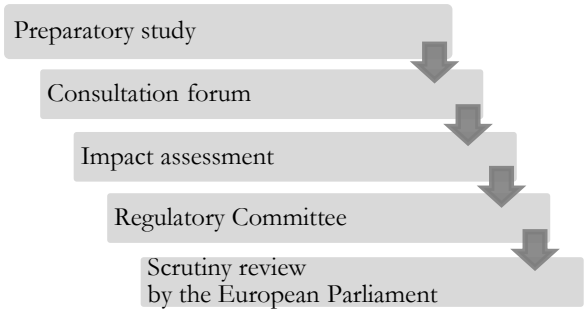
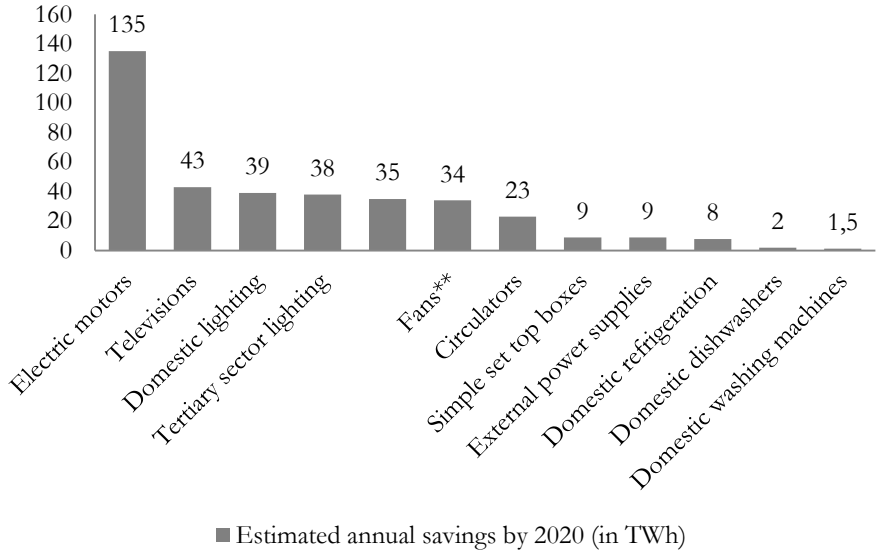


Figure 3-3. Illustration of the decision-making process.

Source: adopted from EC, 2012c

elaborate a foundation for the development of adequate ecodesign requirements. The MEErP provides the structure for this study which needs to be adhered to. (Kemna et al., 2011b) The result of the preparatory study is the proposal of the draft IM which are provided as an EC Working Document. (EC, 2012c) A consultation forum follows, the participation in which is limited to a total of 60 members, namely 27 EU member states representatives, 3 European Economic Area (EEA) member states representatives and 30 stakeholders including, but not restricted to business federations, consumer organisations and environmental organisations. The forum serves as a platform for the experts to contribute to the definition and review of the IM and to assess industry self-regulatory initiatives. (EC, 2012c) An impact assessment[9] is then conducted to view potential energy efficiency savings. It needs approval by the cabinet and accompanies the EC Working Document. An inter-service consultation takes then place followed by the Ecodesign Regulatory Committee, in which one representative from each EU member state and one delegate of the EC vote on the drafted IM.[10] (Ökopol, 2012) Then, the IM undergo a scrutiny review by the European Parliament before they are adopted and published in the Official Journal. (Kemna et al., 2011b)

Figure 3-4.Effectiveness of the first 12 product group regulations



* of electrical and electronic equipment (household and office)
**driven by motors with electric input power btw 125 W and 500 kW

Source: EC, 2012d

[9] The Impact Assessment, is an internal document, which is then published with the legislation. (Kemna et al., 2011b)
[10] The regulatory committee is being advised by the EC during the process attached to adapting a new working plan. (Ökopol, 2012)

In ex-ante assessments, the first 12 Ecodesign product group regulation IM have been evaluated to achieve potential total energy savings of 385 TWh per year by 2020, equivalent to about 14 per cent of EU 2009 household electricity consumption. (Centre for Strategy and Evaluation Services [CSES], 2012 and EC, 2012d) Industrial electric motors account for estimated annual savings of 135 TWh by 2020 as illustrated in figure 3-4, followed by TVs and domestic lighting.

3.2 Generic and specific ecodesign requirements

Generic ecodesign requirements are described in Annex I of the Directive, which emphasize significant environmental aspects with the aim of enhancing the environmental performance of products but refrain from setting limit values. The Directive prescribes the method which is to be used if it is "not appropriate to set limit values for the product group under examination".(Official Journal of the European Union, 2009a, Annex I, para. 1) An example of a product group for which it is not suitable to set a limit value are personal computers for which information needs to be instead provided according to measurement methods described in the Energy Star Program Requirements, such as power use in active mode per product and area, power use in sleep mode, and off mode as well as content of restricted substances and a web page address for information on energy, environment and EoL treatment. Televisions present another example, for which limit values are not suitable and for which ECMA 341 or IEC 62430, constituting checklists and bases for generic ecodesign requirements, are recommended to be applied along with a backlight unit marking in case of mercury content and a declaration of lead in displays. (EEB, 2010, p. 28 and 32)

Annex I further requests and authorizes the Commission to identify the relevant ecodesign parameters from those defined, the information supply requirements and the requirements for the manufacturer. (Official Journal of the European Union, 2009a)

3.2.1 Environmental aspects and ecodesign parameters

The significant environmental aspects of the outlined phases of the product LC are to be identified. The product LC phases are described as: raw material selection and use; manufacturing; packaging, transport, and distribution; installation and maintenance; use; and end-of-life, which refers to the phase in the lifetime of a product following its first, original use until disposal. (Official Journal of the European Union, 2009a) The most relevant LC phases for this work are raw material selection and use, manufacturing and EoL. An assessment of the environmental aspects in each phase, is recommended, where it is relevant. These aspects are outlined as (Official Journal of the European Union, 2009a, Annex I, Part 1, 1.2.):

(a) anticipated material and energy consumption and of other resources including water;
(b) predicted emissions to air, water or soil;
(c) anticipated pollution through physical effects;
(d) expected generation of waste material; and
(e) possibilities for reuse, recycling and recovery of materials and/or of energy, taking into account Directive 2002/96/EC

The parameters to be applied and if necessary to be complemented by other parameters, for evaluating the improvement potential of environmental aspects are specified as (Official Journal of the European Union, 2009a, Annex I, Part 1, 1.3.):

(a) weight and volume of the product;
(b) use of materials issued from recycling activities;
(c) consumption of energy, water and other resources throughout the LC;
(d) use of substances classified as hazardous to health and/or the environment (...);
(e) quantity and nature of consumables needed for proper use and maintenance;

(f) easy for reuse and recycling as expressed through:
- number of materials and components used
- use of standard components
- time necessary for disassembly
- complexity of tools necessary for disassembly
- use of component and material coding standards for the identification of components and materials suitable for reuse and recycling (including marking of plastic parts in accordance with ISO standards)
- use of easily recyclable materials
- easy access to valuable and other recyclable components and materials
- easy access to components and materials containing hazardous substances

(g) incorporation of used components
(h) avoidance of technical solutions detrimental to reuse and recycling of components and whole appliances
(i) extension of lifetime as expressed through: minimum guaranteed lifetime, minimum time for availability of spare parts, modularity, upgradeability, reparability;
(j) amounts of waste generated and amounts of hazardous waste generated;
(k) emissions to air (...);
(l) emissions to water (...);
(m) emissions to soil (...);

3.2.2 Ecological product profile and IM benchmarks

The manufacturer is required to assess the product model throughout its LC and create the ecological profile of the product, however only as and to the extent required by the IM (Official Journal of the European Union, 2009a, Annex I, (3) and Annex IV, 2 c). The basis of the latter are its environmentally relevant product characteristics and measurable physical input and output quantities throughout the product LC. (Official Journal of the European Union, 2009a)

Alternative design solutions and the attained environmental performance are to be evaluated against this assessment, and the benchmarks identified by the EC in the IM. Given that all relevant legislation is adhered to, the importance of obtaining a rational balance between numerous environmental aspects and between environmental aspects and other considerations including safety and health, technical requirements for functionality, quality, and performance, and economic aspects, including manufacturing costs and marketability, is highlighted. (Official Journal of the European Union, 2009a, Annex I, part 3, para 2.)

Annex II introduces the method for setting specific ecodesign requirements, which addresses the improvement of a chosen environmental aspect of a product. They might appear as requirements for the consumption reduction of a selected resource, such as in certain phases of the product LC, for instance with a view to limiting the quantities of a certain material integrated into a product. The EC is to perform a technical, economic and environmental analysis in which representative models of the product considered are to be found along with the technical options for improving the environmental performance taking into account the best available technology and best-performers on the market. The performance of these products on international markets is also to be considered along with other legislation applied by countries outside the EU.

3.3 Internal design control

Annex IV of the Directive refers to the internal design control procedure for the manufacturer or its authorized representative which are to ensure and declare that the product meets the IM requirements. The manufacturer or its representative need to provide a technical documentation

file which is to facilitate the evaluation of conformity of the product with the IM requirements. This file needs to comprise (Official Journal of the European Union, 2009a, Annex IV, para 2.):

(a) a general description of the product and its intended use
(b) the results of relevant environmental assessment studies carried out by the manufacturer, and/or references to environmental assessment literature or case studies, which are used by the manufacturer in evaluating, documenting and determining product design solutions;
(c) the ecological profile, where required by the implementing measure;
(d) elements of the product design specification relating to environmental design aspects of the product;
(e) a list of the appropriate standards referred to in Article 10 (...);
(f) a copy of the information concerning the environmental design aspects of the product provided in accordance with the requirements specified in Annex 1, Part 2; and
(g) the results of measurements on the ecodesign requirements carried out, including details of the conformity of these measurements as compared with the ecodesign requirements set out in the applicable IM.

Most of the responsibility outlined in this Annex remains with the manufacturer who needs to ensure that his products respect and adhere to the design specifications outlined in the IM.

3.4 Related policy instruments with resource efficiency objectives

As discussed in the section on product-oriented RE instruments, ErP account for an important part of energy and resource consumption within the EU. Several IPP instruments, which support the LC objective of the Ecodesign Directive, have been introduced in the introduction and their respective contributions to achieving higher RE, will be further explored in this section.

3.4.1 RoHS and REACH contributions to material selection and use

The two most influential instruments targeting the design and production phase of a product, are Directive 2002/05/EC on the restriction of the use of certain hazardous substances (RoHS) in electrical and electronic equipment. Lead, mercury, cadmium and hexavalent chromium, four heavy metals, and polybrominated biphenyls and polybrominated diphenyl, two chemicals, all six of which are substances with toxic properties regulated under RoHS. The measure applied through the Directive requests a maximum allowed weight concentration for the specific substance.

The EC 1907/2006 regulation on the registration, evaluation and authorization of chemicals (REACH) aims to achieve an improvement in the chemical management and regulation through the demand for more inclusive data for risk assessment and tighter controls of most hazardous chemicals. A revolutionary feature of the regulation relates to its power to replace numerous existing chemical laws along with its requirement to test about 30,000 existing chemical substances between 2007 and 2018 as REACH does not distinguish between new and existing chemicals.

Both RoHS and REACH have potential to support the design and manufacture of products through the identification and regulation of the use of potential hazardous substances, which, once the product reaches EoL, could have negative toxicological and environmental impacts. As recommended in the JRC study conducted by Ardente et al. (2011), requirements for the use of hazardous substances could be included into the Ecodesign IMs, e.g. in the form of a manufacturer's declaration on the content of hazardous substances in the product, or threshold limits on the use of the hazardous substances in the products, the labelling or indication of components which contain hazardous substances to facilitate their identification and the accessibility as well as disassembly of components with hazardous substances at EoL. The study

highlights that a decision for a certain technology and product performance is linked to the use of hazardous substances. A restriction of hazardous substances in turn has an impact on the LC perspective in as far as benefits in one LC phase might cause burdens in another, e.g. less energy efficient performance due to a restriction in hazardous substances' use. (Ardente et al., 2011a)

3.4.2 Energy Label objectives for the product use-phase

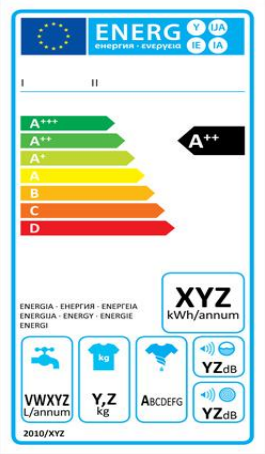


Figure 3-5. The Energy Label.

Source: Europe's Energy Portal, 2012

The Directive 2010/30/EU of 19 May 2010 on the indication by labelling and standard product information of the consumption of energy and other resources by energy-related products applies to ErP with a significant direct or indirect impact on the consumption of energy and, where relevant, on other essential resources during use. (Official Journal of the European Union, 2010)

In essence, the energy label points out the most energy efficient and hence, cost saving appliances to consumers and manufacturers, the latter of whom might be encouraged to improve their own products. The standardised provision of information and its simple design characteristics, both of which allow for comparisons, contribute to its success: Energy levels shown in distinct colour codes rate a product's energy efficiency from A to G, whereby 'A' represents the most energy efficient and 'G' the least energy efficient product. The label was reviewed to add three different classes within the A group: A+, A++ and A+++. (Europe's Energy Portal, 2012) A supply-side focus is inherent to the Ecodesign Directive. In contrast, the Energy Labelling Directive attends to the demand-side. De Wilt (2011) points out that "it is the combined effect of both measures which ensures a dynamic improvement of the market."

3.4.3 WEEE resource efficiency objectives for the product EoL phase

Recycling and recovery of electrical and electronic equipment with the objective to reduce the quantity of e-waste sent for final disposal, constitutes the core objective of the EU Directive 2002/96/EC on waste electrical and electronic equipment (WEEE Directive) of which article nine[11] was replaced in Directive 2003/108/EC. The Directive main principle is extended producer responsibility which requires producers to take WEEE back at its EoL and consumers to return products to the producers. (Official Journal of the European Union, 2003b, c) With a view to product design and RE, article four of the Directive is most relevant. It requires member states to "encourage the design and production of electrical and electronic equipment which take into account and facilitate dismantling and recovery, in particular the reuse and recycling of WEEE, their components and materials." (Official Journal of the European Union, 2003b, Art. 4) Member states are to ensure that design features of products or manufacturing are not used as a way to prevent WEEE from being reused with the exception of overruling advantages which might include safety requirements and, or environmental protection. (Official Journal of the EU, 2003b)

Another particular aspect of the WEEE Directive which is to contribute to RE objectives, is Article seven which introduces weight based objectives for recovery and requires from member states to guarantee that producers or their authorized representatives maintain documentation on "the mass of WEEE, their components, materials or substances when entering (input) and leaving

[11] It addresses the financing of WEEE from non-private household users. (Official Journal of the EU, 2003c, Art.1)

(output) the treatment facility and/or when entering (input) the recovery or recycling facility."(Official Journal of the European Union, 2003b, Art. 7) Ecodesign, combined with the RoHS and WEEE Directive and REACH regulation, jointly addresses the different layers of the waste management hierarchy, as depicted in the Directive 2008/98/EC on waste, commonly referred to as Waste Framework Directive, shown in figure 3-6.

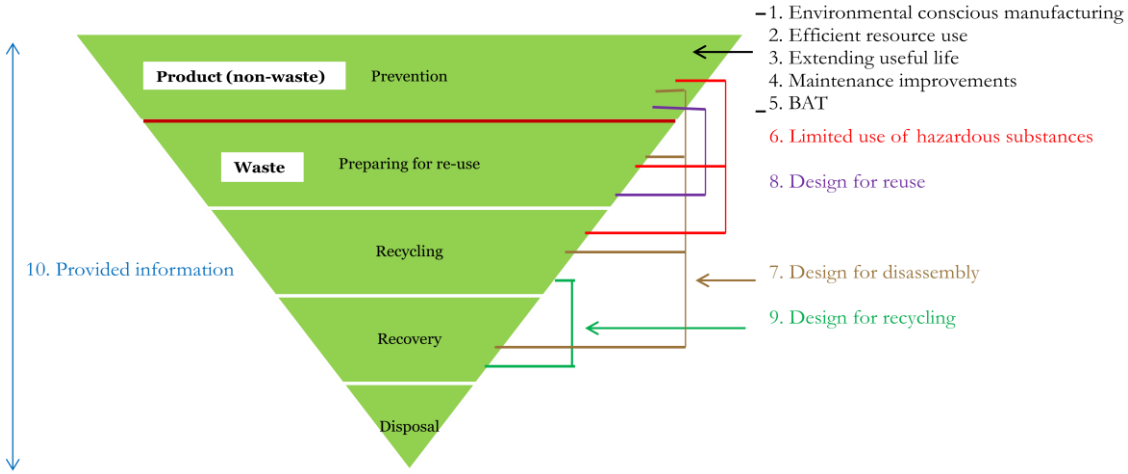


Figure 3-6. Links among Ecodesign strategies and the Waste Management Hierarchy

Source: adapted from Ardente et al., 2011a and EC, 2008a.

3.4.4 The Ecolabel criteria for the entire product life cycle

The EU Ecolabel (EC ENV, 2012), as briefly described in section 1.1.4, takes account of all LC phases of a product and is a type I label according to ISO standard 14024. The EU Ecolabel ecological criteria and the IM of the Ecodesign Directive are complementary as they both address the entire LC of a product, and share similar characteristics[12], whereby the latter cuts the worst performers off the market and the former provides information on the environmental superiority of the product in comparison to others on the market, as illustrated in figure 3-7.

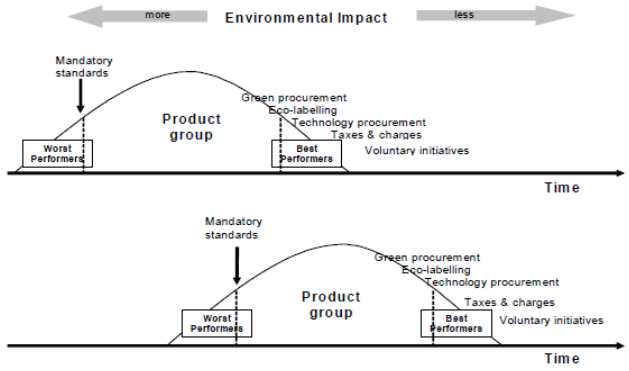


Figure 3-7. Policy instruments and environmental performance of product groups over time

Source: Dalhammar, 2005. Joint figure development by Dalhammar, C., Lindhqvist, T. and Van Rossem, C.

[12] Both instruments "clearly set out a product group definition, are LC based, consider EU market sales, identify differences between technologies in a product group and best practice, identify consumers as being important in the delivery of environmental improvement, involve stakeholder consultation." (Ardente et al., 2011, pp. 121)

Both are dynamic tools in the sense that they need regular revision and upgrading. Their synergies could be best explored if the revision was done at similar times to ensure coherence with a view to the common set of criteria.[13] (Ardente et al., 2011a) A policy mix which combines EU Ecolabel criteria and the IM of the Directive can also lead to an enhancement of Green Public Procurement. (Ardente et al., 2011a)

3.5 Effectiveness and efficiency review of the Directive

The evaluation study was conducted by the Centre for Strategy and Evaluation Services (CSES) in 2012, in response to Article 21 of the Directive and according to the standard evaluation methodology, assessed "the relevance, effectiveness, efficiency and European added-value" of the Directive, besides evaluating the possible extension of the Directive to non-ErPs and transport. (CSES, 2012, p. 1) Stakeholders were consulted in three and data to be used for the assessment was also obtained through an on-line survey and interviews with representatives from the EC, officials from EU member states, and representatives of industry and environmental NGOs. The limitations of the evaluation were in the timing, as most of the nine product groups for which IMs had entered into force in 2008 or 2009 had not yet advanced beyond the first set of requirements, and in available data, which was between two and three years old and correlated to the period before the adoption of the IMs. (CSES, 2012)

The Directive is "well placed as a policy instrument" within the context of its policy framework constituted by the SCP/SIP Action Plan and EU policy for sustainable industrial policy as per Europe 2020 and its two flagship initiatives, as described in section 1.1.5. According to CSES (2012), most stakeholders perceived the aim of the Directive to remove worst performing products from the market, as "appropriate". While an effective link between the Directive and Energy Labelling has been observed, bringing together the Directive with GPP and the EU Ecolabel has not entirely been achieved yet. Several "grey areas" have been discovered regarding the crossing points between the Directive and regulatory instruments including WEEE and RoHS, out of which "missed opportunities" or "inaction" could result. (CSES, 2012)

3.5.1 Effectiveness and Implementing Measures

With a view to the effectiveness of the Directive and the IM, as mentioned above, tier two requirements were still to enter into force for most product groups with adopted IMs and a lack of up-to-date data influenced the evaluation. Against this background, and with relevance for this work, it was expected that "an IM would also make a substantial contribution to changes in the case of electric motors". (CSES, 2012, p. 3) The study revealed no negative impact of the Directive and IM on EuP prices and further concluded that perceptions from industry do not suggest that the Directive "introduced excessive additional costs". It pointed out that due to significant lead times granted in advance of the introduction of demanding tier two requirements to companies, they were able to incorporate production changes into their product design cycles. (CSES, 2012)

Of interest for this work is that the CSES study (2012, p. 3) highlighted the "positive role [of the Directive] in encouraging the adoption of existing innovative technologies and the promotion of innovation (although this is not an explicit objective)". It is further concluded by the study "that the Directive and the relevant IMs provide the necessary framework conditions (...) to support the operation of a competitive market". (CSES, 2012, p. 4) Solely a limited effect on the promotion of BAT and innovation was noted by the identified advanced benchmarks in the IM and it was recommended that their function could be further reinforced. (CSES, 2012)

[13] In section 5.3.2, this point is explained further under the terms of common set of criteria and escalation process.

3.5.2 Efficiency of the process attached to the Implementing measures

The Methodology for the Ecodesign of Energy-related Products (MEEuP), which was reviewed in detail in a parallel study[14], was perceived as fulfilling its main task of identifying significant environmental aspects and the relevant requirements, even if certain aspects of it and the EcoReport tool have been criticised. On average, the development of IM took four years with delays being noted as a result of limited resources within the EC. Further, a requirement for improved harmonization between the process attached to the development of IM and measurement and test standards has been noted. Use of old data in the preparatory study carries the risk of setting requirements which become outdated at the time of the entry into force of IM and might be not stringent enough to allow for a reflection of market and technological development. Regarding market surveillance and enforcement of the Directive, the study (2012) suggests, based on evidence, a non-compliance level between 10 and 20 per cent with one of the compelling reasons being insufficient resources in member states dedicated to monitoring and enforcement. On the positive side, "a very high benefit to cost ratio" has been noted as to the cost-effectiveness of the Directive with expected savings between 90 and 120 billion Euro against implementation costs between 320 and 450 million Euro. (CSES, 2012)

An aspect raised by the study relates to a combination of generic requirements on specific environmental parameters with performance standards, as was proposed for TVs, which is recommended to be reflected on in future IMs and reviews of regulations. The effectiveness of voluntary agreements was not assessed as part of the study, however, it suggests that the process attached to arriving at the agreements is, compared to the one attached to IM, not significantly easier. Further, the benefits are perceived to be in permitting creative approaches to technical issues and in providing a tool to monitor market developments, not part of the IM. (CSES, 2012)

3.5.3 Directive extension to non-energy related products

Against the background of significant environmental impacts of consumer products, specifically non-energy related products (non-ErPs) and the potential positive impact of product design requirements, the Ecodesign Directive appears to be able to contribute theoretically to environmental improvements. Nevertheless, considerations as to the feasibility of including product groups if measurement and testing methods are absent to support the adoption and implementation of requirements need to be made. These considerations are to be extended to the conformity assessment which would have to rely on certification or declaration schemes rather than product testing and would entail "substantial administrative costs for industry and a high risk of non-compliance" since many of the non-ErPs are characterised by global supply chains, large shares of small and medium-sized enterprises (SMEs) and fragmented markets. (CSES, 2012)

The study further highlights chemical products, furniture and mattresses, and toys as priority products if the Directive was to be expanded to non-ErPs while outlining simultaneously that an extension, if funding levels were to be kept the same, would potentially negatively affect the implementation of the Directive in its current scope. Thus, the study recommends voluntary initiatives for some non ErPs as a better, less costly and more flexible, alternative. (CSES, 2012)

3.5.4 Evaluation-based recommendations

The allocation of additional EC resources to allow both for an improvement in clearing the backlog of IM for EuPs and minimum delays in the adoption of IMs for ErPs is recommended

[14] The MEEuP has been revised in a parallel study conducted by Kemna et al. (2011) on behalf of COWI and Van Holsteijn en Kemna B.V. [VHK] for the EC DG Enterprise and Industry. Findings and recommendations are elaborated in section 3.6. (MEErP, 2012)

and is accompanied with the call for more moderate ambitions in case a stock-up in EC resources is unfeasible. Further, increased coherence between the Directive and related policy instruments is considered beneficial and thus the study suggests the development of a practical guidance document for that purpose. Complex or systems of products are to be the subject for special provisions. (CSES, 2012) The IMs review process is perceived to provide options for the introduction of a "dynamic aspect to the Directive" with a potential revision both of the minimum energy efficiency requirements set in the IMs and the initial analysis' conclusions as to the introduction of requirements for non-ErPs. In addition, a scrutiny review as to introducing longer term requirements based on advanced benchmarks could be conducted. (CSES, 2012)

As to the efficiency of procedures and approaches to address the backlog, a prioritisation of products according to their energy saving potential and relative easiness to be regulated, is recommended along with the setting of specific timeframes and deadlines for the completion of each IM. An as early as possible, clear identification of the scope of product categories, guidance documents for the systematisation of the discussion and consultations as part of the path towards IM, and additional work to improve metrics is proposed. The study further advocates voluntary agreements as alternative to IM. (CSES, 2012)

A solution for the improvement in the communication of ongoing developments is perceived to be in a single portal bringing together all activities under and providing information on IM and related policy tools of the Directive. To advance the objectives, the establishment of a "dedicated institutional framework" is advocated which might take the form of an agency or an expansion of JRC responsibilities to the implementation of the Directive and market development monitoring to support measure development in the future. (CSES, 2012)

Concerning market surveillance and enforcement, the crucial role of member states in surveillance is highlighted along with a call for their additional efforts, which is accompanied by a recommendation to request the publishing of their activities' results on a specific website[15], and for a more active promotion of cooperation by the EC. The idea of introducing a registration requirement of new products by the party introducing the product into the internal market, either into the Directive or the product IM is brought up with the purpose of reducing administrative costs, facilitating market surveillance and obtaining an overview of market developments.

Regarding the extension of the Directive scope to non-ErPs, the study takes an explicit stance in not recommending it and emphasizes the necessity to achieve significant progress in its current scope in the meantime. It highlights the need to further explore the use and effectiveness of the generic requirements and the ecological product profile and calls for a support and extension of the effort to develop practicable and widely accepted methodologies which are to identify and measure environmental impacts of products. (CSES, 2012)

3.6 Methodology revision for Ecodesign of Energy-related products

The Methodology for the Ecodesign of Energy-using Products (MEEuP) was drafted with the purpose to support the evaluation of EuP, namely if and in how far they meet the criteria which make them suitable for IM under the Ecodesign Directive 2005/32/EC. The recent MEErP report, which comprised four tasks divided into two parts, was conducted by Kemna et al. (2011a to c), and served on one hand to review the effectiveness of the methodology and update it, where necessary, following its application for five years in the evaluation of IM of EuP in preparatory

[15] This is an approach which has also been adopted by the Energy label.

studies. On the other, the aim of the report was to extend its scope to ErP, and assess new ErP against the criteria underlying the Ecodesign Directive 2009/125/EC. (Kemna et al., 2011a)

A total of 245 stakeholders from European industry associations including SMEs and craft industry, consumer organisations, environmental NGOs, member states representatives, organisations or individual experts and surveillance authorities, were invited, through the established project website[16], to rate the usefulness of the existing MEEuP in a questionnaire and participate in a stakeholder meeting. More than 50 stakeholders' input on the questionnaire was received whereby specific ratings were provided by 35. The MEEuP usefulness was on average rated with 75 per cent. The review of the MEEuP on an international scale revealed its uniqueness in applying a "cradle-to-grave" approach which "can lead to measures for both RE and environmental impacts". (Kemna et al., 2011a, p. 6) Regarding the standard setting through LLCC, the MEEuP is orientated strongly on the US Department of Energy approach for Appliance and Equipment Efficiency Standards. BAT levels as input for product legislation are a core of the Japanese Top Runner Program, which will be described in chapter 4. (Kemna et al., 2011a)

The MEErP structure, depicted in figure 3-8, has been elaborated based on the stakeholder comments and introduces a clear division between tasks one to four and between tasks five, six and seven. While tasks one to four can be carried out simultaneously and aim to collect data as well as present an initial analysis, task five to seven are to be conducted in sequence with the emphasis being on modelling. (Kemna et al., 2011b)

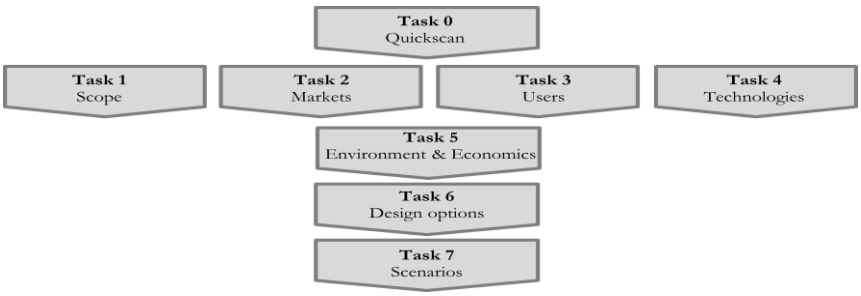


Figure 3-8. MEErP structure

Source: adapted from Kemna et al., 2011b

Task zero is optional and refers to a first product screening as to the environmental impact and potential for improvement in line with Art. 15 of the Directive. It is to be conducted with the aim of narrowing down the product scope for ecodesign. In task one, definitions are elaborated and existing standards and legislation reviewed. Task two is concerned with obtaining data on market volumes and prices. While task three addresses the product demand side, task four attends to the product supply side, including BAT and best-not-available technology. In task five, a base case LCA and LCC are conducted, task six discusses design options, and policy, scenarios and the conduct of an impact and sensitivity analysis form part of task seven.

The most relevant update in the MEErP for this work refers to the addition of critical raw materials (CRM) to the indicators. "Analysts that will carry out preparatory studies should consider CRM, if applicable, as a new element of the MEErP, for example to check possible design options that substitute or make it easier to recover CRM components." (Kemna et al., 2011b, pp. 31) In the summary of the impacts provided in the Annex to the report, the main characterisation and

[16] The project website can be found at www.meerp.eu.

accounting rules applied to the MEErP are provided and a separate indicator for specific materials of interest, which includes CRM input in kg antimony equivalent with a characterisation factor[17] of 0.03 for rare earth metals, or in the kg tungsten equivalent per kg of a 0.15 factor for rare earth metals, is illustrated. (Kemna et al., 2011b, p. 103 and p. 115)

The quantitative analysis of the EoL stage has been made more concrete, demanding for new assessment such as of the stock-effect and the recyclability of parts which are not electronics. The driver for this extension is the policy priority of resource conservation. (Kemna et al., 2011b) An update of the EcoReport[18], an Excel tool in form of a simplified LCA, comprised the adjustment of unit indicator values with the updated characterisation. An input worksheet on extra materials was included to allow manufacturers to define unit indicators of materials or processes which are relevant for a specific product.

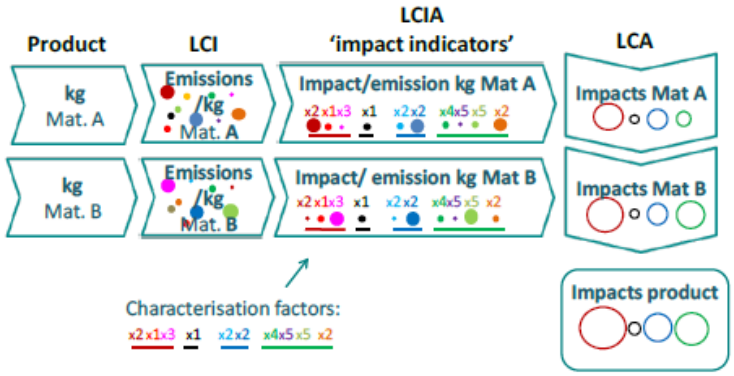


Figure 3-9. Environmental analysis data structure

Source: Kemna et al., 2011b, p. 89

Figure 3-9 provides a simplified version of the steps of data preparation in the conduct of an LCA, the first of which is the compilation of a life cycle inventory (LCI), followed by a life cycle impact assessment (LCIA) in which applied multipliers for each emission generate one measurement unit of an environmental impact, e.g. global warming potential. This result then allows for a final analysis, also referred to as LCA, for which "the unit indicators of the LCIA are multiplied with the amount of materials used which results in the impacts per material use/disposal and the amounts of performance units required". (Kemna et al., 2011b, p. 89)

In the EcoReport, the total impacts of the product are obtainable from the result sheet which shows them, drawing on the normalisation table, as a fraction of the EU-27. The result provides a quick overview to which extent the result and which impacts of it can be called "significant". (Kemna et al., 2011b)

Also, the MEErP provides more guidance on the distinction between "extended product" and "system" approaches. The example in figure 3-10 briefly outlines the extension possibilities from a mere product approach. (Kemna et al., 2011b) The discussion of the extension takes both an

[17] The characterisation factor comprises "EU import dependence, post-consumer recycling rate and substitutability". (Kemna et al., 2011b, p. 103)

[18] The EcoReport works with the input of data from the BOM, energy and other resources used during product life. It also uses key parameters for manufacturing, distribution and end-of-life as input parameters. With the Unit Indicators, the tool generates the environmental impacts for the indicators required for the four product-LC stages: production, distribution, use and EoL. These impacts are summarized on the "Output" worksheet. (Kemna et al., 2011c, d)

economical and a technical perspective. Every step describing the actual use of the product also adds to the economical calculations, in particular the LLCC, which, as described earlier, contribute to defining the ambition in the regulation. From a technical point of view, extra features accompany every new level of detail which comes with the realisation that "the most efficient and performing products are those with a high level of integration of functions, tailored to the specific need." (Kemna et al., 2011b, p. 60)

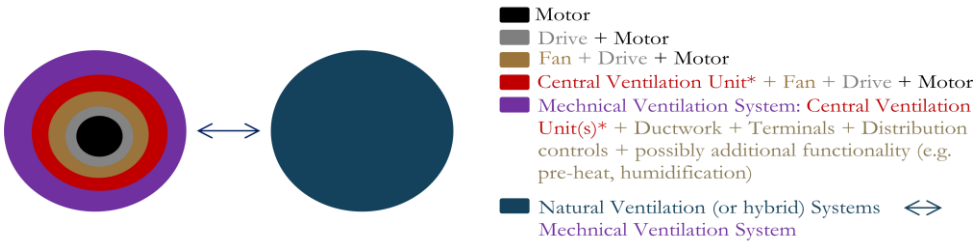


Figure 3-10. Ventilation product example for the extension of the product approach

Source: Kemna et al., 2011b

As highlighted in the findings, the MEEuP revision and its extension to ErP set out at improving the tools available to quicken the process for elaborating IM. It also aims at increasing the emphasis on environmental aspects e.g. through the facilitation of a more simplified EcoReport.

The attempt to quantify material use in more detail and thereby add to the characterisation process as part of the LCA, such as through the additional worksheet on extra materials, in combination with product specific regulations might in the long run encourage changes in the product and potentially promote eco-innovations.

3.7 Eco-innovation

Eco-innovation is a pillar of the renewed EU Lisbon strategy for growth and employment. (EC, 2007) The "strong promotion and diffusion of eco-innovations and environmental technologies" was also approved in the Presidency Conclusions of the 2006 Spring Council. (EC, 2006, part 3 d (76)) The conclusion further highlighted the important role of ETAP and recommended a consideration of performance targets. (EC, 2006)

The EC (2007) report of the Environmental Technologies Action Plan (ETAP) 2005 - 2006, considered eco-innovations and environmental technologies essential to change existing industrial processes, business and products for a more sustainable development. It explicitly states that eco-innovations should become omnipresent in all industries and recommends financial support and regulation as supporting instruments to accomplish the goal and thereby foster a market development towards a competitive and green leading world-economy. In the report, eco-innovations are understood as "any innovation that benefits the environment - embracing technological innovation, process innovation and business innovation". (EC, 2007) Huber (2008) noted that environmental innovations occur in pioneer countries with lead markets, as the most critical stage in the LC of an innovative product is its market introduction. For Jänicke (2008, p. 558), "eco-innovation" is a synonym of ecological modernisation. He adds that "environmental innovations should be as creative as possible to prevent resistance of the losers of “ecological modernisation”. Innovation can also be referred to as “creative *destruction*”, which implies a conflict with vested interest, such as e.g. of power-based resistance to climate change strategies. (Jänicke, 2008) He defines it as the "introduction of environment friendly technology which also increases resource productivity." The *definition of eco-innovation in this report* leans on Jänicke's with the

understanding of it as innovations that introduce technologies which are more environment friendly as a result of increased resource productivity which is due to RE. An increase in RE could be achieved through various changes in the product itself or its LC. Options for adopting RE and the implications attached to its measurement are addressed in the next section.

3.8 Resource efficiency measurement

With the acknowledgement that resource efficiency and the discussions accompanying it, could be a topic of its own, this section solely attempts to provide a brief outline of the main aspects relevant to this work. It will refrain from evaluating indicators or discuss the ones which have been identified for material use, amongst others, in the UNIDO report conducted by Hirschnitz-Garbers et al. (2012), and the report prepared by BIO Intelligence Service, and the Institute for Social Ecology and Sustainable Europe Research Institute (2012).

Dahlström and Ekins (2005) define RE as a basic ratio of two resource variables of the same kind, measuring the physical output per unit of physical input. M*aterial or resource efficiency* is measured as:

useful material output (M_o) per total material input (M_i)[19]

The term *productivity* in general relates to the production of some other useful output or welfare by an input. *Material or resource productivity* would be described as:

the economic output (Yo) per unit of natural resource input (Mi)

Both indicators express different perspectives of eco-efficiency, the resource productivity indicator can demonstrate the effectiveness in decoupling economic growth from resource use. (Dahlström and Ekins, 2005) The challenges of increasing RE remain with the economic and political feasibility and implementation of measures which are tied to the use of quantifiable indicators to demonstrate the effectiveness and efficiency of applied instruments. The EC (2011c, d) has taken up resource productivity and several complementary indicators on key natural resources including water, land and carbon for its measurements of resource use. The *reason for the choice of the RE indicator* over resource productivity is inherent to the ecodesign emphasis prioritizing material use.

Several recommendations have been made for adopting RE in the context of the ecodesign requirements of the Ecodesign Directive. Table 3-2 presents a typology of potential requirements. In the assessment of the parameters identified in the table, namely the 3 Rs, use of recycled materials/ recycled content, use of priority resources, and use of hazardous substances, methods which allow for measurement and verification are needed. In the second deliverable of the study on the integration of RE and waste management criteria in the IM under the Ecodesign Directive, conducted by Ardente et al. (2011a), the essential role of the Bill of Materials (BOM) in characterizing the composition of a product and performing further assessments and calculations, was highlighted. It constitutes "one of the main data sources for the environmental assessment of the product at the design stage" according to a scientific literature review conducted by Ardente et al. (2011a, p. 18) and can contain also additional technical details of the product. The MEEuP is also based on the BOM merged with data from a products' four LC stages. (Ardente et al., 2011a) The study by Ardente et al. (2011a, p. 21), also addresses priority resources, including REE and

[19] Energy efficiency could be defined in a ratio of useful energy output (E_o) per total energy input (E_i) or *Eo*/*Ei*. (Dahlström and Ekins, 2005)

recommends that these are to be "identified and listed in the BOM". It further highlights the need for high detail in the product composition since these materials occur only in small traces. With a view to recycling and reuse, the study recommends that manufacturers design the products in a way that allows for the easy "identification, assess and disassembly of components containing priority resources". (Ardente et al., 2011a, p. 21)

Table 3-2.Typology of potential requirements

	No.	Potential requirements description	Descriptive requirement	Declarative / demonstrative requirement	Threshold requirement
3 Rs and 3 Rs benefits	1	Declaration of the "Reusability Benefit Ratio"		x	
	2	Declaration of the "Recyclability Benefit Ratio"		x	
	3	Declaration of the "Energy Recoverability Benefit Ratio"		x	
	4	Threshold of the Reusability Benefit Ratio			x
	5	Threshold of the Recyclability Benefit Ratio			x
	6	Threshold of the Energy Recoverability Benefit Ratio			x
	7	Manual disassembly of key components	x	x	
Recycled content	8	Declaration of the recycled content of plastics		x	
	9	Threshold of the recycled content of plastics			x
Use of haz. substances	10	Manual disassembly of components containing hazardous substances	x	x	
	11	Content of hazardous substances into key components	x	x	
	12	Limit of hazardous substances into plastics			x
Multiple targets	13	BOM	x		
	14	Identification of plastic components	x		
	15	Contamination of plastics			x
	16	"Monomaterial"			x
	17	Compatibility of labels with recycling			x

Source: Ardente et al., 2011b

For the measurement of the parameters, it is generally required to have a list of used materials, the mass of the materials and the content of e.g. the recycled waste used in the manufacture of the material or in the case of the 3Rs, the technologies available to allow for recycling or recovery. (Ardente et al., 2011a) A RE measurement option feasible for implementation needs to have several characteristics. It needs to be:

- practicable (given that the level of detail in the data required might make the measurement already quite complex, Ardente et al., 2011a),
- easy to understand and adopt, and
- ideally measurable on the product or through other means such as self-declaration.

Within the EU, the emphasis on finding adequate parameters for the measurement of RE has been a result of the understanding that RE contributes to competing successfully in the global market. The next chapter explores the correlation between standards, regulation and competitiveness.

4 Regulation, efficiency standards and competitiveness

While Jänicke (2008) does not perceive innovation to be limited by environmental regulation, Huber (2008) insists that stringent regulation is imperative to innovation. In general, regulatory trendsetters often start with regulation, which then results in global market harmonisation. Jänicke (2008) recognizes the obstacles created by regulation for businesses and industry, but observes also benefits in the regulation for the regulated, namely in that it (1) establishes "support markets for domestic industries". The Japanese Top Runner Program is mentioned as example and will be further described in section 4.1. Another advantage is seen in (2) the market predictability created through regulation. To some extent it reduces the weight of complexity and insecurity carried by innovative firms which operate on a global scale. A further benefit of regulation lies in its inherent (3) certainty. The uncertainty regarding competitors' moves, which exists with voluntary approaches, is taken away, as all affected companies need to adhere to the regulation. Due to its mandatory nature, regulation also (4) cuts obstacles within a firm such as for the adoption of a technological change, which, despite potential energy savings, might not have been taken up earlier as it would have entailed some organisational efforts. An additional benefit in that respect is that e.g. technological changes can be made (5) without reassurance from the value chain as customers simply need to accept regulation-induced change. (Jänicke, 2008)

Regulations often refer to standards. A standard is a published document which has been elaborated collaboratively with stakeholders and serves to provide either a technical specification or other precise criteria which can be consistently applied as a definition, rule, or guideline. Their purpose is to improve many goods and services through augmented effectiveness and reliability. Most important for this work is that they are to be used on a voluntary basis and are not to be understood as regulations, even if regulations sometimes refer to and demand obligatory compliance with them. (British Standards Institution, 2012)

Performance standards for instance, in contrast to best available technology (BAT) and procedural standards, can be matched with green taxes or subsidies. The design of energy efficiency standards is based on three available methods: the minimum standard value system, the average standard value system and the maximum standard value system. (Ministry of Economy, Trade and Industry [METI], 2010) Minimum efficiency standards are considered to be a very effective product strategy for enhancing energy efficiency. (Geller et al., 2006 and Siderius and Nakagami, 2012)

In the minimum standard value system, with the most prominent on a global scale being the Minimum Energy Performance Standard (MEPS), the targeted products must exceed a minimum value. In case the product regulated by the standard, does not exceed the value, product shipments can for instance be suspended. The challenge in applying MEPS is inherent to the careful conduct of evaluations of the economic validity of the standard values to establish efficiency standard values that all products must exceed. (METI, 2010)

In the average standard value system, the target values are determined based on numerous factors including potential impact of categorical improvement and potential technical improvement based on the information provided by manufacturers. The regulated products are to achieve a weighted average value by the target fiscal year whereby the shipment volumes by product category of the manufacturer are considered. Due to the measurement, the manufacturer can outweigh shipments of less energy efficient products against the shipment of a higher energy efficient product in the same product category or the same functional parameter. (METI, 2010)

The maximum standard value system, applied in the Japanese Top Runner Program (TRP), uses the value of the product with the highest energy consumption efficiency on the market at the time of the standard drafting. Potential technological improvements are regarded as efficiency

improvements in the elaboration of the standard values. As in the average standard value system, manufacturers are assessed against their target through weighted average values. (METI, 2010)

Both the average standard value system and the maximum standard value system aim at incentivizing manufacturers to develop products with higher energy efficiency values. (METI, 2010) Higher efficiency both in energy and resource use, is essential to global competitiveness, and as the famous Porter hypothesis adequately puts it: "Ambitious environmental regulations may be challenging for the national industry at the very beginning, but help to improve international competitiveness and to increase exports of the developed environmental technologies." (Porter and van der Linde, 1995, in Blind, 2012)

The increased use of environmental technologies brings along two clear benefits. On one side, the protection of the environment can be facilitated, and on the other, global industrial competitiveness can be enhanced. This idea has been a driver in the drafting of the EU Environmental Technologies Action Plan (ETAP). (Tojo, 2005) The EC (2011c) sees the benefits of innovation in its potential to "drive productivity, growth, and industrial competitiveness". EU continued leadership in environmental performance was also addressed in its Action Plan for Sustainable Consumption and Production (SCP) and Sustainable Industrial Policy (SIP) which recommended, amongst others (EC, 2008c):

- the promotion of eco-innovations with the aim to facilitate EU business orientation towards the market of the future, and
- the support of the competitiveness of eco-industries and thereby contributes to a less-carbon intense global economy.

In the EC (2008c) report on the SCP/SIP Action Plan, patents are depicted as an indicator for the level of innovations. The report refers to OECD data which stipulates an increase in eco-innovation patents in the EU annually juxtaposing the number of patents granted per billion GDP in EUR, whereby the ratio in best performing member states is 3.5 patents. (EC, 2008c)

The EC acknowledges that "new technologies make it possible to produce commercially at ever smaller volumes and advanced materials, (...)."(EC, 2011c, p. 7) A shared understanding relates to the EU need to increase the speed in taking up these technologies in order to stay competitive on a global scale. In that respect, the EC (2012e) has identified six Key Enabling Technologies[20] (KETs), "(...) micro-/nanoelectronics, nanotechnology, photonics, advanced materials, industrial biotechnology and advanced manufacturing technologies (recognised as a "cross-cutting" KET)" which are considered to be "a key source of innovation." (EC, 2012e, p. 3) It is being recognized that these KETs provide building blocks of technology which facilitate numerous product applications, "including those required for (...) improving energy and RE (...)." (EC, 2012e, p. 3) In its KETs promotion, the EC urges quick action, highlighting recent industry specific[21] decreases in the European global production share which benefited competitors in Asia. (EC, 2012e)

Against this background, policies are needed which address both competitiveness and eco-innovations in KETs. Many calls for a EU orientation towards the Japanese Top Runner Program

[20] "A KETs-based product is defined as (a) an enabling product for the development of goods and services enhancing their overall commercial and social value; (b) induced by constituent parts that are based on nanotechnology, micro-/nanoelectronics, industrial biotechnology, advanced materials and/or photonics; and, but not limited to (c) produced by advanced manufacturing technologies." (EC, 2012e, Annex (1))

[21] One of the affected industries is the machine tool industry where " (...)the European share in global production dropped from 44% in 2008 to 33% in 2010, to the advantage of Asian competitors, namely China (including Taiwan) and Korea." (EC, 2012e, p. 4)

(TRP) have been made and the feasibility of adopting a European version is still being investigated. Siderius and Nakagami (2012) noted in that respect the uniqueness of the TRP as compared to the Ecodesign Directive which can be compared to other product efficiency standard schemes such as the US DOE standards (US DOE, 2012) or the Australian MEPS programme (Commonwealth of Australia, 2010).

4.1 The Japanese Top Runner Program

The Japanese Top Runner Program (TRP) was introduced in Japan to improve the use-phase energy efficiency of selected product groups. One of the important characteristics of the TRP is the standard setting manner, which is based on the principle to use the use-phase energy efficiency of the highest achieving product in its class, the "top-runner", as a basis of the energy efficiency standard which is to be met by all manufacturers in the agreed target year. In the target year, the new top runner is assessed and the cycle recommences. Another characteristic of the TRP is that producers are evaluated against their fulfilment of the mandate through the weighted average of energy efficiency in the products they place on the market, also referred to as "fleet average criterion". Therefore, the TRP is "formally not a MEPS. (Siderius and Nakagami, 2012) Targets are set according to the maximum standard value system in which the targets are based on the value of the most energy-efficient products on the market at the time of the value setting process. The standard value is set under consideration of potential technological improvement options which are added as efficiency improvements.[22] (Tojo, 2012)

In general, when disregarding that technological improvement options are taken into account, standards in the TRP can be said to be market driven given that they are set with reference to a product available on the market. A product which is to be considered under the TRP needs to be used in significant quantities in Japan and needs to consume in its use phase a considerable total amount of energy, having the potential for energy efficiency improvements. (METI, 2010) Product catalogues, which are published twice per year and relate all available models regarding their TRP performance, provide an updated overview of the products' market performance.

The TRP can be considered a participatory instrument as stakeholders collaboratively define indicators, methods and target standards, and agree on the compliance period duration. (Nordqvist, 2007) Other policy instruments, both mandatory and voluntary, complement the TRP. An obligation for manufacturers to provide information counts among the mandatory instruments while the labelling and award scheme for retailers is voluntary. (Siderius and Nagakami, 2012)

The TRP applies a "name and shame" approach[23] in the case of non-compliance. (Tojo, 2005) This effective part of the enforcement of the TRP appears to have a country-specific context and therefore, has been questioned, as to its potential effectiveness in a European setting. This discussion is of relevance as recent policy debates have increasingly addressed the feasibility of adopting a similar policy instrument with TRP elements in Europe. Greenpeace Germany has prepared a policy recommendation in 2005, and the German Federal Ministry for the Economy (BMWi) and the Federal Ministry for the Environment (BMU) published and circulated a joint

[22] "This means on one hand that in some cases an outstandingly energy-efficient product does not become a standard setter, especially when achievement of the standard would require the usage of a unique technology applied to the product. On the other hand, when potential technological development is perceived to be great, the level of standards becomes higher than what the top runner product achieves." (Naturvårdsverket, 2005)

[23] The "name and shame" approach is a commonly used term in this context to describe the recommendations made by the METI to the manufacturer in case of non-compliance, which will be published in case the manufacturer does not follow them. (METI, 2010)

concept paper recently. (BMWi and BMU, 2011, and Jepsen et al., 2011a) The following section highlights the main features suggested.

4.2 Proposed EU top runner approach

In their concept paper on the product-related top runner approach at EU level, which is, along with the joint concept paper prepared by BMWi and BMU, also known as the German policy concept, Jepsen et al. (2011a, p. 9) remark that the existing EU product policy mix containing both market push and pull elements[24], is "an appropriate regulatory framework" for ErP and comparable to regulatory schemes in other economic regions.[25] They recommend an alignment of minimum efficiency standards and other ecodesign requirements with BAT in addition to a revision of the "standardised assessment methodology" which emphasizes least life cycle costs (LLCC) for the selection of efficiency options.

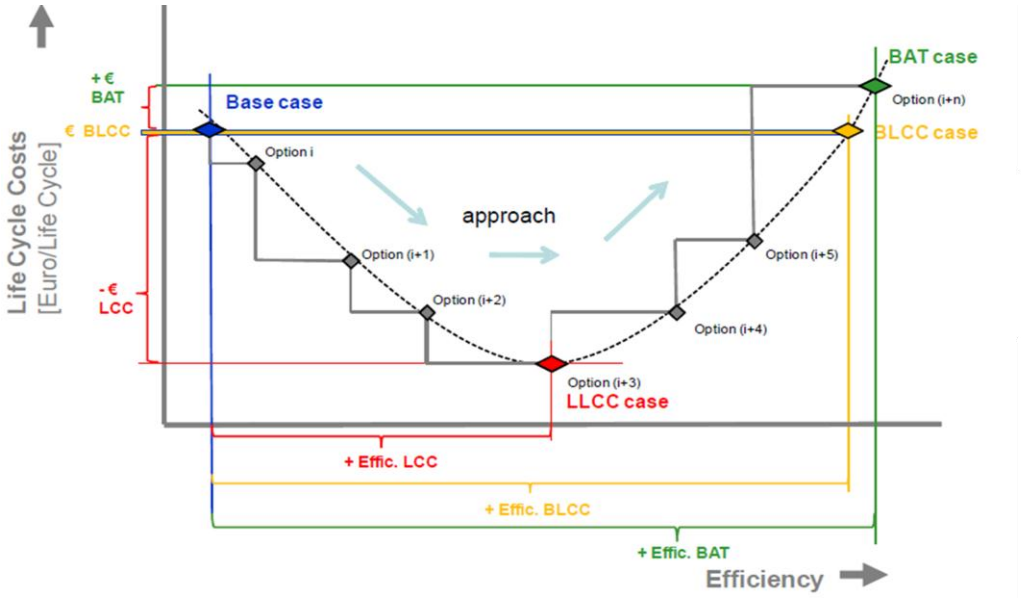


Figure 4-1. Definition of LLCC and BAT case (MEEuP), and recommended BLCC

Source: Figure prepared by Ökopol in Jepsen et al. 2011a, and BAM and Federal Environment Agency, 2012

According to the MEEuP, departing from the base case, the current technical available improvement options are collected and ranked according to their cost efficiency. The base case is being modified with these options as long as the simulated LC costs continue to fall. The LLCC case is the LC cost optimum. All best combinable options are represented through the BAT case. Figure 4-1 illustrates this approach and clearly depicts the differences in the achievable efficiency improvement options, as shown via +Effic. LCC versus +Effic. BAT and in the cost shown as - € LCC versus + € BAT. (Jepsen et al. 2011a) The best life cycle case (BLCC) presents the break-

[24] Market push elements refer to a regulatory "push" induced by mandatory instruments which by the application of e.g. energy labelling or minimum requirements such as through the IMs of the Ecodesign Directive eliminate worst performers among available products. On the contrary, a market pull towards high performing products, is achieved with voluntary but strict environmental performance standards, e.g. in the EU Ecolabel, or through requirements in GPP. (Ökopol "EU mix of policy instruments for EuPs in Jepsen et al. 2011a)

[25] An evaluation of policy concepts from other large economic regions including Australia, Japan, South Korea, Switzerland and the USA, which comprised a comparison of the EU policy mix according to the SCP and SIP Action Plan, revealed that certain elements always form part of the framework, namely: "minimum efficiency requirements, energy consumption labelling schemes, labelling of efficiency front runners and, or requirements for public procurement". (Jepson, 2011a, p. 7)

even point in the MEErP report. (Bundesanstalt für Materialforschung und -prüfung [BAM] and Federal Environment Agency, 2012) Pursuing a BAT approach as compared to the LLCC, could lead to potential higher costs for the user and ecodesign requirements on the level of BAT could thus be in conflict with Article 15 (5) c of the Directive[26]. Even if a BAT orientation appears most beneficial for the environment, due to a lack of product data and the formulation of related interim times, which would reduce potential benefits, "compromise" requirements are to be envisaged instead.(Jepsen et al. 2011b)

In the concept, a reorientation from a technology perspective to a functional approach is recommended with the reasoning that the regulation of many technical variants stops competition in efficiency as the parallel existence of technical solutions with potentially varying energy efficiency is regulated. A functional orientation would entail that minimum standards would be oriented along the more efficient technical solutions and a stronger incentive for innovations would be opened up. With a view to additional product functions, the concept promotes a progressive increase of the level of requirement, which would translate in a reduced share of granted energy use per each additional function. (Jepsen et al., 2011b)

A dynamic adjustment of the minimum efficiency standards is recommended. To date, the Directive promotes the revision of IM in cycles of three to six years, which requires adherence to the comitology or committee procedure (Eurofound, 2012). If ecodesign requirements, and thereby minimum efficiency standards, are adjusted at these times, has not been decided. The concept presents the option of combining different modifications, namely (1) the introduction of additional requirement levels, so called "tiers", and consideration of minimum efficiency standards, which, at the time of the entry into force of the regulation, clearly exceed the LCC point, (2) the establishment of a link between the entry into force of the requirement level with market development, and (3) the binding definition of a reference value as minimum efficiency standard in the framework of the upcoming revision at the end of the defined period. The first option is linked to the principle of the TRP, which could be implemented by an extension of the revision cycle, the definition of several more ambitious tiers of requirements and through the introduction into the IM that a new requirement level is automatically entering into force if a certain share of products on the market exceed the previously defined efficiency value in the IM. (Jepsen et al., 2011a and b) The EC impact assessment revealed the first option as most adequate.

Defined benchmarks relating to the most efficient product on the market, could be, if oriented along the TRP, considered as medium term target standards, if "they are used to present the new minimum efficiency standards to be determined for the next revision of a regulation." (Jepsen et al, 2011a, p. 11) Siderius and Nakagami (2012, p. 1) recommend a focus on structural improvements in the Ecodesign Directive, namely improvements that would apply to all measures taken, rather than focusing efforts on "fine tuning on aspects that are more or less the same".

The TRP appears more flexible as compared to the proposed European version, as it allows for a target reformulation in cases where overall compliance is achieved before the envisaged date. (Nordqvist, 2007) In the case of an adoption of a top runner approach in Europe, many features would need to be altered, such as the sanction system, and it would need to be considered that many European sold ErP are manufactured by international companies. Conflicting requirements for companies which operate internationally need to be avoided. Essential for the functioning of the instrument will be a preliminary check regarding the willingness for participation of European

[26] According to Article 15 (5) c, any ecodesign requirements shall not have any significant negative impacts on the user, specifically regarding the affordability and the life cycle costs of the product. (Official Journal of the European Union, 2009a)

manufacturers in the standard-setting process. (Nordqvist, 2006) Table 4-1 provides a comparison of the proposed European concept for an implementation of the TRP with the original TRP.

Table 4-1. Comparison: Japanese Top Runner Program and the proposed EU Top Runner

	Japanese Top Runner Program	**EU Top Runner (German policy concept)**
Aim	Transformation of markets for EuPs through maximum standard value setting (benchmarking).	Improvement of energy and RE aspect in ErPs. Alignment of minimum efficiency standards and other ecodesign requirements with BAT.
Measured objective	Sales weighted average of a product category needs to meet the standard.	Ecodesign requirement orientation on BAT rather than the to-date minimum efficiency requirements; definition of ambitious standards based on regularly reviewed and potentially higher than LLCC but lower than base case; strengthen benchmark role in ecodesign by indicating target efficiency value for the next minimum efficiency standard; introduction of labelling also for product groups with voluntary agreements.
Structure	Modular and iterative.	Iterative.
Time span between standard setting and target year	Between 3 and 11 years (average: 5.6 years).	-
Focus of the instrument	Supply-side, inclusive and consensus-oriented.	Supply-side, inclusive with a view to the process attached to elaborating IMs
Regulated actors	Manufacturers and importers.	Manufacturers and importers.
Market surveillance	Regulator does not monitor during the compliance period - only at the end. Product catalogues.	Authority needs to ensure strict compliance with time schedules for IMs; regular review of minimum efficiency standards and labelling obligations; options for sanctions to prevent competition distortions. Possibility to review product requirements in practice.
Conformance procedures	Manufacturer provides information.	-
Input legitimacy	High (Stakeholders collaboratively decide on indicators, methods, target standards, and compliance period duration).	Low (as there is no standard setting phase with stakeholders which excludes options for active participation and consensus formation; encouraged is a consultation with member state representatives before the adoption of an act .
Built-in flexibility	High (fleet average, target reformulation).	Low

Source: adapted from BMWi and BMU, 2012, Jepsen, 2011a and b, Murakoshi et al., 2005, Nordqvist, 2006 and 2007, Siderius and Nakagami, 2012

The TRP success is also due to the development of parallel policies, which points to the necessity of harmonizing the existing policy mix to support and allow for the full exploitation of a potentially adopted European top runner version. Within the European product policy mix, the Ecodesign Directive with its LC perspective and options for stringent product regulations appears to be a policy tool which can influence market developments towards more environmentally friendly products. The analysis in the next chapter is to shed light on its political acceptedness and potential contribution to eco-innovations.

5 Eco-innovation potential of the Ecodesign Directive

The Directive objective is to "ensure the functioning of the internal market by requiring products to reach an adequate level of environmental performance." (Official Journal of the European Union, 2009a, preamble 41) Eco-innovations might be key to achieving this environmental performance. A selection of innovation indicators derived from Jänicke (2008), served to obtain an overview of the perceived political support of the Directive and its innovation friendliness. Ten semi-structured interviews which followed an interview guide designed in line with these indicators were conducted. The majority of respondents were representatives of selected EU member state national contact points in charge of the implementation of the Ecodesign Directive. Their views were complemented by those of a representative of the EEB, and of a respondent of the EC DG Environment. The interview guide and selected transcripts[27] are provided in Appendices C and D.

5.1 Political support expressed by industry and political acceptance

Eco-innovation requires political support from politicians and industry (Jänicke, 2008). To facilitate the analysis of support, it was categorized into acceptance by industry and politicians and openness to participation. In general the respondents outlined a high acceptance of the Directive by industry and politicians. The Belgian respondent of the national contact point for the implementation of the Directive highlighted the good representation of industry in the preparatory process as a sign for the good acceptance while the interviewee from the Irish contact point for implementation remarked on the fact that only a very limited number of voluntary agreements were entered into which can be interpreted as a high acceptance of the Directive on behalf of industry. As the Belgian representative pointed out "political agreement can be easier achieved with technical measures" and it has been seen that politicians adopt a technocratic point of view when addressing environmental issues, both of which present reasons for the wide political support of the Directive. Further advantages of the Directive are seen in that it establishes a level playing field and protects industry through the CE marking against poor performance from outside the EU as the UK, Belgian and Irish representatives pointed out. Both the EC DG Environment representative and the respondent from the German national contact point noted that "green" and high-end producers with top-of-the-range applications particularly appreciate the Directive as it is a sort of reward for their proactive approach and their products on the market.[28] The DG Environment representatives highlighted the sensitive nature of ecodesign as it touches upon the core business activity and influences consumer lifestyles, and suggests split incentives as "producers don't pay the energy bill of their customers".

With a view to possible, diverging views as to the acceptance of the instrument, the representative of the German national contact point for the implementation of the Directive pointed out that they are attached to specific, individual points within the product groups. From a broader perspective, different opinions were noted in regards to the importance and methodological development for non-energy-related aspects such as for RE and protection, which extends to the discussion on how to add these aspects to ensure they are addressed in the preparatory study. In a first step, the German respondent noted the addition of critical raw materials as parameter.[29] The German representative also remarked that the need for response with a view to non-energy related aspects is predominantly perceived by politicians rather than by industry.

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[27] Selected interviews, which contributed with a detailed outline of issues addressed, or ideas, have been transcribed.

[28] The Belgian representative raised, based on his experience from a participation in a meeting with a standardisation committee, a concern regarding the perception of an EuP which complying with the Ecodesign Directive, was denoted as "green". The standardisation requirements of the Directive are however solely minimum requirements.

[29] Kemna et al. (2011, pp. 31) stipulate in the report that "analysts that will carry out preparatory studies should consider CRM [Critical Raw Materials], if applicable, as a new element of the MEErP, for example to check design options that substitute or make it easier to recover CRM components."

Belgium revealed the disagreement with the DG ENTR and DG ENER management of the Directive with representatives coming mainly from economy and industry, who have a different agenda and limited awareness of environmental issues. In addition, from the perspective of the regions[30], the Belgian respondent pointed to their dissatisfaction with the Ecodesign Directive, as it does not support their endeavours to recycle waste, a topic which receives a lot of media attention resulting in more support for the Waste Framework Directive as compared to the Ecodesign Directive. In addition, for many politicians the link of energy efficiency with RE is unclear.

Addressing industry acceptance, Slovenia referred to industry opposing the dates for the adoption of IMs, which [the reluctance to be regulated upon] is perceived to be a natural phenomenon.

5.2 Political support expressed by openness to participation

The overall impression by respondents, independent of whether they represented an NGO, the EC, or industry through national contact points of implementation, is that there are many opportunities to participate in the process attached to obtaining binding eco-design product regulation, even if "the process is not perfectly democratic". While the German representative highlighted that participation is a matter of knowledge, the EEB representative outlined several general limits to participation: the circulation of information, the asymmetry of resources, and national representation, whereby the latter two have also been raised by the Irish respondent as impediments for smaller EU member states to participate.

Circulation of information

Traditional limits regarding the circulation of information are observed which includes back door lobbying[31] and, as experienced with e.g. the energy label for TV, might cause a delay in the entering into force of a certain measure. The German representative's emphasis on knowledge as limiting factor for participation is based on the fact that larger institutions including sectoral federations have an advantage over small and medium-sized enterprises (SMEs) as the former are usually familiar with the processes and therefore aware of where they need to concentrate their efforts on. The role of sectoral federations and their responsibility to inform and pass on information to the businesses they represent, is highlighted both by Germany and Belgium. Another element in respect of information circulation is the timing and the finalized stage in which the draft of the impact assessment is being received by industry. Ireland highlighted the benefits of involving industry at an earlier stage, namely through the request of their input during the impact assessment and an earlier receipt of the draft in order to ensure more information provision by industry.

Resource asymmetry

The asymmetry of resources poses another limit to participation. While it is observed by several respondents, including from the EEB, DG Environment, Germany and Belgium, that industry is well represented in the process attached to obtaining IMs, it appears more challenging for smaller market players, including NGOs and SMEs, to take part. The EEB representative exemplifies: "When we have two employees to participate [in the preparatory study], that is already very good. There is an overrepresentation of industry - large players can send two representatives and in addition, one individual is sent from the industry association." Belgium enforces this statement by stating that "legislation is designed for big industry players". And the argument by the UK representative adds to that powerful stance: "Industry representatives lobby member states directly

[30] Belgium is a decentralized, federal state with powers shared among the regions of Flanders, Wallonia, and the Brussels-Capital Region. (Encyclopædia Britannica, Inc., 2012a)

[31] Lobbying is defined as "any attempt by individuals or private interest groups to influence the decisions of government". (Encyclopædia Britannica, Inc. 2012b) The unregulated use of loopholes in lobbying can be referred to as "back door lobbying".

and through European bodies - they have two ways to go through the process." With a view to the consultation forum, participation is limited as per the Directive. Germany highlights the importance of good organisation to ensure proper representation in this part of the process. The DG Environment representative added that the EC already bended its own rules to allow for a higher participation, in particular to receive expert views and relevant product data. Institutionalizing this EC flexibility would require an adaptation of EC Decision 2008/591/EC[32].

National representation and participation of the public

With a view to the consultation process, the lack of national representatives of certain member states in the consultation forum is highlighted by the EEB representative, who notes that this lack signifies no involvement of civil society, consumers or green NGOs. The need for more transparency in the vote of member states is also mentioned along with a proposition for improvement: Member states should be required to inform on their position before voting which would lead to a more in-depth consideration of policy and to more involvement.

With a view to the participation of the public in the process, both the risks and benefits attached to the disclosure of confidential information were mentioned by the EEB representative: A risk is inherent to the technical details which are part of the work and both to the extent to which the public can understand these and to which degree the public is then influenced by negative media. These developments might negatively affect the working progress achieved up until then. While the reasons for keeping the information on the effects of certain policy measures confidential can be understood in the risk attached to it, namely the need to use additional resources to address concerns as a result of negative media, the benefits of informing the public about certain impacts of a policy cannot be neglected. With this background, and as highlighted by the EEB representative, the focus is to collaborate with the EC to achieve two objectives: On one hand, more positive communication which would need to accompany the publishing of confidential information in order to prevent negative media attention and in sequence put a stop to this media being the main voice heard by the EC. On the other, a more pro-active attitude by the EC, to prevent a situation in which for instance tap and shower heads are not put on the working plan for a fear of negative public response. Achieving this EC attitude would bring along numerous benefits also for other topics under discussion, including resource scarcity and efficiency aspects.

5.3 Potential innovation supporting elements of the Directive

Three out of the ten respondents made remarks with a view to the Ecodesign Directive being able to challenge the market, whereby the EEB representative emphasized that it is "running after it" and the German and Belgian interviewees pointed out that its current contribution to innovation is restricted to eliminating old technology and pushing the market in front of itself. The policy instrument with the strongest contribution to innovation was clearly identified by all respondents as the Energy label, which allows for a differentiation among the top-performing products on the market by means of energy efficiency, as elaborated in section 3.4.2.

Energy Label

Belgium rates the label very positively "as it provides a clear base for comparison" with its strong point being the visibility: "If a competitor sees a product with a higher energy performance than its own products can achieve, product innovations will be triggered as the competitor will strive to achieve this new target and aim even higher." According to the EC DG Environment representative, "the Energy label is more important due to it being a powerful communication tool

[32] Commission Decision of 30 June 2008 on the Ecodesign Consultation Forum (2008/591/EC). (Official Journal of the European Union, 2008)

and therefore influential in consumer decisions, in the short run, but in the long run, ecodesign will take the whole market to a higher level." The rationale is attached to a company's economics: If a company has products both with an A+ energy label and a B label on the market, assumingly with a low price difference between the two, the consumer will be drawn to a purchase of the A+ category product and the company will react by either taking the product category with the B label from the market or upgrade it. This is in contrast to the mechanisms with which the Ecodesign Directive works, namely standards which are designed in tiers. Industry knows about their renewal in a certain time and that they are obliged to stop selling incompliant products. Ideally they replace them with better technology. To ensure the latter, standards need to have certain characteristics.

Ambitious long-term standards addressing functionality

As highlighted by the UK representative and supported by the EEB and Irish representative, the standards need to be ambitious and designed for the long term, e.g. with the visions of the products of tomorrow based at the level of best available technology (BAT) today, in order for industry to be able to predict the path towards which it is being directed. In general, the following equation holds: The more stringent the regulation, the more likely it is that the regulation will foster product innovations. The more restrictive regulations are, the less likely are the innovations. On the example of a TV this would mean that manufacturers should not be regulated upon the type of technology they are to apply, they would rather receive standards which must be met. Specifically this translates into the specification of the outcome of the function rather than the product itself. The decision on which technology to choose would remain with the market. With a view to the stimulation of innovation at the desired part of functionality, the DG Environment respondent outlined the importance of carefully deciding on the wording of the clauses in the legislation as they result in the standards which will provide the measureable criteria. This is illustrated on the example of hoods in the kitchen, which are designed to remove grease, even if the real objective would be to remove odours, but as no standards or criteria address the odour, innovations are not stimulated for this part of functionality. A producer who would innovate on trapping the odour would not benefit from this innovation.

Ireland added to the long-term standards that the adoption of the IMs could be extended to span up to five years which would allow industry to adopt its design cycles.

The EEB respondent sees potential in the Directive to translate the before mentioned long-term vision of the product of tomorrow by establishing the legal visibility through ecodesign which has potential to speed innovation as industry is confronted with the BAT of today.

Least life cycle cost, BAT and rebound effect

One impediment on the path to elaborating more ambitious standards is posed by the LLCC in ecodesign regarding energy cost, which is part of the MEEuP applied in the elaboration of IMs, and being highlighted as a definite restriction by three out of ten respondents. Two options are proposed by the EEB respondent which could counteract the current restriction, the second option of which, dependent on a corrective mechanism being found, would allow for a prompt implementation without the need to await the legal revision of the Directive:

The first option is an application of a so-called "equal LC cost" or "equal BLCC", whereby both concepts pursue the same objective which is the facilitation of ambitious requirements as long as the end-user will save energy. In other words, legislation would need to allow for "an option that is cheaper than the current option but not necessarily the cheapest option and would open room for improvements regarding energy efficiency" or as the German interviewee put it, it would need to be open to "an increase in LC costs, which are still not higher than the base case - a scenario in which increased costs resulting from ambitious efficiency requirements would amortize themselves

throughout the entire LC. Simply put: The LC costs would be equal to those of the base case." This described approach would require a revision of the legislation.[33] "The requirements of the Ecodesign Directive should correspond to an advanced level of technology and essentially be oriented at the most efficient technologies on the market whose use allows additional and considerable energy savings to be made as compared to the standard level of minimum efficiency requirements to date. It is important to define ambitious minimum standards that take account of LC costs that are regularly reviewed in line with technological progress and market development. Thus, product LC costs are above the LC cost minimum but are not higher than the base case."

A second option is the regular update of the upfront product cost to account for the technological evolution of a product, possibly a combination of improved energy performance and a decrease in the purchase cost which might result from economies of scale, innovation, or specific requirement effect over the time period, which can span up to ten years, until the requirement is set. The LLCC should be regularly re-calculated so that the upfront cost which was considered at the time of setting the legislation will not remain exactly the same all along the period until the entry into force of the requirement. To date, in the calculation of the LLCC, the upfront cost is taken as a given without applying corrective factors even if the requirement is set up to five or even ten years later. This approach is applied to the example of a TV: In the purchase of a BAT TV today, a very innovative product, the cost will be very important. As technology evolves, today's BAT might become a commonly applied technology over the next five years which will result in the cost decrease of the product. If the overall cost of the product all along the LC is calculated when the product is bought as mainstream technology, it will be a cheaper product in the end, as the upfront cost will have decreased which means that more ambitious energy requirements which still respect the legal requirement of LLCC or most economical option could have been set.

Both options partially work towards limiting the rebound effect, a phenomenon in which a decrease in the cost of one item results in resources made available, usually in monetary form, which are then either spent on either bigger appliances or through a different channel, e.g. another, different purchase and "leaving the initial improvement without a net benefit for the environment." The challenge is to curb the rebound effect by, as adequately framed by the DG Environment representative, "draining the money that is liberated by efficiency gains".

Addressing the rebound effect

As the EEB representative pointed out, the risk of occurrence of a rebound effect is, amongst others a result of the chosen measurement "energy efficiency", applied to the Directive. To date this approach allows for instance for a more energy efficient fridge to consume more energy due to its size, a development which was also noted with TV screens. Counteracting would entail for instance to introduce a cap on the energy consumption when a product reaches a certain size. The UK pointed out that on one side this could be achieved by measuring the absolute energy consumption instead of the energy efficiency. On the other, and as depicted also by Germany, progressive standards could be used. The energy star version five, which was defined in the U.S., illustrates this approach: It addresses the size of the TV and then sets progressive rather than only linear standards for the energy efficiency requirement. For example, once a TV screen reaches a certain size, the energy efficiency requirement increases too. Besides adopting progressive

[33] "Concerning energy consumption in use, the level of energy efficiency or consumption must be set aiming at the LC cost minimum to end-users for representative product models, taking into account the consequences on other environmental aspects. The LC cost analysis method (...) is based on the sum of the variations in purchase price (resulting from variations in industrial costs) and in operating expenses, which result from the different levels of technical improvement options, discounted over the lifetime of the representative product models considered." (Official Journal of the European Union, 2009a, Annex II (1) para. 5)

standards, various other measures need to be undertaken to address the rebound effect, as raised by Germany, including work on creating awareness amongst customers. An ErP market evolution towards stronger innovation incentives could be fostered by a policy concept, presented by Germany, namely a European version of the Top Runner Program (TRP).

Top runner approach

Ireland perceives a European TRP as an option through which better target setting can be achieved. The improvement would manifest itself in an automatically generated upward benchmark shift following the evolution of technology rather than the dependence on the revision of the IMs following a period of three years, which also adds to the current lengthiness of the process attached to obtaining binding IMs, a concern raised by Ireland. Germany distinguishes its policy recommendation from the Japanese TRP through the degree of flexibility. The German suggestion is less flexible[34] when contrasted with the TRP, however, it goes only as far as long as the LC costs do not exceed the current base case since consumers would otherwise be charged for the price increase. The UK strongly supports the German TRP recommendation and perceives a possible North-South European divide due to the expressed support of this policy approach limited to the UK, Ireland, the Netherlands, Denmark and Sweden, and the EEB, as of June, 2012.

Concluding on the overall perceived innovation potential of the Ecodesign Directive, the replies of the respondents can be summarized into two main points: On one hand, the Directive removes worst product performers on the market with its market challenging function being questionable in the light of the Energy label which clearly demonstrates the highest innovation potential among current IPP tools, being due to its visibility a strong communication tool that influences consumer choices and manufacturers. On the other, the interviewees remark that the Directive has innovation potential and could lift the market to a higher level. To live up to its full potential, several aspects, namely, ambitious long-term standards, addressing functionality rather than technology which are oriented towards BAT and being underpinned by a re-definition of the legislative LLCC requirement, would need to be elaborated. The framework which is to embed these amendments is made available by the German TRP policy suggestion, which is being circulated amongst EU member states to check on their support.

Besides these discussed issues which represent the wider picture regarding the innovation potential of the Directive, the second, structured part of the interviews assessed the Ecodesign Directive against its innovation-friendliness, based on selected indicators provided by Jänicke (2008).

5.3.1 Economic incentives

The German representative, draws attention to the energy saving potential inherent to the Directive, namely a total of 385 TWh per year by 2020 through the 12 product groups, according to the ex-ante impact assessment, as described in chapter 3. This sum is equivalent to about 14 per cent of the EU 2009 household electricity consumption. (CSES, 2012 and EC, 2012)

Resources as embedded energy

According to the DG Environment representative, NGOs address RE within the energy efficiency debate, noting that "resources present embedded energy". The illustration of this concept on the example of steel would be along the lines that "if you use less steel, you use less energy as the production of steel also requires energy." According to the DG Environment interviewee, this argument would be appealing to certain policy makers [in the area of energy and climate change].

[34] In terms of flexibility, the Japanese TRP appears more flexible as compared to the German policy recommendation, as it is based on a fleet average criterion, a sales weighted average of a product category, as described in section 4.1.

CE marking

The UK representative adds another incentive: "The protection that the CE marking under the Ecodesign gives them [industry] against poor performance from outside the EU is appreciated."

5.3.2 Policy mix with different product policy instruments

According to Jänicke (2008), a policy instrument is innovation-friendly, if it acts in combination with other policy instruments. The UK sees an advantage in "ensuring consistency between ecodesign, EoL [notably WEEE] and RoHS. Belgium, strongly supporting the Energy label, mentioned that the combination of the Ecodesign Directive with other policy instruments makes it stronger, and the DG Environment interviewee already observes "a gradual improvement in the alignment of various policy instruments as a policy mix conforming to the IPP approach."

Common set of criteria and escalation process

The EEB respondent sees a need in combining the three different policy instruments in a more coherent way and elaborates on the way in which the Ecodesign Directive could be further integrated with other IPP instruments. Specifically, it was suggested, that a common set of requirements is to reticulate through all relevant policy instruments in the form of an escalation process. In practice the approach would ensure that the energy efficiency requirement of a certain regulated upon EuP under Ecodesign would also be reflected in the same methodology with a higher threshold for energy efficiency in GPP and in the EU Ecolabel with the same methodology but at a level which surpasses the GPP requirement. The common set of requirements in combination with the escalation process should not be misinterpreted in the sense that GPP and the EU Ecolabel would only regulate on the same criteria as Ecodesign, but rather that they will apply the same methodology for the common set of criteria. This approach could foster more innovation. The suggestion is illustrated by an example: A certain measurement methodology for the energy efficiency of a washing machine, in the form of a standard formula, e.g. a certain number of washing cycles at a certain temperature, full load and half load, is to be applied in Ecodesign. The manufacturer can only put the product on the market if the result derived from applying the methodology meets the minimum requirement specified in the IM. In contrast, the energy efficiency requirements in the GPP criteria set for washing machines might not necessary use the same measurement methodology and they are not revised at the same time. The TV example outlines the EU Ecolabel threshold as below the minimum requirement for TVs because the EU Ecolabel requirements have not been revised at the same time as the minimum requirements. In the suggested scenario, exactly the same measurement methods would be applied for all three instruments but with a different threshold and when the threshold for the minimum requirement in ecodesign is updated, the criteria on the environmental dimension for GPP and the threshold for EU Ecolabel on this criteria are also immediately updated according to the same formula. A manufacturer could then decide which requirements its product can meet and where it shall be, e.g. the product could comply with GPP or the EU Ecolabel for a certain dimension.

In summary, against the background of a need for a more coherent combination of the existing product policy instruments and the anticipated benefit for the Ecodesign Directive in view of energy efficiency gains and potentially RE, the policy mix could be fostered by an approach which calls for a basic set of requirements jointly reflected in Ecodesign, the EU Ecolabel and GPP, to be measured against the same, common methodology applicable to the identified requirements and a common revision process which is to be applied simultaneously for all three instruments.

5.3.3 Generation of Eco-Innovations in Energy-related Products

Another of Jänicke's (2008) indicators for an innovation-friendly instrument refers to its support of innovation as a process, including by considering different phases of innovation or diffusion.

Tiers

The DG Environment representative considers the Ecodesign Directive as supporting innovation in form of a process respecting different innovation cycles, in as far as tiers, in which the requirements are set, are to be elaborated in a way that they represent a design cycle to enable more thorough design changes on behalf of industry. This method should stimulate innovation which optimizes existing technologies rather than promoting patent protected technologies.

Life-cycle perspective

Promoting a product LC perspective, is a strongly encouraged aim of the Directive. The assumption is that by addressing the LC of a product, the Directive might promote design decisions which could potentially lead to eco-innovations. As the DG Environment representative put it, "ecodesign is [amongst the range of different product policy instruments] most explicit in taking into account LC impacts." All respondents recognized that the Directive has potential for a LC perspective, whereby some interviewees were more explicit in saying for instance, as Germany, that the Directive is based on a LC perspective or, as phrased by the EEB, Ireland and the UK, that it has a clear potential and that good efforts are made to consider the entire LC even if it has not lived up to its full potential yet. As the EEB outlined, it "allows for other dimensions to be addressed" and this is "dependent on the understanding of "significance".

To date, the "significant impact" of an environmental aspect is identified first and then, in a next step, the improvement option and feasibility are investigated. The potential environmental influence of the Directive would be slightly different if "significance" was not understood as the absolute environmental impact only but as the "improvement potential". On the example of resource use, a criterion which is not as significant as energy use today, but shows significant improvement potential, the significance could be addressing the improvement potential rather than the absolute environmental impact per se. This change in the selection filter would open opportunities to claim for additional environmental requirements, including for instance the case of REE. It is known that they are difficult to mine and classified as critical materials, but the fact that they are used in small amounts in products means that they will never be able to compete in terms of absolute environmental impact with energy use. In contrast, if the significance was understood as the improvement potential of REE in one appliance, then, even if the REE absolute impact is minor, the improvement potential might be large, compared to energy use, of which the absolute impact could be very important but its improvement potential could be more and more limited as tougher and tougher requirements are envisaged in the future. The EEB representative further adds that due to the filter or the selection criteria applied, the environmental dimension is immediately stopped because significance is addressed as the absolute environmental impact. A change in the interpretation of this filter could open the range of the environmental dimension which could be addressed rather than leading systematically to an investigation of resource use.

A nuanced position regarding ecodesign being able to address every product, is also presented by the EEB respondent accompanied with the reasoning that no subtleness in the definition of the conditions for a good ecodesign product candidate "could result in an easy counter argument for those who are not in favour of extending the environmental dimension or scope." The expressed need for caution in the definition is underpinned by referring to the example of the investigation to include food amongst the Ecodesign product groups, the rationale of refraining from this approach was also clearly addressed in a case study as part of the MEEuP revision. In the definition of an adequate ecodesign product candidate, two aspects are most important: On one hand, priority resource use aspects that need to be addressed absolutely are to be identified. On the other, it needs to be established which aspects, amongst those identified, are better addressed by Ecodesign and which ones would benefit of being addressed by other instruments, such as by EMAS, and IED documents with BAT reference, called BREF. The EEB interviewee highlights

that the NGO currently investigates the condition for the relevant inclusion of products in the Ecodesign scope neglecting to advocate Eco-design as "the silver-bullet to all our problems."

Germany highlights the simplified LCA being conducted under the Directive and both the UK and IRL agree that the Directive can address issues such as recycled content, recyclability and reuse, with practicality being the impeding element in the implementation. The practicality is predominantly attached to the challenge of measurement, which is a point also raised by Luxembourg, and Ireland enforces it, highlighting that "until [the] LC [perspective] can be measured, energy efficiency will continue to remain the overall target due to the practicality attached to it." The UK strongly supports the expansion of the range of impacts ecodesign supports, especially material selection. It promotes the move towards more absolute energy consumption with less emphasis on ecodesign and more on energy labelling.

Resource efficiency improvement potential

Another aspect in the investigation of whether and to which extent the Directive supports eco-innovations is related to its actual potential to contribute to RE. Most respondents agreed that the Directive has not lived up to its full potential yet regarding RE, with some taking a more positive stance, including DG Environment and Ireland. The former considers RE to be "the next logical step after energy efficiency", while the latter points to the fact that the Directive is not directed towards RE as a primary objective but has nevertheless addressed RE of water in e.g. dishwashers and washing machines, as it is measurable. Belgium remains more sceptical in view of the Directive potential in that respect as a result of a lack of available and accepted indicators to measure RE. The respondent further states that the improvement potential regarding RE and the rebound effect are hard to measure and constitute weak points in product legislation, reinforcing that "neither consumption nor use dynamic can be controlled.." Nevertheless, and as pointed out by the German interviewee, the inclusion of the criterion of critical raw material within the MEErP[35] presented an important starting point towards addressing RE through the Directive. (Official Journal of the European Union, 2009a, Article 15 (6))

The EEB representative added to the previous discussion on the importance attached to adequately defining the criteria which decide over whether a product is a good candidate to be regulated upon by the Ecodesign Directive, that EoL management and resource use aspects were identified as constituting good candidates, specifically the 3 Rs, and hazardous material, which is addressed by RoHS and chemical content, targeted by REACH.

Three options were mentioned as a way to increase RE, including:

1. the restriction of the share of a certain material used in the specific ErP
2. the requirement of a minimum share of recycled material in the ErP, and
3. the concentration of the specific material in the ErP.

According to the German respondent, considering the tools with which the Ecodesign Directive operates, the third option appears to be the easiest to implement. Option one and two could be implemented in the form of horizontal measures on the example of option two by requesting that recycled content should be e.g. 35 per cent. The DG Environment representative agreed with this approach to address RE and implied that it could be quickly implemented, in contrast to the opinion of the German representative. Both agree that option two would bring up the challenge of verification in the form of a final product producers' supply chain certification. Germany notices

[35] Please refer to section 3.5.1 and footnote 17 for further details.

the opportunity provided by the Ecodesign Directive to enter into product chains, with the limit posed by the measurement potential on the product. With a view to the global supply chain, the Belgian representative pointed to the high volume of semi-finished goods which are imported into the country and the entropy related to their import which should also form part of the discussion on increasing RE. The importance of semi-finished goods imports in this discussion was also raised as a crucial factor for the power tool industry, as stipulated by the interviewee of its European Association[36]. A significant share of product components from abroad [outside the European Union] was also noted by the DG Environment representative, who refers to producers requesting information on the Directive and then realize that their global supply chain can easily manoeuvre them into a failure in complying with the Ecodesign Directive if it is not handled carefully.

Against this background, the importance of ensuring the practicability of the requirement attached to measuring the RE of a product, a point made by the German representative, can be better understood. The practicability extends to the data, namely specific versus generic data, that is needed to measure and meet the requirement. As discussed earlier by the DG Environment respondent, the presentation of resources as embedded energy is another approach used by NGOs in their attempt to address RE and raise awareness. Another, already applied approach, to improve RE, as highlighted by the EC DG Environment representative, is the

4. total cost of ownership method.

It has been addressed in the EC work [on setting IMs under the Ecodesign Directive] for transformers[37], appliances which are made of copper with an iron core, which is magnetic. With a view to tendering, and taking into account the very explicit trade-off between material efficiency and energy efficiency, optimum material choice balanced with desired energy efficiency to obtain a certain return on investment, is already applied with transformers, as the DG Environment respondent points out, suggesting that "this approach could be taken up in legislation". It investigates how economically viable it is to put more amounts of copper or iron into the transformer to obtain a more efficient performance.

Addressing RE in different LC phases, the DG Environment representative draws attention to the problem of Ecodesign overreliance on WEEE in preparatory studies in the context of the policy mix idea, emphasizing that "it is taken for granted that everything is treated according to WEEE and discussions are relatively quickly off the table. (...) Not every [energy-related] product is a hundred percent compliant." The respondent suggests that the extent to which WEEE can handle the particular aspects of a product group should be checked in the preparatory study. The DG Environment respondent also introduces the concept of EoL efficiency which represents one option to address RE in the EoL phase. The concept takes all costs from buying virgin material to EoL into account and the optimal EoL treatment of a material is being calculated by comparing the result to the cost of the virgin material. The evident challenge is linked to data availability.

In summary, the majority of respondents agreed that the Ecodesign Directive has potential for facilitating RE improvement and is principally well suited to address RE. The UK interviewee

[36] The interview with the European Power Tool Association (EPTA) representative was conducted as a follow up to the specific questionnaire on drivers of eco-innovation for permanent magnet motors. (EPTA, 2012)

[37] A transformer is defined as a "device that transfers electric energy from one alternating-current circuit to one or more other circuits, either increasing (stepping up) or reducing (stepping down) the voltage. Transformer**s** are employed for widely varying purposes*;* e.g. to reduce the voltage of conventional power circuits to operate low-voltage devices, such as doorbells and toy electric trains, and to raise the voltage from electric generators so that electric power can be transmitted over long distances." (Encyclopædia Britannica Inc. 2012c)

states that the selection and avoidance of particular materials are considered useful elements of the Directive, however it has not yet reached its full potential. Germany sees the challenge in translating the results of the method development into adequate and practical requirements, re-iterating that the methods need to be strong enough to generate an impact. Luxembourg adds the important role of market surveillance. The EEB respondent is convinced that the full potential of ecodesign has not yet been explored, specifically with a view to critical materials, where improvements could be achieved as to the conceived design of the product, namely to ensure an easy disassembly at EoL to facilitate reuse and recycling, and regarding the information requirement on materials used in each product and their physical location. The latter point is to be understood as a precondition to complement the weight-based WEEE qualitatively, which was explored in a DG ENV-JRC collaboration on the assessment of the "resource use environmental impact" [and resulted in a Product Environmental Footprint Guide by Manfredi et al. (2012)].

5.3.4 Strategic planning and goal formulation

The anticipation of new standards on behalf of industry in combination with the process attached to elaborating them, which is to reflect the industry design cycle, can be linked to strategic planning. IM represent the goals which are to enhance the strategic planning of regulated upon enterprises, as they need to comply with them in order to sell their products on the market.

Adopted implementing measures

A majority of respondents explicitly reveal the improvement potential regarding the adopted IMs, and the EEB representative specifically directs it to certain lots in which RE cannot be considered to be satisfyingly addressed beyond energy efficiency. Addressing energy efficiency only, the UK representative explicitly refers to the lack of ambition in the adopted measures, and the DG Environment respondent states that the IMs could be more ambitious against the background of their cost efficiency. Germany rates the measures positively arguing that they move the market even if there are differences in quality and pointing to the first level of requirements which does not challenge, in the sense that worst performers are cut off, the well-developed German market.

With a view to the formulation of the IMs, the respondent for Belgium outlines, by referring to his experience in elaborating Article four of the WEEE Directive, that the challenge is related to translating a generic requirement into legislation that is enforceable. For a successful instrument it is important that it provides a very clear definition, e.g. on what "recyclable" means. And, as added by the EEB respondent, the measure also needs to be able to address some impact, and be measurable. The UK respondent points to the significance of addressing environmental impacts of the product LC in the preparatory study, as, in case they are disregarded at that stage, "it is difficult for the EC to justify including them without European evidence."

The Belgian respondent emphasizes the immense legislative work that accompanies a treatment of products on a product-by-product basis, and highlighted the lengthiness in the process attached to achieving consensus, which can result in outdated measures at the time of adoption. This view is also shared by Ireland, which suggests two options as remedies, one, in form of an 80/20 approach, with the aim to capture most issues during the work on the IMs and the remaining in the following years, and the other in form of an increase in EC resources targeted towards the work on Ecodesign to facilitate a more rapid approach, with the justification being the good return expected from the measures. Regarding the lengthiness, the UK comments upon an observation made, where industry refrains from engaging and sharing data in order to delay the process.

In addressing the implementation process, the EEB interviewee remarked that it is not such a political process as technical experts are dealing with it and the Luxembourg representative reported on the challenges attached to the shift in the proof of product conformity. Specifically it

was revealed that market surveillance authorities have had no practical experience in checking product conformity as checks have been limited to the administrative level until recently. Since a few years the testing level has been extended to include also laboratories, but as the budget available covers both safety and ecodesign tests, a prioritization is necessary and safety comes first. The representative positively remarks that an anticipated cooperation between market surveillances of different member states might increase the possibilities in checking ecodesign requirements.

Stringency in adopted ecodesign requirements

Low ambitions in the ecodesign criteria are a result of reference data sets of the past, which are used to investigate and set long term requirements. The EEB representative refers to the work on the boiler product group, which, having been initiated in 2007, is still ongoing, as of June 2012, and is based on data from 2005/06 with the requirement being set for 2015 and beyond. "Even if mechanism are available to correct the risk of obsolete data, there is still too much of a gap between the reference data used and the requirement which will be set for the future", according to the interviewee, who outlines that the NGO therefore promotes more continuous market monitoring to enable the design of requirements according to real-time data and to allow for more flexibility in adapting requirements. Difficulties in the practical implementation are a result of data location, data confidentiality, and the cost of data acquisition. The DG Environment interviewee emphasizes that "ecodesign requirements which have turned inefficient only a few years following their implementation, are a sign that they were not ambitious". The economic logic calls for more ambitious requirements, stressed by the DG Environment interviewee who then points to many interests on a national level being sometimes to the detriment of the general interest.

As the EEB respondent points out industry responses to ambitious long term requirements differ with some industry representatives insisting that innovation will be constrained, an argument that is commonly used by the IT industry which struggles to achieve high energy efficiency and additional functionality. Their suggestion is to adapt a service-energy efficiency approach. Other responses are directed towards the acceptability of the Directive scope, namely, with a perception of the role of ecodesign being limited to getting rid of worst performers only and that e.g. the energy label is to provide the incentive by allowing industry to differentiate itself by using this additional policy instrument. The natural reluctance of industry to be regulated upon and channelled in their development results in complaints about too stringent and over-regulation.

The Belgian interviewee points out that stringent regulation comes at a cost and industry might enter a stage of blackmailing, underlining this argument with the case of compact fluorescent lamps when industry moved production to China which led to an incandescent light bulb cost increase by factor 10. The interviewee then indicates that regulations are not stringent enough from a national perspective. A view shared by the UK, which adds the emphasis on energy use rather than wider resource, LC and EoL issues that the Directive could address. The respondent also sees a benefit in increasing the focus on raw material and material use issues in the future.

5.4 Interview Analysis: Does the Directive support Eco-innovations?

The interviews revealed a high political support of the Directive by industry and among politicians, which was assessed through perceptions of representatives of multiple EU member states' national contact points for the implementation of the Directive. The good acceptance is considered to be a result of the technical measures with which it works, as this approach supports the achievement of political agreement. Diverging views regarding the acceptance of the Directive relate to the importance and methodological development for non-energy related aspects including RE, which is partially also influenced by doubts about how to address these aspects best. A disagreement with the DG ENTR and DG ENER management of the Directive was raised in connection with the different, less environment-focused agenda these representatives pursue. Several limitations were

noted regarding the Ecodesign Directive openness to participation of a wide range of stakeholders in the process for elaborating specific IMs: knowledge, circulation of information, asymmetry of resources, and limited or no national representation by some member states in consultations.

The responses regarding the perceived innovation potential of the Ecodesign Directive clearly pointed to the Directive success in removing worst performing products from the market. However, among the IPP instruments, the strongest innovation potential was noted with the Energy label due to its clear and visible communication influencing both consumer choices and manufacturers. Interviewees noticed the Directive innovation potential in lifting products to a higher environmental level, whereby several aspects, above all ambitious long-term standards, addressing functionality rather than technology which are oriented towards BAT and underpinned by a re-definition of the legislative LLCC requirement to account for technological progress and partially address the rebound effect, would need to be put in place. A suggested European top runner policy concept, to some degree oriented at the Japanese TRP, was highlighted as feasible framework to address and facilitate these needed adjustments.

An analysis of the Directive against selected innovation drivers from Jänicke (2008), which evaluate it against its innovation friendliness was conducted in sequence. With a view to the *economic incentives* indicator the analysis revealed that NGOs address RE within the energy efficiency debate, presenting resources as embedded energy and thereby adding an economic incentive. The CE marking was mentioned as a further motivation as it provides protection against products from outside the EU with poor energy efficiency performance.

The assessment of whether the Directive *acts in combination with other policy instruments*, resulted in observations that the Directive does so with the EU Ecolabel, the Energy label and GPP and that improvements to better align them, and other instruments including WEEE, RoHS and REACH, are undertaken. In that regard, designing a common set of criteria for the instruments which address the same criteria, jointly with the same evaluation methodology and a review of each instrument's criteria at the same time, whereby an escalation process is followed that provides for a different threshold to be achieved under each instrument, was recommended.

Jänicke's third indicator rates an instrument as innovation friendly if it supports *innovation as a process* which considers different phases of innovation. In that respect it was remarked that the ecodesign requirements are set in tiers which are to represent industry's design cycle. Further, the Directive inherent LC perspective adds to the innovation potential which could be fostered, as an interviewee emphasized, if the understanding of significance in environmental aspects was related to their improvement potential. Respondents saw the Directive contribution towards a RE improvement dependent on available, accepted indicators whereby the critical material indicator addressed in the MEErP presented a first step. The easiest option to increase RE through the Directive was seen in horizontal measures requiring a certain concentration of a specific material through ecodesign. Supply chain certification was mentioned as another option, with the limitations imposed by the practicability, namely available data on a certain requirement.

The Directive performed well on the fourth indicator, *strategic planning and goal formulation*, as new standards can be anticipated and the elaboration of IM, the goals, is its corner stone. Interviewees remarked that eco-innovations could be fostered by ensuring that environmental aspects are addressed in the preparatory study. Adopted IMs were not considered to be stringent enough and more continuous market surveillance for real time data was recommended.

6 Electric Motors

Amongst the 31 product groups covered by the Ecodesign Directive, electric motors in lot 11, are of high importance accounting for a "large fraction of the generated electrical energy worldwide", namely between 30 and 40 per cent. They have particular potential for product LC and RE improvements. (Grundfos, 2008) Electric motors are applications which convert electric energy into mechanical energy. (De Almeida, Ferreira, Fong and Fonseca, 2008) Amongst EU industries with motor-driven production processes they are "the most important type of electric load (...)". They operate within an electric motor driven system (EMDS), depicted in figure 6-1, the regulation of which is being discussed. EMDS make up about 70 per cent of industrial electricity use and the cost-effective improvement of their energy efficiency is estimated in the range of 20 to 30 per cent, or even 30 to 60 per cent according to Grundfos (2008), whereby the use of energy efficient motors accounts for "one of the major factors in such improvements". Motors in EMDS therefore are a priority product for ecodesign requirements. (Official Journal of the European Union, 2009b)

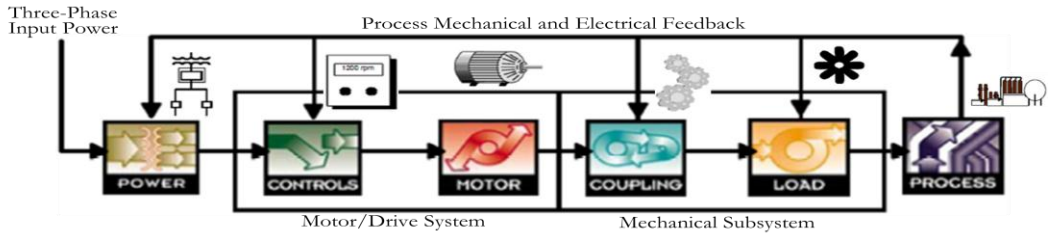

Figure 6-1. Electric motor system approach.

Source: De Almeida et al., 2012a

The installed base of industrial electric motors in Europe amounts to approximately 85 million, whereby about 85 per cent are standardised "general purpose" motors, which vary in output range from 0.75 kW up to 300 kW. In 2008, they accounted for an energy consumption of about 900 TWh with their main applications in pumping, ventilation, compressors, and conveyor belts. (Grundfos, 2008) Electric motors are broadly categorized into direct current (DC) and alternating current (AC) motors, whereby the first group comprises permanent magnet (PM) motors and the second, induction motors, as depicted in figure 6-2. (De Almeida et al., 2008)

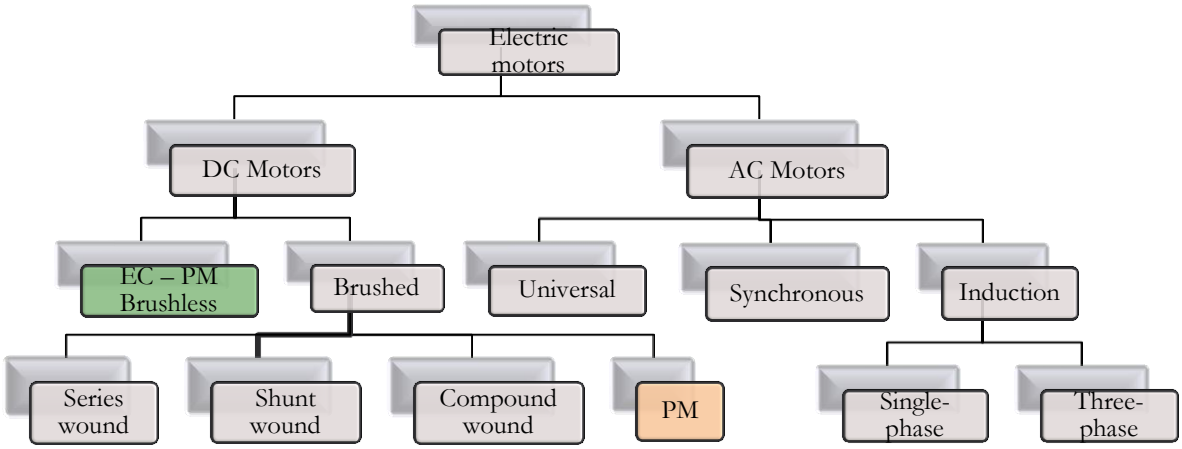

Figure 6-2. Electric motor categorization

Source: De Almeida et al., 2008

For this study, the DC motor category is most important, specifically the brushed (PM) and the brushless PM motor groups. (De Almeida et al., 2008 and 2012) As discussed in chapter four, standards provide technical specifications for products and guidelines for comparison. On an international level, the IEC 60034-30 standard facilitates the comparison of motor efficiencies.

6.1 IEC 60034-30 standard

Standard IEC 60034-30:2008, was designed to harmonize different energy efficiency classification schemes for induction motors in the world. It provides three energy efficiency levels:

- IE3 - Premium efficiency
- IE2 - High efficiency, and
- IE1 - Standard efficiency.

Table 6-1 matches different international standards with the three IE levels. EFF1 and 2 refer to an EU voluntary motor efficiency agreement launched in 1998, which was valid while IE standards were being elaborated. It continued as registered trademark until 2011. (CEMEP, 2012)

Table 6-1. Different classifications used worldwide

EU	IE3, IE2 (comparable to EFF1), IE1 (comparable to EFF2)
USA	NEMA Premium (equivalent to IE3) / EPAct (comparable to IE2)
Australia	Minimum Efficiency/High Efficiency
China	Grade 1, 2 and 3

Source: adapted from De Almeida et al., 2012a

A Super Premium Efficiency class was also introduced, IE4, however without definition due to an underdeveloped market at this level and insufficient data. The IE4 level is to have 15 to 20 per cent lower losses as compared to IE3. While small standard motor induction technology might not reach this level, advanced technologies, such as PM motors, are expected to enable IE4 motor design fitting existing motors of lower efficiency classes. (De Almeida et al., 2012a, p. 11) The IEC 60034-30 standard refrains from specifying a minimum efficiency class for motors. This is the role of national laws and directives, such as the EC electric motor regulation 640/2009.

6.2 Lot 11 - EU Electric motor regulation

The electric motor product group regulation 640/2009 entered into force in July 2009 and denotes minimum requirements for the ecodesign of electric motors and the use of variable speed drives (VSDs). (Official Journal of the European Union, 2009b) The EC regulation is more limited in its scope as compared to the international standard IEC 60034-30. Most important for this work is that PM motors are not part of the scope of either the standard or the regulation. (CEMEP, 2011)

The EC regulation specifies electric motors as "an electric single speed, three-phase 50 Hz or 50/60 Hz, squirrel cage induction motor" with 2 to 6 poles, a rated voltage of UN up to 1000 V, a rated output PN (nominal power in kW) between 0.75 kW and 375 kW and is rated on the basis of continuous duty operation. (Official Journal of the European Union, 2009b) It prescribes the following minimum efficiency performance standards (MEPS):

- Since 16.06.2011: Minimum efficiency class IE2
- From 01.01.2015: IE3 for motors of the output range 7.5 to 375 kW, or, alternatively IE2 equipped with a VSD

- From 01.01.2017: IE3 extension to the output range of 0.75 kW, again with the option to meet the IE2 efficiency level instead being equipped with a VSD

Recognizing the importance of regulation for minimum efficiency standards, it was realized that the motor regulation in place is not comprehensive enough to account for the total energy efficiency potential savings which could possibly be achieved. Thus, the electric motor product group is to be extended in lot 30, with the aim to identify the environmental improvement potential of motors to-date not covered by the EC regulation 640/2009, including amongst others, PM motors. (ISR-University of Coimbra and Atkins, 2012) Draft documents were prepared in line with the MEErP for the first ErP preparatory study stakeholder meeting on 26th June, 2012.

6.3 Lot 30 - Extension of the electric motor product group

The preparatory study, as briefly pointed out in section 3.1, presents the first step on the way to elaborating IM of the Ecodesign Directive, which will result in a regulation to apply to the motors to be specified in the extension of the product group. While the preparatory study drafts will potentially categorize the motors into three power range groups, namely,

- small motors in the power range of 150 W (0.15 kW) to 750 W (0.75 kW),
- medium motors in the power range of 0.75 kW to 375 kW, and
- large motors in the power range above 375 kW, up to 1000 kW,

for the purpose of this work, despite brushless PM motors being included in the small motor range, medium motors are most relevant, as they account for approximately 68 per cent of the electricity consumed by electric motors on a global scale. PM motors including line-start PM motors form part of this category. (ISR-University of Coimbra and Atkins, 2012)

6.3.1 Medium power range and permanent magnet DC motors

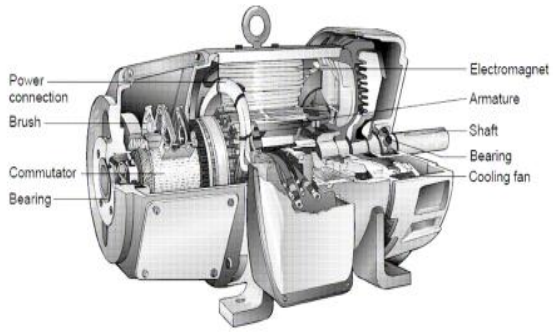

Figure 6-3. Brushed DC Motor

Source: Reliance Electric in De Almeida et al., 2008

The operation of a brushed DC motor is dependent on a direct voltage source. Its windings in the fixed part are referred to as stator. When an external voltage is applied to the windings, a magnetic field is produced. "A classic DC motor has a rotating armature, which contains several separate windings, which are fed through brushes that make contact with a rotary switch, the commutator." This device facilitates to switch the electric current in the several armature windings so that the magnetic field of the stator and armature are permanently misaligned to produce maximum torque." (De Almeida et al, 2008, p. 15)

The market share of conventional DC motors is decreasing. (ISR-University of Coimbra and Atkins, 2012) In contrast, PM DC motors, which are to-date mostly customized products, are to commercialize. In 2010, line-start PM motors, which, as suggested by their name, can be started through direct connection to the main supply, are not dependent on an electric controller, have been introduced to the market. It is previewed that their market share will increase. Brushless PM DC Motors, whose PM are to be found in the rotor rather than in the stator, as with brushed DC motors, also count on an electronically controlled communication method. (De Almeida et al., p. 17) The advantages of these motors are twofold: They are able to achieve IE4 efficiency levels and are available in standard frame sizes which facilitates their integration into products and retrofitting. (De Almeida et al., 2012b, p. 10)

6.3.2 Parallels between motor repairs and energy efficiency losses

Some studies, such as SAVE (De Almeida et al., 2000), disclosed an efficiency loss of 0.5 to 2 per cent in motor repairs. Medium power induction motors above 11 kW are repaired approximately two to four times during their lifetime. PM motor average life including repairs is estimated to be similar to the one of AC induction motors for which the motor power is decisive. While an AC induction motor of the power range of 1.0-7.5 kW is expected to have a life time of 12 years, the lifetime of a motor in the power range of 75 to 250 kW is approximately 20 years. (De Almeida et al., 2012b) Figure 6-4 compares repair prices with new motor prices and shows that small motors' repair prices exceed their purchase price. A motor repair is usually conducted in less than 24 hours, while sourcing a new one might require more time. The trade off between the cost related to a slightly reduced efficiency of an older motor compared to a new one and the cost of unscheduled plant downtime, normally ends in favour of repairing the old motor and avoiding plant downtime. Motor repair therefore is important.

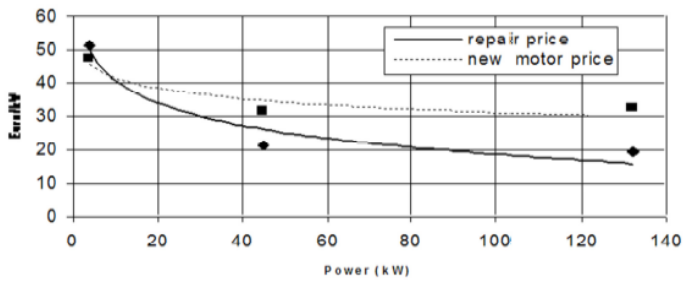

Figure 6-4. Comparison between repair prices and new motor prices

Source: De Almeida et al., 2012b

The power range of 5 to 40 kW, which is part of the medium motor category, represents the threshold where motors are rather replaced than repaired. (De Almeida et al., 2012b)

6.3.3 Permanent magnet dependence on rare earth elements

Permanent magnets are an essential part of these motors, as they create the rotational motion. The production of these magnets commonly entails the use of power metals of REE such as dysprosium (Dy), which is classified as less abundant heavy rare earth[38], and neodymium (Nd), and praseodymium (Pr), more abundant light rare earths, as depicted in figure 6-5. (DOI, U.S. Geological Survey, Circular 930-N. in Humphries, 2011) Dy is used to keep the magnetic properties of Nd at high temperatures. (Du and Graedel, 2011)

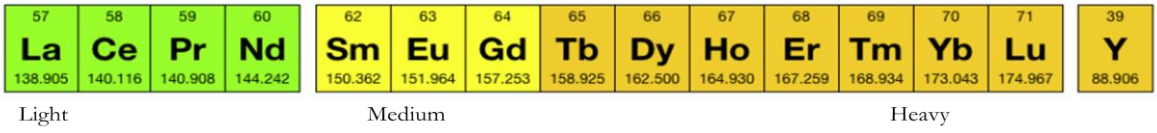

Figure 6-5. One of several classifications of rare earth elements

Source: Technology Metals Research (2012), p. 13

REE occur in mineral deposits or Rare Earth Ore of different forms and in different concentrations and impurities across the world. (Houses of Parliament, 2011 and ABSCO Materials, 2012) Up to date, China clearly dominates the REE production having accounted for 97 per cent of world REE production in 2009. (EC, 2010) It has acquired the necessary technical expertise in processing REE. The EC (2012a) characterizes this production concentration in the

[38] Their deposits occur only in certain geographical areas, and therefore these heavy REE are more costly. (DOI, U.S. Geological Survey, Circular 930-N. in Humphries, 2011)

non-EU country with a heightened supply risk. (Houses of Parliament, 2011 and ABSCO Materials, 2012) China applied export restrictions by raising export taxes and reducing export quotas, which has, in combination with increased demand for REE, resulted in price increase of a factor 106 for Dy between 2003 and July 2011. (Wellmer, 2011, BRGM, 2011 and metal-pages.com, 2012) In June 2010, China cut the export quota for domestic companies by 32 percent and by 54 percent for foreign-invested companies which translated into total exports of 30,000 tons and stood against total demand of 50,000 - 60,000 tons. (Badkar, 2012) The protection of resource bases as a part of industrial development strategies as well as the EU principle of national sovereignty and the General Agreement on Tariffs and Trade influence the political discussion of and to which extent the measures taken by China are legitimate.[39] With increasing market prices[40], and in the light of fostering supply security outside of China, it becomes more feasible to expand production in other parts of the world. Several mining initiatives including in the US, Australia, Brazil and India, are currently ongoing and expected to contribute light REE to the global supply of REE by 2014. (Houses of Parliament, 2011, and Lifton, 2012) In the meantime, the British Geological Survey Risk List (2011), put REE on the second highest rank with a relative supply risk[41] index number of 8.5. (NERC, 2011) Against this background, a UNEP study on the identification and prioritization of metals clearly highlighted a need for prioritization of REE as shown in figure 6-6. The ranking of prioritization was based on the parameters supply risks, demand growth and recycling restrictions, whereby those materials in the overlapping area of the three circles present those in need for prioritization. REE were identified as "critical" for future sustainable technologies, including for energy efficient technologies. Their criticality was established for the medium term, the next ten years. (Buchert et al., 2009 and Technology Metals Research, 2011) Efforts of the EU to obtain access to REE include an agreement of cooperation on raw materials with Greenland which was signed in June.[1](EC, 2012f) Greenland appears to be able to deliver on six of the 14 critical raw materials, most importantly for this work, on REE and especially heavy REE. (EC, 2012d) Given the resource-intense processes needed to obtain PMs, from the extraction of the ores to the final product, the PM production steps which can be viewed from figure 6-7, increasing their RE, both from an political-economic and ecological point of view, is a valid and needed objective.

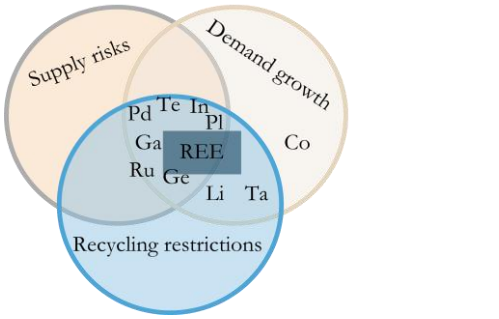

Figure 6-6. Prioritization of critical materials

Source: Buchert et al., 2009

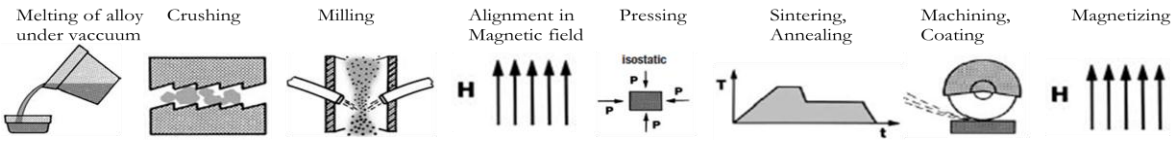

Figure 6-7. Production steps of rare earth magnets

Source: adapted from Vacuumschmelze, 2012b

[39] A more detailed elaboration of these geo-political issues can be found in Appendix E.

[40] Despite a decrease in REE prices due to the global economic slowdown, German industry does not anticipate a significant improvement anytime soon. It reacts by trying to tap new rare earth sources, to use fewer REE in products and to recycle these elements where possible. (The Financial Times, 2012)

[41] Supply risk is based on four criteria, namely crustal abundance (in parts-per-million or ppm), reserve base distribution (in per cent), production concentration (in per cent) and political stability. (NERC, 2011)

A motor recycling project, MORE, led by Siemens AG and conducted by several partners from industry and academia[42], studies the extraction of REE from electric motors and takes account of the entire value chain from design and manufacturing of engines to reverse logistics and reuse. Its deliverables are expected for 2014. (Siemens AG, 2012) Another project, REEgain, funded partly by the Danish government and the consortium partners including academia, several companies using REE, a recycling business and a mining company, is to start in early October 2012 and will explore both ways for in Greenland mined REE processing and their recycling. (REEgain, 2012)

6.4 Correlation between REE resource use and efficiency classes

Energy density, the unit of storable magnetic energy, can be said to be one of the most important properties of magnets. Other important characteristics include the required magnetizing field, namely the magnetic requirements of the circuit, thermal stability, namely the physical needs of the material, mechanical properties, corrosion resistance, manufacturability and cost. (Roozee, 2002 and Froböse, 2011) "When these materials [rare earth elements] are optimally combined, their energy density exceeds 400 kilojoules per cubic meter (kJ/m^3). That value is so high that magnetic systems, compared to conventional magnetic materials, can be made substantially smaller or significantly more powerful." (Froböse, 2011, p. 100) This is of interest with a view to designing motors, since, if they are designed to reach a higher efficiency class, they also require more material. "Motors of efficiency class IE3 require a much greater use of materials than motors of efficiency class IE2." (CEMEP, 2011, p. 13) Motor producer VEM explains that "each percentage point of efficiency improvement serves to further increase the quantity and quality of the materials used", and adds that "to raise the efficiency by one per cent, the material input must increase by six per cent." (VEM, 2011, p. 2) "Use of conventional materials, such as iron and copper, results in a heavy machine." says Dr. Gotthard Rieger, who heads Magnetic Materials Development at Siemens Corporate Technology (CT). (Froböse, 2011, p. 100) This explains the focus on REE magnets, particularly Samarium Cobalt (SmCo) and NdFeB magnets over the last decades, as depicted in figure 6-8. (Waide and Brunner, 2011 and Öko-Institut, 2011). As Dr. Ulrich Bast from the Technology Innovation at CT puts it: "The excellent properties of REE have led to the development of new products, which have boosted the market further". (Bast in Froböse, 2011)

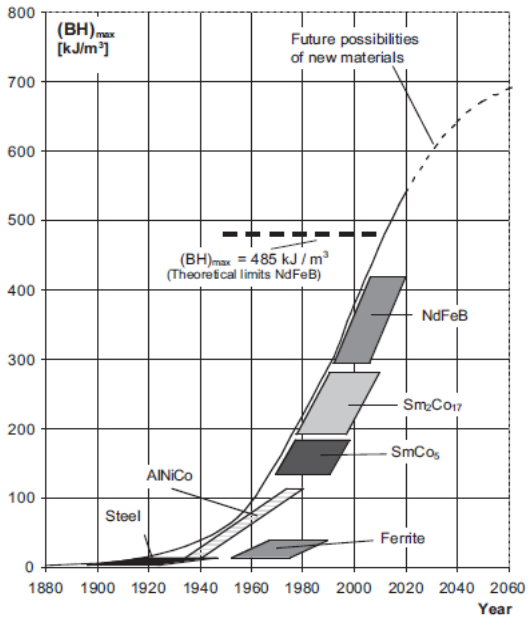

Figure 6-8. Development of energy densities (BH)max of PM and their potential

Source: Vaccumschmelze, 2012

Motor regulation and efficiency standards aim to achieve higher energy efficiencies in these devices. REE substantially contribute to achieving them. The second element of the research aim, is to identify the drivers for eco-innovation in PM motors on one hand and to investigate, on the other, to which extent the extension of the Ecodesign Directive motor regulation to PM motors could influence innovation activities of motor manufacturers with a view to attaining REE RE.

[42] The project is funded by the German Federal Research Ministry and Siemens AG and counts on Daimler AG, Umicore AG (2012), a global materials technology group, Vacuumschmelze GmbH (2012a), PM producer, University of Erlangen-Nürnberg, Technical University Clausthal, Fraunhofer ISI, and Öko-Institut. (Siemens AG, 2012)

7 Multi-level perspective on eco-innovations in PM Motors

This case study is guided by Geels (2002) multi-level perspective of technological transitions and the innovation drivers selected from Blind (2012), Jänicke (2008), Van den Ende and Kemp (1999). In the next sections which represent the levels of the framework, the extent to which these drivers, the Ecodesign Directive, and its potential extension to PM motors affect the development of PM motors and especially the technological transition towards more RE of REE, is explored. The data for both the landscape development and the socio-technologic regime level has been collected through questionnaires, available in Appendix F, sent out to representatives of PM motor manufacturers who attended the first preparatory study meeting.[43] Two responses, complemented by three semi-structured in-depth interviews with PM material experts from academia and a PM manufacturer, all of whom participate in the REEgain project, serve as basis for this analysis.[44]

7.1 Landscape developments for permanent magnet motors

The seven wider technology - external factors provided by Geels (2002), are aggregated by the selected innovation drivers which influence the landscape developments of PM motors, namely export intensity, price volatility and uncertainty, for innovation. The self-ranked export intensity of the PM motor manufacturers businesses, which is indicated as the share of the company's business attributed to exports, is in the range of 30 to 60 per cent. The obtained figure suggests that the business of both manufacturers is not intensely oriented towards exports but it plays a noteworthy role. This first assessment provides a good starting point for the eco-innovation analysis since Blind (2012) argues that export-oriented businesses need to be successful in innovation as serving customers from abroad results in a broader array of demand-side requirements. While the influence of international customers' demand on PM motor innovation activities was ranked to have a medium impact in the business of motor manufacturer A, it is perceived to have a high impact in the innovation activities of motor manufacturer B. Both manufacturers clearly rank fluctuating prices of REE as a high impact factor for innovation activities. Price volatility as innovation driving force suggested by Jänicke (2008) is thereby strengthened. The impact of uncertainty, namely the insecurity about environmental pressures and requirements, on innovations, is less clear. Motor manufacturer B observes it as high, while it is of less than medium importance for manufacturer A.

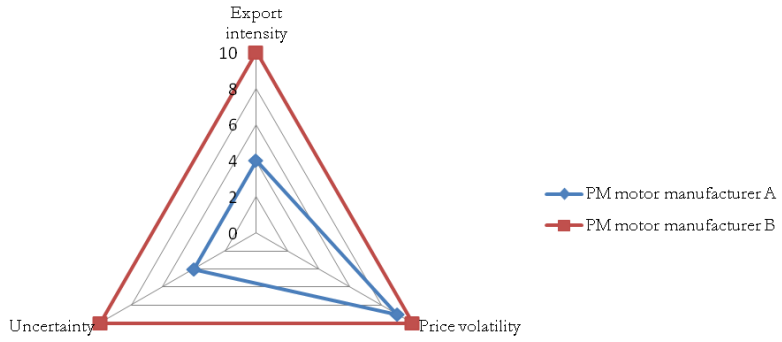

Figure 7-1. Impact of international demand, price and uncertainty on PM motor innovation

Source: own data.

[43] It was also sent out to attendants of industry associations and other businesses whose motor manufacture is not a core activity. Since a comparison with their replies would add a high degree of unclearity to the analysis, their indications were solely used to compare tendencies which were depicted in the PM motor manufacturers' responses.
[44] The respondents' tabularized replies are made available in Appendix G and the interview transcripts in Appendix H.

In summary, price volatility of REE, as one of the three selected innovation indicators for this analysis, visibly constitutes the landscape development factor driving innovations in PM motors.

7.2 Rule set and regulation within the socio-technical regime

Rip and Kemp (1998) paraphrased Geels (2002) socio-technical regime definition by referring to it as "the grammar or rule-set " within a technology determining "the search activities of engineers and the policies and actions of other technology actors including public authorities". They perceive rules as integral part of technology, distinguishing between formal and informal rules.[45](Van den Ende and Kemp, 1999) According to anticipated rankings, both PM motor manufacturers clearly identified regulatory standards with an average of 9.5 points out of 10 as having the highest influence on innovation activities within their companies. Coherent perceptions were also noted regarding the influence of design rules and production practices on innovation activities, which received an average ranking of 5.5 points. These rankings can be considered to be in line with Van den Ende and Kemp (1999) rule set as driving factor for innovation in which core, hard and transient rules influence the technical regime and innovations. The influence of product and compatibility standards on innovation activities within the company, on the contrary, was ranked at high importance by manufacturer B and of low importance by manufacturer A. This divergence is illustrated in the left radar of figure 7-2. Analysing this result, one of the reasons for these divergent views might be attached to the understood definition of product and compatibility standards, namely as regulatory standards which would explain the high ranking with manufacturer B. They should rather be understood as non-binding standards which provide guidelines and technical specifications which would explain their low ranking on behalf of manufacturer A.

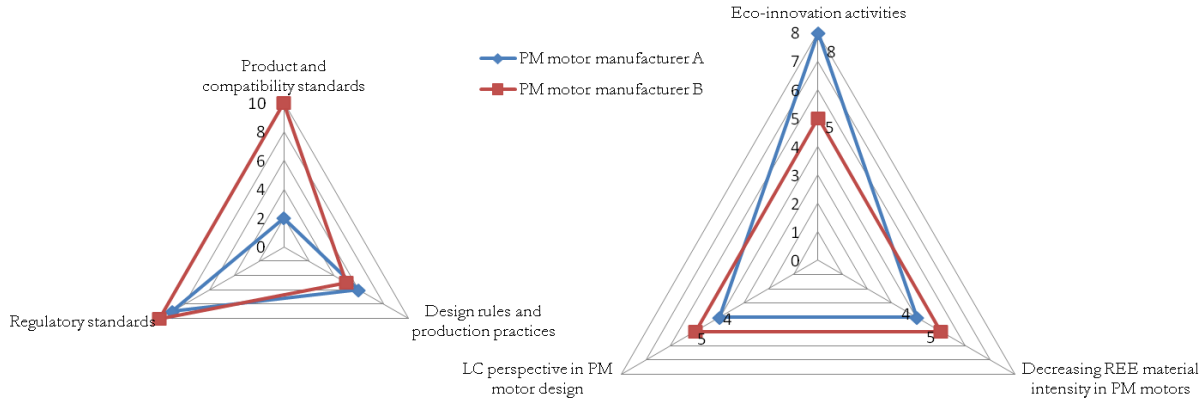

Figure 7-2. Rules influencing innovations (left); Directive contribution to RE aspects (right)

Source: own data.

With a view to the ranking of the Ecodesign Directive contribution to its aspired RE aspects, the results of which are depicted in the right radar of figure 7-2, the perceptions of manufacturer A and B notably differed as to eco-innovation activities. While manufacturer A ranked the Ecodesign Directive contribution to eco-innovation activities in his business at 8 points, manufacturer B perceived solely a medium impact. On the contrary, the Directive contribution to a reduction in material intensity of REE in PM motors and in following a LC perspective in PM motor design was considered to be of medium influence in both companies. These rankings might be interpreted in the light of the perceptions obtained from the generic interviews which suggested

[45] Informal rules relate amongst others to engineering practices. (Van den Ende and Kemp, 1999)

that the full potential of the Directive regarding the product LC and RE improvements has not been exploited yet. Against this background, the influence of an anticipated extension of the motor regulation to PM motors on eco-innovation activities in these motors, is assessed.

The potential for a company to anticipate regulation improves its possibility to predict markets and competitors, and encourages timely innovations. (Jänicke, 2008) Manufacturer B indicates that obtaining both an understanding of and ensuring compliance with ecodesign requirements are the main reasons for participating in the preparatory study. In addition, striving to manufacture an energy saving and environmental friendly product, suggests further ambitions. In contrast, the reasons given by manufacturer A are directly connected to its motors being regulated. Regarding the manufacturers' perception as to an anticipated extension of the electric motor product group to PM motors influence on PM motor innovation activities, both deviate from the focus on regulation and emphasize that prices of magnets [and REE] are of high importance. Manufacturer A adds that "an inclusion of EU efficiency ratings would accelerate new innovations" and emphasizes the influence of market demand for PM motor innovation activities. Manufacturer B, having produced PM motors for several years and focusing current internal efforts on reducing their costs while exploring other, less expensive technologies yielding same efficiency results, welcomes an inclusion of PM motors in the electric motor product group. A different ranking of importance in innovation drivers was noted when comparing PM motor producers and other businesses' replies, for whom the motor manufacturing is a secondary aspect of their operations.

7.3 Technological niches for permanent magnet motor development

PM motors are expected to enable IE4 motor design. (De Almeida et al., 2012a) The commercialisation of PM DC motors has started recently with the market introduction of line-start PM motors in 2010. (De Almeida et al., 2012b) Substituting REE in PM motors is an alternative, which to-date results in a reduction of energy density and thus, an energy performance loss. PM which are composed of iron oxides with admixtures of other oxides instead of REE already exist. On average, without pre-treatment, these sintered ceramic magnets have only one tenth of the energy density of magnets made with REE making them unsuitable for many motor and generator applications. (Froböse, 2011) As a result, the increase in PM recyclability and thereby its facilitation for recycling, is gaining importance in being an option for achieving higher RE rates of REE, beyond the exploration of ores and opening up of mines. To date, there are no methods for REE recycling and most commonly, electric motors EoL is in smelters, where their REE content is contaminated with other materials and lost. (Froböse, 2011) According to Geels (2002), technological niches represent locations for learning processes and provide space to build social networks which support innovations. One of these niches constitutes the Siemens AG (2012) led motor recycling project, described in section 6.3.2., which links industry and academia to investigate options for the extraction of REE from electric motors, considering their entire value chain. In the REEgain project, also described in section 6.3.2., the aim is to find innovative ways for processing the ore and the REE, and to explore technologies for their recycling along with investigating ways for creating a recycling infrastructure. (Christiansen, 2012) Technological niches are also incubation rooms for radical novelties. (Geels, 2002). The removal of magnets from an old motor and their installation in a new motor is usually restricted by their customization which prevents their reuse in new motors. Efforts could be undertaken to design PM from the outset in a manner that allows for their removal from a motor, either for reuse or to facilitate their recycling. (Froböse, 2011) This advanced planning for product retirement is facilitated in product design e.g. by applying a reverse fishbone diagram. A more efficient use of REE could result from this, such as instead of distributing Dy throughout all the material in the magnet, a structure is created "in which this element is concentrated only along the crystallite boundaries within the NdFeB part of each magnet." (Rieger in Froböse, 2011, p. 101)

The Ecodesign Directive potential to contribute to the RE of REE through a motor regulation, which might also trigger eco-innovations in PM motor design, is illustrated in table 7-1 on the basis of several legal standards it could work with and require. It has been elaborated with data obtained through interviews with material experts of the REEgain project. The traffic light colour code highlights options appearing most feasible to-date in green while less realistic options in red.

Table 7-1. Standards facilitating RE improvement and perceived feasibility for PM motors

	Potential legal standards	Instrument with potential to facilitate the standard	Perceived feasibility in PM motors
Design			
BOM	Product composition	Ecodesign Directive	It characterizes the composition of a product and is the main data source for the environmental assessment of a product at the design stage. (Ardente, 2011a)
Design for dismantling	Modularisation	Ecodesign Directive	To date, only about 10 to 15 per cent of machines with REE (typical hard disc magnets) can be recycled, the remainder ends up as dust in scrap yards or as pollutant in steel melts. (Anonymous respondent, 2012) Design for dismantling appears to be a good starting point for increasing REE RE of PM motors. (Christiansen, 2012 and Pryds, 2012)
Design for recycling	Change in the PM material	Ecodesign Directive	It is very difficult to change the PM material to allow for a later reuse. (Pryds, 2012)
	Material concentration	Ecodesign Directive	Options to concentrate the PM material rather than spreading it within the magnet are being explored. If the attempt is successful, it could facilitate RE. (Froböse, 2011)
Recycled content	Horizontal approach: e.g. 30 % of a material need to be from a recycled source.	Ecodesign Directive - Supply chain certification	To-date recycling options are being explored. (Pryds, 2012) Applying a recycled content standard will depend on finding economically feasible recycling options.
Manufacture			
Material restriction	Chemical content	RoHS and REACH	To-date NdFeB magnets are the worldwide best magnets (Pryds, 2012). They are produced from powder materials, classified as chemicals under REACH. (Anonymous representative of a European PM producer, 2012)
Material streams	Purity in material stream	Ecodesign Directive	Most NdFeB magnets are sintered magnets which means their production involves the mixing of magnetic powder material, which is then pressed, and heated (Pryds, 2012). Different processing methods are explored at the moment but to date, achieving more purity in the material stream seems not feasible.

	Potential legal standards	Instrument with potential to facilitate the standard	Perceived feasibility in PM motors
Use			
Energy efficiency	Stricter energy efficiency requirements	Ecodesign Directive	It appears to have the highest potential regarding RE improvements until REE recycling options are discovered. As PM motor manufacture is price sensitive, an increase in REE prices triggers either a turn towards other technologies (ferrite magnet example by anonymous PM manufacturer representative, 2012) whereby their energy efficiency might be lower (leading to more resource use of other materials with less energy density resulting in bigger devices), which would lead to increased efforts in reducing the use of REE (if possible) and/or improve their use. Eco-innovations could be the result.
End of life			
3 Rs	Take-back obligation	WEEE combined with Ecodesign Directive	Despite long motor lifetimes, their return to the producers at their EoL by the consumer would need to be ensured. This is the precondition for any RE improvement of REE in PM motors.

Source: own data.

The Ecodesign Directive promotion of higher energy efficiencies in motors is considered to result in more innovations, especially if REE are readily available as their energy density potential allows for both smaller, lighter designs and high performance levels (higher torque) in motors. (Kozawa, 2011) According to Pryds (2012), it is very difficult to change the PM material to allow for a later reuse. The production of PM is dependent on the use of powder materials, which are classified as chemicals under REACH, a point made by the anonymous representative of a European PM producer (2012). Against this background, elaborating IM which emphasize the use of the BOM in product design, are focused on stricter energy requirements jointly with a demand for improved dismantling potential (and ideally, prevent the PM to be covered by plastics, which prolongs the dismantling effort according to the Öko-Institut Study (2011)), appears to benefit RE of REE in PM motors most. In any economically feasible recycling scenario, the emphasis should be on recycling the PM without losing its properties, a point highlighted by Pryds (2012). As European REE recycling projects recently commenced, only estimates as to a trade-off between REE recyclability and energy efficiency can be made. Christiansen (2012) suggests that REE recycling is not expected to influence their magnetic properties. The set up of a functioning recycling scheme would require an improved EU legal framework. (Öko-Institut, 2011) According to Tukker (2012, May), recycling of PM is reasonable at high REE prices, for concentrated waste such as magnetic resonance instruments or wind turbines (a point also made by Christiansen, 2012) and if the magnets are already collected for other [e.g. RE] reasons. Tukker (2012, May) points out that it takes several years to set up a recycling scheme, and it would be beneficial to explore waste from in use stocks, such as urban mines. He mentions examples where unpredicted price and technical changes destroyed recycling schemes in the past. While Tukker (2012) considers that "technical progress may make recycling obsolete", reasoning that NdFeB magnets are used in high-tech products which are characterized by "quick innovation and short product life times", the author disagrees with this stance with a view to PM motors as to-date the use of REE in the magnets is essential to achieving higher energy efficiency classes and will continue to be until other materials are found that demonstrate similar or higher energy densities at limited material use.

8 Discussion

The drafting and adjustment of existing policy instruments to better address competitiveness and facilitate innovations in KETs, along with an increase in RE, as one of the flagship initiatives of the Europe 2020 Strategy, are clear objectives of the EC and its EU member state governments. Given the limited availability of literature which jointly addresses the Ecodesign Directive and its RE potential, this work adds to ongoing discussions. It moves beyond discussing feasible indicators on their own to discussing how the Ecodesign Directive could contribute to RE and especially, given that the tool with which it operates are ecodesign requirements, in how far it can facilitate innovations which foster an increase in RE. The empirical data collection from national contact points for the implementation of the Directive adds, according to the author's view, a new perspective on the Directive's contribution and possibilities in that regard. The author also perceives that this work further enhances the debate by introducing the RE issue within the specific product group of electric motors. It is shown that a potential extension of the motor regulation to PM motors would provide for different approaches, in the form of legal standards, in addressing RE of REE.

8.1 Validity of the Analytical Framework

The analysis of the data and results obtained from interviews through the perspective of selected innovation drivers followed a conventional approach in policy analysis whereby indicators are used instead of a framework to analyze findings. For the case study, the author departed from Geels (2002) original multi-level perspective on technological transition by aggregating the original seven dimensions into multiple innovation drivers corresponding to the landscape development and technologic regime level. To facilitate the comprehension, the author designed an analytical framework which illustrated how the first research aim was to flow into the case study. One limitation attached to the use of this framework could be seen in its reliance on qualitative data analysis, given that policy analysis often draws on quantitative analyses to juxtapose negative with positive effects, such as potential welfare gains. The author however perceives the method applied as adequate for the scope and aim of this work with ten interviews conducted. As the emphasis was on obtaining different insights and perceptions of respondents on the potential Ecodesign Directive contributions to eco-innovations, the analysis thereof might have been less useful and adequate if it had been performed in a quantitative way.

The author perceives that the results derived from the use of selected innovation drivers in the generic interviews conducted to assess the Directive, revealed new insights, including the influence of other policies' promotion on the popularity and acceptedness of the Ecodesign Directive, the possibility for a wider inclusion of environmental aspects if significance was understood as improvement potential, and preferred sector-specific industry ideas for the scope of the Directive, to mention but a few interesting aspects.

Geels (2002) multi-level perspective on technological transitions was chosen to facilitate the provision of a more comprehensive picture in the case study which aims to underline the specificities attached to REE and PM motor innovations. As indicated in section 2.2.3, the multi-level perspective is not undisputed. To adjust the framework to the specific needs of this work the author, as discussed above, tailored the dimensions of the landscape and regime level to selected innovation drivers which were also used as guide in the questionnaires. The author perceives that this adjustment benefitted the work in as far as specificities in eco-innovation activities attached to the PM motor manufacture could be revealed. Among the revelations was the influence of REE prices and customer demand on PM motor innovation, along with, as can be expected, regulatory standards as drivers. Against the background of customer demand being decisive for PM motor innovations, promoting the gains from improved RE along with facilitating RE measurement is considered to carry numerous potential benefits. The complementary interviews with material

experts are seen to disclose new views as to the feasibility of the selected legal standards which are to contribute to the RE objective and could be fostered by the Ecodesign Directive.

8.2 Facilitating Resource Efficiency Measurement

The challenge with RE measurement is twofold: On one hand, the measurement shall be easily understandable and implementable, ideally to be based on readily available data. On the other hand, RE, as the term already suggests, is a complex field and the discussions revolving around its measurement reveal the multitude of measurement issues attached to it. One of the issues relates to the requirement for a certain level of detail, preciseness and comprehensiveness attached to it in order to obtain usable results, which is also a precondition for the conduct of a LCA, a simplified version of which is part of the MEErP. The revised worksheet available within the MEErP EcoReport tool appears to be a good attempt to facilitate data collection and decision making on behalf of the manufacturer.

What adds to the discussion is its practical implementation through a policy instrument, the Ecodesign Directive, where measurement on the product is in principle required but a supply chain certification would theoretically also be feasible. Both cost of requiring declarations and, or thresholds such as of recycled content, and practicality issues pose other challenges to resource efficiency measurement.

8.3 Fostering Eco-Innovations through Incentives

As has been pointed out by the interviewees, the Energy label, which works well with the Directive, is perceived to be the instrument within the IPP mix which provides for the highest innovation incentives as a result of its clear and visible communication allowing for comparison of energy efficiency performances within a product category. The voluntary EU Ecolabel, being observed as less well linked with the Directive, also builds on visibility. Throughout the interviews, it was pointed out that generating publicity also acts as an incentive for the pursuit of attaining the objectives of one instrument as opposed to another by public authorities. For instance, less attention was paid to the Ecodesign Directive amongst Belgian authorities on a regional level compared with the Waste Framework Directive.

The presentation of resources as embedded energy both in the course of public awareness through informative instruments which emphasize its benefits for society and the environment, and in the process oriented towards elaborating IMs, could result in both a better understanding of the issues inherent to it and in sequence in more openness towards including environmental aspects in preparatory studies. On the example of the specific case on permanent magnet motors, it could easily be argued that a resource efficiency improvement of rare earth elements would allow for further innovation activities potentially leading to better permanent magnet motor performance levels as rare earth element prices are the determinant factor in permanent magnet motor innovations in combination with customer demand and regulatory standards.

8.4 Ecodesign Directive Decision-Making Process Improvements

While it has been noted that the treatment of products in individual categories is a resource and cost intense process, suggestions have been made for approaching various product groups in a system perspective. The difficulties attached to that process are that products would also need to be addressed individually even if they were to be regulated in a system as the individual product's energy efficiency would affect the entire system's energy performance.

When it comes to improving the participation of SMEs in the decision-making process leading to IMs, the role of industry associations needs to be addressed as they would need to take increased

responsibility in fostering the participation of SMEs, at the minimum by sharing and passing on information and ensuring their feedback is being reflected in the decision-making process.

Another point which deserves attention is the inclusion of EU citizens' voice in the decision making process which can be only ensured through the participation of non-governmental organisations and national representatives. As one NGO representative pointed out, it would be beneficial to the process if it was required that planned votes on behalf of member states' national representatives would need to be made public before the event as efforts could then be undertaken to raise awareness or make more information available if a need for that was noted.

The process accompanying the elaboration of IM could also benefit from a closer alignment with ongoing elaborations of international standards as product regulations often turn to the standards for guidance and more coherence in requirements would allow for further improvement potential.

The complexity attached to regulating certain product groups such as PM motors, would demand for experts from several different backgrounds, including from physics and metallurgy with a view to magnetic materials, and from electromagnetic engineering for the development of magnets, as the variety of aspects of relevance presented in the case study show. In the lot 30 preparatory study, mainly machine engineers participated. The challenge is to find ways to include a broad spectrum of views from experts of different backgrounds in the process for the elaboration of IM.

8.5 Permanent magnet recycling and resource efficiency

The aim for improved resource efficiency is driven by several interlinked factors. On one hand, there is a general understanding that resources are scarce and that a diligent handling of available resources ensures both their longer use and increased benefit from them amidst growing environmental pressures and an increased demand for resources, resulting in higher prices. On the other, the need for a careful use of resources is embedded within geopolitical, strategic thinking, as discussed in chapter 4 and section 6.3.2. European economic growth and competitiveness are strongly linked to resource use and certain critically classified materials. Among them are the rare earth elements, which are key to the high-tech industry and sustainable technologies, as their chemical properties allow for a simultaneous reduction in appliance sizes and energy efficiency increases which makes them potential enablers for eco-innovations.

Their prolonged use, and improved resource efficiency, could be facilitated through improved product and component recyclability. Besides physical and chemical limitations for recycling PM, and finding economically feasible technologies to recycle them, the challenge is, given that a decision in favour of setting up a recycling scheme is taken, in establishing the scheme. It might take several years during which mining initiatives are also expected to supply the market with rare earth elements influencing the economic rationale of implementing a scheme. A precondition for the recycling scheme is the successful collection of PM and PM motors. The emphasis in the collection objective will need to be defined whereby a focus on larger, concentrated sources of rare earth elements in the first phase could facilitate a start up, even if the collected amount of ErP with smaller concentrations of rare earth elements should not be neglected. Another aspect to be considered is the long lifetime of PM motors. For the successful functioning of the scheme, also infrastructure planning is essential which needs to take into account specificities attached to PM such as with a view to transportation, which excludes air freight as the magnets might disturb the plane and, in general, PM need to be demagnetized for transportation. To make the most of urban mining, further controlling of scrap exports to detect illegal exports containing critical metals, in a tighter alignment e.g. through qualitative targets with WEEE, will be needed. In general, increased know-how transfer and international cooperation are perceived to be beneficial.

9 Conclusion

The recognition of growing environmental pressures fostered policy action towards sustainable development, including through "A Resource Efficient Europe", one of seven flagship initiatives of the Europe 2020 Strategy which is to support the transition towards a resource-efficient and low-carbon economy. An increase in resource efficiency is considered crucial for the development and competitiveness of the EU economy, since 14 materials, including rare earth elements, which are key to the development of sustainable and efficient technologies, and have been, due to observed global supply imbalances, classified as critical. The EU product-oriented environmental policy, building on the integrated product policy, is an essential pillar in attaining improved resource efficiency. Several product policy instruments address different phases of the product life cycle, including RoHS, REACH, the Energy Label and WEEE. Other instruments attempt to address a wider life cycle perspective including the EU Ecolabel and GPP.

The orientation towards a life cycle perspective is also reflected in the Ecodesign Directive which, however, through its prime objective of increasing the energy efficiency of energy-related products by means of EU product-specific regulations that are to harmonize the internal market, addresses primarily the product use phase. Nevertheless, its ecodesign requirements provide for a base to put its prime objective to the benefit of society and the environment by requiring design changes from manufacturers that allow for product life cycle improvements, specifically an increase in resource efficiency. Against this background, and understanding that these design changes depend on innovations emphasizing resource efficiency, namely eco-innovations, the following question was addressed: *How may the Ecodesign Directive contribute to promoting eco-innovations?*

Empirical data was obtained in ten guided by *selected innovation drivers*, in-depth interviews, with representatives from national contact points for the implementation of the Directive, the European Environmental Bureau, an NGO representing European environmental organisations and citizens, and the EC DG Environment section on product policy. In a first step, a basic assumption needed to be confirmed, namely its *political support*, the first innovation driver**.** This was to be evaluated through the perceptions regarding its political support amongst industry and politicians, and its openness for participation of a wide selection of stakeholders. In essence, a wide political and industry support was noted, and except for several, most of which were classic, limitations to participation of stakeholders, its openness for participation was assessed positively, thus a good political support was perceived.

In a second step, four selected innovation drivers, which were to establish whether the Directive is an *innovation friendly instrument***,** guided this part of the interviews: 1) economic incentives provided by the Directive, 2) the Directive acting in combination with other product policy instruments, 3) its emphasis on strategic planning and goal formulation, and 4) its support of innovation as a process.

1) The declaration of conformity in form of the *CE label* was perceived as a good incentive due to its protection-granting nature against worse performing products available outside the EU market. It was suggested that promoting the view of *resources as embedded energy* was an option to increase the visibility of economic incentives.

2) It was found that the Directive *acts well in combination with the Energy label*, which was highlighted as a stronger driver for product innovations, and less well with the EU Ecolabel and GPP. Efforts to create more coherence between the Directive and policy instruments such as with WEEE, RoHS and REACH could start by drafting a *common set of criteria* for the instruments which address the same criteria, jointly with the *same evaluation methodology* and **a** *close to simultaneous review* of each instrument's criteria. This approach would

benefit from a combination with an *escalation process* that would require a higher threshold to be reached under each instrument.

3) The Directive was evaluated well on *strategic planning and goal formulation*, as it allows for the anticipation of new standards and its goals, in the form of IMs, are clear, even if they were considered to be not stringent enough. More continuous market surveillance for real time data was perceived to be key to elaborate stringent standards.

4) Regarding *innovation being supported as a process* which takes into account different phases of innovation, it was noted that the ecodesign requirements are set in tiers which intend to represent industry's design cycle.

From an overall point of view, respondents rated the Directive positive regarding its potential to support innovations, whereby a clear stance was taken in that it has not lived up yet to its full potential regarding non-energy related aspects, including in increasing *RE*. Respondents remarked on the need for available, accepted indicators if the Directive was to contribute towards RE improvements. In addition, it would need to be ensured that they are addressed in preparatory studies. It was considered that the Directive could best achieve an increase in RE through

a) *horizontal measures*, whereby a *concentration of a material* in a product was perceived to be the easiest option to be implemented through it. *Supply chain certifications* of the final product producer would be needed to measure compliance with the other raised options through which RE improvements could be accomplished, including e.g. a demand for a certain amount of recycled content of a material used in a product. The second option's limitations were seen in the practicability, namely data available for a certain requirement. Other options discussed were the total cost of ownership method and EoL efficiency.

b) the *understanding of significance* in environmental aspects which was to reflect their improvement potential. Nonetheless, the inclusion of a *critical material indicator in the MEErP* was considered a starting point.

In a wider sense, if it was agreed that the aim of the Directive was to extend beyond an improvement in product energy efficiency levels and removing worst performers from the market, namely to *lift the market to a higher level* through an improved product LC performance, several adjustments in the drafting of requirements would have to be envisaged, including:

- the facilitation of the elaboration of *ambitious long-term standards*
- an emphasis on addressing *functionality* rather than technology
- a *BAT orientation* of standards underpinned by a change of focus from LLCC to *BLCC*

These adjustments were to work best if the *coherence* of the Directive *with other product policy instruments* was ensured. Also, a framework which could take the form of a *European top runner*, in some elements oriented towards the Japanese original, and was to embed these amendments was considered beneficial. It is understood that regulation and technological improvements on their own will not be sufficient to halt environmental deterioration and global warming. Nevertheless, the Directive is considered to be a useful policy instrument especially due to its technical and product group specific orientation. It is perceived that its potential to provide incentives which could trigger eco-innovations that increase RE could be better harnessed if the discussed adjustments were to be put in place.

With a view to the *case study* on the extension of the electric motor product group regulation to possibly comprise PM motors and the ex-ante assessment of how and in which form the Directive could contribute to innovations in these motors that enhance resource efficiency of REE, the PM manufacturers revealed *regulatory standards* as most influential innovation driver, besides price volatility of rare earth elements and customer demands. The interviews with material experts added insights on the processing of permanent magnets and contributed to rating the feasibility of applying some legal standards capable of fostering resource efficiency of REE in PM motors, as opposed to others. This insight added to the PM motor manufacturer perspective on the Directive eco-innovation potential on motors and their anticipation that a demand of *new, higher motor energy efficiency levels* in the EU could be a further incentive. It also clearly outlined the enforcement of *a design for recycling*, namely the improved *dismantling potential* of motors, as being the standard with most RE potential in PM motors, under the precondition that an informed decision for REE recycling was taken and a recycling scheme was set up. Against this background and with a view to potential future developments towards REE recycling, a closer alignment with WEEE to facilitate a take-back and recycling scheme, was considered to be of benefit. The feasibility of other available legal standards, such as a material concentration to facilitate recycling, was seen dependent on preceding innovations in PM manufacturing technology with current research efforts investigating various options.

9.1 Further areas for research

With RE being at the forefront of political debates, it is also a topic that gains increasingly importance among researchers. While its measurement is being investigated with the aim to derive an adequate, easy to understand and implement and thus, accepted indicator, several other areas, which are beyond the scope of this research could benefit from further research:

- Based on the perceived success of the Energy label, an investigation into which extent resource efficiency and an accepted resource efficiency indicator could also be translated into being a powerful communicator, e.g. in the form of an unequivocal label that increases the visibility of resource efficiency on a product.

- The proposed concept for a European top runner could benefit, against the background of IPP, from a review on how it could be best linked with existing product policy tools and which adjustments within both the scheme and the instruments would benefit the overall purpose of lifting the energy using products market towards improved product LCs.

- Linking into the previous recommendation, an in-depth review on compatibilities among criteria applicable to various product policy instruments to facilitate the design of a common set of criteria, followed by a review of the management of these policy instruments which is to comprise the drafting of a common methodology for this set along with an agreement on a short timeframe during which all applicable instruments' indicators are to be reviewed, would be desirable. The attempt could extend to elaborating options for an escalation process.

- Addressing resource efficiency and innovations from a system perspective, namely in an extended product approach, e.g. on the example of electric motor-driven systems, needs further investigation.

- With a view to decreasing the time needed to derive IMs, it could be worthwhile researching, given that significant energy savings can be attained, in which way structural adjustments and an EC increase in resources for ecodesign could benefit this endeavour.

- The socio-economic and geo-political implications of rare earth element recycling, with simultaneous ongoing rare earth ore exploration and mining activities, could be further explored in relation to potential effects on PM motor design options enhancing their dismantling and on the technological advances in PM recycling.

9.2 Transferability of the study

The generic aspect of this study which addresses the Ecodesign Directive potential to contribute to eco-innovations could be interesting to be explored also in the context of other policy instruments with similar objectives, above all the EU Ecolabel, as it is also centred around a life-cycle perspective, has a visibility element and aims to lift the market towards improved product life cycles. In a wider sense, this aspect of the study could also be transferred to the policy instruments addressing product design and end-of-life issues, including RoHS, REACH and WEEE.

The case study, in particular the adjusted multi-level perspective with the integrated innovation drivers on the landscape development and technological regime level, could be replicated for other Ecodesign Directive product groups which show significant improvement potential with ecodesign requirements and a complexity of factors on different levels influencing their development. The questionnaire used for this work would then need to be adjusted to address product-specific issues.

The findings on the legal standards which could comparably be most easiest implemented through the Directive motor regulation to foster resource efficiency in PM motors and potentially encourage eco-innovations in motor design, could possibly in parts also apply to other Ecodesign regulated ErP groups which have a long life-time and whose energy efficiency performance is at least partially linked to the use of REE, for instance pumps. As this product group also has specific characteristics, the exact transferability would need to be tested, through for instance, interviews with material experts for which an adjusted version of the interview guide prepared for this work could be used.

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Appendix A: Critique on the multi-level perspective

The criticism towards the multi-level perspective (MLP) mentions three weaknesses which address the conceptualisation of transitions: Berkhout et al. (2004, p.54) raised concern about the unclearness attached to applying conceptual levels at the empirical and analytical level, and Smith et al. (2005, p. 1492) highlighted the neglect of agency, and the over-emphasis on technological regimes as a generator for regime change. (Geels and Schot, 2007)

Geels and Schot (2007) address the critiques and clarify misconceptions related to the application of the conceptual levels outlining the difference between empirical levels and analytical levels and suggesting that analysts are to segregate the empirical level of the analyzed object in a first step in order to then operationalize the MLP. As to the operationalization, they refer to the numerous organisational levels provided by institutional theories and note that "transitions in socio-technical regimes are situated at the level of organisational fields." (Geels and Schot, 2007, p. 402) The definition provided by DiMaggio and Powell (1983, p. 184) is applied for the identification of actors. It outlines key suppliers, resource and product consumers, regulatory agencies, and other organisations that produce similar services or products as constituents of the organisational field. Concerning the critique on neglected agency, the authors clarify that the graphical conceptualisation with arrows might lead to this misconception. Geels and Schot (2007, p. 402) outline that technological niches and socio-technical regimes are "similar kinds of structures" even if they are differentiated in size and stability. Both are characterized as organisational fields which implies that they are formed by communities of interacting groups. A multidimensional model of agency brings about the notion. Actors, despite being surrounded by rule structures, actively use and make rules. Socio-technical landscapes "provide deep-structural 'gradients of force' that make some actions easier than others" (Geels and Schot, 2007, p. 403) as described earlier in this section. With a view to the critique on the niche emphasis, Geels and Schot (2007) highlight that this approach represented the early work in strategic niche management and refer to Geels (2002) advise to increase the level of attention paid to continuing processes at the landscape and regime level.

Appendix B: List of interview partners

	Affiliation	Position	Type of interview and date
1	European Environmental Bureau	Senior Policy Officer Products and Waste	Telephone interview, 08.06.2012
2	Federal Public Service. Health, Food Chain Safety and Environment. Directorate-General environment, Product Policy	Head of Unit. National contact point in charge of the implementation of the Ecodesign Directive 2009/125/EC. (Belgium)	Telephone interview, 15.06.2012
3	Ministry of Infrastructure and Spatial Planning / Energy Directorate	National contact point in charge of the implementation of the Ecodesign Directive 2009/125/EC. (Slovenia)	Written reply to the interview questions, 19.06.2012
4	Sustainable Energy Using Products Team	Department for Environment, Food and Rural Affairs (Defra). National contact point in charge of the implementation of the Ecodesign Directive 2009/125/EC. (UK)	Telephone interview, 21.06.2012
5	Competitiveness and Climate Change Unit, Department of Enterprise, Trade and Innovation.	National contact point in charge of the implementation of the Ecodesign Directive 2009/125/EC. (Ireland)	Telephone interview, 22.06.2012
6	Energy Department. Ministry of Economic Affairs and Communications.	National contact point in charge of the implementation of the Ecodesign Directive 2009/125/EC. (Estonia)	Telephone interview, 25.06.2012
7	DG5 Environment | Product policy	Attaché senior. Product policy.	Telephone interview, 27.06.2012
8	Federal Environment Agency. Section III 1.3 Ecodesign, Environmental Labelling, Environmentally Friendly Procurement.	National contact point in charge of the implementation of the Ecodesign Directive 2009/125/EC. (Germany)	Telephone interview, 28.06.2012
9	Service Climat et efficacité énergétique Direction générale de l'énergie et du climat MEEDDM/DGEC/SD5	National contact point in charge of the implementation of the Ecodesign Directive 2009/125/EC. (France)	Telephone interview, 04.07.2012
10	Institut Luxembourgeois de la normalisation, de l'accréditation, de la sécurité et qualité des produits et services (ILNAS).	National contact point in charge of the implementation of the Ecodesign Directive 2009/125/EC. (Luxembourg)	Telephone interview, 09.07.2012

Appendix C: Generic interview guide

Political framework

1. Do you get the impression that the Ecodesign Directive 2009/125/EC is a **well-accepted framework directive** amongst stakeholders, in particular industry and politicians?
   - Yes
   - No

   If no, which aspects of it are less well accepted?

2. How do you perceive the current possibility for a wide selection of stakeholders to participate in the process attached to obtaining binding eco-design product regulations?

The Ecodesign Directive

3. Against the background of several instruments, such as the EU Energy label or GPP, addressing a specific phase in a product life cycle only: What is your view regarding the Ecodesign Directive pursuing product-specific ecodesign regulation which fosters a life-cycle perspective?

4. Do you think the Ecodesign Directive 2009/125/EC is an efficient policy instrument for achieving higher resource efficiency in energy-related products ?
   - Yes
   - No

5. What is your perception regarding the ability of the Directive to foster product innovations?

6. What is your impression of the implementing measures adopted so far?

7. How do you perceive the stringency in adopted ecodesign requirements of the product-specific regulations in view of attaining higher resource efficiency?

Appendix D: Selection of generic interview transcripts

Interview transcript 1, 08.06.2012

Interviewee: Stéphane Arditi, European Environmental Bureau

Questions

Political framework

1. Do you get the impression that the Ecodesign Directive 2009/125/EC is a **well-accepted framework directive** amongst stakeholders, in particular industry and politicians?

   Yes.

   It's a confidential Directive and many stakeholders enter into the process. The 2009 extension of the Directive scope to ErP forced decision makers to look at the broader picture, a system approach with an innovative perspective. With a view to the revision of the legislation, even if I was not personally involved in the definition of the legislation at that stage, I must say that *the main improvement has been the extension of the scope to ErP which presents a potential in terms of innovative policy namely because ErP would force the decision-maker to address energy-wider aspects as compared to energy in the use stage only, as we had when we were dealing with EuP*. Particularly today I see that with windows we start speaking about a system approach, we could identify the impact in terms of energy consumption of one equipment but with regard to the overall energy-consumption of a building. *This extension of the scope will definitely trigger some innovative approach and this has been confirmed by the new methodology, the MEErP, which clearly stresses the new investigation needed to address the ErP.*

   Energy remains the main focus of the Directive. The 2009 Directive does provide a lot for other dimensions to be addressed. *There is potential to address any dimension but I would say there is no real obligation to make sure that we properly assess the impact and that we properly assess the improvement potential particularly because of this understanding of what we call "significance"* where it looks like, in the way we understand this policy, we first identify "significant impact" and then investigate the improvement option and improvement feasibility. *This would be slightly different if we could understand "significance" not as the main environmental impact only but as the "improvement potential"*. E.g. if we have criteria such as resource use, which are not as significant as energy use but where the improvement potential will be significant, and that the significance will be, at this stage, addressing the improvement potential rather than the absolute environmental impact per se. Then we could e.g. have more opportunities to claim for additional environmental requirements.

   I have got nevertheless good hope that this could happen, for two reasons, one is the *political reason as there are more and more pressures to addresses these critical materials and this is also pushed by DG Enterprise which is co-chairing this policy with DG Energy*. The second thing is that, in new MEErP, as revised in 2011/12 we have got some additional criteria, such as addressing the societal cost, e.g. being able to value and monetarize the impact on human health and air emission and also critical resource use in products. But this is more of a question mark. At the moment we haven't really started to define implementation measures for products which are ErP and not EuP. There is a delay in ecodesign. You first have the working plan and then you have got strategies and work on the individual implementation measures. So it's not because the scope has been extended, that these products will be addressed as a priority, but they will be addressed sometime in the future.

Regarding the formulation of 2009, I cannot say I am satisfied, I am not really satisfied as I was not there to assess the potential and result, but what I can see regarding addressing additional resource beyond energy or maximizing the energy saving potential, I think it was a rather good revision. And now, *it all depends on the implementation process* which is not such a political process but a more confidential process where technical experts which are dealing with the case. At the moment, when I see very important lots, which go beyond energy use, such as computers, or game consoles we cannot really be satisfied in regards to how they address resource use beyond energy use.

At the moment, *we understand significance as the absolute environmental impact, we select the criteria according to the absolute environmental* impact e.g. for washing machine we also identify water use as an important significant impact, and at the end of the day, in the regulation, despite the fact that a washing machine is clearly an EuP, we also have requirements for water. *If we could, in the future, understand the significance in terms of the improvement potential, that could mean that, even if in terms of absolute impact, something is not as huge as energy use impact, if the improvement potential is significant, then this should be a clear sign to address this issue.* Today I sometimes get the impression that the filter or the selection criteria for what environmental dimension we will address is in a way immediately stopped because we consider the significance as the absolute environmental impact.

An example related to REE, it might be that the very small amount of REE will never make it a potential candidate, if we address the significant impact as the absolute impact. Because we have got to be realistic, *even if REE is a nightmare to mine and critical, the small amount we have got in the product will never be able to compete in terms of absolute environmental impact with the energy use*, but now if we say, the significance is understood as what is the improvement potential to address the case of REE in one appliance. *So even if REE absolute impact is minor, maybe the improvement potential is huge, compared to energy use, which could be very important in terms of absolute impact but where the improvement potential maybe is more limited and limited in the future as we go for tougher and tougher requirements.*
That is a more subtle way of understanding significance. And that's why we try to promote the way we should understand significance. That does not mean that it should lead systematically to an investigation of resource use, rather it is an option to open the range of the environmental dimension we could address if we set the filter at the improvement potential.

2. How do you perceive the current possibility for a **wide selection of stakeholders to participate** in the process attached to obtaining binding eco-design product regulations?

The way it is organized is quite open. For example, as green NGO we have got a permanent seat in the consultation forum and the same for consumer and health. We could potentially have 8 representatives in each consultation forum - 2 for EEB, 2 for ECOS , 2 for Inforse[46] and 2 WWF. And on top of that, when we participate we are always given the floor by the chairman of the consultation forum when we ask for it, so there is no exclusion of the NGO voice. Nevertheless, some limits to participation are perceived:

1. With a view to the *circulation of information* there are only the *traditional limits* to public participation in form of back door lobbying which goes even beyond the desk officer in charge, e.g. another channel within the chain of authority. Using

[46] International Network for Sustainable Energy (INFORSE, 2012)

the example of energy label for TV, the Director (Commissioner Öttinger) needed to intervene which caused a delay in the entering into force. I would not say it is perfectly democratic, but we have a real possibility to participate.

2. The *asymmetry of resources* poses another limit when compared to industry. When we have two employees to participate, that is already very good. There is an overrepresentation of industry - large players can send two representatives and in addition, one individual is sent from the industry association.
3. *National representation.* Ex. Denmark has a proper consultation process, but there are member states without a national representative in the consultation forum and there won't be involvement of civil society or consumers or green NGOs. There is a need for more transparency in the vote of member states. Specifically this means that member states should need to *inform on their position before the vote* which would put member states in a position where they would need to consider policy more and be more involved.

The additional point addresses the *disclosure of confidential information* and the benefit for the European Union if it was disclosed. There is a risk associated with going more public with information when it is a technical issue since the nitty-gritty might not be understood by the public and the public might be negative media which might negatively affect the progress achieved up until then. We work with the EC to move towards m*ore positive communication* (which does not mean saying that everything is good but that the bad press is not the main voice heard by the EC) which would need to accompany the publishing of confidential information in order to avoid bad press (in popular tabloids and journals). Also, there is a need for a *more pro-active attitude by the EC*, e.g. tap and shower heads have not been put on the working plan for a fear that it might not be a publicly accepted topic. This is a concern for decision makers at EU-level when they decide what to say.

At the moment some say "maybe it's better to go ahead and to stay confidential rather than going public and being even slow in the decision because we have to address an additional concern, the bad press". We are trying to *balance this risk* still delivering some positive message about the impact of this policy but also try to gather enough evidence and data so that we can react in case of bad press. The resource scarcity aspect is affected by this constraint. Having a more pro-active attitude by the EC as opposed to a fear-driven approach would be beneficial.

The Ecodesign Directive

3. Against the background of several instruments, such as the EU Energy label or GPP, addressing a specific phase in a product life cycle only: What is your view regarding the Ecodesign Directive pursuing product-specific ecodesign regulation which fosters a **life-cycle perspective**?

   It is a *good effort to consider the whole LC and to identify the significant impact* with a view to the previous discussion on the significance. At the moment we try to develop a nuance position, because we are *sceptical about claims that ecodesign can address everything.* This has also been stressed by the study on evaluating the effectiveness of the Directive which has revealed that e.g. the product category "food" does not feed into the scope of the Directive. With ecodesign you need to be able to address some impact, as a sort of baseline, which can be measured when placing the product on the market, and can be also enforced by the member state. Market surveillance activities, the compliance aspect of the Directive, which are not really addressed, are the problem at the moment. *The more ambition for regulation there is, the more enforcement activities are desirable.*

4. Do you think the Ecodesign Directive 2009/125/EC is an efficient policy instrument for **achieving higher resource efficiency** in energy-related products ?
   Yes.
   At the moment what we try to develop, in cooperation with university, are the conditions which ensure which environmental aspects can be really addressed by ecodesign. There are two important aspects:
   1. Priority resource use aspects identified that we need to address absolutely and which ones are best addressed by ecodesign, and
   2. amongst them, which aspects are better addressed by other instruments, e.g. EMAS, sectoral reference document, IED draft document, and so forth.

   So, what are the conditions for a certain product and a certain environmental dimension to be a good candidate to be regulated upon by ecodesign. What we identified is that *EoL management and resource use aspects could be good candidates* because in fact, you can imagine, when you place a product on the market you have to respect certain requirements for recyclability, reusability, or information provision of where critical materials are located and the process that we do not lose the opportunity when the product reaches EoL. Also some chemical aspects can also be addressed by Ecodesign, because when placing a product on the market, industry can measure it and again, the market surveillance authority can check this at the end. For us, hazardous material, chemical contents, recycling, reusing, recovering of material could be properly addressed by ecodesign.

   But it is a bit more subtle than saying "oh, ecodesign can address whichever job you ask for the resource efficiency agenda". And this is a big risk for us, because, if we are not a bit subtle in what are the conditions to identify a good candidate for ecodesign, we could result in an easy counterargument for those who are not in favour of extending the environmental dimension/scope. *At the moment we like to investigate the condition for the relevant inclusion [*of products*] in the ecodesign scope and ecodesign environmental performance we can challenge rather than saying eco-design will be the silver-bullet to all our problems.*

   If we consider critical material, for sure, I am convinced, we have not explored the full potential of ecodesign yet, and I have mentioned two dimensions:
   One is about the *information requirement* (we could have associated to each product, where is every material, and how we could best recover them which could complement WEEE qualitatively, as WEE targets are weight-based, and REE would never be addressed and this could be complementary and not an overlap) and,
   the other is about *how the design of the product is conceived* so that when it or its critical components reach EoL, we can disassemble it/them and replace the component or make sure that recyclers can recycle these critical materials.

   To date, DG ENV elaborate together with JRC collaborate on the *assessment of the "resource use environmental impact"* rather than resource weight in recycling. We are in a learning process and the suggestions are still a bit complicated which provides room for argument. I expect a lot from collaborating with universities and researchers who don't have a technocratic perspective only.

5. What is your perception regarding the ability of the Directive to **foster product innovations**?
   The evaluation study revealed that the Directive, first, is cost-effective, generally speaking, second, it doesn't undermine EU competitiveness but the question mark is

whether the Directive really challenges the market. *Sometimes we get the impression that ecodesign is more running after the market than challenging it*. We should more combine in a coherent way the different product policy instruments we have, namely, GPP, eco-label, the energy label. If we could, as it is now proposed by Germany, adopt the top-performer approach[47] and make sure that at any stage we also create a long-term vision on the *product of tomorrow should be at the level of BAT of today and provide this legal visibility through ecodesign*, we could for example put a bit more pressure on the market to *speed innovation not in terms of absolute fundamental innovation but at least in terms of industry realising what is today BAT and still emerging technology*. So that is one way forward and the second is, in combining the different product policy instruments, at the moment what we also try to push is: *Could we consider a basic set of requirements that could in a way reticulate in all policy instruments?*

So for example, if I have a requirement on energy efficiency for a certain product in ecodesign, e.g. TV, *can I make sure that the GPP will also in a way include the same methodology that sets a higher threshold for the energy efficiency requirement and that the Ecolabel will also align with the same measurement methodology but have an even higher level.* This will not mean that GPP and Ecolabel should only regulate on the same criteria as ecodesign, but that *on the common set of criteria, we could create this kind of escalation process between the different product policy instruments at EU level and then maybe give more triggers for innovation.*

For example, when you want to measure the energy efficiency of a washing machine, you have a measurement methodology in ecodesign which is a certain number of cycles at a certain temperature, full load and half load. This is a standard formula to calculate the energy efficiency and then the manufacturer cannot put a product on the market which according to this formula does not conform with the minimum requirement. But when I go to GPP criteria for washing machines, the energy efficiency requirements are not necessary calculated according to the same measurement methodology and they are not revised at the same time. Example: TV. Today we have eco-label threshold for TV which are below the minimum requirement for TV because they haven't been revised at the same time. So imagine we have exactly the same measurement methods for all three instruments but with a different threshold and when you update the threshold for minimum requirement in ecodesign you immediately you update the criteria on this environmental dimension for GPP and you immediately update the threshold for Ecolabel on this criteria according to the same formula. So that other manufacturer can decide where they will be, e.g. my product complies with GPP or Ecolabel for this dimension. This should not mean we should restrict the GPP and Ecolabel criteria to exactly the same but that, on the basic set of requirements which we could command on this instrument we should also have a common methodology and a common revision process.

[47] Clarification on the German top performer approach: To begin with, the Japanese top runner approach is rather a voluntary commitment by industry. We have got to accept the difference in regulation making: The US uses more a standardisation process, the EU a regulatory process and the Japanese economic acceptance by the industry, which is to move on without necessary standards or regulation. The Germans called their approach top performer, and it's not only about semantics, it is also to say that we should not necessarily align with all the patterns of the policy option taken here and there but we should adapt the idea of creating a continuous improvement of the market to the EU legislation.

6. What is your impression of the **implementing measures** adopted so far?
   [excerpt from reply on question 1] (...)The implementation process is not such a political process but a more confidential process where technical experts are dealing with the case. At the moment, when I see very important lots, which go beyond energy use, such as computers, or game consoles we cannot really be satisfied in regards to how they address resource use beyond energy use.

7. How do you perceive the **stringency in adopted ecodesign requirements** of the product-specific regulations in view of attaining higher resource efficiency?
   Very often we have seen that the *ambition of the ecodesign criteria were not high enough also because the reference data set we use to investigate and then to set the long term requirement are data sets of the past*. To give a clear example, now we are still dealing with boilers and this lot has been initiated in 2007 building on available data from 2005/06 at the best and we will set the requirement for 2015 and beyond. *There is too much of a gap between the reference data we use and the requirement we set for the future*. Even if there is some mechanism to correct this risk of obsolescence of data, we still have the problem of a long time between the reference data we use and the requirement we set. For this, at the moment, we also promote, and the EC is investigating this, *more continuous market monitoring* so we have more up-to-date data and we are able to design the requirements according to real-time data. If we could shorten the time between the reference data and the requirement, that would enable *more flexibility - adapting the realisation of these requirements to market evolution due to constant and continuous data* - the practical implementation is difficult - due to data location and confidentiality, as well as the cost of the data acquisition, but we should go into this direction of better market monitoring.

   Coming back to the acceptability of the industry to set more ambitious long term requirements, you have divided positions:

   1. Some industries say that if you *set long-term requirement - you will constrain innovation*, e.g. from IT industry - EE vs. additional functionality (consumes more energy but provides more functionality). They sometimes suggest service-energy efficiency approach.
   2. There is also a *problem of acceptability*, namely, where the role of ecodesign is perceived to be limited to get rid of worst performers only and that e.g. the energy label provides the incentive. Let's have the industry differentiate itself by using this additional policy instrument and ecodesign should not pretend it will do the whole job, it can play a part, but it should not undermine the role of other policy.
   3. Finally, there is the *obvious, natural reluctance of industry to be regulated upon*, and channelled and mainstreamed in their development, complaints about too stringent regulation and over-regulation, which are not fair arguments as there is also clever policy settings.

   So these are the reasons for some industry's reluctance to the German top performer approach, because they say you cannot decide now where the market will be in ten years. From our point of view, obviously, we like this idea of challenging the industry and *we think that long term requirement can really make ecodesign also contribute to channel and mainstream innovation towards more sustainable solutions in the future*. So we are really supporting the top performer approach by Germany even if we can consider that some of the arguments of industry are fair but we think just dismissing the whole idea is maybe too much.

According to our understanding the EC could also investigate how the German initiative could be addressed.

We have a *concern regarding the least life cycle cost (LLCC) in ecodesign regarding energy use*. We should always set the requirement at the LLCC for consumer or end-user, which is basically: What is the most economical option when you consider the whole LC, that is the upfront acquisition cost of the product and the cost of running the product during use (the energy it will consume) or for ErP, the energy it will save. This is challenging for setting the ambitious requirement because if suddenly you have two important upfront costs that will offset the savings you can do during use stage then you are not respecting the legislation and in a way, you are not allowed to set this ambitious requirement level. For this argument, we have two kind of answers:

1. Maybe during the revision process, we could try to say that *it is not the most economical option that should be targeted but any option that would be less costly for the consumer than the current product*, which is referred to as *"equal life cycle cost"*, as suggested by Hans Paul Siderius, the Dutch expert on ecodesign. Germany now uses "equal best case LC cost" which is the same idea, namely as long as you can ensure that the end-user will save energy, you can be ambitious in terms of requirements.

   [Clarification on the most economical option which is the cheapest option versus an option that is cheaper than the current option but not necessarily the cheapest option but that would open room for improvements regarding energy efficiency.] This described approach would require a revision of the legislation.

2. *Regular update of the upfront cost*. Example: fridges. US data set shows that despite more energy efficient fridges, the cost of fridges did not rise. So, they show both a better energy performance and a decreasing cost. Sometimes when we calculate the LLCC, we take upfront cost as given data and we do not apply corrective factors to the upfront cost (with regard to when we will set the requirement - sometimes we will set it 5, 7, or even 10 years later). But if we consider the evolution of the upfront cost of a product along this time period, we may realize, because of economies of scale, and/or because there will be a signal the requirement will set, that the price will not be stable or maintained, but will decrease (again due to innovation and/or economies of scale) and then the *LLCC should be regularly re-calculated so that we do not consider that the upfront cost we had considered at the time of setting the legislation will remain exactly the same all along the period until the entry into force of the requirement*.

   [Clarification with an example: Today you buy a TV with the last technology (BAT) and the cost is very important as it is a very innovative product. Maybe this technology will become mainstream in the next 5 years which will result in a cost decrease of the product. Then, if you calculate overall cost of the product all along the LC, you will have a cheaper product at the end, because the upfront cost will decrease which means that you could have set more ambitious energy requirements which still respect the legal requirement of LLCC or most economical option. This is very important, since as we could find a corrective mechanism for this, we could even start it now and would not have to await the legal revision of the Directive.]

3. The last point we try to promote, and which will also trigger innovations: If we could *address the risk of rebound effect*, namely the effect of a decrease in price resulting in people buying bigger and bigger appliances, as long as you stay with *energy efficiency and not absolute energy consumption*, then you can have a more efficient fridge which consumes more energy due to its size. This is what happened with TV screens. We should try to curb the requirement to cap the energy consumption after a certain size. Energy star version five, defined in the U.S., just addresses the size of the TV and then sets progressive rather than only linear standards for the energy efficiency requirement.

A visionary approach was introduced by the American Council for an Energy-Efficient Economy, ACEEE, which can be seen as the equivalent of the European Council for Energy Efficiency. It *looks at connecting different appliances together and goes beyond the product and its immediate environment to comprise also the secondary environment in which the product is embedded*, e.g. the technology infrastructure. This shows the improvement margin we still have to explore.

Interview transcript 2, 15.06.2012

Interviewee: Representative of the national contact point for the implementation of the Directive, **Belgium**

Questions

Political framework

1. Do you get the impression that the Ecodesign Directive 2009/125/EC is a **well-accepted framework directive** amongst stakeholders, in particular industry and politicians?
   Yes. It is widely accepted among politicians and among industry representatives, especially since industry is well represented in the preparatory process.

   Belgium is a decentralized state, and the federal Minister is in charge of the environmental quality of products, while the regions are responsible for environmental quality. The latter must manage the impact of products during use phase and the EoL phase including recycling. *In the regions, the Directive is not well accepted. One reason is related to the management of the Directive for which DG Enterprise and Industry (DG ENTR) and DG Energy (DG ENER) are in charge, and DG Environment (DG ENV) is not involved. DG ENTR and ENER, with representatives coming mainly from economy and industry, have a different agenda and their awareness of environmental issues beyond CO_2 emissions is limited.* It would be desirable, to have a higher participation of other representatives.

   Another issue is related to the lack of available and accepted indicators to measure resource efficiency. To date, the *domestic material consumption (DMC) indicator*, an economic indicator, suggests a an average DMC of 18 tons per inhabitant per year. This indicator is short of including global trade flows and a professor from Brussels University has estimated that an average European citizen consumes between 60 to 70 tons per year if all material flows are accounted for. Belgium imports many semi-finished products and the entropy related to their import also needs to be taken into account.

   There is a general belief amongst politicians that technical measures will solve many environmental problems. Political agreement can be easier achieved with technical measures and the Ecodesign Directive can manage a lot of environmental problems in theory, but politicians don't present all options, as there is no clear goal with a view to resource efficiency as it is e.g. for CO_2 reductions. The DMC indicator falls short regarding material consumption which occurs outside of national boundaries.

2. How do you perceive the current possibility for a **wide selection of stakeholders to participate** in the process attached to obtaining binding eco-design product regulations?
   The consultation forum gathers all stakeholders, industrial associations, even if the representation of NGOs is minor. Industrial stakeholders are already involved in the preparatory process and influence the direction of the regulations as well and inform on the technical feasibility. *The inclusion of SMEs in the process presents the biggest challenge as for most of them, it is difficult to send representatives and follow the consultation. It is evident that legislation is designed for big industry players, a situation which would also require some philosophical discussions.*

The Ecodesign Directive

3. Against the background of several instruments, such as the EU Energy label or GPP, addressing a specific phase in a product life cycle only: What is your view regarding the Ecodesign Directive pursuing product-specific ecodesign regulation which fosters a **life-cycle perspective**?
   If the regulation is too stringent, industry will enter into a stage of blackmailing, as it was the case with compact fluorescent lamps when industry closed down its old European factories and moved production to China. Stringent regulation comes at a cost. Incandescent light cost increased by a factor of 10.

4. Do you think the Ecodesign Directive 2009/125/EC is an efficient policy instrument for **achieving higher resource efficiency** in energy-related products ?
   No. The improvement potential is hard to measure, a weak point in product legislation, and so is the rebound effect. The consumption dynamic cannot be controlled, neither can be the use dynamic.

5. What is your perception regarding the ability of the Directive to **foster product innovations**?
   The Directive contributes to innovation in the sense that it *eliminates old technology*. Its *combination with other instruments makes it stronger.*

   I believe more in Energy labelling as it provides a clear base for comparison. *The strong point of Energy labelling is linked to the visibility on products.* If a competitor sees a product with a higher energy performance than its own products can achieve, this will immediately trigger product innovations as the competitor will strive to achieve this new target and aim even higher.

   I believe green washing is a potential threat posed by the Ecodesign Directive. I have seen a case in a meeting with a standardisation committee where it was announced that a product is "green" if it conforms with the Ecodesign Directive. *The standardisation requirements are solely minimum requirements.*

6. What is your impression of the **implementing measures** adopted so far?
   Since 2003, I have been involved with Art. 4 of the WEEE, which presents the general requirement that all products which are put on the market need to be easy recyclable. *The challenge is always to translate a generic requirement into legislation that is enforceable.* For a successful instrument it is important that it *provides a very clear definition*, e.g. on what "recyclable" means. It requires immense legislative work if products are treated on a product-by-product basis. Also, it takes several months and even up to years to achieve consensus, which means that the measures agreed upon might be outdated at the time of adoption.

7. How do you perceive the **stringency in adopted ecodesign requirements** of the product-specific regulations in view of attaining higher resource efficiency?
   From a national point of view, the regulations are definitely not stringent enough. The regions are quite unhappy about the Ecodesign Directive, stating that the *Directive does not help to recycle waste.* In addition, they *already follow the hierarchy outlined in the Waste Framework Directive, for which a lot of publicity is done* and that is one of the reasons why the Ecodesign Directive is not so popular in the regions. *Further, there is general unclearity regarding energy efficiency and its link to resource efficiency.* The unclearity extends to questions such as: Does resource efficiency mean that less material is to be used? How is the functionality affected if substitute materials are used which have different properties?

Written response to the interview questions 3, 19.06.2012

Respondent: Representative of the national contact point for the implementation of the Ecodesign Directive, S**lovenia**

Questions

Political framework

1. Do you get the impression that the Ecodesign Directive 2009/125/EC is a **well-accepted framework directive** amongst stakeholders, in particular industry and politicians?
   Yes. It is well accepted. Of course there are some details which industry is opposing (i.e. dates of application – sometimes they thing that there is not enough time to change their technology to be in line with directive demands). On the other side industry wants to have strict regulations to know how it will be and to get prepared for new demands.

2. How do you perceive the current possibility for a **wide selection of stakeholders to participate** in the process attached to obtaining binding eco-design product regulations?
   All factors should be involved in the process adopting eco-design product regulations. It is of no use to put down some demands that are unable to be done in a reasonable way. I think that a clear mind and the care for our future should be ranking first when writing regulations – not the eagerness to earn a lot of money. Having profit is of course necessary, but on the long run with saving our planet.

The Ecodesign Directive

3. Against the background of several instruments, such as the EU Energy label or GPP, addressing a specific phase in a product life cycle only: What is your view regarding the Ecodesign Directive pursuing product-specific ecodesign regulation which fosters a **life-cycle perspective**?
   The Directive tries to regulate all stages of the product: from the materials that are included through its working-time, till the end of it, when it becomes waste or is maybe recycled. It is good that this kind of regulation is in force, because every day the human population produces a huge amount of waste / hazardous waste. So it is very important that we have products, that are made of recyclable materials, are efficient which will not burden the environment with dangerous or non-recyclable substances at their end-of-life.

4. Do you think the Ecodesign Directive 2009/125/EC is an efficient policy instrument for **achieving higher resource efficiency** in energy-related products ?
   Yes. The Directive with its regulations is an efficient instrument to save energy and to minimize the burden on the environment. Regulations should be updated regularly to maximize their effect and to ensure that only best performing products are on the market. This can be done only with the help of surveillance authorities.

5. What is your perception regarding the ability of the Directive to **foster product innovations**?
   Every new stricter demand requires new technology, new innovations.

6. What is your impression of the **implementing measures** adopted so far?
   I think that a great job was done by the Commission.

7. How do you perceive the **stringency in adopted ecodesign requirements** of the product-specific regulations in view of attaining higher resource efficiency?
   IM should be strengthened from time to time – of course there are physical limits. But as the world needs more energy every year, products should be more efficient in all aspects.

Interview transcript 4, 21.06.2012

Interviewee: Representative of the national contact point for the implementation of the Ecodesign Directive, **United Kingdom**

Questions

Political framework

1. Do you get the impression that the Ecodesign Directive 2009/125/EC is a **well-accepted framework directive** amongst stakeholders, in particular industry and politicians?
   Yes
   Politicians, and now I am talking about UK politicians, have very little understanding of what it does. Ministers, who have responsibilities, do, but don't have a wide understanding of what it does and can do. Industry, the part of industry we deal with, generally thinks it is a good thing and it is well accepted. They see the benefits of a level playing field. The protection that the CE marking under the Ecodesign gives them protection against poor performance from outside the EU and this is appreciated. And in fact, the Confederation of the British Industry (CBI), which represents industry in negotiations with the government, also agrees with it. Collectively, the base of industry agrees with it.

2. How do you perceive the current possibility for a **wide selection of stakeholders to participate** in the process attached to obtaining binding eco-design product regulations?
   There is wide participation. I do think the engagement of the stakeholder is a good thing as it helps to ensure a good understanding amongst everyone on what is going on.
   European representatives communicate with national representatives. In the UK at least, industry learns before national representatives do. I would also say that industry representatives lobby member states directly as well as through European bodies so they have got two ways to go through the process. It does span a range of interests from environmental NGOs all the way through to industry.

The Ecodesign Directive

3. Against the background of several instruments, such as the EU Energy label or GPP, addressing a specific phase in a product life cycle only: What is your view regarding the Ecodesign Directive pursuing product-specific ecodesign regulation which fosters a **life-cycle perspective**?
   There is a need to distinguish between potential and reality. The Directive's potential to cover a wide range of issues is clear; it can get into issues such as recycled content and recyclability. To date, it has not. Nevertheless, the UK is strongly behind the Commission expanding the range of the impacts that Ecodesign supports, especially the material selection issue. So, in principle, it could, in practice, it hasn't. And I suppose the other part to that is the extent to which it engages with WEEE and RoHS.

   There might need to be more attempts to ensure consistency between Ecodesign and the EoL and RoHS but in principle if those three worked together, there is a chance for the LC perspective, it just doesn't happen yet.

   The selection and avoidance of particular material are considered useful elements of the Directive - as part of a wider material agenda.

   We start to wonder whether we should start to move towards more absolute energy consumption for things, not so much ecodesign but energy labelling. We may need to identify more clearly to consumers the amount

of energy that their product is going to use than their efficiency. You can have a triple plus A label for a small product using very different amounts of energy and material than an larger product with the same label. We would prefer a single absolute expression of energy consumption rather than a relative energy consumption where we can.

Would you say there is a need to look more into a system perspective?
A system perspective is desirable, but in practice it maybe too difficult. We would aspire to that approach but we recognise that the practicalities would make it too difficult.

4. Do you think the Ecodesign Directive 2009/125/EC is an efficient policy instrument for **achieving higher resource efficiency** in energy-related products ?
   Yes, it could do a lot in principle. In practice it hasn't delivered what it could have.

5. What is your perception regarding the ability of the Directive to **foster product innovations**?
   The answer is again: Yes, it can do. Where it can do that is by setting ambitious long-term standards, the industry can understand where we are going. *The more stringent the regulation, the more likely it is the regulation will foster product innovations. The more restrictive regulations are, the less likely innovations are.*

   For example, TV manufacturers should not be told which type of technology to apply, but should be given standards which need to be met. Let the market decide. *The idea is to specify the outcome of the function rather than the product itself. Let the market decide on the technology.* If a market player uses regulation to secure their position, this would be considered an anti-competitive approach.

   Japanese top runner seems to be a good approach. Look at the market leader and say: "they can do it, you can do it." Some might have a few years edge but as long as you don't limit with the technology, it should work. The UK strongly supports the German front runner policy approach, *which uses a combination of ecodesign and labelling to develop that approach taking the best performer as a benchmark for the future standard. There appears to be a North-South European divide in respect of a support of this policy approach with the UK, the Netherlands, Denmark and Sweden supporting this policy approach as to date.*

6. What is your impression of the **implementing measures** adopted so far?
   Two words: *Lacking ambition. Virtually everything we have in terms of ecodesign standards, we think we can do better - we should have more stringent standards.*

   There is no specificity attached to the six outlined LC stages?
   If the preparatory study doesn't address an impact in the lifecycle stage, it is difficult for the European Commission to justify including things where there is no European evidence. So, that suggests that future preparatory studies need to be much more consciously looking at the wider environmental impact and the wider material use issues than earlier preparatory studies did.
   There is a fear that industry doesn't engage, and doesn't share data because it wants to delay the process. *It has the opportunity to make its views clear in the preparatory study and it chooses not to share data until the last minute to stop things happening.* If industry was more engaged upfront, it wouldn't have to play games.

7. How do you perceive the **stringency in adopted ecodesign requirements** of the product-specific regulations in view of attaining higher resource efficiency?
   Again, I suspect my answer is that for the previous discussion, which is that so far for most of the products it is energy use rather than the wider resource LC and EoL issues that it could do. So, it is probably quite limited in that effect. The energy standard could be more stringent. It would be helpful in the future to have much more focus on raw material and material usage issues.

Interview transcript 5, 22.06.2012

Interviewee: Representative of the national contact point for the implementation of the Ecodesign Directive, **Ireland**

Questions

Political framework

1. Do you get the impression that the Ecodesign Directive 2009/125/EC is a **well-accepted framework directive** amongst stakeholders, in particular industry and politicians?
   Yes.
   It provides a level playing field for industry and we don't see any problems with the Directive. *In addition, not many voluntary agreements have been made which can be, to some extent, interpreted as the industry being happy with the Directive.* Also, industry works relatively closely with the European Commission, e.g. in the preparatory study.

2. How do you perceive the current possibility for a **wide selection of stakeholders to participate** in the process attached to obtaining binding eco-design product regulations?
   The possibility is there, however there is some room for improvements such as regarding the time for stakeholders to comment, which can be quite short. Also, there is a limitation when it comes to the resources in smaller member states. In addition, it seems the input into the impact assessment from industry is to some extent limited. *When the draft of the impact assessment is being received, it appears to be finalized and doesn't seem to request further input from industry.* Another way would be to request input from industry during the process of impact assessment and to receive the draft earlier so more information could be provided by industry.

The Ecodesign Directive

3. Against the background of several instruments, such as the EU Energy label or GPP, addressing a specific phase in a product life cycle only: What is your view regarding the Ecodesign Directive pursuing product-specific ecodesign regulation which fosters a **life-cycle perspective**?
   The potential for a life cycle perspective is there. So far, the Directive is mostly concentrated in the use phase. It does have the scope for a life-cycle perspective but the practicalities related to it, hold it back. Among the practicalities there are two particular reasons which hold the Directive back from including a LC perspective:
   1) Measurement need. LC stages such as recycling and reuse need to be measured. *Research on LC measurements continues and until it is really measureable, energy efficiency will continue to remain the overall target due to the practicality attached to it.* The practicality issue presents the largest barrier to the LC perspective being a more important target of the Directive.
   2) The lengthiness of the process attached to produce implementing measures is another setback. A lot of resources are needed on the way, which slows things down.

4. Do you think the Ecodesign Directive 2009/125/EC is an efficient policy instrument for **achieving higher resource efficiency** in energy-related products ?
   Yes. It has potential, but it is not directed towards it as a primary objective.
   However, for example, with dishwashers and washing machines resource efficiency of water was addressed simultaneously as it is measurable.

5. What is your perception regarding the ability of the Directive to **foster product innovations**?

There is a possibility for the Directive. *It is a trade Directive.*[48] We came up with several ideas how innovations could be fostered, e.g. (1) through better target setting, such as along the lines of the top runner approach, which is a dynamic approach. We agree in principle with it. *So, rather than having implementing measures reviewed following a period of three years, the idea would be to have something in the implementing measures which allows to move forward, something which facilitates an upward benchmark shift if technology has evolved*. The tricky part is to avoid a situation in which one manufacturer only is leading the field and the benchmark would need to solve this situation. Also, (2) *long-term targets within the implementing measures which would span up to five years would allow industry to adopt its design cycles.*

6. What is your impression of the **implementing measures** adopted so far?
   We have a good impression. It's fine. The problem we see is related to the length of the process for implementing measures, as the data used is out of date. A few options would exist to address this problem: (1) *an 80/20 approach which suggests that most issues are captured now and the remaining in the next years*; (2) an increase in Commission resources available to work on ecodesign could facilitate a more rapid approach and ecodesign is generally perceived to bring a good return so this would justify the input of higher resources. With a view to the standards and what can be put into the implementing measures: do what you can do quickly and leave the other things until later on.

   It takes up to a couple of years until implementing measures are elaborated. For instance, boilers are very tricky and have taken a long time and an exceptional two consultation forums were held for this product group.

7. How do you perceive the **stringency in adopted ecodesign requirements** of the product-specific regulations in view of attaining higher resource efficiency?
   Until we can measure resource efficiency better, energy efficiency will be leading the way.

[48] Elaboration of the trade comment in reference to the EC (2012e, 1st paragraph) clarification that it "prevents disparate national legislations on the environmental performance of these products from becoming obstacles to the intra-EU trade. This should benefit both businesses and consumers, by enhancing product quality and environmental protection and by facilitating free movement of goods across the EU."

Written reply on the interview questions and transcript of the follow-up interview 6, 27.06.2012

Interviewee: Member State representative, DG Environment Product Policy Unit

Questions

Political framework

1. Do you get the impression that the Ecodesign Directive 2009/125/EC is a **well-accepted framework directive** amongst stakeholders, in particular industry and politicians?

Doubt: At least some smaller stakeholders (SMEs) are unaware of the content of Implementing Measures (IM) concerning their products. This is due to the lack of time they can spend on follow-up of the consultation and legislative process. They rely on sector federations to defend their interests, but these are not always aware of relevant specificities of niche products or small producers.

SMEs produce quite specific products which are easily looked over. There I have some doubt whether the Directive is accepted by them or not. They feel they cannot do much about it. It's more imposed to them, whereas larger firms and federations have a voice in the process and for them it should be acceptable. Some SMEs are happy with the Ecodesign Directive but sometimes they and their environmental concerns are overlooked.

It is important that industry participates, but for some reason, it does not always happen for SMEs. They rely on their sector federation. Near the end of the process, the SMEs receive an advanced draft version, and they see that their products are in the scope contrary to what they were told by sector federations or they see that criteria are quite stringent for their specific products and it is very hard for them to meet and comply with these criteria. (And they only see these criteria in the final draft version of implementing measures, when they are told by their sector federations.) SMEs who are not members have even more limited opportunity to participate. *I think it is really a problem of time and resources and maybe also some enterprises realize only very late that it can have a high impact. Ecodesign touches upon the core business of enterprises, designing and selling products. For some reason the process of stakeholder involvement is not really efficient. We see it ourselves: We do national stakeholder consultations and it is very difficult to know all enterprises in your country that produce a specific product and it is difficult to reach them sometimes. We can send meeting requests to sector federations and ask to forward it and we also use other media, but sometimes it is not enough.*

It is a democratic process, normally the possibility is there to participate, but I know some enterprises can't or won't be able. I can see how it is difficult for SMEs, if there is one person in charge of several processes, that there is only a chance to read through the final draft document of the implementing measures. And sometimes they might then realize that a certain, specific aspect of a product has not been taken into account.

Accepted: Ecodesign tries to fix market failures. It sets minimum criteria for all and creates a level playfield obliging designers to take into account environmental concerns. 'Green producers' and producers of high-end / top-of-the-range applications are particularly happy with this. They are front runners and then have a (temporary) competitive advantage (e.g. Bosch-Siemens vs Zanussi; also see http://www.coolproducts.eu/resources/documents/120618.joint-statement.pdf). All

other producers have to take time to look at environmental performance and improvement, an activity not considered profitable in their strategy of producing cheap, being first to the market, … But now everybody being equal to the law, everybody has to do it. So no competitive disadvantage amongst bottom market products.

Less accepted: There is the so called split incentive: producers don't have to pay the energy bills of their customers. They have no direct interest to improve efficiency. They are sometimes not capable to convert their business and steer to inambitious criteria.

There seems to be political hesitation to liberate more resources for Ecodesign, although it is very cost-efficient in reducing energy use, GHG emissions and possibly other environmental impacts (resource efficiency). Touching product design touches the core of business and reaches into consumers all day life, so I think it is perceived as being sensitive. None the less Ecodesign stimulates EU industry and prevents the Internal Market becoming a dumping ground for bad products.

There appear to be some contentious product groups which are prone to give bad press (e.g lamps). The Commission hesitates to keep taps and showerheads in the new working plan, probably for fear of consumer reaction and possible negative media attention.

However, if Ecodesign didn't exist, the Internal Market would be fragmented with each Member State rightfully having its own legislation this would run counter to the economic and ecologic objectives. The EU has to move as a whole to be efficient.

2. How do you perceive the current possibility for a **wide selection of stakeholders to participate** in the process attached to obtaining binding eco-design product regulations?

   Consultation starts with the creation of a project website and the launch of a preparatory study. The website adds a lot to participation I think. Much depends on the consultant and his possible subcontractor(s) and their address books. These consultants should have excellent contacts and relevant experience in the product group /sector under investigation. Sometimes this is clearly the case, but this depends from product group to product group.

   It is a matter of time and resources. Wide stakeholder participations is part of the IPP approach. The EC is already bending the rules by allowing more consultation forum members than foreseen. This involvement is good and necessary to receive expert views and relevant product data. Decision 2008/591/EC on the CF would need to be adapted to allow a more important number of members.

   Consumer and Environmental NGOs make very good efforts to be present in meetings and issue position papers on all lots.

   Smaller EU technical working groups[49] are also used where this can be of help (e.g. transformers).

[49] Clarification on working group: They have not been used as much. They have been used for the product group of lighting, transformers boilers and professional refrigeration. They are real technical expert groups and normally they

We organize national consultations at key moments in our offices. Recently we also use a written procedure which is less cumbersome and which works equally well when there are few reactions expected. In this instance a meeting can still be arranged, or even visit of production facilities. Usually we also seek information over the phone.

For professional equipment (DG ENTR lots) it has happened that the comments we make on EC working documents are send to our national stakeholder group to be revised by experts from industry.

The Ecodesign Directive

3. Against the background of several instruments, such as the EU Energy label or GPP, addressing a specific phase in a product life cycle only: What is your view regarding the Ecodesign Directive pursuing product-specific ecodesign regulation which fosters a **life-cycle perspective**?

These policy instruments should be aligned and work together as a policy mix (IPP approach). This is gradually improved. Ecodesign is most explicit in taking into account LC impacts (except for resource extraction). In practice however IM address energy use during the use phase as this turns out to be the most important. (This focus doesn't come as a surprise of course with the background of the EU 2020 strategy and the climate change debate). Future reviews could change this.

At some point of the debate it reaches the economical stage. If it is not economically viable, it will not happen.

After energy efficiency, resource efficiency seems to be the next logical step with recycling or sustainable sourcing. But I think there is a lack of ISO standards.

The recent draft IECTC. 111 Technical regulation DR 62-65 Guidelines for end of life info management provision from manufacturers and recyclers and recyclability rate of Electrical and electronic equipment could be a first step.

A chain of custody is missing in resource efficiency, such as FSC [the Forest Stewardship Council], where players in the value chain are certified and the material flow through the supply chain is monitored and where you can guarantee that e.g. your wood comes from a sustainable source. And this could be applied for instance to plastic where you can then prove to which extent your plastic originates from a recyclable source. You have producers saying that 70 per cent of this plastic is recycled content, but is not verifiable by an independent 3th party.

You need standards to calculate things. *We think it is an issue that resource efficiency is not addressed. NGOs often address resource efficiency within the energy efficiency debate by saying that "resources present embedded energy"*. For example, if you use less steel, you use less energy as the production of steel also requires energy. And this argument would also be more appealing to certain policy makers.

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are chaired by e.g. an ISO committee / organized by the EC. They are industry experts and put on paper technical proposals but don't make political positions. Ecodesign legislation is very technical.

4. Do you think the Ecodesign Directive 2009/125/EC is an efficient policy instrument for **achieving higher resource efficiency** in energy-related products ?

Very likely. Yes, but there are no precedents.

You could treat resource efficiency in a horizontal way, by for instance requesting that recycled content should be e.g. 35 per cent and maybe not by product group. This could be quickly done. Recycled materials are used but there is not much information on it. Market failures exist and Ecodesign could try to address this.

Company representatives are calling who state that they buy components from outside the EU and ask whether they have to comply. They need to check with supplier if the component complies.

Usually, if someone comes with one questions, there are several issues, e.g. with motors or fans.

End of life efficiency where you take all costs into account from buying virgin material, to EoL, a computer program could calculate the optimal EoL treatment of a certain material compared to the cost of virgin material is the most economic. But there is a data problem.

One aspect in regards of resource efficiency that has come up in the work for transformers: huge instruments which are made of copper with an iron core, which is magnetic, and they use a *total cost of ownership method* where they look how economically viable it is to put more kgs of copper or iron in the transformer to obtain more efficient transformers and this depends on the load profile these transformers will be charged with during their operation. Big high/medium voltage distribution transformer, (for distributing energy to our houses), or a big step up transformers (at the power plant) are energized most of the time and this justifies using more copper compared to smaller transformers in rural areas where currents runs through them less intense.

In tendering, *optimum material choice balanced with desired energy efficiency* to obtain a certain return on investment, is already applied with transformers. There is a very explicit trade-off btw material efficiency and energy efficiency. This approach could be taken up in legislation.

The problem of Ecodesign is that in preparatory studies, it is taken for granted that everything is treated according to WEEE and that recycling is quite high. This is quite controversial and open for debate. Not every product is a hundred percent compliant. There is the problem of waste exports. Also WEEE categories are too broad (e.g. Small household equipment) and do not correspond to Ecodesign lots. Mobile phones fall in the category of ICT products, but they are known to contribute relatively little to the WEEE objectives. Because of their size they are lost or end up in 'residual waste'.

There is no official collection scheme for transformers. *Household appliances EoL discussions are relatively quickly off the table due given that WEEE is to address this aspect, also in the context of the policy mix idea.* This is always treated very fast and the extent to which WEEE can handle the particular aspects of a product group should be checked. This is an area that could be taken up and improved during the preparatory study.

5. What is your perception regarding the ability of the Directive to **foster product innovations**?

   In the short run Energy labeling is probably more important, but in the long run Ecodesign will take the whole market to a higher level.

   If you are a company which has different product ranges and the energy label is applicable to your products, and you have more expensive A+ product and a less expensive B product, at a certain point you will have to decide to remove the B class product range from the market or maybe upgrade it, because if the price difference between the B and the A+ label is too small, everyone will buy the A+ level anyway, because labeling is quite influential in consumer decisions. And if you are obliged to put a B on your second product range, which is a bit cheaper, there is a risk that it will not be sold that much anymore. It will take away the success of a lower price product, which is less efficient. The visible effect of the B label will make consumers reconsider this product range. The energy label makes a good classification of products. It is a powerful communication tool to consumers. I think it really works. And this is something that could be done in the short run by making smaller, more stepwise improvements to jump the energy class or by removing certain products from the product range, because they are perceived as not good anymore if there is a good A label product range available.

   Then, Ecodesign: There are always several tiers. Industry knows that in a certain time there will be new standards, and they are obliged to take everything of the market that doesn't meet the standards and hopefully replace it with something new, with better technology. The tier should be designed to represent a design cycle so industry has the opportunity to redesign their products and to make more thorough design changes and this should stimulate innovation. *Innovation is mainly for the optimization of existing technologies - we don't want to promote technologies which are protected by patents.* Of course, patents will also result as companies see the benefits of research and development to meet future tiers/requirements. Ecodesign will therefore take the market in the long run to a higher level.

   Sometimes we have to be very careful with the wording and the criteria in implementing measures, since if we don't make the clauses in legislation right, then innovation cannot benefit from it. E.g. For the kitchen appliances, you have hoods, which are designed to remove grease, but what you really want is to remove odors, but there is no standards or criteria for it. So someone who makes this, will not benefit from it. *If it is not put in, it will not stimulate innovation on this part of functionality, as if there are no standards, there are no criteria for measurement.*

6. What is your impression of the **implementing measures** adopted so far?

   They could be more ambitious, as they are very cost efficient. There are net savings as prices of appliances are not rising (indications of a decrease) and as they consume less. During the review of the framework directive, *criteria should not be set at least life cycle costs (LLCC) but at a level of the base cases*[50], allowing slightly higher purchase prices and achieving even better efficiency.

[50] The definition of base cases entails setting requirements not at the legally required least life cycle cost but as a constant life cycle cost. E.g. if over the total product life cycle, the product cost is EUR 100 , whereby the product purchasing price is EUR 50 and the energy consumption is EUR 50. We will set criteria that the product purchasing

This could avoid 'rebound effects'. Otherwise money saved from efficiency gains will be invested in extra/bigger electric appliances, leisure, etc. undoing environmental improvements (efficiency vs sufficiency discussion).

Being environmentally efficient means that you have to make environmentally benign investments, so you have to drain the money that is liberated by efficiency gains by maybe imposing on consumers to spend a little more money on efficient products. You can do that on a voluntary basis, by e.g. using the energy label as an indicator. There are also social aspects coming into the picture since not everybody can make that investment. Basically it is the approach of keeping the life cycle cost constant to avoid the rebound effect which would lead people to buy e.g. holidays, bigger appliances and so forth leaving the initial improvement without a net benefit for the environment.

7. How do you perceive the **stringency in adopted ecodesign requirements** of the product-specific regulations in view of attaining higher resource efficiency?

I think they should be more efficient. As you can see, we have the problem of rebound effect. The GDP of Europe would increase if you adapt certain efficiency measures. We would be saving money so it would not be logical not to implement measures. *There is an economic logic to adopt more ambitious requirements but you have many interests on a national level, from stakeholders, and so forth, that have to be taken into account. Sometimes this is to the detriment of the general interest, which is not always served by national interests or powerful stakeholder lobbies or political views. In general there are good economic reasons to adopt more stringent ecodesign requirements.* If ecodesign requirements are not efficient anymore a few years following their implementation then this can be taken as a sign that they were not ambitious enough.

Sometimes certain decisions are taken just to continue the process and to finalize a process. There is a backlog, and sometimes you have to be pragmatic and you enter more personal and political choices.

cost is EUR 60, because it is more efficient, but only costs EUR 40 in energy consumption, but the total life cycle cost remains at EUR 100. If you keep your costs constant, you will prevent from the rebound effect, which occurs if people save money, they can spend it.

Interview transcript 7, 27.06.2012

Interviewee: Representative of the national contact point for the implementation of the Ecodesign Directive, Germany

Wir begleiten soweit auf Basis der Personalressourcen moeglich, alle Produktstudien und vor dem Hintergrund der Erfahrungen, die wir im Bereich Produktpolitik und Energieeffizienzpolitik haben, geben wir entsprechende Stellungnahmen ab. Im Konsultationsforum wird Deutschland durch die Bundesanstalt fuer Materialforschung und -prüfung zusammen mit dem Umweltbundesamt vertreten. Insgesamt liegt die Federfuehrung fuer die Ökodesignrichtlinie bzw. fuer die nationale Umsetzung für das energieverbrauchsrelevante Produktegesetz beim Wirtschaftsministerium und die nachgeordnete Behörde des Wirtschaftsministeriums ist die Bundesanstalt für Materialforschung und -prüfung (BAM). Das Wirtschaftsministerium kooperiert mit allen betroffenen Ressorts, immer mit dem Umweltministerium und gegebenfalls auch mit anderen, betroffenen Ministerien. Wir, als Umweltbundesamt, unterstützen das Umweltministerium und im Konsultationsforum sind die Fachbehörden Deutschlands vertreten und bereiten die Stellungsnahmen vor. Im Regelungsausschuss, wo es um die Abstimmung geht, sind die Ministerien vertreten. Insofern verfolgen wir alle Regelsetzungsprozesse. Auf nationaler Ebene lädt die BAM vor den Kosultationsforen zum Beraterkreis ein, dies ist eine Anhörung auf nationaler Ebene. Das UBA nimmt daran ebenfalls immer teil. Auf Basis der Prüfung der Dokumente und der nationalen Anhoerung bereiten wir dann gemeinsam mit der BAM eine Stellungnahme vor, die wir dann im Konsultationsforum einbringen.

BAM ist die beauftragte Stelle für die Marktaufsicht und koordiniert den Bund-Länder-Arbeitskreis zur Marktaufsicht. Bei diesem wirken wir begleitend mit.

Wir prüfen aufgrund unseres Fachwissen aber auch aufgrund der Anhörung aller interessierten Kreise, nicht nur Industrie sondern auch Umwelt- und Verbraucherschutzverbände, die Voerschläge der Kommission und geben dazu Stellungnahmen beziehungsweise Verbesserungsvorschläge ab.

Political framework

1. Do you get the impression that the Ecodesign Directive 2009/125/EC is a **well-accepted framework directive** amongst stakeholders, in particular industry and politicians? (*Translation to German: Wuerden Sie der Annahme zustimmen, dass die Oekoesign Richtlinie 2009/125/EC eine weit akzeptierte Rahmenrichtlinie unter Interessensvertreteren, im besonderen aus der Industrie und der Politik, ist?*)
   Insgesamt gibt es eine *sehr hohe Zustimmung bei allen Interessensgruppen*. Heute, 28.06. 2012, haben die Umweltverbaende auf EU Ebene gemeinsam mit Herstellern eine Stellungnahme herausgegeben, wo sie sich dafuer einsetzen, dass die *Prozesse schneller werden muessen*. Insgesamt, vom allgemeinen Ziel, von dem wie die Richtlinie aufgebaut ist, gibt es bei allen betroffenen Kreisen in der Politik eine sehr grosse Unterstuetzung der Richtlinie. Im Detail machen sich die Meinungsunterschiede an konkreten, einzelnen Punkten innerhalb Produktgruppen fest, aber insgesamt, als Instrument mit Schwerpunkt Energieeffizienz ist es sicherlich sehr weit akzeptiert und gewollt. *Gerade auch die Industrie weiss dass sich, bei einigen Produktgruppen auch aufgrund der vielen Hersteller, der Markt nicht allein reguliert, und es ist sozusagen eine "Belohnung" fuer Hersteller, die proaktiv sind und umweltfreundliche Produkte am Markt haben.*

   Ein Teil, der noch nicht so gut ausgefuellt ist, wo es sicherlich unterschiedliche Meinungen bezueglich Wichtigkeit und Ausreifung der Methoden gibt, das sind die

nicht-Energie Aspekte. Bisher ist vorwiegend die Energieeffizienz massgeblich und nur in wenigen Bereichen werden nicht-Energie Aspekte geregelt. Wir selbst und Umweltverbaende mahnen, dass Nicht-Energie-Aspekte stärker berücksichtigt werden müssen. Das ist auch ein Bereich, der teilweise von der Methodik der Vorstudien noch nicht gut genug abgebildet wird. Es laufen derzeit Studien, um die Methodik zu verbessern. Erste neue Parameter für *nicht-Energie relevante Aspekt etwa zur Ressourceneffizienz und -schonung* (wie der Anteil an kritischen Rohstoffe oder maximaler Recyclatgehalt) wurden bereits bei der Überarbeitung der Methode eingeführt. In dem Bereich gibt es ein Handlungsbedarf, dessen Notwendigkeit vor allem von der Politik wahrgenommen wird und weniger von der Industrie.

[Zischenfrage zur Methode]
Einerseits gibt es die Rahmenbedingungen der Richtlinie und dann gibt es eine vorgegebene Methode, inklusive einer vereinfachten Ökobilanz, die zur Erarbeitung der Vorstudie angewandt werden muss, und vorgibt was in den einzelnen Kapiteln ausgearbeitet werden muss. Das ist eine einheitliche Methode, die fuer jede Vorstudie angewandt werden soll. Diese Methode wurde gerade ueberprueft und es wurde, unter anderem, eingefuehrt, dass man einen Parameter berechnen soll, naemlich den Anteil an kritischen Rohstoffen, welche in einer Mitteilung der Europaeischen Kommission definiert wurden.

2. How do you perceive the current possibility for a **wide selection of stakeholders to participate** in the process attached to obtaining binding eco-design product regulations? (*Translation to German: Wie wuerden Sie im allgemeinen die Moeglichkeit der Teilnahme einer breiten Zahl an Interessensvertretern, an dem Prozess, in dem verbindliche Ökodesign Produktregulierungen entschieden werden, einschaetzen?)*

Es ist eine breite Moeglichkeit gegeben. Es ist eher eine Frage inwieweit alle Akteure die Information erhalten. Die grossen Verbaende kennen den Prozess und wissen, worauf sie achten müssen, während kleine Unternehmen, deren Produkte betroffen sind, das nicht immer wissen. Prinzipiell ist das auch eine Aufgabe der jeweiligen Verbände, die Informationen weiterzugeben. Aber im Grunde kann jeder, der Interesse hat, an der Vorstudie teilnehmen. Jeder kann die Dokumente lesen und die Auftragnehmer sind fuer Informationen immer sehr dankbar und die eingereichten Informationen werden dann bewertet. Manche Unternehmen sind dann enttäuscht, wenn Anregungen nicht angenommen wurden. Das liegt natürlich in der Bewertung des jeweiligen Auftragnehmers. Aber ich denke, wenn man von der Vorstudie weiss, ist es sehr einfach das zu verfolgen, eine Stellungnahme abzugeben und an den Interessensvertretermeetings teilzunehmen.

Bei dem Prozess, der staerker von der Kommission gesteuert wird, da ist die Teilnahme am Konsultationsforum natuerlich insofern begrenzt als die Zahl und die Art der Teilnehmer beschränkt ist und die Organisationsfähigkeit ist gefordert. Prinzipiell sind Industrie, Handel, Umwelt- und Verbraucherschutz und Mitgliedsstaaten vertreten.

The Ecodesign Directive

3. Against the background of several instruments, such as the EU Energy label or GPP, addressing a specific phase in a product life cycle only: What is your view regarding the Ecodesign Directive pursuing product-specific ecodesign regulation which fosters a **life-cycle perspective**? (*Translation to German: Wie sehen Sie die Möglichkeit der Richtline die Lebenszyklusperspektive zu verstaerken?)*

   Die Richtlinie basiert ja prinzipiell auf einer Lebenszyklusperspektive. Es wird ein vereinfachtes Life cycle Assessment gemacht. In der Regulierung ist sie aber eine Richtlinie, die sich alleinig auf das Produkt bezieht. *Zum Beispiel bei Umweltzeichen werden mitunter auch Anforderungen an die Herstellung gestellt (z.B. Emissionen beim Herstellungsprozess) und das ist rein rechtlich bei der Ökodesign Richtlinienur begrenzt möglich, da die Eigenschaften am Produkt selbst überprüfbar sein sollten. Die Marktaufsicht kann nur das Produkt selber und dazugehörige Dokumentationen, aber keine Produktionsanlagen überprüfen.*

   Wenn man z.B. Aspekte der Materialeffizienz adressieren will, muss zunächst die Methode diesen Aspekt ausreichend abbilden und nachweisen, dass es ein relevanter Beitrag zu den Umweltwirkungen bezogen auf den gesamten Lebensweg ist. Wenn sich dazu dann geeignete Anforderungen formulieren lassen, um die Umweltwirkungen zu vermindern, so ist das prinzipiell möglich. Aber man muss die *Praktikabilität* berücksichtigen. Die Umweltwirkungen der Rohstoffgewinnung können je nach Standort unterschiedlich sein.. In Datenbanken hat man oft Zugriff auf generische Daten, die den Durchschnitt bilden, wobei bei einem Abbauprozess eventuell weniger Umweltauswirkungen entstehen als in einem anderen. Wenn man mit generischen Daten rechnet, ergibt sich kein Unterschied zwischen Produkten, wenn man mit Daten rechnen will, die konkret zu den spezifischen Vorketten der jeweiligen Materialien gehören, so ist das sehr aufwändig. *Man kann aber prinzipiell z.B. den Gehalt an bestimmten Materialien begrenzen, wenn dadurch eine signifikante Verminderung der Umweltwirkungen erreicht wird. Hierbei können aber große Eingriffe in die Freiheit des design entstehen. Oder es ist auch vorstellbar einen Mindestanteil an Recyclat oder für bestimmte Materialien einen Mindestrecyclatanteil zu fordern.* Da entsteht allerdings wieder das *Problem der Nachweisbarkeit.* Bei Metallen kann man z.B. am Produkt selbst nicht nachweisen ob es aus einem Recyclingprozess stammt oder nicht, d.h. man muss mit *Zertifizierungen in der Kette* arbeiten. Der Energieverbrauch eines Produktes kann gemessen werden, ob z.B. die enthaltene, seltene Erde aus dem Recycling kommt oder nicht, ist wahrscheinlich kaum festzustellen. Man wuerde *vom Hersteller Lieferwege zertifizieren* lassen muessen. Die Frage ist, wie man das in einen machbaren Prozess bringen kann. *Denkbar wäre auch prinzipiell Komponenten, die recyclingrelevante Stoffe (kritische Rohstoffe) enthalten, in leicht entnehmbaren Komponenteneinheiten zu konzentrieren um sie so einem Recycling wirtschaftlicher zuführen zu können,* Das sind Aspekte die ueber das Ökodesign prinzipiell umsetzbar sind. Waehrend *die Umsetzung eines Recyclinganteils einen etwas schwierigeren Schritt darstellt*, weil man Nachweise braucht, dass ein gewisser Anteil aus dem Recycling kommt. *Eine Konzentration oder eine bestimmte Anordnung in der Komponente oder im Produkt, um es recyclingfaehig zu machen, ist leichter umsetzbar.*

   [Zwischenfrage: Haben Sie bereits ein Modell gesehen bei der man versucht, eine Kombination aus einer Forderung nach Recyclatanteil und einer Konzentration der Anordnung des kritischen Stoffes zu erreichen?]

   Es gibt noch kein Beispiel fuer so eine Anforderung.

[Zwischenfrage zur Akzeptanz einer Systemperspektive]

Die Kommission ist hier sehr aufgeschlossen. *System eher im Sinn eines erweiterten Produktes*, das ist auf alle Fall moeglich. Wenn das System am Ende zu gross ist, dass es kein Produkt mehr im eigentlichen Sinn ist, dann ist es schwierig. Aber ein erweiterter Produktansatz ist moeglich und gut. Das war auch die Diskussion bei den Motoren, naemlich, dass die groesste Einsparung bei den Motoren aufgrund der Drehzahlregelung erreicht wird und man mit der Effizienzanforderung an Motoren nur einen kleinen Anteil schaffen kann. *Bei dem Systemzugang ist immer wieder das Problem, dass man am Ende trotzdem Komponenten regeln muss, weil ja nach wie vor auch Komponente als Ersatzteile verfuegbar sind bzw. Systeme aus Komponenten bestehen*. Beispielsweise bei der Drehzahlregelung, wenn ein Prozess nur bei konstanter Geschwindigkeit gefahren wird, macht die Drehzahlregelung keinen Sinn sondern verbraucht sogar zusaetzlich Strom. Man muss immer sehen, was in der Praxis am Markt gebraucht wird und dass man sowohl die Komponenten regelt als auch die erweiterten oder zusammengesetzten Produkte.

4. Do you think the Ecodesign Directive 2009/125/EC is an efficient policy instrument for **achieving higher resource efficiency** in energy-related products? (*Translation to German: Denken Sie, dass die Ökodesign Richtlinie 2009/125/EC ein effizientes, politisches Instrument fuer die Erreichung einer hoeheren Ressourceneffizienz in Energie-bezogenen Produkten ist?)*

Da stellt sich zuerst die Frage, *was man unter Resourceneffizienz versteht. Wenn man da die Energie hinzuzaehlt, dann auf alle Faelle*. Wenn es eher in Richtung Materialeffizienz geht, ist sie prinzipiell gut geeignet, aber es besteht noch *die Herausforderung, sowohl die Methode der Vorstudie um entsprechende Ansätze zu ergänzen und die Erkenntnisse in adaequate und praktikable Anforderungen zu uebersetzen*. Sie ist prinzipiell geeignet, aber in der praktischen Implementierung muss noch Arbeit geleistet werden.

5. What is your perception regarding the ability of the Directive to **foster product innovations**? (*Wie nehmen Sie die Moeglichkeit der Richtlinie wahr, Produktinnovationen zu foerdern?)*

Der staerkere Treiber fuer Produktinnovationen ist sicher die Energieverbrauchs-kennzeichnung, weil sie die Differenzierung der Spitzenreiterprodukte am Markt aufgrund der Effizienz ermoeglicht. Die Ökodesign Richtlinie schneidet eher die schlechteren Produkte vom Markt weg. Damit hat sie auch einen Einfluss auf Innovation, in dem sie den Markt vor sich "herschiebt" aber *das staerkere Innovationsinstrument ist das Label.*

[Zusatzfrage zur guten Akzeptanz der Visibilitaet des Energielabels - Koennte man durch die Veranschaulichung von Ökodesign im Rahmen eines Labels mehr erreichen, etwa auch hinsichtlich Innovation?]

Ja, auf alle Faelle. *Ein Label muss immer vom Verbraucher verstanden werden und muss am Ende entscheidungsrelevant sein*. Prinzipiell halte ich es für erstrebenswert weitere Parameter zu Materialeffizienz hinzuzufuegen. Hier muss man jedoch fragen:

1. *ob sich die Produkte daran tatsaechlich unterscheiden lassen* (Beispiel: Unterscheidet sich der Kuehlschrank A von Kuehlschrank B tatsaechlich an diesen Parametern? Um dies festzustellen, braucht man sehr genaue Daten.) und

2. *welche Parameter den Verbraucher interessieren?* Bei der Energieeffizienz gibt es fuer Verbraucher einen Eigennutzen, naemlich die Einsparung im Energieverbrauch und damit in den Energiekosten. Bei den anderen Parametern geht es allgemein um Umweltbewusstsein.

Prinzipiell ist es ein richtiger Weg, aber es gilt zu pruefen, was *geeignete Parameter sind* und *ob sie zu einer Unterscheidung zwischen den Produkten fuehren* und welchen *Aufwand* es fuer Unternehmen bedeutet, diese *Informationen* bereitzustellen.

6. What is your impression of the **implementing measures** adopted so far? *(Translation to German: Welchen Eindruck haben Sie von den bisher angenommenen Durchfuehrungsmassnahmen?)*

Auf alle Faelle positiv. Es war wichtig, dass das Instrument implementiert wird. Die Durchfuehrungsmassnahmen bewegen den Markt. *In der Qualitaet gibt es Unterschiede.* Es gibt einige, die passen genau. Es gibt einige, die sind sehr ambitioniert, das ist sehr erfreulich, wie zum Beispiel die Heizungsumwälzpumpen und es gibt andere, wo man vielleicht haette weitergehen koennen, aber wo man sich jetzt erst einmal so geeinigt hat. Aber prinzipiell denke ich mir, ist es ein ganz wichtiger erster Schritt, auch mit der Energieeffizienz. In den meisten Faellen auch relativ ambitioniert. *Ein Nachteil aus unserer Sicht, ist, dass die erste Stufe der Anforderungen fuer den deutschen Markt meistens nicht wirklich viel bewegt.* Der deutsche Markt ist da schon so gut entwickelt, dass nicht wirklich etwas weggenommen wird. Zumindest die zweite Stufe veraendert den Markt weiter hin zu mehr Energieeffizienz und das ist ein wichtiger Schritt.

[Frage nach der Klarstellung zu der ersten und zweiten Stufe] Die erste und zweite Stufe bezieht sich auf die Strenge der Anforderung; die meisten Durchfuehrungsmassnahmen sind so aufgebaut, dass es eine erste und meistens eine zweite und bei manchen sogar eine dritte Anforderungsstufe gibt, wo vor allem die Energieeffizienzanforderungen immer weiter verschaerft werden und dann ist meist nach fuenf Jahren die Frist fuer die Ueberpruefung der Massnahme. Das ist je nach Produktgruppe verschieden, aber fuer viele ist es derzeit fuenf Jahre.

[Zwischenfrage zur Einschaetzung von der Vorstudie bis zur Zeitrahmen der Vorstudie] In der Evaluierungsstudie wurden die Mindest- und Maximalzeiten genau erfasst. Die Richtlinie ist 2005 verabschiedet worden und die erste Erarbeitung von Massnahmen wurden 2008/09 implementiert, also vier Jahre nach Beginn, waehrend bei den Heizkesseln die Studie 2005/06 angelaufen ist und sie dieses Jahr zur Verabschiedung kommen sollte, also sechs Jahre.

7. How do you perceive the **stringency in adopted ecodesign requirements** of the product-specific regulations in view of attaining higher resource efficiency? *(Translation to German: Wie wuerden Sie die Strenge der bisher angenommenen Oekodesignanforderungen bezueglich Produkt-spezifischer Regulierungen hinsichtlich der Moeglichkeit, eine hoehere Resourceneffizienz zu erreichen, einschaetzen?)*

Es gibt eine Abschaetzung von Ökopol, die zeigt (Resourceneffizienz kann man im Moment nur in Bezug auf Energieeffizienz bewerten, da alle anderen Aspekte bisher kaum addressiert sind), dass in Bezug auf Energieeffizienz alle Oekodesign Produktmassnahmen zwischen 14 und 17 Prozent an Energieeinsparungen erreichen koennen.

Es ist ein guter erster Schritt. *Wir halten es für notwendig, dass man mehr gestufte Anforderungen stellt, die sich im Ziel an der beste verfuegbaren Technik orientieren*. Die Richtlinie bezieht sich derzeit auf die geringen LebenszykluskostenWenn man Verbesserungsoptionen anwendet, geht der Energieverbrauch zurück unten und die Kosten fuer die Nutzung ebenso und fuer die Anschaffung entstehen häufig höhere Kosten. Die Summe aus Anschaffungs- und Nutzungskosten sind im Kontext der Ökodesign Richtlinie die Lebenszykluskosten und der geringste Punkt stellt die Referenz für die Anforderungen dar. *Auch wenn die Lebenszykluskosten zunehmen, sind sie noch zwangsweise hoeher, als der Ausgangsfall (derzeitiger Produktdurchschnitt). Wir sind der Meinung, dass man Effizienzanforderungen setzen kann, solange sie sich innerhalb der Nutzungszeit amortisieren, d.h. also dass die Lebenszykluskosten gleich gross sind, wie die, des derzeitigen Ausgangsfalles.* Und das laesst die Richtlinie derzeit aber noch nicht zu. Wir sind der Meinung, dass man noch ambitioniertere Anforderungen, als es jetzt der Fall ist, stellen kann.

[Zusatzfrage zum Boomerang-Effekt] Der Boomerang-Effekt muss natuerlich auch mit anderen Massnahmen begegnet werden. Einerseits vom generellen Bewusstsein der Verbraucher, wir haben den Effekt, dass immer groessere Produkte verwendet werden, etwa groessere Fernseher, groessere Kuehlschraenke, neuere Anwendungen, die es vorher nicht gab und das beeinflusst natuerlich auch den Gesamtenergieverbrauch. Ein weiterer Zugang waere, *progressive Anforderungen* zu stellen, dass etwa Geraete, die groesser werden, strengere Anforderungen haben. Eine Effizientanforderung ist ja meist mit einer funktionellen Einheit verknuepft, etwa mit Bildschirmdiagonale oder Kuehlschrankvolumen und das ist meist eine Gerade. In Zukunft muesste die Kurve keine Gerade mehr sein, sondern die Kurve muesste eben Richtung der groesseren Groessen abgeflacht sein mit verschiedenen Ebenen und eben *ambitioniertere Anforderungen*, damit man dem Boomerang/Rebound Effekt zumindest ein Stueckchen begegnen kann.

[Zusatzfrage zum Deutschen Frontrunner Modell] *Mindestanforderungen muessen strenger werden um den Markt zu mehr Effizienz zu bewegen (siehe oben).* Der Japanische Toprunner Ansatz ist ja insofern unterschiedlich, weil hier einen Flottenansatz gilt. Die Ökodesign Richtlinie ist ein produktspezifischer Ansatz, wo jedes Produkt diese Anforderungen erfuellen muss. Dieser Flottenansatz in Japan ermoeglicht eine groessere Flexibilitaet - man hat ein paar sehr gute und ein paar, die schlechter sein duerfen. *Wir wollen ambitionierte Anforderungen insofern die Lebenszykluskosten nicht ueber das hinausgehen, was der derzeitige Ausgangsfall ist* weil sonst wuerde das heissen, dass die Konsumenten das bezahlen muessen. Ansatz wuerde in Schritten funktionieren: Als Ziel soll die Effizienz der besten verfügbaren Technik dienen. Man hat eine Ueberpruefung in fuenf Jahren und dann sieht man, wenn die Produkt- und Energiepreise steigen, dass der naechste Schritt moeglich ist, d.h. dass was bei Erlass der vorhergehenden Verordnung die beste verfügbare Technik war und als Ziel festgeschrieben wurde, dann bei der Überpürfung der Methode (z.B. nach 5 Jahren) als neue Mindestanforderung festgelegt werden kann. Dabei sind aber nochmals die Lebenszykluskosten zu prüfen und alle Rahmenbedingungen nach Artikel 15 der Ökodesign-RL müssen eingehalten sein. man Wir hoffen, dass ein solches gestuftes Vorgehen Zustimmung findet. Wir (UBA und BAM) haben das Konzept bei der Kommission und den Mitgliedstaaten vorgetragen und hoffen, dass man in die Richtung weiterkommt.

Appendix E: China protecting its rare earth elements

Protecting resource bases as part of industrial development strategies by applying measures such as export quotas, taxation and subsidies has been frequently noted over the past years, notably since production is geographically concentrated. Company responses to price can vary from stockpiling, price hedging in the form of futures contracts and negotiating long-term contracts. (EC, 2010 and EC, 2011d)

The principle of national sovereignty, which is fully recognised in the EU, guarantees every nation the right to apply measures regarding the regulation of the exploitation of its natural resources, as long as they conform with applicable international agreements or supranational organisations' rules which the nations has adopted or of which it is a member. This regulation includes trade policy. (EC, 2010)

Trade agreements such as the General Agreement on Tariffs and Trade (GATT) and supranational organizations including the World Trade Organization (WTO) systematically aim at reducing market protectionism and trade barriers. (Kannegiesser, 2008) GATT Article XX in particular specifies the conditions under which trade restrictive measures related to the conservation of exhaustible natural resources can be applied by WTO member states. Against the background of a conservation approach, it is crucial that trade restrictions are matched with a reduction in domestic production.

China remains under close scrutiny by the EU which monitors the country's compliance regarding *GATT Article XX*, and has already made allegations that its environmental protection measures favour "domestic industry providing it with privileged access to raw materials while discriminating against foreign operators and jeopardising the level playing field that is to be expected among WTO members". (EC, 2010, p. 29)

Appendix F: Questionnaire for PM motor producers

Export intensity

1. Which *share* of your company's overall business is approximately attributed to *exports*?

0 - 30%	30-60%	60-90% and more

2. How does the *demand of international customers* influence your company's permanent magnet motor innovation activities?

1	5	10
(low impact on innovation)	(medium impact on innovation)	(high impact on innovation)

Price volatility

3. Which impact do *fluctuating prices of rare earth elements* have on your company's innovation activities?

1	5	10
(low impact on innovation)	(medium impact on innovation)	(high impact on innovation)

Uncertainty

4. How would you rate the *impact of environmental pressures and requirements* on your innovation operations in the area of permanent magnet motors?

1	5	10
(low impact on innovation)	(medium impact on innovation)	(high impact on innovation)

Set of rules

5. How would you rank the *influence of the following rules on innovation activities* within your company?
   a. Influence of *product and compatibility standards* on our company's innovation activities:

1	5	10
(low impact on innovation)	(medium impact)	(high impact)

   b. Influence of *supplier-user relationships* on our company's innovation activities:

1	5	10
(low influence on innovation)	(medium influence)	(high influence)

   c. Influence of *design rules and production practices* on our company's innovation:

1	5	10
(low influence on innovation)	(medium influence)	(high influence)

   d. Influence of *regulatory standards* on our company's innovation activities:

1	5	10
(low influence on innovation)	(medium influence)	(high influence)

6. On a scale from 1 to 10, how would you *rank the Ecodesign Directive contribution*
   a. to your company's *eco-innovation activities*?

1	5	10
(low influence on innovation)	(medium influence)	(high influence)

   b. to your company's work on *decreasing the material intensity of rare earth elements* (REE) in permanent magnet motors?

1	5	10
(lowest influence on material intensity of REE	(medium influence)	(high influence)

   c. to your company following a *life-cycle (LC) perspective* in permanent magnet motor design?

1	5	10
(lowest influence on a LC perspective)	(medium influence)	(high influence)

Preparatory study

7. Which motives have influenced your company's decision to participate in the preparatory meeting for the electric motor product group extension?

8. How do you think the anticipated extension of the electric motor product group to permanent magnet motors will influence your research and development / innovation activities?

Appendix G: Summary of questionnaire replies

	Motor manufacturer A	**Motor manufacturer B**	**Crane manufacturer**	Average motor manufacturers	Total average
Export intensity					
1	30-60%	30-60%	60-90%	30 - 60%	
2	4	10	2	7	5.3
Price volatility					
3	9	10	3	9.5	7.3
Uncertainty					
4	4	10	1	7	5.0
Set of rules					
Rules influence on innovation in firm					
5					
Product & compatibility standards - a	2	10	10	6	7.3
Supplier-user relationships - b	6	5	6	5.5	5.7
Design rules & production practices - c	6	5	8	5.5	6.3
Regulatory standards - d	9	10	9	9.5	9.3
Ecodesign Directive contribution to					
6					
eco-innovation activities - a	8	5	9	6.5	7.3
decreasing material intensity in REE in PM motors - b	4	5	1	4.5	3.3
following a LC perspective in PM design - c	4	5	3	4.5	4.0

	Motor manufacturer A	**Motor manufacturer B**	**Crane manufacturer**
ErP Preparatory study on Lot 30			
Motives for participation 7	Motors are under direct influence of EU regulation for minimum efficiency	To understand/comply with the ecodesign requirement. Strive to manufacture an energy saving product with a friendly environment impact.	Our motors are of duty class S3 and excluded from ErP Directive. An energy efficiency classification for S3 motors would benefit crane manufacturers and customers.
Views of influence of anticipated PM motor regulation on innovation **8**	Innovation activities are dependent on market demand for PM motors. Inclusion of new EU efficiency ratings & falling prices for magnets would accelerate new innovations.	Our enterprise has always been at the forefront of motor technology, thus an extension of the electric motor product group to include permanent magnet motors is welcome, this technology though costly is part of our production a number of years now, our target now is to have the costs reduced, explore other technologies that should yield same results in terms of efficiencies with reduced costs.	Most likely a very low impact - PM motors used in special applications of lifting equipment only. Main reason is not the price of the magnet but the lack of benefits compared to special design cage-induction motors. PM motors would be of duty type S3 and if S3 is exempt from the prep study, there will be little effect on our research activity.

Source: own source. The data has been obtained from the questionnaires.

Appendix H: Specific interview transcripts

Interview transcript 1, 18.06.2012

Interviewee: Anonymous industry representative from a European PM producer

Questions

Competitiveness and innovation related to rare earth elements (REE)

1. How would you rate the importance of REE supply security to the **competitiveness** of your enterprise on a scale from 1 to 5, where 1 corresponds to "no importance" and 5 to "high importance"?

   1 - of no importance
   2 - of little importance
   3 - of some importance
   4 - of high importance
   5 - of very high importance
   Ensuring the supply of REE is the most strategic element in our business, but as of now, we have easy access to REE.

2. How would you rate the potential of REE to contribute to **innovations** within your enterprise on a scale from 1 to 5, where 1 corresponds to "no importance" and 5 to "high importance"?

   1 - of no importance
   2 - of little importance
   3 - of some importance
   4 - of high importance
   5 - of very high importance

Permanent magnet design

3. **Which criteria for permanent magnet design** does your department/enterprise follow?
   The R&D Department can decide on the criteria. The two most important criteria are corrosion resistance and high temperature stability, as the majority of products made are bonded magnets.
   There is no guidance regarding the design criteria from a legal department.

4. Which of the before-mentioned criteria are considered to have an **eco-design element**?
   A few years back, our Department has obtained a patent for a material, which is non-toxic, can be reused, and is to be used in bonded magnet types. This was a clear push towards ecodesign. Our company deals mostly with powder materials which are considered as chemicals by REACH, not as alloys, therefore there is an incentive to reduce their use.

5. Do you get the impression that the criteria applied to the design process of the magnets take into account a **possible supply scarcity**?

   Supply scarcity regarding rare earth elements was a problem about half a year ago. A lot of end-users of rare earth element technologies switched to ferrites (which do not show the same energy-efficiency potential, but the next generation will comply with the regulation). The market has dropped a lot since as the consumption has decreased. At the same time, several rare earth ore mines have opened up outside of China to supply the market.

   Two years ago, it was decided that our company will pursue to produce 100% NdFeB magnets; in the last year the decision was changed to supplying 70% ferrites instead, leaving the NdFeB magnet production at 30%.

   It is our customers who request a technology change from us. And our customers are, besides one most important customer with focus on electric motors and pumps, active in the automotive and household appliances industry.

6. In which order of importance would you **rank these criteria** in the design process?
   - Reduction of critical material use
   - Increase of material efficiency
   - Facilitation of recycling through modular, standardised design / adapted production process

   1) Facilitation of recycling
   2) Efficiency
   3) Reduction of rare earth element use

Ecodesign Directive and Lot 30 preparatory study

7. How would you classify the **approach** of your company regarding anticipated **upcoming legislative requirements** as part of the Ecodesign Directive? (please choose only one of the three response options; the sub-parts are to help you in your choice)

   - pre-emptive approach:
     a. our enterprise anticipates legislation under preparation and
     b. tries to actively influences the preparation process by collaborating with industry associations and other stakeholders

   - active approach:
     a. our enterprise is actively involved in the process related to drafting the product specific legislation for permanent magnet motors and/or
     b. actively participates in the preparatory studies and stakeholder consultations

   - reactive approach:
     a. our enterprise implements legislative requirements but does not actively participate in the drafting process

8. How does your enterprise **respond to the ecodesign requirements** of the Ecodesign Directive? (multiple responses possible)
    a. It views the requirements as an opportunity for innovations
    b. It aims to be at the forefront of the ecodesign process
    c. It sees the Directive as a tool to stay competitive within the global market
    d. It pushes for higher requirements/standards within the industry

The Directive restricts global competitiveness as partners and competitors close their production facilities in Europe and move to China, where less stringent regulation allows for cheaper operations.

The administration of REACH and the measurements related to it cost a lot, which reduces competitiveness outside of Europe.

We aim to be at the forefront in designing products, e.g. we are drivers to ourselves in the sense that we wanted to improve our work environment and therefore decided to work on an epoxy-free environment.

In many cases, the economic driver is also an important incentive. As to date, only about 10 to 15 per cent of machines with rare earth elements (typical hard disc magnets) can be recycled, the remainder ends up as dust in scrap yards or as pollutant in steel melts.

A system approach viewing the entire life cycle of a product, has been attempted, where an additional EUR 10 would be charged for the recycling at the time of purchase, e.g. of a pump. However, this measure has not been taken serious as the average pump life-time is about 15 years and once the product reaches the end-of-life phase, the customer does not care about its disposal.

Following the participation in a seminar on the cradle2cradle approach, I realized that our company, in comparison to our competitors, had already undertaken half of the steps needed on the path to obtaining certification. This was the main driver to pursue the certification which would differentiate our products on the market.

Interview transcript 2, 06.09.2012

Interviewee: Professor Nini Pryds, Head of the Thermoceramics Programme, Fuel Cells and Solid State Chemistry, Technical University of Denmark (DTU), Department of Energy Conversion and Storage

Background: Research at the DTU centres on the synthesis of materials for energy system applications such as solid oxide fuel cells, thermoelectric devices and magnetic cooling as well as research on cradle-to-cradle development and design of electric machines for wind turbines and electric cars, with respect to recycling of magnetic materials. (REEgain, 2012) The research focus of the Thermoceramics Programme is on magnetic refrigeration, thermoelectric ceramics for high temperature applications, pulsed laser deposition for thin film processing, functional metal/oxide thin film deposition and to obtain a fundamental understanding of nucleation and growth mechanisms using RHEED. (DTU, 2012)

Questions

1. Are the methods you research in the Thermoceramics Programme also of potential relevance for permanent magnets?
   Yes, of course. Permanent magnet is material and we have all the equipment to characterize material, but also look at the performance and the modelling of these materials. We don't work on optimizing the composition of permanent magnets at the moment but we are working a lot with optimizing permanent magnets systems by trying to reduce the amount of permanent magnet in the component. So we try to find a way numerically how to reduce the amount of the existing magnet.

2. Which importance do see in rare earth elements regarding their innovation and energy efficiency potential?
   Of course it is very important because these permanent magnets include rare earth elements. Any reduction of their amounts in magnets is desirable. For example, keeping the strength of the magnet and reducing the amount of rare earth elements used, would be beneficial for many applications. The problem is that achieving a reduction or rare earth elements is not so easy. Unfortunately the best magnets, the rare earth containing magnets, namely the NdFeB magnets, they are already optimized and one cannot change them a lot. One can try to manipulate their configuration but changing the composition will be a major challenge.
   (In this project where you are addressing the configuration of the magnet, are you looking at reducing the magnet size?)
   We work on the configuration of the magnet:
   - In one of our projects, we work with magnetic refrigeration, where the permanent magnet is used to activate the material inside. In that technology we need a very high magnetic field and at the same time the system need to be cheap. Therefore electromagnet is not an option, but a permanent magnet. The magnetic field is scaled with the amount of magnet. So if we want a very high field, we need a very large magnet, so to say. And this costs money, of course. We therefore trying to calculate numerically how we can reduce the amount of magnet and still maintain a high magnetic field. This has nothing to do with the material itself, but with the structure of the whole system.

- In the REEgain project we aim at improving the magnet by changing its composition. I will not be able to go into detail and say how we will do it but as mentioned we will try to change the Nd in the NdFeB by using a mixed rare earth elements. The main question is: How much the magnetic field is affected if we use a mixture of the rare earth elements. That's something that we look into.

The processing of these materials is another challenge, and an aspect that we also look into. NdFeB magnets are usually sintered magnets which mean that the processing is sometimes very costly. There are different ways of processing these materials. At the moment I don't think we can do it better than what other people in the world do, but maybe during the REEGAIN project we can find other ways. (That probably has also an impact on the life-cycle of the product given the high energy consumption during manufacture of the product.) The sintering of these materials requires heating the material to high temperature a process which is expensive. We are talking about tons of material which need to be heat treated, process as mentioned which requires a lot of energy.

We are trying to target these challenges in three ways, namely by

- exchanging some of the rare earth elements with some cheaper material,
- optimizing the processing and thereby reduce the cost of producing the magnet
- addressing the system itself, by modelling, through which a new configurations of structures is to be found.

Some of these efforts are already ongoing and some will start soon.

3. In how far do you consider the recycling of rare earth elements (economically) feasible?
   This is something we are going to investigate. I cannot say a lot about it. We are going to try to recycle it. But, how we are going to do that I cannot say a lot right now. Certainly, as you say, the opportunity of recycling rare earth elements is an issue. A permanent magnet is permanent, so if one can recycle it somehow, there is a lot to gain.

4. How could permanent magnet motors be designed to facilitate the recycling of their rare earths in the magnets?
   That would depend on the processing of these materials. I have no clear answer at the moment.

   The Ecodesign Directive works with implementing measures, which are binding regulations that prescribe the ecodesign criteria for a specific product group.
5. Which type of implementing measure would you consider most beneficial for permanent magnet motor recycling?
   - Stricter energy requirements
   - Measures to improve the dismantling potential
   - Measures to improve pure material streams
   - Measures to improve the use of chemicals, and
   - Measures targeted towards the Bill of Materials

   All points are interesting. With a view to the soon-to-be most available option, I would say recycling will be. There is no one answer and it is difficult for me to say something without knowing it exactly. Each measure is important in its own way and each has its own advantages. I think it would be much easier if one can find a way, a cheap way, to

recycle the material in such a way that you can maintain somehow its properties however by using a cheap and fast processing route. From your response, I deduct that any legal option that would try to improve pure material streams would be not feasible. Yes, I believe that this is very difficult. And the same would apply to the feasibility of improving the use of chemicals, as they are part of producing the magnet. Yes. Looking at REACH, which classifies the powders used in the alloys as chemicals further adds to this argument. Of course. That is what I wanted to say, if one can find a cheap way to refine a material (any material), then one can crush it, and recycle it again. Separating the elements in the crush material is another option but this requires probably a large amount of investment. Does this make sense? I don't think so, because it will require a lot of energy to separate the elements. So of course, if you can find a cheap way of recycling it, and I mean by saving energy, I think that would be, in my opinion, the way to go. To-date, nobody has the absolute answer, as it is currently being investigated.

Thank you for the interview.

Interview transcript 3, 07.09.2012

Interviewee: Jens Christiansen, REEgain Manager and Head of the Plastic technology section at the Danish Technological Institute (DTI)

Background: DTI is a provider of technical services including consultancy, materials analysis and testing. The Institute also has pilot facilities for advanced processing. The combination of these two aspects gives DTI a strong interaction with industry and academia. (REEgain, 2012)

1. Is the material analysis and the advanced material processing conducted at DTI also conducted with relevance for permanent magnets?

   We analyze the materials, and the properties of materials, for instance how the micro-structure of magnets changes, if they are oxidized. We don't analyze magnetic properties. This part is carried out by our project partners at DTU.

2. In how far do you consider the recycling of rare earth elements (economically) feasible?

   Actually, I don't know. I don't think they are recycled, because they are not so common. The recycling is mainly done of the big elements such as copper, iron, and of the expensive elements such as gold and platinum and so on. I don't think the recycling level of rare earth elements is so high at the moment. At least HJ Hansen, a recycling company, who is also a partner in the REEgain project, doesn't recycle rare earth elements. They have not had focus on this waste product yet. There are a lot of rare earth elements in cars and electric motors but they haven't recycled it yet. (Clarification: HJ Hansen is having difficulties to access products at their end-of-life phase which use rare earth elements? – I don't think it's difficult for them. They just didn't have the focus) I am not sure if it is a problem, but they haven't been concerned about it yet. They have only processed the big materials like iron and copper so far. (So it will be interesting for HJ Hansen to participate in REEgain to find out about recycling options of rare earth elements. – they are in the consortium)For instance, it is interesting for the windmill industry, as each windmill contains approximately two tons of magnets. There is a good potential to look at the recycling of these magnets. The windmills are still out in the field and they haven't been replaced yet. Therefore the recycling has not been a big issue so far. Old wind mills were not produced with rare earth magnets. It is a quite new technology to have rare earth magnets in the wind mills. So the recycling will probably start within five or ten years' time when the first new windmills will have to be replaced. The advanced rare earth magnets replace a mechanical gear system in the windmill. Windmills don't have to have a gear box if they using these magnets. The gear box is a problem for the windmill. Especially, when windmills grow even larger. The problem is related to its lifetime and maintenance and it was solved by using rare-earth magnets. Now, the new problem is the price of the rare earth elements, which just exploded in 2010 and 11.

3. How do you think the design of permanent magnet motors can be optimized to facilitate the recycling of their rare earths in the magnets?

   I think mainly the magnets can be improved. We can optimize the shape of the magnets. If we optimize the shape then we can reduce the amount of magnetic material in each product. That's one way to solve the problem. And then, when we have the used magnets, the question is how they should be processed in order to be used again.
   Here we basically need to investigate whether we have to break the magnets down into the elements again or whether we can just crush them down and then use them again.

When you make these magnets, you use a metallic powder, a powder that is fused together. So the question is: Can we just crush it down and make a new magnet or do we have to separate it into the elements and basically start from the beginning. We don't know that yet, but we will investigate it.(So I understand if it is required that the magnets are broken down to the elements, more energy will be needed. - yes)If we have to go back to the elements, we will have to apply a process which will require a lot of energy. If we can just make an intermediate product, we can both safe time and energy. Once we have identified the way to break the magnet down and rebuild it, we also have to find a route for recycling the magnets. We have to develop a system where we can collect the old magnets and sell them to magnet producers. That system is not developed.

At the moment we get the rare earth elements from China. One of our project partners is a mining company which has found large deposits of rare earth elements in Greenland and it is part of the project to find processes to obtain the rare earth from the ore and then process it.

4. In which way do you think legislative requirements could support the recycling of rare earth elements?
   A recycling scheme should be established on a European scale. But this is more a political topic.

5. Which type of implementing measure would you consider most beneficial for permanent magnet motor recycling?
   - Stricter energy requirements
   - Measures to improve the dismantling potential
   - Measures to improve pure material streams
   - Measures to improve the use of chemicals, and
   - Measures targeted towards the Bill of Materials

   I would consider number two most beneficial, when motors are collected and can be taken apart. That would be the simplest way from a technological point of view. You can probably not use the magnets from there but hopefully, you would just need to crush them down and then reshape them.

   Additional question: When you crush the magnets down and then press them into the shape needed, would they still have the same energy density afterwards?
   Probably. I think there is potential that it has the same magnetic properties.

   Thank you for the interview.