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Integration of resource efficiency and waste management criteria in European product policies – Second phase

Report n° 1

Analysis of Durability (final)

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Executive Summary

In addition to parameters studied in the project Ecodesign Phase 1[1], the current project includes an analysis of the durability of products. The aim of the analysis is the proposal and testing of a method for the environmental assessment of different durability/lifetime of energy related products (ERP) for its use in European product's policies in order to assess whether the option of increasing durability/lifetime is likely to be desirable from an environmental perspective.

The analysis has been based on the following stages:

a. Analysis of the scientific literature. Scientific publications and standards have been analyzed to identify potential methods for the assessment of the durability of products. Two different approaches have been identified: the first focuses on the estimation of the expected duration of products (e.g. based on resistance to loads and failure models); the second introduces durability concepts in the sustainability assessment of products (e.g. to identify if an extension of the useful life can produce environmental benefits in a life-cycle perspective). The second approach has been applied for the next stages. Also potential approaches to extend the operating time of products have been illustrated.

b. Definition of a method for the environmental assessment of durability. Although the environmental assessment of changes/increases of the durability of products has been performed by various researches, a single and (relatively) simply standard method to carry out such assessment has not been established yet. The present project, therefore, defined a method suitable for ERP and potentially suitable for other product groups. The aims of the method are twofold: 1) to estimate the life cycle environmental benefits (if any) of extending the operating life of the considered product by a given additional *time-span*; 2) to assess the relevance of such environmental benefits (if any) compared to the product's *life cycle impacts*. The method developed is based on the comparison, in a life-cycle perspective, of different scenarios concerning the lengths of the useful life of the product and its potential substitution with better performing alternative products. The method does not take into account consumers behaviours (e.g. "fashion items")[2]. The method has been presented in Report n° 3.

c. Application of the method to a case-study. The method has been applied to the washing machine (WM) product groups. The two exemplary products described in Report n° 2 of this project have been analysed. The application demonstrated that the extension of the operating time generally produces environmental benefits for the two products. The benefits are, however, largely variable, mostly depending on several parameters, including the selected environmental impact category, the length of the extension of the operative life and the efficiency of the replacing product.

d. Identification of potential product policy criteria for the extension of the operating time of WMs. This phase focuses on the identification of product 'hot spots' for lifetime or durability: meaning here those key components that are functionally critical for the product and that can influence the

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[1] Project between JRC/IES and DG Environment titled: "Integration of resource efficiency and waste management criteria in the implementing measures under the Ecodesign Directive". Deliverable of EP1 available at: http://lct.jrc.ec.europa.eu/assessment/projects.

[2] These aspects can be part of further researches.

product’s lifetime (i.e. those that are most likely to cause the failure or reduced durability of a given product). According to the literature review, main ‘hot spots’ of WMs are: motor, pump, drum and control boards. It is relevant to highlight that some of these ‘hot spots’ for durability (such as motor and control boards) are also the product components responsible for the highest life cycle impacts of the WM[3]. Potential product policy criteria aimed at achieving the extension of the product’s lifetime have been discussed, including: non-destructive disassemblability of key functional components (hot spots); adoption of product specific standards on durability (when available or can be developed); introduction of extended warranties/guarantees for the product or some of its components; provision of information for users.

It is highlighted that the analysis performed here was affected by some uncertainties mainly related to:

- assumptions about the case-study's composition (based on the analysis in Report n°2)
- assumptions about life-cycle impacts of the products, including assumptions on the use phase (based on the analysis in Report n°2)
- uncertainties in the setting of some key parameters of the method: the impacts of repairing “Rn”, the extension of the operative life “X” and the energy consumption “δ” of a potential replacing product.

The simplified index for the environmental assessment of the durability has been applied in order to assess the potential benefits/drawbacks of extending the operating time of the analysed products. Although simplified, this index is scientifically robust for the scope of the assessment, as proved by similar applications in the scientific literature. However, in order to face the potential uncertainties previously underlined we performed the analysis of different scenarios based on sufficiently large variations of key parameters. However, it is highlighted that the general method for the environmental assessment of durability can be applied when additional data about the case-study are available (through e.g. estimations and/or extrapolations).

It is also highlighted that some additional parameters (such as consumer behaviour) can influence the durability of products. These issues have not been investigated and could be part of future research).

Finally, based on current available data it was not possible to estimate precisely by how much identified criteria could prolong the lifetime of product. However the relationship is in the positive direction (i.e. lifetime extension) and possible extensions of the WM’s operating time have been estimated and potential environmental benefits for the product category have been assessed.

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[3] For further details, see Report n°2 – Chapter 6.

Abbreviations

ADP el - Abiotic Depletion Potential Elements
CED – Cumulative Energy Demand
DEFRA -Department for Environment, Food, Rural Affairs
EC – European Commission
ErP – Energy Related Product
EuP – Energy Using Product
GWP – Global Warming Potential
HRS – “high repairing” scenario
LCA – Life Cycle Assessment
LCC – Life Cycle Costing
LRS – “low repairing” scenario
PCB - Printed Circuit Board
TE – Terrestric Ecotoxicity
WM – Washing machine

Introduction

“Durability of products” is a concept often related to resource efficiency. However, the way of interpreting and assessing durability is not commonly agreed in the scientific literature. The present report aims at:

- Identifying key issues concerning the durability of products;
- Analysing methods and standards for the assessment of whether increased durability is likely to generate environmental benefits over the whole life cycle;
- Identifying potential product policy criteria for durability.

The analysis of ‘durability’ is a new research task that was not included in the previous Ecodesign Phase 1 project[4].

The analysis of durability concepts has been used to support the development of a method for the environmental assessment of whether increasing the durability of products is likely to generate environmental benefits over the whole life cycle of the product considered (presented in Report n°3, together with other project’s methods).

The first part of this report focuses on a survey of the literature to establish:

- What is generally intended with durability of products?
- How durability of products can be measured and verified?
- How a product’s durability can be extended and what are the possible technical barriers?
- How beneficial/impacting the improvement of durability of products can be?

The second part of the report illustrates the application of the method for the environmental assessment of whether increasing durability (i.e. extension of operating lifetime) of the ‘washing machine’ product group is likely to generate some potential benefits.

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[4] Project of JRC/IES and DG Environment titled: “Integration of resource efficiency and waste management criteria in the implementing measures under the Ecodesign Directive” (reports available at http://lct.jrc.ec.europa.eu/assessment/projects).

1. Literature review on the ‘durability’ of products

1.1 Introduction

The following sections introduce a literature review of durability. In particular the review focuses on the methods for assessment of durability and related potential product policy criteria. The outcomes of the review are used for the development of the method for the assessment of Durability (Report n° 3-Chapter 5) and following exemplary application to a case-study product (Chapter 2 of the present Report)[5].

1.2 Literature review

1.2.1 Approaches for the assessment of durability

The review was based on scientific reports/papers and standards published on the topic of durability. The review focused on the following issues:

- Definition of durability;
- Methods for the assessment of durability (from an environmental point of view) and their application to exemplary product groups;
- Key issues related to durability;
- Remarks on the analysis and potential recommendations for the analysis;
- Possible product policy criteria
- Main conclusions of the studies.

The following tables present a short summary of documents relevant to the scope of the present project. In particular, it has been observed that two different approaches are used to assess “durability”:

1) development of models to forecast the expected duration of products based, for example, on resistance to loads and failure models (including the expected time before failures). This is the classical approach on durability, mostly based on studies on civil engineering. Table 1 illustrates main studies referring to this approach, while Table 2 illustrates a list of some standards dealing with the durability issues of specific products.

2) durability issues are introduced in a more complex model to assess sustainability of products and to identify best ecodesign alternatives. This is a more comprehensive approach that involves technical, environmental as well social issues in the evaluation. Table 3 illustrates main studies referring to this approach.

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[5] The literature review here presented has also been summarized in Report n°3 - Section 5.2.

Table 1 Summary of the review in the scientific literature on durability: approach based on the estimation of the expected life-span

REPORT / PAPER TITLE	DEFINITIONS OF DURABILITY	METHOD ADOPTED	ANALYSED PRODUCT	KEY ISSUES FOR DURABILITY	RECOMMENDATIONS / REMARKS	POTENTIAL PRODUCT CRITERIA	CONCLUSIONS	REFERENCE
Further steps towards a quantitative approach to durability design	the durability design objective is to keep the probability of failure within a specified time interval (or service life) below a certain threshold value that depends on the consequences of failure of the component or system.	Semi-probabilistic integrated approach for the assessment of the durability (applicable to building components).	building components	Loads and resistance degradation. Failure of the component or system	Need of reliability-based approaches for durability	(not provided)	Durability design and service life prediction are based on keeping the lifetime probability of failure below a certain target value	[Lounis et al., 1998]
EcoDesign for Ceramic tiles and Sanitary Ware	1) robustness so that products can toughly work even in heavy users. 2) timelessness so those products can hardly be antique one.	Development of "check sheets" for product assessment and re-design	Ceramic tiles and Sanitary Ware	1) selection of raw material; 2) reduction of maintenance cost; 3) optimal adaptation of technical innovation to commodity design; 4) Easy cleaning 5) maintenance friendly	(not provided)	(not provided)	RE-design of case-study product to fulfil expected performances	[Takada et al., 1999]
Design for environment: a method for formulating product end-of-life strategies[6]	Wear-out life: the length of time until the product no longer meets the original function(s). Product is obsolete when it is no longer able to perform its intended function; e.g., because of failure of key components or it is outmoded	The method determines what end-of-life strategy is possible according to the products' technical characteristics. Furthermore, the research validates the method by comparing (by LCA) the proposed end-of-life strategies with current industry practice.	electronic products	Failure of parts, obsolescence.	Difference among "Product wear-out life" and "technology cycle"	(not provided)	Provided model can be useful to improve product's end-of-life	[Rose, 2000]
Timber - Design for Durability	The capacity of a timber product, component, system, building or structure to perform for a specified period of time, the function for which it was intended – be it aesthetic, structural or amenity.	Durability assessed by relating timber's performance standards with historical and test data.	timber products	Factors to be considered in Design for Durability: 1) Design life; 2) Reliability required from the structure or component; 3) Initial building costs versus the maintenance costs	Best practises to improve durability of timber products are provided.		Standard of the sector to improve durability of timber products.	[National Association of Forest Industries, 2003]

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[6] The study from [Rose, 2000] couples information about technical life-span of the products with life-cycle considerations. Therefore the study could be considered also as part of Table 3.

REPORT / PAPER TITLE	DEFINITIONS OF DURABILITY	METHOD ADOPTED	ANALYSED PRODUCT	KEY ISSUES FOR DURABILITY	RECOMMENDATIONS / REMARKS	POTENTIAL PRODUCT CRITERIA	CONCLUSIONS	REFERENCE
Durability and the construction products directive	Durability of a product is the ability of a product to maintain its required performance over a given or long time, under the influence of foreseeable actions.	Assessing Durability by: a) Direct assessment by testing or calculation; b) Indirect (proxy) testing (of durability); c) Indirect assessment.	buildings and constructions	Durability is thus dependent on the intended use of the product and its service conditions. It is influenced by exposure conditions, chemical and physical characteristics.	Subject to normal maintenance, a product shall enable a properly designed and executed works to fulfil the Essential Requirements for an economically reasonable period of time (working life of the product).	Criteria potentially based on available standards	The assessment of durability can relate to the product as a whole or to its performance characteristics, insofar as these play a significant part with respect to the fulfilment of the Essential Requirements. Durability should be assessed according to the state of the art of testing methods	[EC, 2004]
Making functional sales environmentally and economically beneficial through product remanufacturing	(not provided)	Analysis of remanufacturing facilities focusing on technical and economic aspects of remanufacturing.	household appliances and automotive parts	Ease of access, ease of handling, ease of separation and wear resistance.	Product information should be accessible for the remanufacturing personnel and the products should be adapted for the remanufacturing process. Parts that are worn out quickly in the product, or parts that require frequent upgrading, to be placed in the product structure in such a manner that they are easy to replace with new parts.			[Sundin et Bras, 2005]
Object-oriented framework for durability assessment and life cycle costing of highway bridges	Durability is to ensure that construction defects and life cycle maintenance requirements are kept to minimum.	Mathematical model that encapsulates design and decision-making variables in the problem domain; computational and decision-making modules including life-cycle costing.	highway bridges	Materials durability; life cycle costs; environmental exposures; constructions methods; protection options (cathodic protection against corrosion of reinforcements)	To choose cost-effective design solutions based on life-cycle costs.	(not provided)	Construction project can be optimized by life-cycle costs considerations, estimating and assessing the building durability.	[Ugwu et al., 2005]
Survey of ecodesign and manufacturing in automotive SMEs	Designing products to last longer reduces both resource use and waste generation.	Survey (by questionnaires) to identify drivers and barriers for Ecodesign in the SMEs of automotive sectors.	automotive sector	Upgradeability or modular design to extend the useful life. Lack of financial as barrier to the implementation of eco design	Use as LCA to support decision making	Upgradeability or modular design is a form of product life extension. Public incentives for SMEs.	Increasing durability may have an adverse effect by reducing the adoption of more environmentally beneficial technology with increased energy efficiency or emission controls.	[Veshagh et Li, 2006]

Table 2 Summary of some standards about durability of certain products

STANDARD N°	TITLE
ISO 7173:1989	Furniture -- Chairs and stools -- Determination of strength and durability
EN 60662:1993 A4:1994A5:1994A6:1994A7:1995A9:1997A10:1997	High-pressure sodium vapour lamps – Performance specifications
EN 60064:1995	Tungsten filament lamps for domestic and similar general lighting purposes - Performance requirements
ISO 12543-4:1998	Glass in building -- Laminated glass and laminated safety glass -- Part 4: Test methods for durability
EN 60081:1998 Amendments: A1:2002A2:2003A3:2005A4:2010	Capped fluorescent lamps. Performance specifications
EN 60969:1993/A2:2000	Self-ballasted lamps for general lighting services - Performance requirements
EN 1728:2000	Domestic furniture - Seating - Test methods for the determination of strength and durability
EN 13733:2002	Products and systems for the protection and repair of concrete structures - Tests methods - Determination of the durability of structural bonding agents
ISO 17398:2004	Safety colours and safety signs -- Classification, performance and durability of safety signs
EN 60357:2003/A3:2011	Tungsten halogen lamps (non-vehicle) - Performance specifications
ISO 7170:2005	Furniture -- Storage units -- Determination of strength and durability
ISO 21015:2007	Office furniture -- Office work chairs -- Test methods for the determination of stability, strength and durability
ISO 21016:2007	Office furniture -- Tables and desks -- Test methods for the determination of stability, strength and durability
ISO 21887:2007	Durability of wood and wood-based products -- Use classes
ISO 13823:2008	General principles on the design of structures for durability
ISO 15928-3:2009	Houses -- Description of performance -- Part 3: Structural durability
ISO 15206:2010	Timber poles -- Basic requirements and test methods
ISO/TS 12747:2011	Petroleum and natural gas industries -- Pipeline transportation systems -- Recommended practice for pipeline life extension
EN 12464- 1 and 2	Light and lighting - Lighting of work places - Part 1: Indoor work places - Part 2: Outdoor work places
operational motor lifetime test: Section 6.10 of , IEC 60312-1:2010 + A1:2011 durability of the hose: Section 6.9, IEC 60312-1:2010 + A1:2011	Durability of certain components of Vacuum Cleaners (namely operational motor lifetime test", and " durability of the hose").

Table 3 Summary of the review in the scientific literature on durability: sustainable assessment approach

REPORT / PAPER TITLE	DEFINITIONS OF DURABILITY	METHOD ADOPTED	ANALYSED PRODUCT	KEY ISSUES FOR DURABILITY	RECOMMENDATIONS / REMARKS	POTENTIAL PRODUCT CRITERIA	CONCLUSIONS	REFERENCE
The durable use of consumer products	Product life (or durability) is the product's actual life in use. It should be differentiated among the product's economic life (determined by the opportunity cost) and product's technical life (determined by the duration of the product's ability to fulfil its technical function).	Comprehensive analysis of factors influencing durability and analysis of practical experiences.	Various (cars, households, digital equipment)	1) technical quality to increase durability; 2) building a relationship with the customers (after-sale satisfaction); 3) durability-cost pricing; 4) pricing and guarantee; 5) communications to deal with anti-durability bias (incentive to consume); 6) case studies to find the most successful options; 7) planned obsolescence	Various recommendations for companies and policy-makers are provided. for a comprehensive understanding of the durability issues	Extended product's responsibility for durability; improvement/incentives for availability of spare parts and repairing services; incentives and removal of legislative barriers.	Product durability is a particular case of a broader issue of optima use and intelligent consumption.	[Kostecki, 1998]
The environmentally optimised lifetime: a crucial concept in life cycle engineering	(not provided)	Determination of optimal life-time by minimizing the life-cycle impacts.	cars and refrigerators	Durability differentiated for: products without technical changes; products with sudden technical changes and products with continual technical changes.	Due to decreasing efficiency of worn-out products as well as due to technological progress, lifetime extension proves to be not always the optimal strategy.	(not provided)	Developing mathematical models to assess the optimal useful life	[Dewulf et Duflou, 2004]
Design for Environment - Do We Get the Focus Right?	The longer the life of the product, the fewer the materials used for producing a new product and the lower the environmental impact.	Systematic analytical approach based on:.1) to identify the functions provided by the product and an analysis what might be the optimal way of providing this function; 2) to identify "environmental hot spots; 3) to implement design for environment according to the indentified priorities	Products in general (the way of intending durability is more oriented to non-energy using products).	The design for durability focuses on longer product life through maintenance or remanufacture and extension of life.	(not provided)	(not provided)	The focus and requirements in the product development process must be based on an understanding of the life cycle impacts of the product.	[Hauschild et al.,2004]
Life cycle optimization of household refrigerator-freezer replacement	(not provided)	Life Cycle Optimization model to analyze optimal lifetime (by environmental and cost factors) including modelling factors as: 1) deterioration of energy efficiency, 2) future energy performance (based on historical data and forecasts); 3) energy intensities of materials, 4) manufacturing and end-of-life.	refrigerator	Durability of the product and maintenance influence the deterioration behaviours	Extension of a product lifetime avoids environmental impacts associated with production of new products. On the other hand, replacement of an older, inefficient product with a newer, more-efficient product may reduce energy consumption and emissions during the use phase.	(not provided)	There exist tradeoffs between the optimal lifetimes for energy and cost objectives.	[Horie, 2004]

REPORT / PAPER TITLE	DEFINITIONS OF DURABILITY	METHOD ADOPTED	ANALYSED PRODUCT	KEY ISSUES FOR DURABILITY	RECOMMENDATIONS / REMARKS	POTENTIAL PRODUCT CRITERIA	CONCLUSIONS	REFERENCE
Eco-Efficiency Analysis of Washing machines.	(not provided)	Life cycle costing (LCC) and LCA based on different scenarios. CED and GWP indicators are used (jointly with an aggregated impact index).	Washing machines	(not provided)	The results of the analysis are largely dependant on the assumption about the life-span and the energy consumption during the use phase and the behaviour of the user (load, temperature of washing, number of cycles, etc.).	(not provided)	Authors conclude that there are small differences among the scenarios on life-span. Concerning the substitution of WM, this is worth for very old machine. Economically there is always a convenience into not substituting.	[Rüdenauer et Gensch, 2005a ; Rüdenauer et Gensch, 2005b]
The environmental and economic consequences of product lifetime extension: Empirical analysis for automobile use	Durability assimilated to the product lifetime.	Use of a stochastic lifetime model and environmental input–output model to provide a quantitative understanding of the effects of the lifetime extension on the environment and economy over the sample period.	cars	Influenced by the physical product durability and consumer psychology.	The product lifetime extension brings about a decline, not only in production levels, but also in the commercial and transportation services required for production activity.	(not provided)	Interdisciplinary analytical frameworks for the assessment of possible rebounds effects of the durability.	[Kagawa et al., 2006]
Environmental Issues within the Remanufacturing Industry	(not provided)	Literature review of LCA on practical applications	Households	Typology of product considered; consumption during the use phase; Upgradeability	Life cycle savings for remanufacturing may be less for products with high-energy intensity during its user phase.	(not provided)	The analyses show that remanufacturing is in general preferable to other end-of-life scenarios or new production from a material resource perspective.	[Lindahl et al., 2006]
Design for Durability	The concept of Durability in design embraces longer lasting products that focus on a better use of finite resources through, for example, combining functionality, opportunities for secondary lives, and increasing overall lifespan and product information.	Survey of the literature and interviews	(not applied)	In the context of 'design for durability' the different drivers of action are mainly divided by a technical view (economical driver) or a human view (social driver);	inter-relate design, individual values and limits of growth to provide convincing durable outputs and processes	(not provided)	1) To support a new role for design towards durability; 2) encouraging a dialogue between production and consumption	[Monteiro de Barros et Dewberry, 2006]
Life cycle, sustainability and the transcendent quality of building materials	Durability is the characteristic of those objects or materials that maintain their properties over time.	Life Cycle Assessment - LCA	building materials	The greater the material durability, the lower the time and resources required to maintain it	Two concepts are important and different: the durability of the materials and the durability of the engineering works	(not provided)	Implementation of LCA into buildings' projects.	[Mora, 2007]

REPORT / PAPER TITLE	DEFINITIONS OF DURABILITY	METHOD ADOPTED	ANALYSED PRODUCT	KEY ISSUES FOR DURABILITY	RECOMMENDATIONS / REMARKS	POTENTIAL PRODUCT CRITERIA	CONCLUSIONS	REFERENCE
An evolutionary model of recycling and product lifetime extension	(not provided)	Simulation model to identify the impacts of the environmental Research & Development strategies of business firms on the economy and the environment.	products in general	(not provided)	(not provided)	(not provided)	To introduce policies aiming at encouraging firms to invest both in product recyclability and lifetime. Environmental benefits are the production of less waste and the use of less resources	[Brouillat, 2009]
Product life-cycle implications for remanufacturing strategies	(Extension of the useful life of products by remanufacturing)	LCA to assess the end-of-life of the products in order to predict possible strategies for remanufacturing	products in general	Analysis of demand and supply of remanufactured products; flexibility of the remanufacturing processes.	Remanufacturing products with less environmentally sound technology can have a negative impact, especially if the major environmental impact are due to the use-phase	(not provided)	To provide remanufactured products in an effective way during the product's life-cycle.	[Östlin et al. 2009]
Environmental Life Cycle Assessment (LCA) Study of Replacement and Refurbishment options for household washing machines	(not provided)	Full comparative LCA	Washing machines	(not provided)	(not provided)	(not provided)	Immediate replacement of A and C rated machines with A++ machines generally represents the most environmental preferable option. Refurbishment of an A rated machine is environmentally preferential to immediate replacement with an A or an A+ rated machine.	[WRAP, 2010]
Longer Product Lifetimes	design for durability: extending the life of products	Life Cycle Optimisation (LCO) model which balances estimated production and end of life burdens for each product examined against use phase impacts over a 50 year time period.	Laptop computer, Washing machine, T-shirt, Toaster, Mobile phone, Domestic carpet, Carpet tile office flooring, Printer/scanner, Sofa	Technological innovation; Lack of consumer demand/fashion; Loss of revenues due to reduced sales; Repair/servicing too expensive; Consumers/Customers behaviours and care of products.		Possible measures include: Design for durability, Leasing business models; After-care services, Deposits schemes/ product buy-back; Consumer awareness campaigns, Government support; Enhanced Capital Allowances; VAT incentive; Voluntary product durability standards; Mandatory durability declaration; Green public procurement; Individual Producer Responsibility; Extended warranties	Product lifetime extension is likely to reduce environmental impacts across the lifecycle for the vast majority of products examined. The benefits largely result from 'avoiding' manufacturing and supply chain impacts.	[Downes et al., 2011]

REPORT / PAPER TITLE	DEFINITIONS OF DURABILITY	METHOD ADOPTED	ANALYSED PRODUCT	KEY ISSUES FOR DURABILITY	RECOMMENDATIONS / REMARKS	POTENTIAL PRODUCT CRITERIA	CONCLUSIONS	REFERENCE
Public understanding of product lifetimes and durability	(not provided)	Qualitative approach, involving literature review, followed by twelve discussion groups (involving 115 individual participants) considering product's purchase, use and end-of-life.	30 products among sectors: Clothing, Electronics, Furniture/interiors, Small appliances, Major appliances	Products categorised, according to attitude towards product lifetime: 1) workhorse (expect to last until broken);2) up-to-date (expect to last until updated);3) investment products (last long enough to pay me back).	Help consumers to reduce the risk of making the wrong choice; Focus on value and perceived value; Improve service performance to help keep products in use	Improvements of warranties/guarantees and repair services; provision of information to consumers; products easily to be repaired or upgraded; reduction of worn out.	Consumers view expected product lifetime as a subjective and variable entity that changes according to the product and person.	[Brook Lyndhurst, 2011]
Methodology for Ecodesign of Energy-related Products	(not provided)	Qualitative judgments (supported by life-cycle results from the "Methodology for Ecodesign of Energy-related Products")	(various)	Environmental impacts of the products during their life-cycle (with particular focus on the energy efficiency during the use phase)	In ecodesign studies and working documents on light sources (e.g. performance criteria for CFLs and LEDs) and on vacuum cleaners the product life plays an important role	extension of lifetime as expressed through: minimum guaranteed lifetime, minimum time for availability of spare parts, modularity, upgradeability, reparability;	Long product's life can have a (significant) negative impact on realizing savings.	[VHK, 2011]
1.2.4 Buying Guides for Durability and Repair	(not provided)	Guides focus on the most beneficial design specifications that can be 'easy to achieve' within existing product price-point constraints	laptop computers; power tools; televisions; vacuum cleaners; and washing machines	Upgradability, reparability, identification of key parts, availability of spare parts at reasonable cost, availability f information. Technical characteristics to avoid failures (product specific)			Significant environmental benefits achievable by extending the lifetime of electrical that have high production impacts, and tend to be replaced more frequently for newer technology.	[WRAP, 2012]

Concerning the definition of durability, main conclusions from the review are:

- Often the considered studies do not provide a definition of ‘durability’. In some cases the concept of durability, although not directly defined, is somehow expressed in the text. However, there is not a common understanding of the concept of durability.
- The majority of authors associate, more or less explicitly the durability of products to their resistance. For example Foster (2001) defines durability as "the degree to which a product tolerates stress or trauma without failing".
- It is observed that, in general, the definition of durability is linked to two aspects:
    - Ability of the product to perform its intended functions (physical product durability);
    - Ability to accomplish the expectancies of the users (consumer psychological durability).
- The definition of the durability of products can be also associated to durability of its materials. These concepts are related although differentiated (i.e. durability of products is function of durability of its constituting materials). This differentiation is especially introduced into standards focusing of the physical resistance of the product over time[7].

The identified key issues of durability are related to the way of interpreting durability. As previously discussed, two approaches are mainly followed: one based on forecasting of the ‘expected/planned/estimated’ life-length or functions of the product, and the other based on the sustainability assessment of durability of products.

According to the approach of the expected/estimated lifetime and/or functions, some key issues of durability are:

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

According to the approach of the sustainable assessment of products, some key issues of durability are:

- Ease of access, cleaning, repairing, substitution of components
- Low costs for maintenance/repair
- Adaptability to technical innovation (e.g. upgradability, modularity)
- Analysis of social factors influencing durability (e.g. fashion, planned obsolescence)
- Consumer awareness

However, such differentiation between the two approaches is not strict, and in some cases common views among the two approaches have been observed. For example, independently from the

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[7] For example the standard ISO 13823 defines the durability “the capability of a structure or any component to satisfy, with planned maintenance, the design performance requirements over a specified period of time under the influence of the environmental actions, or as a result of a self-ageing process” [ISO 13823, 2008].

adopted approach, the "design for durability" is generally intended as the design of the product in order to extend its life-time.

Possible product policy criteria suggested in the scientific literature to improve durability are:

- Identification of key components for the considered product category;
- Development of criteria based on product specific standards (e.g. thresholds of the expected product life-span or provision for a minimum time of some technical functions);
- Easy disassembly, repair and/or substitution of key components;
- Low costs for maintenance/repair (including availability of spare parts at reasonable prices compared to new devices);
- Extended producer responsibility (e.g. by warranties/guarantees)[8];
- Provision of information to improve consumer awareness.

Concerning the assessment of durability various methods have been proposed, based on the different scope of the studies and the different way of interpreting durability. Concerning the estimation of the expected/estimated life-time and/or functions, methods are generally based on:

- Statistical and stochastic methods.
- Direct/Indirect assessment (by testing or calculation), of durability based on specific standardised methods for the considered product.

Concerning the sustainable assessment of durability of products, methods are generally based on:

- Life Cycle Assessment (LCA), mainly based on different scenarios.
- Life Cycle Costing (LCC).
- Ecodesign tools (embodying also life-cycle environmental and life-cycle cost issues)
- Qualitative analysis, based on interview, questionnaires and literature review.

Concerning the sustainable assessment of durability of products, it is observed that recommendations from various studies can be very different. The main reasons for such differences are:

- Results of the environmental balances are largely based on initial assumptions about: duration of the expected life-lengths, performances and impacts of new products/technologies, considered impact categories, system boundaries of the studies. The assessment of the energy efficiency of substituting products can be based on a number of assumption about, for example, the energy efficiency of products to be developed in the future and related to technologies not developed yet.
- Different typologies of products have been analyzed. Some authors point out that extending the lifetime of products is always beneficial. This is due because authors focuses only on non-Energy Using Products (EuP) or non-Energy Related Product (ErP). Alternatively this

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[8] Warranty is intended as the promise to replace or repair an item if it does not satisfy the terms of the warranty. Guarantee is intended as the promise to return the money paid to purchase an item if the item does not satisfy the terms of the guarantee.

conclusion is also stated in some studies for EuP where it is assumed to compare the extension of the operating life of the product in comparison to its substitution with a product with the same energy efficiency.

- Assessments are based on different impact categories. Environmental benefits of extended durability of products are particular evident in terms of reduces use of resources and less production of waste. Benefits concerning the Global Warming Potential (GWP) and the Cumulative Energy Demands (CED) are generally low or, in some cases, null/negative.

A common understanding is that for EuP/ErP "due to decreasing efficiency of worn-out products as well as due to technological progress, lifetime extension proves to be not always the optimal strategy" [Dewulf et Duflou, 2004]. However there can be deviation from this generic understanding for different products type depending on a number of factors (e.g. marginal decreasing return of improvements in energy efficiency, energy using products which are inherently efficient (laptops, mobile phones, etc) and for which the production phase account for a significant part of the total life cycle impacts.

Concerning the standards on durability, they are always "product specific" and refer to specific product's components or properties. In some cases, standards have been developed modelling the probability of failure of the products (including the assessment of the expected lifetime) and/or the conservation of performance.

The majority of standards, however, focus on constructions and construction materials (e.g. [ISO 12543-4, 1998; ISO 13823, 2008, ISO 15928-3, 2009] and furniture (e.g. [ISO 7170, 2005; ISO 21016, 2007]). These standards generally assess the resistance of products to loads and external stresses.

Few standards refer to ErP. Particularly interesting is the case of the standard CIE 097, which introduced a method concerning the maintenance of indoor electric lighting systems [CIE 097, 2005]. This method represents also an interesting example of correlation of durability to the functionality of the product (the energy output of the device). The method of CIE 097 has been adopted by some implementing measures for lighting systems to introduce threshold Ecodesign requirements concerning the following parameters [EC, 2009; EC, 2009b]:

- *the 'lamp lumen maintenance factor', which is the ratio of the luminous flux emitted by the lamp at a given time in its life to the initial luminous flux*;
- *lamp survival factor', which is the defined fraction of the total number of lamps that continue to operate at a given time under defined conditions and switching frequency.*

The following sections provide a more detailed overview of some standards and studies analyzed during the literature review.

1.2.2 Durability in ISO 14000 series standards

The concepts of durability of products, design for durability and assessment of durability have been explored by several ISO standards and technical reports of the series ISO 14000.

Although the product is generally not directly controlled by the manufacturers after being sold, product's design can affect impacts during some product's life cycle stages (e.g. use phase, EoL).

According to ISO 14001, the durability of products is therefore part of indirect environmental aspects of the company, meaning "aspects that it can influence, e.g. those related to goods and services used by the organization and those related to products and services that it provides" [ISO 14001, 2004].

ISO technical report 14062 on "integrating environmental aspects into product design and development" defines the "design for durability" as "considering the product's longevity, reparability and maintainability, considering environmental improvements emerging from new technologies" [ISO/TR 14062, 2002]. Furthermore, it states that [ISO/TR 14062, 2002]:

- "when developing products, there may be considerable value in thinking in terms of functionality (how well the product suits the purpose for which it is intended in terms of usability, useful lifetime, appearance, etc.)"
- "when defining the product's lifetime as part of its function, increasing the durability and extending the services associated with the product can reduce adverse environmental impacts".
- "a balance is also necessary between extending a product's lifetime and applying the latest technological advances that may improve the environmental performance during use".

These considerations have been used as basis for the development of the method for the environmental assessment of durability of products (in Report n°3 - Chapter 5).

Life Cycle Assessment represents a suitable methodology for the assessment of the environmental impacts due to changes in product's design, including the effects of potential changes in the product lifetime. The key methodological issue is then represented by the setting of the functional unit, as the reference "to which the inputs and outputs are related. This reference is necessary to ensure comparability of LCA results" [ISO 14040, 2006].

Guidance on how different lifetimes can be considered in the LCA of different products is provided by the [ISO/TR 14049, 2012]. For example, the technical report illustrates the example of comparison of two light bulbs. These can be "*regarded as comparable in spite of their difference in lifetime. This difference is simply taken into account in the calculation of the reference flow*" [ISO/TR 14069, 2012]. Furthermore the report noticed that "*for long-lived products, such as refrigerators with lifetimes of 10 or 20 years, technology development may be a factor that cannot be disregarded. One refrigerator with a lifetime of 20 years cannot simply be compared to two successive, present-day refrigerators with a lifetime of 10 years. The refrigerators available 10 years from now are certain to be more energy efficient (i.e. lower energy input per functional unit) than the present, the energy efficiency of the second refrigerator of the 10 + 10 option is determined by a trend projection, while the energy efficiency of the 20 years option is fixed*" [ISO/TR 14069, 2012].

These aspects concerning the setting of the operating service life of comparable products and the changes in the energy efficiency of products have been included in the setting of the method for the assessment of durability of products (Report n° 3- Section 5.3.1).

1.2.3 Obsolescence of products

The present section shortly discusses the concept of obsolescence of product, which is a key issue generally introduced in various studies. For example Cooper (2004) categorised three different types of obsolescence, technical obsolescence; economic obsolescence; and psychological obsolescence, and in so doing began to describe the design attributes and levers within the production and consumption relationship.

A product can be considered obsolete when it is no longer able to perform its intended function [Rose 2000]. “Products reach their end-of-life for a variety of reasons. A product typically reaches its end-of-life because it is worn-out or because it is outmoded. A product is worn-out when crucial components supporting the key functions of the product fail. A product is outmoded when the user feels the functions are not the best on the market due to technology innovation” [Rose 2000].

For example, a frequently failing part (i.e. a part that needs to be serviced frequently) could be made of a more durable material in a following design.

Consumers, who are fashion purchasers, purchase the latest design to satisfy psychological needs or aesthetic preferences rather than technological requirements.

Marketing strategies are employed to limit the product life by rendering their symbolic components obsolete (e.g. by accelerating the change of fashion), or by consciously promoting technological obsolescence[9] [Kostecki, 1998]. It means that “publicity and promotion reinforce consumer preference for novelty, rendering numerous useable products obsolete well before their technical or functional capacities are fully used” [Kostecki, 1998]. Psychology is also used to induce consumers to consume more and more, using for example the fascination of novelty (symbol manipulation) [Kostecki, 1998]. The messages of "new" constitute a more attractive selling proposition than the benefits of optimal use of products.

Two main reasons explain this situation [Kostecki, 1998]:

- First, "new" is appealing in a society where terms such as "change", "youth or "dynamic" are perceived more positively than in previous generations. The return on the investment in the symbolic value of "new" is higher than that in "durable".
- Second, the consumer's benefits of durable use are complex and more apparent ex post than ex ante.

In some case the life-span of the product can be extended, delaying so far the obsolescence. For example reparability ([Kostecki, 1998; Downes et al., 2011; Brook Lyndhurst, 2011; WRAP, 2012]) or upgradability ([Sundin et Bras, 2005; Lindahl et al., 2006; Veshagh et Li, 2006; Brook Lyndhurst, 2011; WRAP, 2012]) can contribute positively to extended product lifetime.

However some products (as e.g. light bulbs) cannot be upgraded and their repair is not possible and/or not economically convenient. Therefore the lifetime of the products is basically decided by decision at the design and manufacturing stage.

Numerous authors argue that many consumer durables are designed to have uneconomically short life spans, with the intention of forcing clients to repurchase more frequently [Kostecki, 1998]. This phenomenon is referred to as ‘planned obsolescence’[10]. Some authors suggest that “a limited life span of numerous consumer durables is the cost imposed by the monopolistic producers to overcome the time consistency problem. Others suggest that planned obsolescence is necessary to achieve

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[9] New technologies can render numerous products obsolete both in technical and economic terms.

[10] “Products are designed to have uneconomically short lives, with the intention of forcing consumers to repurchase too frequently” [Kostecki, 1998].

technological progress. If products are too durable, 'potential innovators may lack the incentives to invest in the development of a new technology and the economy may stagnate as a result” [Kostecki, 1998]. Also in this case there is a fascination with technological change. The change is implemented at all costs as a matter of "innovative strategy", the company's image or technological leadership, etc. The question is rarely asked as to whether the consumers have equal preferences for the new technology and whether the technological change truly adds to the consumer's value chain. In addition, little regard is paid to the issue of technological compatibility” [Kostecki, 1998].

Technological changes also influence other end-of-life aspects as, for example, reuse. “Products with few changes in technology have high reuse potential and retain their value at end-of-life. However, products with rapid technology cycles are not prone to reuse after the first consumer” [Rose, 2000].

Figure 1 illustrates some average lifetime of products based on the estimated product’s “wear-out life” and “technology cycle” [Rose, 2000]. The technology cycle and wear-out life, separate the products into three sections. The high technology products, or new economy products, are located in the lower-left hand corner, until the first diagonal. The region in the middle, between the two diagonal lines, is comprised mostly of consumer products. Commercial products dominate the region in the upper right hand corner. If the product wear-out is longer than the technology cycle, there are various redesigns of the product released before the first product released reaches its wear-out life. There are products with technology cycle longer than product wear-out life such as single use camera, shipping container and electric power steering motor [Rose, 2000].

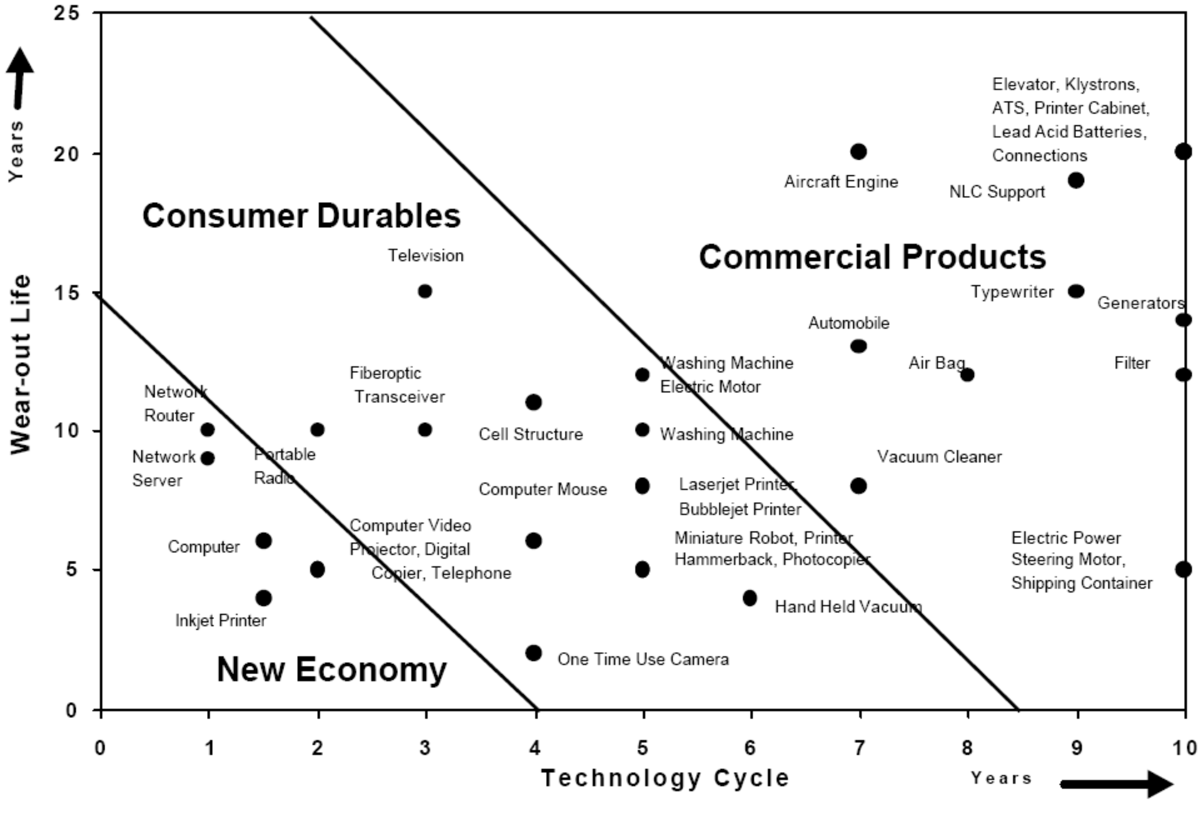

Figure 1. Wear-out Life and Technology Cycle of some products (adapted from [Rose, 2000])

The improvement of durability should be focused on products that have longer technological cycles, i.e. products that are less affected by frequent technological changes. For example, vacuum cleaner and washing machine are, among the "consumer durables", products with relatively large technology cycle, and it is a product group potentially relevant target for "design for durability" actions.

1.2.4 "Eco-Efficiency Analysis of Washing machines"

In 2005 the Öko-Institut published a study on WMs with the aiming, among the other, at answering at the following questions [Rüdenauer et Gensch, 2005a]:

- What is the optimal life span of a washing machine regarding the next approximately 20 years?
- Does it make sense to further use an old washing machine or is it better (in environmental and economic terms) to buy a new one?

The method applied was an LCA and LCC based on different scenarios. The LCA considered the following phases:

- Production and distribution of a washing machine (including raw material supply)
- Use phase: washing and drying of clothes
- End-of-life treatment of washing machine

The considered environmental impact categories are:

- Cumulative Energy Demand (CED)
- Global Warming Potential (GWP)
- Total environmental burden (aggregated and weighted index).

In order to answer to the previous questions, authors had to estimate the specific consumption figures and the spin speed of future washing machines. In fact, "a long life span results in […] smaller environmental impact and costs for production and end-of-life-treatment but maybe in higher impacts during the use phase (as potential efficiency gains are not realised), whereas a shorter life span results in higher impact and costs for production and end-of-life-treatment but presumably in lower impacts and costs through usage" [Rüdenauer et Gensch, 2005a]:.

Concerning the optimal life-span, main conclusions are [Rüdenauer et Gensch, 2005a]:

- the differences about the environmental impact of different life spans of WMs are small compared to
    - the variation due to different households and the consumer behaviours;
    - the overall environmental impact of private households.
- Analogously difference in the LCC are not relevant

According to the authors, the relatively small differences of environmental impacts and costs between the regarded life spans for all regarded scenarios can be seen into ways. On the one hand there is no environmental or economic incentive to either substitute an existing washing machine very quickly or to use it for a very long time. On the other side, manufacturers and consumers should keep other qualities in mind when designing or buying a new WM (e.g. quicker washing cycles, better performance, aesthetic considerations, noise reduction etc).

It is however highlighted that the estimated low benefits can be related also to the use of restricted set of environmental impact categories, mostly related to the energy consumption, used in order to draw conclusions on the significance of the environmental savings from increasing durability of washing machines.

Concerning the extension of the use of old devices, authors conclude that [Rüdenauer et Gensch, 2005a]:

- When regarding the CED, the substitution of old WMs (from 1985 to 1995) with a new model is justified. The payback periods are approximately 2, 3 and 5 years respectively.
- When regarding the global warming potential only the substitution of washing machines of 1985 and 1990 with a new model is justified. The payback periods are approximately 3 and 5 years respectively.
- Under economic perspective the substitution of none of the regarded washing machines amortizes within 5 years.

1.2.5 "Environmental Life Cycle Assessment (LCA) - Study of Replacement and Refurbishment options for household washing machines"

In 2011, WRAP published a study about WMs, investigating and comparing replacement and refurbishment options for household washing machines at the end of their lifetime [WRAP, 2010].

Whilst the manufacture and delivery of a replacement washing machine will incur an environmental cost, it is assumed that new machines will have an equal or improved energy efficiency compared to the machine they replace. Conversely, refurbishment will result in lower manufacturing burdens compared to producing a new washing machine and will delay the purchase of a replacement machine.

The study was based on the LCA methodology, considering various EU energy label rated WMs (from C class to A++ class) and different replacement options (immediate substitution or delayed substitution after 3, 6 and 9 years). The assessment was based on a multi-criteria analysis.

The study findings are as follows.

- Immediate replacement of A and C rated machines with A++ machines represents the most environmental preferable option for all impact categories except solid waste generation and photochemical oxidation.
- With the exception of water use, refurbishment of an A rated machine is environmentally preferential to immediate replacement with an A or an A+ rated machine (according to the authors, A rated machines will continue to represent for the UK the majority of both sales and stock of WMs until 2020).
- The relative benefits of refurbishing a C rated machine compared to its immediate replacement with A or an A+ machine are dependent on the lifetime extension achieved by refurbishment, and the impact category under consideration.

It is also noticed that there is a large degree of variability in the washing performance of a single machine depending on the way it is used: the size of wash load, the types of garments, how the garments are placed in the machine and how well they mix during the cleaning process.

The ability for machines to be designed to meet the challenge of cost effective refurbishment therefore is important, both for machines currently on the market, and increasingly so for future models including A++ rated machines. Where future energy efficiency improvements may be small, product impacts can be reduced by increasing their lifetime. Therefore, authors recommend that, until there is a significant step-change in the energy performance of washing machines available to the market, machines should be designed for easy repair and to ensure that repaired or refurbished machines continue to operate for a long time.

1.2.6 DEFRA studies on Durability

To investigate opportunities for lengthening products' lifetimes, the Department for the Environment, Food and Rural Affairs (DEFRA) in UK recently commissioned two parallel studies: one to model lifecycle environmental benefits and the feasibility of extending product lifetimes; the other to explore consumer understanding of, and appetite for, longer product lifespan. These studies are following summarized.

1.2.6.1 Longer Product Lifetimes

The study analyzed possible solution to reduce UK's environmental impact by extending the life of products and to identify and to assess possible measures or interventions to achieve lifetime extension [Downes et al., 2011].

The authors developed a Life Cycle Optimisation (LCO) model which balances estimated production and end of life burdens for each product examined against use phase impacts over a 50 year time period. Three environmental impact indicators were considered:

- Global Warming Potential (kg CO2 eq.);
- Abiotic Resource Depletion (kg Sb_{eq});
- Water consumption (direct and indirect) (litres).

For each of the nine example products[11], the LCO model compared two reference product scenarios: an example 'typical' lifetime and an 'extended' lifetime. In each case, authors looked at the different phases of the product life cycle namely: production (raw materials and assembly); consumer use; refurbishment (if undertaken); and disposal (via recycling, incineration or landfill). However the study does not compare the scenario of extending the product's lifetime with, for example, the possibility to replace it with more efficient devices.

Authors conducted sensitivity analysis to establish whether the conclusions drawn from the reference scenarios would be likely to hold true under different circumstances.

It was necessary to make a number of assumptions in the LCO model, these included: whether energy-using products may be replaced with more efficient models at the end of life; the manner in which electricity in the UK will be generated in the future; and forecasted trends in the energy efficiency of products etc.

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[11] Laptop computer, Washing machine, T-shirt, Toaster, Mobile phone, Domestic carpet, Carpet tile office flooring, Printer/scanner, Sofa.

The study concluded that, from an environmental perspective, there is an argument for optimized lifetime extension strategies for all consumer products and in particular, for products in which manufacturing, supply chain and waste management impacts dominate over the life cycle.

An important finding of the study is that for the energy using products examined in the research the predicted improvements in energy efficiency do not overcome the ‘avoided’ manufacturing impacts which result from extending product lifetime. The benefits largely result from ‘avoiding’ manufacturing and supply chain impacts because lifetime extended products are kept in service for longer, so do not need to be replaced as frequently. The research however did not examine products such as vehicles, heating systems and TVs because it was identified (although not quantified) that foreseen and paradigm shift types of energy efficiency innovation had the potential to outweigh the benefits of lifetime extension.

For example, for the WM product group the study indicates that the use of the long life span washing machine reduces the environmental impacts compared to a typical washing machine, though this is based on a number of use-related assumptions, such as the number of wash cycles per year, a wash temperature of 60°C cotton wash cycle, load sizes, product lifetimes, energy and water consumptions, servicing and energy efficiency reduction of appliances.

1.2.6.2 “Public understanding of product lifetimes and durability”

The study carried out research into consumer attitudes towards product lifetimes of a range of consumer products [Brook Lyndhurst, 2011]. The interest in lengthening product lifetimes – through the manufacture of more durable products and by consumers keeping products in use for longer – stems from the potential that longer product lifetimes have for reducing the material and carbon impacts of consumption. However, as evidenced by other authors, this assumption is not necessarily true for EuP. However, the impacts due to the use of less efficient products were not considered in the study.

The method of analysis was based on a literature review, followed by twelve discussion groups (involving 115 individual participants) considering product's purchase, use and end-of-life. Thirty case-study products have been considered belonging to various sectors: Clothing, Electronics, Furniture/interiors, Small appliances, Major appliances.

The study noticed that consumers are aware that a product’s ‘lifetime’ is not fixed and that it is determined by both the inherent durability of a product and the actions taken by the owner in use. An important conclusion from the work was that products can be categorised into three types, according to consumer attitude towards product lifetime:

- *Up-to-date products* are defined in the study as products routinely disposed of by consumers because of their desire to update, e.g. fast fashion clothing, costume jewellery, mobile phones, televisions.
- *Investment products* are products worth spending extra on for either their style and/or their function e.g. expensive/luxury clothing items, furniture.

- *Workhorse* products are products which are relied upon for their function. Such products tended to be kept in use by most consumers until they break (for example certain large and small appliances such as washing machines, irons, lawnmowers).

However the expected product lifetime is a subjective and variable entity that changes according to the product and person. Also the categorization among the above three categories is subjective.

Some barriers hinder lengthening the product lifetime. In particular the easy affordability of new products and the need to be up-to-date present two significant challenges.

Based on the analysis authors identified some key themes across the various opportunities for extending product lifetimes:

- To recognise the fundamental importance of consumers' need to be 'up-to-date';
- Help consumers to reduce the risk of making the wrong choice: provide them with clearer and more certain means for judging the expected lifetimes of products and repairs
- Focus on value and perceived value: longer life products have to offer consumers clear and apparent value when compared with shorter life, possibly cheaper alternatives.
- Improve service performance to help keep products in use: this potentially includes both innovations in product service systems as well as improvements to warranties/guarantees and repair services.

Possible measures to extend the lifetime of "up-to-date" products include, among others [Brook Lyndhurst, 2011]:

- Working with manufacturers to develop the potential for up-datable and up-gradable products that do not have to be replaced in their entirety.
- Building on existing consumer interest in the care of up-to-date electronic products.
- Working with manufacturers and service providers (particularly of electronic products, and specifically of mobile phone services) to improve the level of service offered to consumers after purchase based on rewards for keeping products.

Possible measures to extend the lifetime of "workhorse" products include, among others [Brook Lyndhurst, 2011]:

- Better product lifetime information for consumers thinking about purchasing workhorse products, with an emphasis on bringing value to the consumer.
- Working with manufacturers to encourage product design more amenable to repair, including the availability and affordability of spare parts.
- Working with the providers of warranties (both manufacturers and third parties) to improve both the reputation and service performance of warranties.
- Working with manufacturers to improve the level of service offered to consumers after purchase.
- Exploring how repair networks could be supported and encouraged, including online information resources for consumers.

- Providing clear information to consumers on key points of product care, based on manufacturers' knowledge of product performance.

1.2.7 Buying Guides for Durability and Repair

The UK WRAP organisation developed a list of guidelines about durability and repair of products [WRAP, 2012]. These guidelines represent a useful guide to provide suggestions to improve product durability including identification of key components for durability.

For example, the guide on Washing Machines (WM) highlights that [WRAP, 2012b]:

- "*Basic fault diagnostics advice to be available in the user's instruction booklet and on-line*
- *Items requiring user access for replacement or cleaning (such as filters, detergent drawers, external hose connections), should be easily accessible and removable/replaceable without the need for tools.*
- *The machine should be of robust construction to avoid mechanical damage in use*" (including for example):
    - *"Function-critical parts (such as on-off switches, selector dials and filters) are in strong housings or away from exposed areas and corners.*
    - *Door catches and handles are robust to ensure durability and resist fatigue in operation* […]"
- "*The machine should be of robust electrical design to avoid failure in use. This can be achieved by specifying that* […]:
    - *Electrical components such as control boards are placed away from potential water leaks*.
    - *Key components on the power and control boards are protected from power supply faults. […]*
- *Machine repair manual and exploded parts diagrams should be available on the brand or manufacturer's website (free of charge).*
- *All major components (motor, pump, drum, control boards) should be easily accessible without the need to remove other parts for access – such as back panels fixed with one access screw.*
- *Key components to be repairable through replacement (such as motors that have replaceable brushes).*
- *All parts to be clearly listed on the manufacturer's website with relevant pricing and information on parts stockists.*
- *All spare parts12 to be available for at least 10 years*[13] *following the end of model production.*

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[12] "*Spare parts are those more likely to fail in normal use and need replacing. These include hoses, door seals, door latches, detergent trays, motors, pumps, bearings and control boards. Parts which typically exceed the life of the product are not to be considered as spare parts*" [WRAP, 2012b].

[13] "*The UK Sale of Goods Act (SOGA) offers protection against faulty goods when the manufacturer's guarantee has expired and states that goods must last a "reasonable time" which can be claimed anything up to six years from the date of*

- *Spare parts and sub-assemblies to be reasonably priced to facilitate repair outside of warranty*[14].
- *All major repairable or replaceable components to be easily accessible by repairers (such as selector dials, internal filters, motors, catches, seals, hoses, drive belt and shaft")[…].*
- *Product warranty period should be at least 2 years*[15] *for medium-cost models […] and at least 5 years for high-cost models […] and should favour repair over replacement and cover parts and labour*

Analogously for the LCD Television case-study, the guidelines highlight that [WRAP, 2012b]:

- "*Basic fault diagnostics advice available in the user's instruction booklet and online.*
- *The product to be of robust construction to avoid mechanical damage in use*" (including for example):
    - *Protecting function-critical leads, switches and ports in strong housing and away from exposed areas or corners […]*
    - *Supporting connector blocks by the case moulding – not relying on solder alone on the circuit boards to keep them in place.*
    - *Using access fixings for repair that can withstand a number of repair cycles – such as the back panel.*
- *The product to be of robust electrical design to avoid failure in use. This can be achieved in products by […]:*
    - *Adequately spacing and cooling high temperature components and circuits – by specifying heat sinks or fans to prolong life […].*
    - *Electrically protecting power and control board components from power supply faults.*
    - *Preventing faults on key components causing faults to other components – by avoiding components being interconnected […].*
- *Repair manual and exploded parts diagrams to be available on the brand or manufacturer's website (free of charge).*
- *All spare parts to be clearly listed on the manufacturer's website with relevant pricing and information on stockists.*
- *All spare parts to be available for six years*[16] *following the end of model production.*

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purchase. 12 years availability of spares is specified under the EU Eco-label for washing machines. 10 years is considered reasonable to reflect the typical lifetime of most washing machines" [WRAP, 2012b].

[14] "*To facilitate cost-effective repair, replacing the drum assembly parts or motor should be no more than 40% of the cost of an equivalent new machine, and other spare parts no more than 25% of the cost of the new machine*" [WRAP, 2012a].

[15] "*Warranty of 2 years including parts and labor are available for some medium-cost machines. 10 year warranties available for some high-cost machines including parts and labor*" [WRAP, 2012c].

[16] "*The UK Sale of Goods Act (SOGA) offers protection against faulty goods when the manufacturer's guarantee has expired and states that goods must last a "reasonable time" which can be claimed anything up to six years from the date of purchase. Six years availability of spares is specified under the Blue Angel Eco-label scheme in Germany. Most of the larger manufacturers currently meet this requirement. 7 years is specified for the EU Eco label*" [WRAP, 2012b].

- *Spare parts and sub-assemblies to be reasonably priced to facilitate repair outside of warranty*[17].
- *All major repairable/replaceable components (such as screen assembly, control circuit board, inverters and speakers) to be easily accessible once the rear casing is removed […].*
- *Minimum guarantee*[18] *of 2 years, and 3 years on high-cost models that favours repair over replacement and covers parts and labour.*

1.3 Outcomes of the literature review

First of all the following definition are provided. Definitions will be the basis for the development of the method for the assessment of the durability and its exemplary application to case-study.

Definitions:

- *Durability:* the ability of products to maintain their functions and performances over their life-cycle[19].
- *Design for Durability*: considering the product's longevity, reparability and maintainability; considering environmental improvements emerging from new technologies [ISO/TR 14062 2002]*;*
- *Operating time*: Average time frame during which the product is supposed to be used. Operating time can be derived from product's statistics or from estimating models.
- *Extension of operating time*: Estimated time frame extension of the operating time that can be achieved due to specific design and maintenance actions
- *Assessment of the environmental effects of product's Durability*: assessment of environmental benefits/drawbacks of extending the operating time of products in comparison to their replacement with newer ones.

The method for the assessment of durability will focus only on the environmental impacts. Economic, social and psychological issues will be not considered. The method will be illustrated in Report n° 3-Chapter 5. Compared to studies on the scientific literature[20], the main original contribution is the setting of a general a comprehensive mathematical framework for the assessment based on some variation of some key parameters. In particular the method is based on the application of the LCA methodology to various scenarios representative for the extension of the operating time of studied products in comparison to their replacement with newer products. Due to the relevance of the selected impact categories, the method will be flexible (different life-cycle impacts can be considered for the calculation).

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[17] "*To facilitate cost-effective repair outside of warranty no individual spare part is more than 20% the cost of a new television and the LCD screen assembly is no more than 60% of the cost of a new television*" [WRAP, 2012b].

[18] "*Manufacturer warranties are available for 3 years on some mid-cost televisions and 5 years on some high-cost models. Warranty does not necessarily mean that products are repaired (as products can be disposed of and replaced during warranty). To encourage longer life, warranties should include parts and labour*" [WRAP, 2012b].

[19] This definition has been adapted from several similar definitions in the scientific literature including e.g. [Kostecki, 1998; Rose, 2000; ISO/TR 14062, 2002]. Durability can be influenced by several aspects including e.g. technological cycles, fashion, costs, user behavior, etc.

[20] See for example [Rüdenauer et Gensch, 2005a ; Rüdenauer et Gensch, 2005b; WRAP, 2010]

By applying the method to a case-study product, it will be possible to assess if there is environmental benefits in extending the operating time [21]. If these benefits are observed, the attention should focus on possible measures and product's policy criteria to improve the product durability. These measures can include, for example:

- Identification of key components for durability for the considered product category. These are components that, based on the experts of the sector, are more often affected by failures (this requires the existence or development of an agreed methodology to measure e.g. the lifetime of the key components).
- Non-destructive disassemblability[22] of key components and their reparability and/or possibility of substitution.
- Low costs for maintenance/repair (including availability of spare parts at reasonable prices compared to new devices)
- Extended producer's responsibility (e.g. by warranties/guarantees)[23]
- Provision of information to improve consumer's awareness and support disassembly, repair and substitution of key components).

Finally, when available, standards to measure the average product's life-spam and the ability of the product to fulfil its technical functions should be considered for the settlement of product's policy criteria for specific product groups.

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[21] It is highlighted that other aspects can influence the durability of products (e.g. fashion and users behaviors). However these have been not considered in the current project but could be part of the future research.

[22] Non-destructive disassembly implies the ability to disassembly the component without damaging it and the other product's parts. This condition is more restrictive than the simple "disassemblability" (as discussed, for example in Report 2 – Section 3.2.2.2 and Report 3- Section 1.2.2.), which do not imply the conservation of the integrity of the components and connecting parts.

[23] Warranty is intended as the promise to replace or repair an item if it does not satisfy the terms of the warranty. Guarantee is intended as the promise to return the money paid to purchase an item if the item does not satisfy the terms of the guarantee.

2. Assessment of the Durability for the Washing Machine case-studies

2.1 Introduction

The present Chapter illustrate the application of the method for the assessment of Durability[24] to a case-study product group (Washing Machine – WM – introduced in Report n° 2)[25].

The method has the scope to identify if and to what extent a potential extension of the operating time of a product could be relevant in terms of life-cycle environmental benefits. The assessment of the durability of the case-study product is based on the comparison of two different scenarios, following a life-cycle approach:

- Base-case Scenario: it is assumed that the case-study product "A" is substituted, after its average operating time, by a new product "B".
- Durability Scenario: it is assumed that the operating life of product "A" is extended of an additional time frame, and only afterwards it is substituted by a new product "B.

2.2 Environmental assessment of the durability of case-study products

2.2.1 Identification of a potentially relevant case-study

The identification of a relevant case-study for the analysis has been performed during the "case-study" selection task[26], under the criterion "Relevance of the case-study to potential requirements on the durability".

The analysis of potential case-studies focused on product categories for which the changes of the technological cycles are not often, compared tot the expected lifetime. As underlined in Section 1.2.3, the improvement of durability should focus mainly on products that are less affected by frequent technological changes. On the other sides, products affected by frequent technological changes are more likely to be substituted when still perfectly operative. For some typologies of products the extension of the lifetime can be not useful or counterproductive. This is linked to the concepts of technological obsolescence and fashions (shortly introduced in Chapter 1).

Although social issues have been not considered in the current analysis, these issues could be part of the methodology in the selection of potentially relevant product group for the lifetime extension.

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[24] Report n° 2 - Chapter 6.

[25] Report n° 3 - Chapter 5.

[26] Report 2 – Chapter 2.

In the present analysis, the washing machine (WM) product' group has been identified as potentially relevant for the scope of the project. It is also highlighted that WM is, among the "consumer durables", a product with relatively large technology cycle, and it is a product group potentially relevant target for "design for durability" actions (see for example Figure 1).

2.2.2 Assumptions for the environmental assessment of the durability of WMs

The Report n° 3 introduced various original indices for the assessment of the durability. The following section will apply the simplified method[27] for the calculation of the "Simplified Durability index D'_n" for the "n" impact category[28]. The following assumptions have been introduced:

- The two case-study products (WM1 and WM2) are analyzed. The function considered for the analysis if the cleaning of clothes[29];
- The index "D'_n" is here calculated for three impact categories[30]: GWP, Terrestric Ecotoxicity (TE) and Abiotic Depletion Potential Elements (ADP el). These three categories have been selected because one (GWP) dominated by the energy consumption, one is dominated by the manufacturing phase (ADP e) and the last one (TE) is more or less equally influenced by both the life-cycle stages.
- The average operating time "T" for WMs is: 11.4 years;
- The energy consumption during the use phase of the case-study products (WM1 and WM2)[31] is:133 kWh/year (1.52 MWh/life);
- The extension of the operative time "X" is assumed ranging from 1 to 4 years;
- The energy consumption of the substituting product "B" during the use stage is assumed ranging from 100% to 70% of that of the WM1/WM2. Water consumptions are supposed not modified;
- The life-cycle impact for production "P_n" of the case-study products are calculated as the sum of impacts for manufacturing and production of materials[32];
- The life-cycle impacts "R_n" for the additional treatments (i.e. repairing) for extending the operating time of the WMs are not available. It is assumed to perform a scenario analysis ("low repairing scenario - LRS" and "high repairing scenario - HRS")[33], in which "R_n" has been set:

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[27] For symbols and further details on the method, see Report n° 3 – Section 5.3.2.

[28] It is highlighted that the extensive analysis of the durability requires detailed market analysis with the assessment of the case-study product and potential new substituting products. This is, however, out of the scope of the present project.

[29] Some washing machines perform also additional services (e.g. drying). However the current analysis if limited only to the cleaning function. Quality of the service (e.g. the quality of the cleaning process) is not considered.

[30] The three impact categories have been here considered to present only a summary of representative results. This is mainly to avoid a too large number of figures/tables for the several considered scenarios. The full set of impact categories (as used in Report n°2) will be used for the assessment of potential benefits for the WM product group (see Chapter 3).

[31] Assumptions: 175 cycles/year, washing 4 kg load. For further details on the energy consumption, see Report n° 2 – Section 6.4.2.1.

[32] For further details on the assumptions for the LCA of WMs, see Report n° 2 – Section 6.4.2.1.

- From 2.5% to 5 % for the GWP impact category;
- From 10% to 20 % for the TE impact category;
- From 10% to 30 % for the ADP el impact category.

Table 4 summarizes the main assumption for the calculation of the Simplified Durability index D'_n; Table 5 illustrates the life cycle impacts of the WM1 and WM2 case-studies.

Table 4 Summary of the assumptions for the calculation of the Simplified Durability Index "D'_n"

Product "A" (WM1 and WM2)		
Average operating time "T"	11.4	[years]
Energy consumption (during use)	133	[kWh/year]
Total energy consumption for use (during the whole life)	1.52	[MWh]
Extension of life time "X"	From 1 to 4 [years]	
Product "B" (substituting product)		
Energy consumption (δ) of product "B" compared to "A"	from 70% to 100%	

Table 5 Life cycle impacts of WM1 and WM2 for the calculation of the Simplified Durability Index "D'_n"[34]

Life cycle impacts for WM1						
	GWP		Terrestric ecotoxicity.		Abiotic Depletion Potential Elements	
	[kg $CO_{2\ eq}$.]		[kg DCB_{eq}.]		[kg Sb_{eq}.]	
P_n	2.0E+02		2.7E+00		4.6E-03	
D_n	8.2E+00		2.6E-01		2.5E-06	
U_n	8.4E+01		1.9E-01		1.7E-05	
R_n	*LRS*	4.9E+00	*LRS*	2.7E-01	*LRS*	4.6E-04
	HRS	9.9E+00	*HRS*	5.4E-01	*HRS*	1.4E-03
Life cycle impacts for WM2						
	GWP		Terrestric ecotoxicity.		Abiotic Depletion Potential Elements	
	[kg $CO_{2\ eq}$.]		[kg DCB_{eq}.]		[kg Sb_{eq}.]	
P_n	3.1E+02		5.6E+00		1.3E-02	
D_n	1.2E+01		6.6E-01		2.9E-06	
U_n	8.4E+01		1.9E-01		1.7E-05	
R_n	*LRS*	7.7E+00	*LRS*	5.6E-01	*LRS*	1.3E-03
	HRS	1.5E+01	*HRS*	1.1E+00	*HRS*	4.0E-03

LRS - low repairing scenario
HRS - high repairing scenario

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[33] The "low repairing scenario" can be considered representative of a minor intervention for the prolongation of the useful life (corresponding, for example to the substitution of a low impact part, as the porthole). The "high repairing scenario" is instead representative of a major intervention of repairing (e.g. substitution of a main component as e.g. the motor or a Printed Circuit Board).

[34] For further details on symbols see Report n° 3 – Section 5.3.2. Life cycle impacts are those calculated in Report 2 – Section 6.4.2.1 and 6.5.2.1.

2.2.3 Analysis of the simplified Durability index "D'_n"

The following Figure 2 and Figure 3 illustrate the simplified index for the case-study WMs in the LRS scenario, while Figure 4 and Figure 5 refer to the HRS scenario. The Annex 1 illustrates all the numerical data in all the considered scenarios. From the analysis of the figures it can be observed that:

- The extension of the operating time for the WM case-study generally produces some environmental benefits.
- The lower is the energy consumption "δ" of the replacing product, the lower are the environmental benefits in all the scenarios. In some cases (e.g. Figure 2 for GWP) it is possible identify a threshold of the value "δ" below which there is not benefit anymore into extending the operating time. This threshold is function of the extension "X" of the operative life.
- Longer extension "X" of the operative life produces higher benefits.
- Benefits of WM2 are larger than those of WM1. This is related to the higher impacts for the production of the WM2 case-study.
- The parameter "R_n" concerning the life-cycle impacts for the additional refurbishment treatments is very relevant. Benefits of the LRS scenario (Figure 2 and Figure 3) are always higher than those of the HRS scenario (Figure 4 and Figure 5). In some case it could be that there is no benefit into prolonging the operating life. For example, in the HRS scenario for the WM2 (Figure 5), there are benefits for the ADP el. impact only extending the operative life more than 2 years.
- The benefits are larger for the ET and ADP el. Impacts. The figures of the "D'_n" index for these categories has a lower slopes, being these category not largely influenced by the use phase. On the other hand, the benefits for the GWP are instead lower, due to the high influence of the use phase on this impact category.

From the environmental assessment of the durability, it can be concluded that the extension of the operating time generally produces relevant environmental benefits (in a life-cycle perspective) for the WM's product group, even if it delays the replacement with a more energy efficient product. The benefits are, however, largely variable, mostly depending on the selected impact category and on the efficiency of the replacing product. Concerning the potential benefits, it is observed that

- The extension of the lifetime of the WM1 of 4 years (Figure 2) can reduce the life-cycle GWP of 3%, compared to the replacement of the old product with a new one 10% more efficient.
- The benefits for the GWP of the extension of the lifetime of the WM1 from 1 to 4 years are comparable to the replacement of the old product with a new one 20% more efficient
- The extension of the lifetime of the WM2 of 3 years (Figure 3) allows the saving of about 3% of the GWP impact category. The benefits of the same extension are furthermore comparable to the replacement of the old product with a new one 30% more energy efficient.
- The benefits are generally more relevant for the some impacts categories as ADP_{el} and ET. For example the extension of the lifetime of the WM2 of 4 years (Figure 3) can reduce the life-cycle ADP el. by about 25%, independently from the energy efficiency of the replacing product. However, in the case of large impacts for the repairing (scenario HRS -Figure 5) these benefits are 5% of the life-cycle ADP el.

Figure 2. Simplified Durability index for WM1 (LRS scenario)

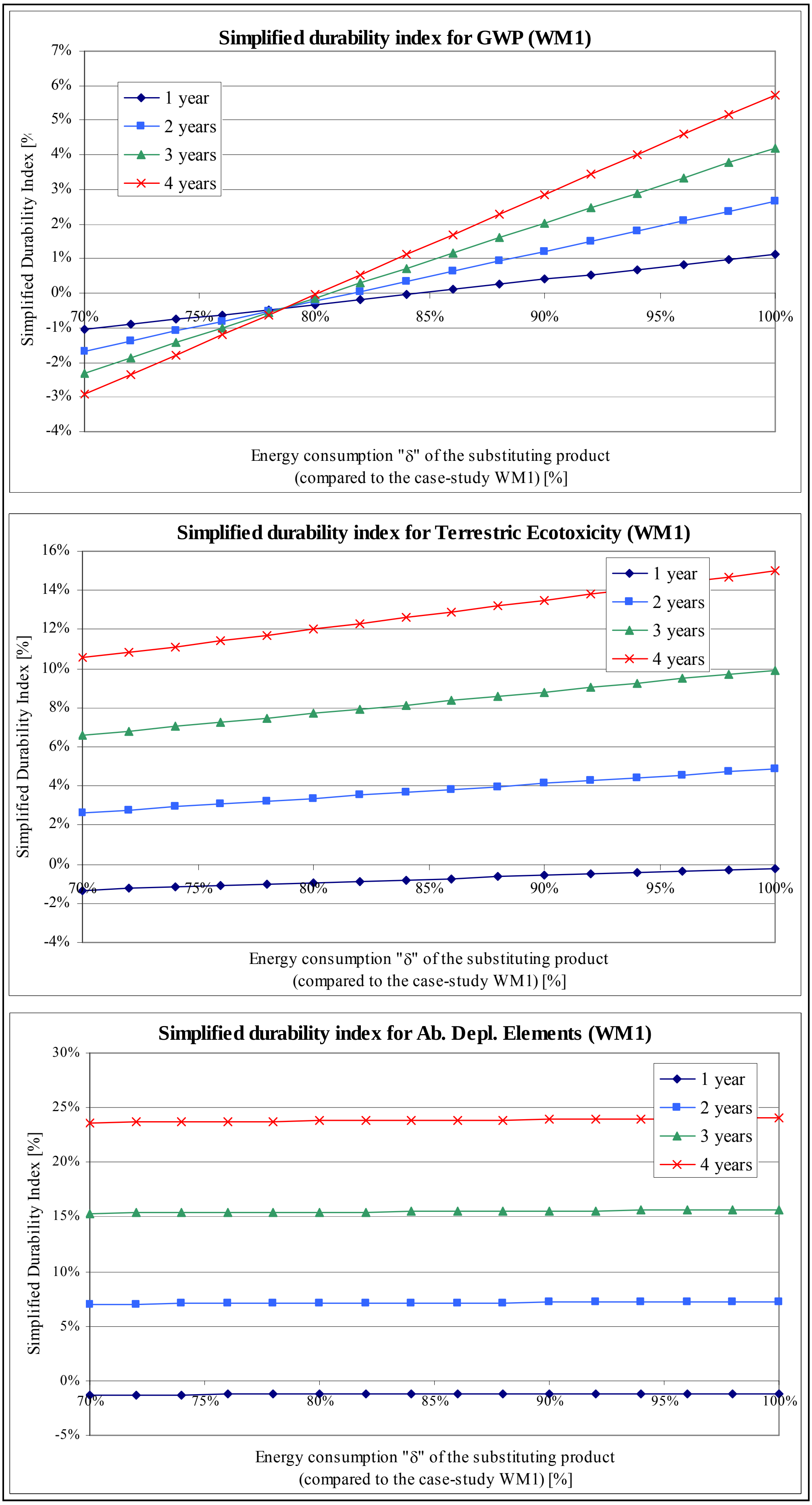


Figure 3. Simplified Durability index for WM2 (LRS scenario)

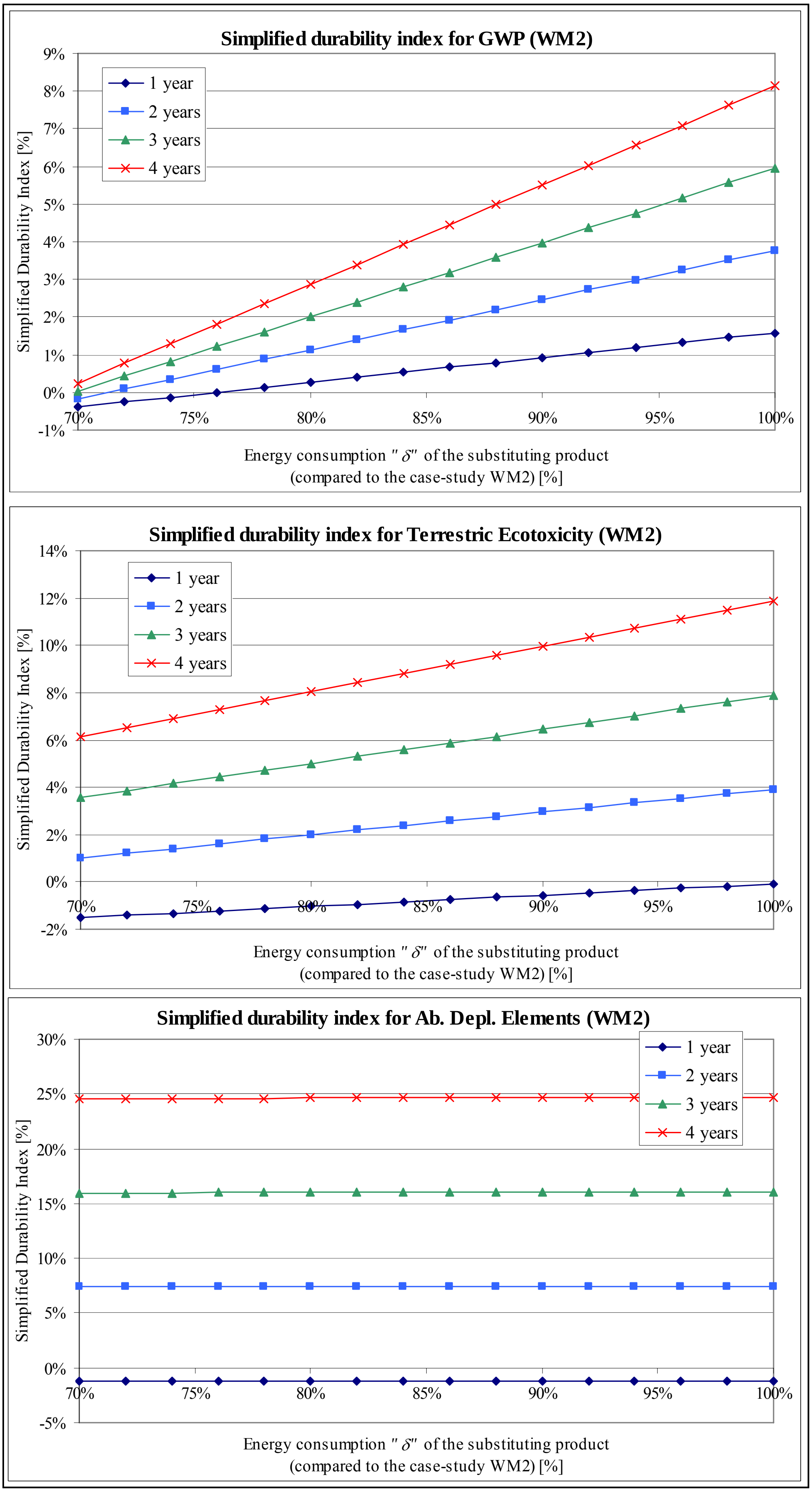


Figure 4. Simplified Durability index for WM1 (HRS scenario)

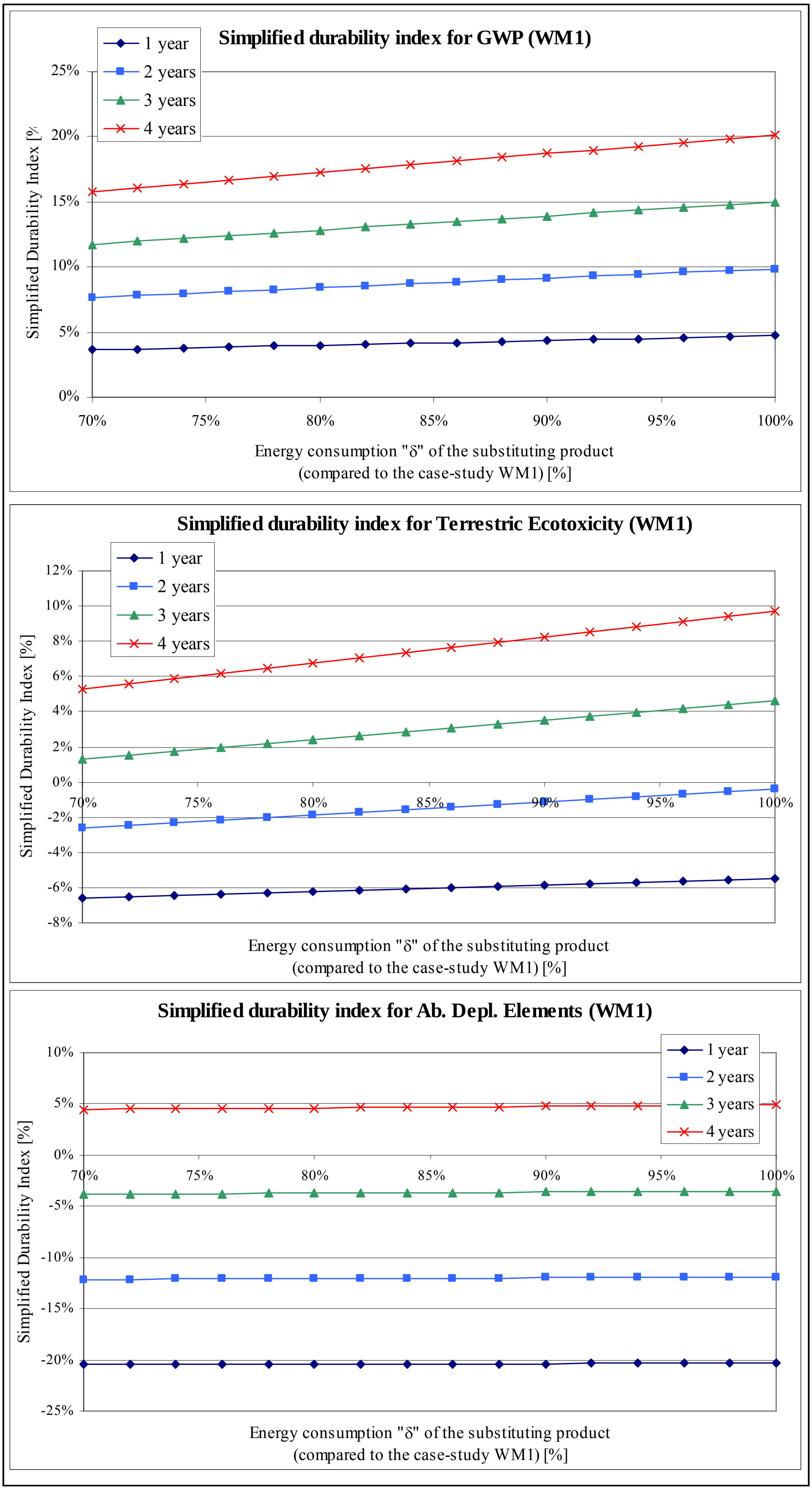
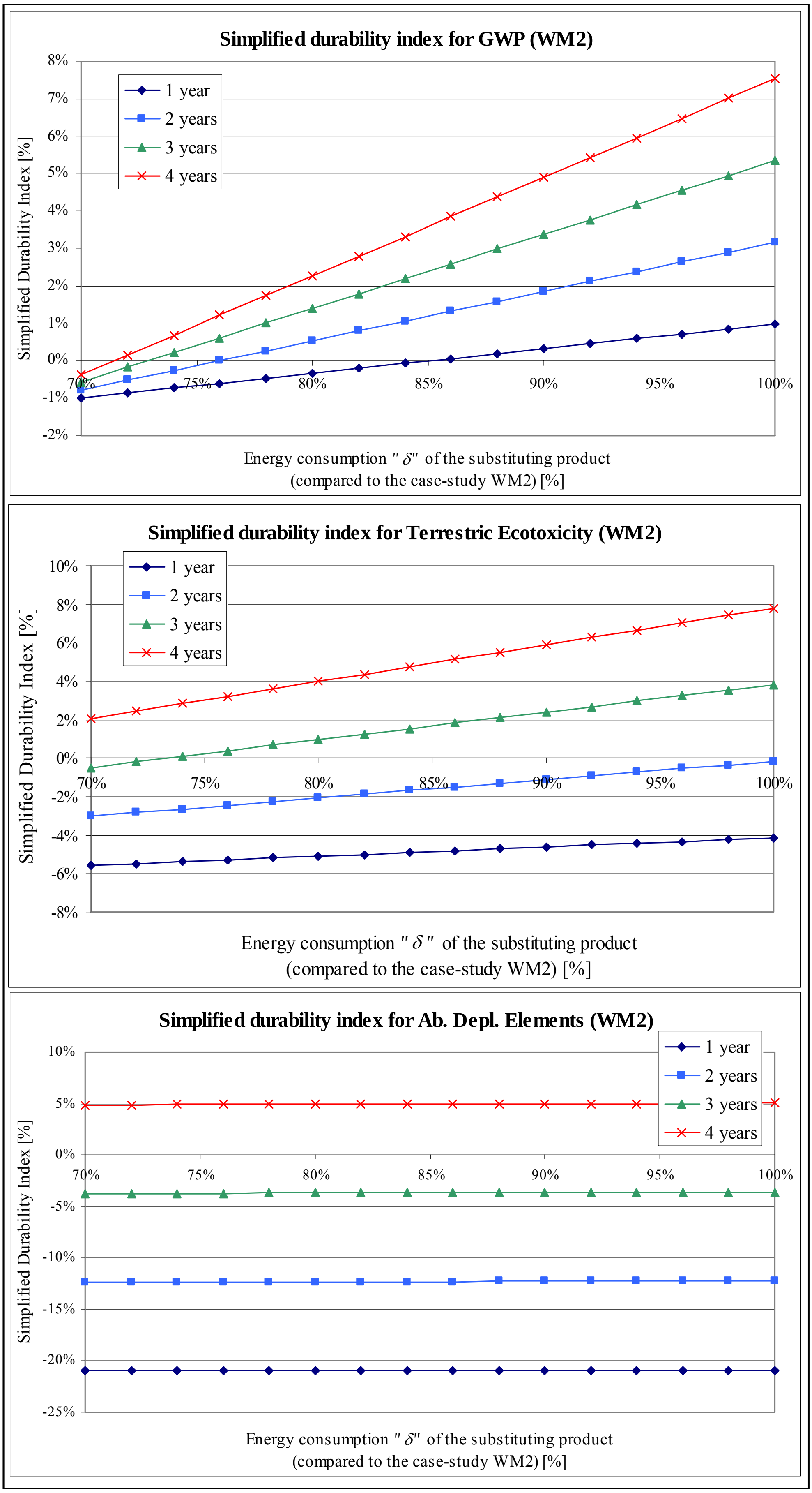


Figure 5. Simplified Durability index for WM2 (HRS scenario



2.3 Summary and conclusions on the case-study analysis

The application of the method for the environmental assessment of durability to two Washing Machine case-studies suggests that the extension of the operating time of the products generally produces some relevant environmental benefits (in a life-cycle perspective), even if it delays the replacement with a more energy efficient product.

The benefits are, however, largely variable, mostly depending on the selected impact category and on the efficiency of the replacing product. For example, some potentially relevant benefits are:

- The extension of the lifetime of the WM1 of 4 years can reduce the life-cycle GWP of 3%, in comparison to the replacement of the old product with a new one 10% more energy efficient.
- The benefits for the GWP of the extension of the lifetime of the WM1 from 1 to 4 years are comparable to the replacement of the old product with a new one 20% more energy efficient
- The extension of the lifetime of the WM2 of 3 years allows the saving of about 3% of the GWP impact category. The benefits of the same extension are furthermore comparable to the replacement of the old product with a new one 30% more energy efficient.

For comparative purposes it is useful to mention here that the latest Energy labelling Delegated Act setting EU energy labelling scheme for washing machine[35] set new energy labelling classes for washing machine that go beyond A, indeed setting A+, A++ and A+++. The difference between A and A+ in terms of energy efficiency improvements is around 10%. The different between A and A+++ is around 25% or more.

In general the benefits of WM2 are larger than those of WM1. This is related to the higher impacts for the production of the WM2 case-study.

It is highlighted that the analysis here performed was affected by some uncertainties mainly related to:

- assumptions about the case-studies composition
- assumptions about life-cycle impacts of the products, including assumption on the use phase
- uncertainties in the setting of some key parameters of the method: the impacts of repairing “Rn”, the extension of the operative life “X” and the energy consumption “δ” of a potential replacing product.

The analysis also showed that for values of “R_n” over some thresholds (variable depending on the considered impact category) there is no more environmental convenience into extending the length of product’s life.

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[35] See http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:314:0047:0063:EN:PDF

3. Extension of operating time of WMs and potential related benefits

3.1 Introduction

The previous Chapter 2 tested and illustrated the application to the WM product group of the developed method for the environmental assessment of durability. The present Chapter will illustrate some potential product's policy criteria that contribute to the extension of the operating time of WM.

Furthermore, the chapter assesses the potential environmental benefits for the WM product category related to the potential extension of the operating time.

3.2 Identification of potential key parts for the lifetime of WMs

The previous Chapter 2 demonstrated the key role of the length of WM's lifetime for the life-cycle impacts of the products. The present section will focus in the identification of 'hot spots' for lifetime (or durability) of the WMs: meaning here those key parts that are functionally critical for the product and that can influence the product's lifetime.

However, the developed method in Report 3 does not focus on the identification of such parts. This can be done on the basis of results of studies on the topic for the considered product group, including product's failure statistics and product's tests. Also communications from manufacturers, associations of reusing/recycling companies and consumers can be very relevant for this analysis.

For example, concerning the WM case-study, the literature review identified the following key parts for durability of WMs [WRAP, 2012b][36]:

- motor,
- pump,
- drum,
- control boards

According also to communication from an association of reuse and recycling companies, some common problems and failures that key parts of the WM can suffer are:

- Ball bearings get pressed into plastic outer casing of the washing machines, which wear out the bearing carrier/bearing seat and dramatically reduce product's lifespan. The replacement of the

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[36] Other function critical parts of WMs are [WRAP, 2012b]: on-off switches, internal filters, catches, seals, hoses, drive belt and shaft.

ball bearings generally also needs the replacement of also at least part of the casing. In many cases it is also necessary to substitute the complete casing including the drum.

- Problems with the rubber pump fittings/sealants/washers, which can degrade quickly or can easily become blocked.
- Electronic steering components linked to the timer can fail. These failures are difficult to be identified, especially due to the increased numbers of electrical components.
- The membrane of pressure switches (pressostat) can degrade overtime which leads the WM over time to take on more water than designed.
- Heaters can stop working prematurely, especially in regions with hard water (high lime content).

This list of key parts of WM is, however, still exemplary. The list should be refined according to an extended survey of products in the market and available statistics and tests.

Furthermore, according to the previous literature review, no standards have been indentified for the assessment of the durability and lifetime of washing machines or some of its key components.

3.3 Identification of potential product's criteria for the extension of operating time of WMs

The key role of reparability an improved maintenance has been recently underlined by the EC in a Commission's staff document "Exploiting the employment potential of green growth", highlighting the need of "moving away from a wasteful economy towards one based on durability and reparability of products is likely to create job opportunities throughout the product lifecycle in terms of, maintenance, repair, upgrade, and reuse" [EC, 2012].

The relevance of extending the product's lifetime has been also highlighted by the Ecodesign Directive [EU, 2009]. In fact, the Annex 1 of the Directive about the "Method for setting generic ecodesign requirements " lists some parameters that "must be used, as appropriate, and supplemented by others, where necessary, for evaluating the potential for improving the environmental aspects" of ErP. Among these parameters it is cited the *"(i) extension of lifetime as expressed through: minimum guaranteed lifetime, minimum time for availability of spare parts, modularity, upgradeability, reparability*" [EU, 2009].

The previous Chapter 2 demonstrated the potential environmental convenience into extending the operating time of WMs. As discussed in the literature review in Chapter 1, this extension could be achieved by means of some general strategies, including:

  - Identification of key components for durability.
  - Non-destructive disassemblability[37] of key components and their reparability and/or possibility of substitution[38].

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[37] Non-destructive disassembly implies the ability to disassembly the component without damaging it and the other product's parts. This condition is more restrictive than the simple "disassemblability" (as discussed, for example in Report 2 – Section 3.2.2.2 and Report 3- Section 1.2.2.), which do not imply the conservation of the integrity of the components and connecting parts.

  - Availability of spare parts.
  - Extended warranties.
  - Provision of information.

The present section focuses on the translation of such strategies into some potential product's policy criteria for the improvement of the durability of WMs. A criterion can be, for example, the following.

Potential product's policy criteria: Design for Durability of the WM

The manufacturer should design functional key components of the WM (including motor, pump, drum and printed circuit boards)[39] in a way that:

- These parts can be disassembled[40] in "X"[41][42] minutes for repairing or for replacement
- Spare parts of the key component are available for purchasing[43, 44]
- Detailed information on the disassembly and repair of key components are provided.

Verification:

Manufacturer shall provide technical information for the disassembly of key parts (in the product's or service manuals and company's websites) and provide (to the market surveillance authority on request) a declaration to this effect, together with appropriate supporting technical documentation, including:

- disassembly report, tests[45] and7or videos proving that key components can be disassembled without damaging them nor other parts of the WM;
- proofs[46] that spare parts of key components are available
- information on the disassembly and repair of key components available in the product manuals and manufacturer's website

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[38]

[39] This list is only exemplary. Other key parts can be included, on the basis of a more comprehensive analysis of the product group, and involving associations of reuse/recycling companies, manufacturers and association of consumers.

[40] This criterion refers to non-destructive disassembly meaning: the part should be suitable for disassembly without damaging the part itself and other parts of the product.

[41] The threshold times for non-destructive disassembly should be set based on a more complete the analysis of products (similarly to other criteria for disassemblability already discussed in Report n° 2- Sections 6.6 and 7.6).

[42] On criteria to improve the accessibility and disassemblability of key parts, WRAP noticed that "as a minimum providing simple and easy to access panels to key components, minimising screw numbers, e.g. through use of lugs and slots, using standard screw heads (no more than three head sizes) using easily removable electrical connectors (clip or screw) rather than soldered or crimped joints where access is required. Self-tapping screws, irreversible snap-fits or adhesives should be avoided where access is required. Fixing points for main access screws should be minimal and allow numerous access cycles (e.g. by brass threaded mounts). Tamper-proofing (such as plastic covers or labels) should only be used to ensure authorised repair under warranty and should not inhibit other repairs outside of warranty" [WRAP, 2012b].

[43] In some cases it could be relevant to focus on the time-frame during which these spare parts are available. On this topic WRAP observed that "The UK Sale of Goods Act (SOGA) offers protection against faulty goods when the manufacturer's guarantee has expired and states that goods must last a "reasonable time" which can be claimed anything up to six years from the date of purchase. 12 years availability of spares is specified under the EU Eco-label for washing machines. 10 years is considered reasonable to reflect the typical lifetime of most washing machines".

[44] Some authors also pointed out the need of criteria for cost-efficient repairing. On this topic WRAP observed that "to facilitate cost-effective repair, replacing the drum assembly parts or motor should be no more than 40% of the cost of an equivalent new machine, and other spare parts no more than 25% of the cost of the new machine" [WRAP, 2012b].

[45] The disassembly tests should be based on a standardizes procedure, analogous to the procedure recommended for the disassemblability of key parts for recycling (See Report n° 2- Annex 5).

[46] These proofs could include, for example, the list of spare parts available for purchasing and provided in the product's manuals and/or manufacturer's website.

Alternatively other potential product's policy criteria could be based on extended warranties on the WM or its key parts, as following.

Potential product's policy criteria: Extended warranty of key parts of the WM

Functional key parts of the WM (including motor, pump, drum and printed circuit boards)[47] should have a minimum warranty time (compared to the basic product's warranty[48]) of "X"[49] years.

Verification:

Commitment of the manufacturers for the replacement/repairing of the key components free of charge for the consumers (including costs for labour).

However, the set of this potential criterion still requires additional research concerning the relationship between extended warranties and the extended lifetime. This would also include the investigation of extended warranties of the product as whole.

It is furthermore highlighted that the literature review in Chapter 2 did not identify available standards on durability of WMs (or some of their components). However, other potential product's policy criteria for WMs could be set based on specific standards for durability, when available, potentially structured as following.

Potential product's policy criteria: Durability of key parts of the WM

Functional key parts of the WM should have a minimum lifetime of "X" years, measured according to standardized methodology (if available).

Verification:

Lifetime of the key parts should be measured according to the standardized methodology (if available).

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[47] This list is only exemplary. Other key parts can be included, on the basis of a more comprehensive analysis of the product group, and involving associations of reuse/recycling companies, manufacturers and association of consumers.

[48] European product's warranty as regulated by the Directive 1999/44/EC [EU, 1999].

[49] The time frame of the extended warranty should be set according to an extended analysis of products in the market.

3.4 Calculation of potential environmental benefits related to the extension of operating time of WMs

3.4.1 Assessment of potential environmental benefits for the two case-study products

The previous section illustrates some potential product's policy criteria contributing to the extension of the operating time of WM and, in particular, the improvement of the disassemblability/reparability of key parts.

However, it is not possible to directly establish what lifetime extension could be achieved trough their enforcement. This would require a survey about average product's failures and the effects of possible repairing. This survey is out of the scope of this analysis.

In order to estimate the potential environmental benefits related to the extension of the operating time of WMs, a possible scenario is here assumed and estimated.

According to the research by [Rüdenauer et Gensch, 2005b] concerning the assessment of the optimal life span of WM, average lifetime of WM can range from 10 to 15 years. The analysis of the previous Chapter 2 assumed 11.4 for the average life of WM. Therefore, it is assumed that it is possible to achieve up to an extension of 4 years of the operating time of WM.

These figures are also confirmed by other studies on the environmental assessment of replacing, repairing or refurbishing WMs (see e.g. [WRAP, 2010]) that assumed a lifetime extension from 3 to 9 years.

Furthermore it is estimated that the extension of the operative life would be more relevant for WM belonging to the medium/high price segment (as the considered WM2) more than for those belonging to the low price segment (e.g. WM1).

Fort the current analysis, it is therefore assumed that:

- The useful life of WM1 will be extended by 2 years (17% of the product's lifetime). Impacts for the additional treatments for durability "*Rn*" are in line with the previously introduced low repairing scenario (LRS) scenario (Section 2.2.2)[50];
- The useful life of WM2 will be extended by 4 years (35% of the product's lifetime). Impacts for the additional treatments for durability "*Rn*" are in line with the previously introduced high repairing scenario (HRS) scenario (Section 2.2.2)[51];
- The extended operative time of the WM1 typology allows to delay the purchasing of a WM with 10% less energy consumption during the use phase;

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[50] "Rn" is 2.5% (for the impact categories: Climate change, Abiotic Depletions– fossils, Ozone Depletion, Acidification, Photochemical oxidants, Respiratory effects, Eutrophication marine and Eutrophication freshwater) and 10% (for all the other impact categories) of the impacts for the production.

[51] "Rn" is 5% (for the impact categories: Climate change, Abiotic Depletions– fossils, Ozone Depletion, Acidification, Photochemical oxidants, Respiratory effects, Eutrophication marine and Eutrophication freshwater), 20% (for the impact categories: Human toxicity, Aquatic ecotoxicity and Terrestric exotoxicity) and 30% (for the impact category Abiotic Depletions– elements) of the impacts for the production.

- The extended operative time of the WM2 typology allows to delay the purchasing of a WM with 20% less energy consumption during the use phase.

All the other assumptions concerning the life cycle impacts of the WMs are analogous to those in Report n°2 - Sections 6.4, 6.5 and 6.6. Results of the analysis are illustrated in Table 6 and Table 7. It is observed that the extension of the operative life of both WMs produces environmental benefits for all the impact categories except the Ozone Depletion. This last is, in fact, dominated by the use phase with a low relevance of the production phase and therefore influenced negatively by the life extension.

Table 6 Environmental consequences (per unit of product) related to the extension (2 years) of operative life of WM1

WM1 - extended operating time (2 years) - LRS scenario											
Climate change	Acidification	Photochemical oxidant	Ozone depletion	Respiratory effects	Eutrophication freshwater	Eutrophication marine	Human toxicity	Acquatic Ecotoxicity	Terrestric ecotoxicity	Abiotic Depl. - element	Abiotic Depl.- fossil
GWP	AP	POFP	ODP	PMFP	FEP	MEP	HTP	FAETP	TETP	ADP elements	ADP fossil
kg CO2-eq.	kg SO2-eq.	kg NMVOC-eq	kg CFC11-eq.	kg PM10-eq	kg P-eq	kg N-eq	kg 1,4-DCB	kg DCB-eq.	kg DCB-eq.	kg Sb-eq.	MJ
1.4E+01	9.5E-02	4.3E-02	-1.6E-06	3.1E-02	1.0E-02	1.3E-02	3.4E+01	3.5E-01	2.8E-01	3.5E-04	1.4E+02

Table 7 Environmental consequences (per unit of product) related to the extension (4 years) of operative life of WM2

WM2 - extended operating time (4 years) - HRS scenario											
Climate change	Acidification	Photochemical oxidant	Ozone depletion	Respiratory effects	Eutrophication freshwater	Eutrophication marine	Human toxicity	Acquatic Ecotoxicity	Terrestric ecotoxicity	Abiotic Depl. - element	Abiotic Depl.- fossil
GWP	AP	POFP	ODP	PMFP	FEP	MEP	HTP	FAETP	TETP	ADP elements	ADP fossil
kg CO2-eq.	kg SO2-eq.	kg NMVOC-eq	kg CFC11-eq.	kg PM10-eq	kg P-eq	kg N-eq	kg 1,4-DCB	kg DCB-eq.	kg DCB-eq.	kg Sb-eq.	MJ
2.9E+01	3.0E-01	1.1E-01	-8.3E-06	1.2E-01	3.3E-02	2.7E-02	8.5E+01	1.3E+00	9.3E-01	6.7E-04	1.4E+02

3.4.2 Assessment of the potential benefits at the WM product group level

In this section, the benefits per single devices are multiplied by the total number of WMs currently produced and that will be wasted at their EoL. It is estimated that in 2012, about 20.7 millions/year of WMs have been sold. It is assumed that 60% of WMs sold belong to the medium-low price typology (WM1) and 40% to the medium-high price typology (WM2)[52].

The estimated yearly benefits are illustrated in Table 8. Benefits have been normalized according to the overall impacts of the product group (WM) and of EU27[53].

The benefits have been also compared to the estimated benefits that derive from the ecodesign implementing measures for the "Washing Machine" product group already adopted by the EU [EC 2010]. According to these estimations, the implementing measures will grant the yearly saving of 1.5 TWh (end-use electricity in 2020)[54]. Life cycle benefits related to this amount of saving have been

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[52] For further details on the WM product group, see Report n° 2 – Section 6.6.

[53] Normalization is here referred to the overall environmental impacts of the EU-27 for all the economic sectors. Normalization factor those Report n° 2 – section 1.3.4.

[54] European Commission. DG Enterprise and Industry website (http://ec.europa.eu/enterprise/policies/sustainable-business/ecodesign/product-groups/index_en.htm; access September 2012)

calculated according to average life-cycle inventory of average 1 kWh of electricity in the EU27 [ELCD, 2010].

Considering normalized values to the product group, it is observed that benefits range of extending durability of WM by 4 years varies from the saving of 0.6% (for the acidification potential), to 1.7% for GWP, to 2.5% for Abiotic Depletion Potential (elements), to more than 3% (for the Human toxicity potential).

Only for the ozone depletion impact category the extension of the operating time would cause negative impacts that, however, are negligible at the EU-27 level.

Table 8 Yearly benefits for the WM product group (absolute and normalized) related to the extension of the operating time

	Climate change	Acidification	Photochemical oxidant	Ozone depletion	Respiratory effects	Eutrophication freshwater	Eutrophication marine	Human toxicity	Acquatic Ecotoxicity	Terrestric ecotoxicity	Abiotic Depl. - element	Abiotic Depl.- fossil
	GWP	AP	POFP	ODP	PMFP	FEP	MEP	HTP	FAETP	TETP	ADP elem.	ADP fossil
	kg CO2-eq.	kg SO2-eq.	kg NMVOC-eq	kg CFC11-eq.	kg PM10-eq	kg P-eq	kg N-eq	kg 1,4-DCB	kg DCB-eq.	kg DCB-eq.	kg Sb-eq.	MJ
Overall benefit	4.2E+08	1.2E+06	5.3E+05	-2.0E+01	3.9E+05	1.3E+05	1.6E+05	4.2E+08	4.4E+06	3.5E+06	4.3E+03	1.7E+09
Normalized benefits (WM product group)	1.7%	0.6%	0.9%	-0.4%	0.9%	1.6%	0.9%	3.2%	2.2%	2.6%	2.5%	0.7%
Normalized benefits (Ecodesign implementing measures for WM)	47.2%	17.3%	26.2%	-9.5%	26.5%	57.5%	25.4%	549.6%	176.5%	294.6%	7188.9%	19.2%
Normalized benefits (EU27)	0.01%	0.004%	0.002%	0%	0.005%	0.04%	0.003%	1.25%	0.001%	0.01%	0.01%	0.01%

In addition, it is observed that the potential benefits related to lifetime extension of WM amount to about 19% of the global energy saving (ADP fossil) and 47% of GWP of the benefits estimated to be achieved by the current Ecodesign implementing measures for WM. For other impacts categories (as ecotoxicity and ADP elements) the benefits of the lifetime extension are much higher than those of the current Ecodesign implementing measures (due to the low incidence of the use phase for these impact categories).

Therefore, based on the assumptions stated and the analysis carried out in this report, it is possible to summarise that the extension of durability of WM could addition benefits on GWP (additional to the existing Ecodesign measures on WM) as well as significant additional benefits on other environmental impacts from WM such as Abiotic Depletion Potential-elements, Human toxicity potential and acidification potential.

It has been also estimated the masses of materials potentially saved thanks to the extension of the operating times of WMs. This can be calculated, based on the number of devices used for a certain time-frame, in the base-case scenario and the extended lifetime scenario:

Formula 1

$$n_{base-case} = \left(\frac{X}{lifetine_{base-case}} \right)$$

Formula 2

$$n_{extended} = \left(\frac{X}{lifetime_{extended}} \right)$$

Where:

- $n_{base-case}$ = number of products, in the base-case scenario, used for the time-frame of X years [dimensionless];
- $n_{extended}$ = number of products, in the extended lifetime scenario, used in the time-frame of X years [dimensionless];

- X = time-frame for the analysis [year];
- $\text{Lifetime}_{\text{base-case}}$ = lifetime of the product in the base-case scenario [year];
- $\text{Lifetime}_{\text{extended}}$ = extended lifetime of the product in the new scenario [year].

The number of saved products for the considered timeframe, thanks to the extended lifetime, will be:

$$Saved\ \ products = \left(\frac{X}{lifetine_{base-case}} - \frac{X}{lifetime_{extended}} \right)$$

Formula 3

The number of saved products (per year) in the considered timeframe, thanks to the extended lifetime, will be:

$$Saved\ \ products\ (per\ year) = \frac{Saved\ \ products}{X} = \left(\frac{1}{lifetine_{base-case}} - \frac{1}{lifetime_{extended}} \right)$$

Formula 4

It is important to highlight that this number is independent from the considered time-frame “X”.

In particular, for the present analysis, it is assumed that the operating time of 11.4 years of WM1 and WM2 will be extended to 13.4 and 15.4 years respectively. The number of yearly ‘saved’ products[55] is illustrated in Table 9, while the yearly saved masses of some materials is illustrated in Table 10.

Table 9 Number of saved products (WM1 and WM2) for the assumed extensions of lifetime

	Base-case scenario	Extended lifetime scenario
lifetime WM1 [years]	11.4	13.4
lifetime WM2 [years]	11.4	15.4
	Number of saved products per year [dimensionless]	
number of saved WM1	0.013	
number of saved WM2	0.023	

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[55] The number of saved products per year represents the number of WMs that are avoided, thanks to the prolonged lifetime of devices, in order to deliver the same function (washing cycles) for the considered reference time-span of the analysis.

Table 10 Estimated amount (absolute and normalized values) of masses of materials potentially saved annually by extending products' lifetimes

Materials	A. Yearly saved masses [10^3 kg/year]	B. Mass yearly used in EU27 [10^3 kg / year]	Ratio (A/B) [%]
Acrylonitrile butadiene styrene (ABS)	426	752,039	0.06%
Aluminium	1,058	5,020,336	0.02%
Copper	472	3,525,913	0.01%
Gold	0.04	130	0.03%
Palladium/platinum	0.01	720	0.002%
Polymethylmethacrylat (PMMA)	35	180,002	0.02%
Polypropylene (PP)	1,914	8,727,089	0.02%
Polystyrene (PS)	36	1,851,821	0.002%
Silver	0.1	12,050	0.001%
Steel and cast iron	18,058	79,926,821	0.02%

It is estimated that the yearly amount of saved masses thanks to the extended lifetime of WMs is ranging from 0.01% to 0.06% for several materials.

3.5 Summary and conclusions

Identified products "hot spots"

This analysis concerned the identification of product's hot spots, meaning those key components/parts that are functionally critical for the durability of the products. Identification of hot spots should be based on studies and surveys of the considered product, including e.g. failure tests and statistics.

The current analysis was based on a literature review and on some communications from a stakeholder[56]. It results that some "hot spot" of WMs are: motor, pump, drum and control boards. Other potentially relevant hot spots include, among the others: Ball bearings, rubber pump fittings/sealants/washers, Electronic steering components, membrane of pressure switches, heaters, etc.

It is relevant to highlights that some of these hot spots for durability (as motor and control boards) are also the product's components responsible of the highest life cycle impacts of the WM[57] (as identified in Report n°2 – Chapter 6).

Potential product's policy criteria

Potential product's policy criteria for the extension of the product's lifetime should focus on:

- Non-destructive disassemblability of key functional components (hot spots) and their reparability and/or possibility of substitution.
- Suitability of the product for repairing (including availability of spare parts) and/or availability of additional warranties of the product (or for some of its hot spots)

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[56] Association of reuse/recycling companies

[57] For further detail, see Report n°2 – sections 6.4 and 6.5.

Based on these strategies two exemplary product's criteria for the extension of the lifetime of WMs have been illustrated. In order to effectively enforce and verify these criteria some additional work and specifications are needed, especially concerning, e.g., the standardized procedure for the disassemblability of the key parts, the thresholds of the disassembly time and the information for the consumers.

For the future, if methodologies are developed to measure the durability of such key components, then potential product policy criteria could include specific durability requirements for such key components.

Some of the requirements summarised here can be more suitable for only some of the existing EU product policies (e.g. more suitable for voluntary policies vs. mandatory policies).

Assessment of potential benefits related to the extension of the operating time

Although the present research did no focus on how the enforcement of the proposed criteria would influence the lifetime extension, a potential scenario for the WM product group has been assessed. The analysis concluded that:

- Considering normalized values to the product group, it is observed that benefits varies from the saving of 0.6% (for the acidification potential), to 1.7% for GWP, to 2.5% for Abiotic Depletion Potential (elements), to more than 3% (for the Human toxicity potential).
- The potential benefits related to lifetime extension of WM amount to about 19% of the global energy saving (ADP fossil) and 47% of GWP of the benefits achieved current Ecodesign implementing measures for WM. For other impacts categories (as ecotoxicity and ADP elements) the benefits of the lifetime extension are much higher than those of the current Ecodesign implementing measures (due to the low incidence of the use phase for these impact categories).
- Considering normalized values to the EU27 impacts, the highest benefit is related to the Human toxicity impact (about 1.2%). Benefits from 0.01% to 0.04% are observed for GWP, Abiotic Depletion Potential (fossils and elements), terrestric ecotoxicity and freshwater Eutrophication.
- Only for the ozone depletion impact category the criteria on durability would cause negative impacts. Ozone depletion is, in fact, dominated by the use phase with a low relevance of the production phase and therefore influenced negatively by the life extension. However, the negative impacts of durability criteria on this impact category are, however, negligible at the EU-27 level.

Therefore, based on the assumptions stated and the analysis carried out in this report, it is possible to summarise that the extension of durability of WM could addition benefits on GWP (additional to the existing Ecodesign measures on WM) as well as significant additional benefits on other environmental impacts from WM such as Abiotic Depletion Potential, Human toxicity potential and acidification potential.

Conclusions

The present reports defined a method[58] for the environmental assessment of the durability of energy related products (ERP). The aims of the method are: 1) to estimate the life cycle environmental benefits of extending the operating life of the considered product by a given additional *time-frame*; 2) to assess the relevance of such environmental benefits (if any) compared to the product's *life cycle impacts*[59]. The developed method is based on the comparison, in a life-cycle perspective, of different scenarios concerning the lengths of the useful life of the product and its potential substitution with better performing alternative products[60].

The method has been developed on the basis of an analysis of the scientific literature focused on scientific publications and product standards. A set of different indices has been derived, including some simplifications to handle some potential difficulties that could arise due to data availability.

The simplified durability index has also been tested on two Washing Machine (WM) case-studies. The case-studies demonstrated that the extension of the operating time generally produces environmental benefits. The benefits are, however, largely variable, mostly depending on the selected impact category and on the efficiency of the replacing product.

For example, some potential benefits are:

- The extension of the lifetime of the WM1 by 4 years can reduce the life-cycle GWP by 3%, in comparison to the replacement of the old product with a new one 10% more energy efficient.
- The benefits to the GWP for the extension of the lifetime of the WM1 from 1 to 4 years are comparable to the replacement of the old product with a new one 20% more energy efficient.
- The extension of the lifetime of the WM2 by 3 years allows the GWP impact category to be reduced by about 3%. The benefits of the same extension are furthermore comparable to the replacement of the old product with a new one 30% more energy efficient.
- The extension of the lifetime of the WM2 by 3 years reduces the life-cycle ADP Elements indicator by about 15%, independently of the energy efficiency of the replacing product.

The parameter "R_n" concerning the life-cycle impacts for additional repairing is also very relevant. As it is difficult to estimate the impacts of replacing spare parts, two scenarios have been analyzed (low impact repairing scenario and high impact repairing scenario). The analysis showed that for values of "R_n" over certain thresholds (variable for each impact category) there is no more environmental convenience in extending the length of product's life.

In order to extend the product's lifetime some potential product policy criteria could be based on:

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[58] The method has been presented in Report n° 3 – Chapter 5.

[59] For example, it is possible to set a "threshold of relevance (Y) [%]" over which the extension of the operating time is relevant. For further details, see Report n° 3 – Section 5.3.1.

[60] The method did not consider how consumer behavior could influence the product's durability.

- Non-destructive disassemblability of key functional components (hot spots) and their reparability and/or possibility of substitution.
- Adoption of product specific standardised procedures for the measurement of durability (when available).
- Availability of additional warranties for the products (or some of their hot spots).
- Provision of information for the users

It is observed that the analysis performed here was affected by some uncertainties mainly related to:

- assumptions about the case-studies composition (based on the analysis in Report n°2)
- assumptions about life-cycle impacts of the products, including assumptions on the use phase (based on the analysis in Report n°2)
- uncertainties in the setting of some key parameters of the method: the impacts of repairing "Rn", the extension of the operative life "X" and the energy consumption "δ" of a potential replacing product.

The environmental assessment of the durability of WM has been performed by the simplified index for durability (see Report 3 – Section 5.3.2). Although simplified, this method is scientifically robust for the scope of the assessment, as also proved by similar applications in the scientific literature. However, in order to face potential uncertainties previously underlined we performed the analysis of different scenarios based on sufficiently large variations of key parameters. However it is highlighted that the general method for the environmental assessment of durability can be applied when additional data about the case-study are available (through e.g. estimations and/or extrapolations).

Subsequently, some product policy criteria for the extension of the lifetime of the WMs have been illustrated. Although the present research did not focus on how the enforcement of the proposed criteria would influence lifetime extension, a potential scenario for the WM product group has been assessed. In particular, the following environmental benefits have been estimated:

- Considering normalized values to the product group, it is observed that benefits vary from savings of 0.6% (for the acidification potential), to 1.7% for GWP, to 2.5% for Abiotic Depletion Potential (elements), to more than 3% (for the Human toxicity potential).
- The potential benefits related to lifetime extension of WM amount to about 19% of the global energy saving (ADP fossil) and 47% of GWP of the benefits achieved with the current Ecodesign implementing measures for WM. For other impacts categories (such as ecotoxicity and ADP elements) the benefits of the lifetime extension are much higher than those of the current Ecodesign implementing measures (due to the low incidence of the use phase for these impact categories).
- Considering normalized values to the EU27 impacts, the highest benefit is related to the savings of the Human toxicity impact (about 1.2%). Savings from 0.01% to 0.04% at EU level are observed for GWP, Abiotic Depletion Potential (fossils and elements), terrestrialecotoxicity and freshwater Eutrophication.

- Only for the ozone depletion impact category, would the criteria on durability cause negative impacts. Ozone depletion is, in fact, dominated by the use phase with a low relevance of the production phase and therefore influenced negatively by life extension. However, the negative impacts of durability criteria on this impact category are negligible at the EU-27 level.

Therefore, based on the assumptions stated and the analysis carried out in this report, it is possible to summarise that the extension of durability of WM could addition benefits on GWP (additional to the existing Ecodesign measures on WM) as well as significant additional benefits on other environmental impacts from WM such as Abiotic Depletion Potential, Human toxicity potential and acidification potential.

References

[Brouillat, 2009] E. Brouillat. “An evolutionary model of recycling and product lifetime extension”. Technological Forecasting & Social Change 76 (2009) 471–486.

[Brook Lyndhurst, 2011] Brook Lyndhurst Ltd. Public understanding of product lifetimes and durability. (1). Final Report to the Department for Environment Food and Rural Affairs. July 2011 (http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=17254 Access August 2012).

[CIE 097, 2005] CIE 097. Maintenance of indoor electric lighting systems Edition: 2nd. Commission Internationale de L'Eclairage. 2005.

[Cooper, 2004] Cooper, T.). Inadequate Life? Evidence of Consumer Attitudes to Product Obsolescence. Journal of Consumer Policy, Vol. 10, 2004. pp. 421 - 449

[Dewulf et Duflou, 2004] W. Dewulf, J. R. Duflou. “The environmentally optimised lifetime: a crucial concept in life cycle engineering”. Proceedings of the Global Conference on Sustainable Product Development and Life Cycle Engineering pages: 59-62. 2004.

[Downes et al., 2011] J. Downes, B. Thomas, C. Dunkerley, H Walker. Longer Product Lifetimes. Prepared by the “Environmental Resources Management”. – Department for Environment, Food, Rural Affairs (DEFRA). February 2011. (http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=17047 Access August 2012)

[EC, 2004] European Commission. “Durability and the construction products directive - Guidance Paper F - (concerning the Construction Products Directive - 89/106/EEC)”. Enterprise and Industry Directorate-General. December 2004.

[EC, 2009] Commission Regulation (EC) No 244/2009 of 18 March 2009 implementing Directive 2005/32/EC of the European Parliament and of the Council with regard to ecodesign requirements for non-directional household lamps.

[EC, 2009b] Commission Regulation (EC) No 245/2009 of 18 March 2009 implementing Directive 2005/32/EC of the European Parliament and of the Council with regard to ecodesign requirements for fluorescent lamps without integrated ballast, for high intensity discharge lamps, and for ballasts and luminaires able to operate such lamps, and repealing Directive 2000/55/EC of the European Parliament and of the Council.

[EC 2010] European Commission. Commission Regulation (EU) No 1015/2010 of 10 November 2010 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for household washing machines

[EC, 2012] European Commission. Commission Staff Working Document. Exploiting the employment potential of green growth. Strasbourg, 18.4.2012 –SWD (2012) 92 final. (http://ec.europa.eu/social/BlobServlet?docId=7621&langId=en).

[ELCD, 2010] European Commission – Joint Research Centre, European Reference Life Cycle Database (ELCD) core database (Version II), http://lca.jrc.ec.europa.eu/lcainfohub/index.vm (access on May 2012).

[EU, 1999] Directive 1999/44/EC of the European Parliament and of the Council of 25 May 1999 on certain aspects of the sale of consumer goods and associated guarantees.

[EU, 2009] Directive 2009/125/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for the setting of Ecodesign requirements for energy-related products (recast).

[Foster, 2001] T. Foster. Managing Quality an Integrative Approach. Upper Saddle River, New Jersey: Prentice Hall, 2001. Page 6.

[Hauschild et al., 2004] M.Z. Hauschild, J. Jeswie, L. Altingl. “Design for Environment - Do We Get the Focus Right?” CIRP Annals - Manufacturing Technology. Volume 53, issue 1, 2004, Pages 1-4

[Horie, 2004] Y. A. Horie. “Life Cycle Optimization of Household Refrigerator-Freezer Replacement”. Center for Sustainable Systems, Report No. CSS04-13, University of Michigan, Ann Arbor, Michigan, August 14, 2004.

[ISO 12543-4, 1998] ISO 12543-4. Glass in building -- Laminated glass and laminated safety glass -- Part 4: Test methods for durability. International Organisation for Standardisation. 1998.

[ISO/TR 14062, 2002] ISO Technical Report 14062. Environmental management — Integrating environmental aspects into product design and development. Organisation for Standardisation. First edition 2002-11-01

[ISO 14001, 2004] ISO 14001. Environmental management systems — Requirements with guidance for use. Organisation for Standardisation. Second edition 2004-11-15.

[ISO 7170, 2005] ISO 7170. Furniture -- Storage units -- Determination of strength and durability. International Organisation for Standardisation. 2005.

[ISO 14040, 2006] ISO 14040. Environmental management — Life cycle assessment — Principles and framework. Organisation for Standardisation. Second edition. 2006-07-01.

[ISO 21016, 2007] ISO 21016. Office furniture -- Tables and desks -- Test methods for the determination of stability, strength and durability. International Organisation for Standardisation. 2007.

[ISO 13823, 2008] ISO 13823. General principles on the design of structures for durability. International Organisation for Standardisation. 2008.

[ISO 15928-3, 2009] ISO 15928-3. Houses -- Description of performance -- Part 3: Structural durability. International Organisation for Standardisation. 2009.

[ISO/TR 14049, 2012] ISO Technical Report 14049. Environmental management - Life cycle assessment - Illustrative examples on how to apply IS0 14044 to goal and scope definition and inventory analysis. Organisation for Standardisation. Second edition. 2012-06-0 1

[Kagawa et al., 2006] S. Kagawa, T. Tasaki, Y. Moriguchi. "The environmental and economic consequences of product lifetime extension: Empirical analysis for automobile use". Ecological Economics 58 (2006) 108– 118

[Kostecki, 1998] M. Kostecki (Editor), "The Durable Use Of Consumer Products: New Options For Business And Consumption". Publisher: Kluwer Academic Publishers (Jun 1998).

[Monteiro de Barros et Dewberry, 2006] M. Monteiro de Barros, E. Dewberry. "Design for Durability". Seminar 11th of April, 2006. Design Council London, WC2E 7DL.

[Lindahl et al., 2006] M. Lindahl, E Sundin, J. Östlin. "Environmental Issues within the Remanufacturing Industry". Proceeding of the 13th CIRP International conference on Life Cycle Engineering. Leuven, 31st May -2nd June 2006. pp 447- 452.

[Lounis et al., 1998] Lounis, Z.; Lacasse, M. A.; Siemes, A. J. M.; Moser, K. "Further steps towards a quantitative approach to durability design". Construction and the Environment - CIB World Building Congress - Gavle, Sweden, 1998.

[Mora, 2007] E. P. Mora. "Life cycle, sustainability and the transcendent quality of building materials". Building and Environment 42 (2007) 1329–1334.

[National Association of Forest Industries, 2003] National Association of Forest Industries. "Timber - Design for Durability". National Association of Forest Industries. Timber Datafile P4. 2003. (www.superfloats.com/reference_library/alum&timber/timber%20manual%20datafile-%20timber%20design%20for%20durability.pdf, access August 2012)

[Östlin et al. 2009] J. Ostlin, E. Sundin, M. Bjorkman. "Product life-cycle implications for remanufacturing strategies". Journal of Cleaner Production 17 (2009) 999–1009.

[Rose, 2000] C. M. Rose. Design for environment: a method for formulating product end-of-life strategies. PhD Thesis Stanford University 2000 (www.seas.columbia.edu/earth/RRC/documents/2000.dfe.diss.rose.pdf access August 2012).

[Rüdenauer and Gensch, 2004a] I. Rüdenauer, C. O. Gensch. "Eco-Efficiency Analysis of Washing machines. Refinement of Task 4: Further use versus substitution of washing machines in stock". Commissioned by European Committee of Domestic Equipment Manufacturers (CECED). Freiburg, March 18th, 2005

[Rüdenauer et Gensch, 2005b] I. Rüdenauer, C.O. Gensch. “Eco-Efficiency Analysis of Washing machines – Life Cycle Assessment and determination of optimal life span”. European Committee of Domestic Equipment Manufacturers (CECED). Freiburg, March 18th, 2005.

[Sundin et Bras, 2005] E. Sundin, B. Bras. Making functional sales environmentally and economically beneficial through product remanufacturing. Journal of Cleaner Production 13 (2005) 913-925

[Takada et al., 1999] J. Takada, Y. Ito, M. Yoshikawa, H. Ishida. “EcoDesign for Ceramic tiles and Sanitary Ware”. Proceedings of First International Symposium on EcoDesign '99. 1-3 Feb 1999

[Ugwu et al., 2005] O.O. Ugwu, T M.M. Kumaraswamy, F. Kung, S.T. Ng. Object-oriented framework for durability assessment and life cycle costing of highway bridges” Automation in Construction 14 (2005) 611– 632

[Veshagh et Li, 2006] A. Veshagh, W. Li, “Survey of Eco Design and Manufacturing in Automotive SMEs”. Proceeding of the 13th CIRP International conference on Life Cycle Engineering. Leuven, 31st May -2nd June 2006. pp 305-310.

[VHK, 2011] van Holsteijn en Kemna B.V. (VHK). “Final Report. Methodology for Ecodesign of Energy-related Products MEErP 2011.Methodology Report Part 2: Environmental policies & data. (28 November 2011)”, and “Eco-Design of Energy Related/Using Products. Ecoreport 2011. Version 2.” (http://www.meerp.eu/documents.htm; access April 2012)

[WRAP, 2010] WRAP, Environmental Life Cycle Assessment (LCA) Study of Replacement and Refurbishment options for household washing machines, MDD019. Report prepared by G Fisher, Banbury, WRAP, 2010.

[WRAP, 2012] WRPA. Buying Guides for Durability and Repair. Available at: http://www.wrap.org.uk/content/buying-guides-durability-and-repair (Access August 2012).

[WRAP, 2012b] WRAP. Buying Specification Guides for Durability and Repair. Washing machines. Available at: http://www.wrap.org.uk/content/buying-guides-durability-and-repair (Access August 2012).

[WRAP, 2012c] WRAP. Buying Specification Guides for Durability and Repair. LCD Television. Available at: http://www.wrap.org.uk/content/buying-guides-durability-and-repair (Access August 2012).

Annex 1 – Simplified Durability Index for washing machine (WM) case-studies

Table A1.1 Simplified Durability index (D'_n) for Washing Machine 1 (WM1), calculated for different values “δ” of the efficiency of the substituting product and different values “X” of the extended operative time environmental impact categories (low repairing scenario – LRS).

D'n (WM1 for GWP)					
		"X" [years]			
		1	2	3	4
δ [%]	*100%*	1.1%	2.7%	4.2%	5.7%
	99%	1.0%	2.5%	4.0%	5.5%
	98%	1.0%	2.4%	3.8%	5.2%
	97%	0.9%	2.2%	3.6%	4.9%
	96%	0.8%	2.1%	3.3%	4.6%
	95%	0.8%	1.9%	3.1%	4.3%
	94%	0.7%	1.8%	2.9%	4.0%
	93%	0.6%	1.6%	2.7%	3.7%
	92%	0.5%	1.5%	2.5%	3.4%
	91%	0.5%	1.4%	2.3%	3.1%
	90%	0.4%	1.2%	2.0%	2.9%
	89%	0.3%	1.1%	1.8%	2.6%
	88%	0.3%	0.9%	1.6%	2.3%
	87%	0.2%	0.8%	1.4%	2.0%
	86%	0.1%	0.6%	1.2%	1.7%
	85%	0.0%	0.5%	0.9%	1.4%
	84%	0.0%	0.3%	0.7%	1.1%
	83%	-0.1%	0.2%	0.5%	0.8%
	82%	-0.2%	0.1%	0.3%	0.5%
	81%	-0.3%	-0.1%	0.1%	0.2%
	80%	-0.3%	-0.2%	-0.1%	0.0%
	79%	-0.4%	-0.4%	-0.4%	-0.3%
	78%	-0.5%	-0.5%	-0.6%	-0.6%
	77%	-0.5%	-0.7%	-0.8%	-0.9%
	76%	-0.6%	-0.8%	-1.0%	-1.2%
	75%	-0.7%	-1.0%	-1.2%	-1.5%
	74%	-0.8%	-1.1%	-1.4%	-1.8%
	73%	-0.8%	-1.2%	-1.7%	-2.1%
	72%	-0.9%	-1.4%	-1.9%	-2.4%
	71%	-1.0%	-1.5%	-2.1%	-2.6%
	70%	-1.0%	-1.7%	-2.3%	-2.9%

D'n (WM1 for Terrestric ecotoxicity)					
		"X" [years]			
		1	2	3	4
δ [%]	*100%*	-0.2%	4.9%	9.9%	15.0%
	99%	-0.2%	4.8%	9.8%	14.8%
	98%	-0.3%	4.7%	9.7%	14.7%
	97%	-0.3%	4.6%	9.6%	14.5%
	96%	-0.4%	4.6%	9.5%	14.4%
	95%	-0.4%	4.5%	9.4%	14.2%
	94%	-0.4%	4.4%	9.3%	14.1%
	93%	-0.5%	4.3%	9.1%	13.9%
	92%	-0.5%	4.3%	9.0%	13.8%
	91%	-0.5%	4.2%	8.9%	13.7%
	90%	-0.6%	4.1%	8.8%	13.5%
	89%	-0.6%	4.0%	8.7%	13.4%
	88%	-0.7%	4.0%	8.6%	13.2%
	87%	-0.7%	3.9%	8.5%	13.1%
	86%	-0.7%	3.8%	8.4%	12.9%
	85%	-0.8%	3.7%	8.3%	12.8%
	84%	-0.8%	3.7%	8.1%	12.6%
	83%	-0.8%	3.6%	8.0%	12.5%
	82%	-0.9%	3.5%	7.9%	12.3%
	81%	-0.9%	3.4%	7.8%	12.2%
	80%	-0.9%	3.4%	7.7%	12.0%
	79%	-1.0%	3.3%	7.6%	11.9%
	78%	-1.0%	3.2%	7.5%	11.7%
	77%	-1.1%	3.2%	7.4%	11.6%
	76%	-1.1%	3.1%	7.3%	11.4%
	75%	-1.1%	3.0%	7.1%	11.3%
	74%	-1.2%	2.9%	7.0%	11.1%
	73%	-1.2%	2.9%	6.9%	11.0%
	72%	-1.2%	2.8%	6.8%	10.8%
	71%	-1.3%	2.7%	6.7%	10.7%
	70%	-1.3%	2.6%	6.6%	10.5%

D'n (WM1 for Ab. Depl. El.)					
		"X" [years]			
		1	2	3	4
δ [%]	*100%*	-1.2%	7.2%	15.7%	24.1%
	99%	-1.2%	7.2%	15.6%	24.0%
	98%	-1.2%	7.2%	15.6%	24.0%
	97%	-1.2%	7.2%	15.6%	24.0%
	96%	-1.2%	7.2%	15.6%	24.0%
	95%	-1.2%	7.2%	15.6%	24.0%
	94%	-1.2%	7.2%	15.6%	24.0%
	93%	-1.2%	7.2%	15.6%	24.0%
	92%	-1.2%	7.2%	15.6%	23.9%
	91%	-1.2%	7.2%	15.6%	23.9%
	90%	-1.2%	7.2%	15.5%	23.9%
	89%	-1.2%	7.2%	15.5%	23.9%
	88%	-1.2%	7.2%	15.5%	23.9%
	87%	-1.2%	7.1%	15.5%	23.9%
	86%	-1.2%	7.1%	15.5%	23.9%
	85%	-1.2%	7.1%	15.5%	23.8%
	84%	-1.2%	7.1%	15.5%	23.8%
	83%	-1.2%	7.1%	15.5%	23.8%
	82%	-1.2%	7.1%	15.5%	23.8%
	81%	-1.2%	7.1%	15.4%	23.8%
	80%	-1.2%	7.1%	15.4%	23.8%
	79%	-1.2%	7.1%	15.4%	23.8%
	78%	-1.3%	7.1%	15.4%	23.7%
	77%	-1.3%	7.1%	15.4%	23.7%
	76%	-1.3%	7.1%	15.4%	23.7%
	75%	-1.3%	7.1%	15.4%	23.7%
	74%	-1.3%	7.1%	15.4%	23.7%
	73%	-1.3%	7.0%	15.4%	23.7%
	72%	-1.3%	7.0%	15.3%	23.7%
	71%	-1.3%	7.0%	15.3%	23.6%
	70%	-1.3%	7.0%	15.3%	23.6%

Table A1.2 Simplified Durability index (D'_n) for Washing Machine 2 (WM2), calculated for different values "δ" of the efficiency of the substituting product, different values "X" of the extended operative time and different environmental impact categories (low repairing scenario – LRS).

D'n (WM2 for GWP)					
		"X" [years]			
		1	2	3	4
δ [%]	*100%*	1.6%	3.8%	6.0%	8.1%
	99%	1.5%	3.6%	5.8%	7.9%
	98%	1.5%	3.5%	5.6%	7.6%
	97%	1.4%	3.4%	5.4%	7.4%
	96%	1.3%	3.2%	5.2%	7.1%
	95%	1.3%	3.1%	5.0%	6.8%
	94%	1.2%	3.0%	4.8%	6.6%
	93%	1.1%	2.8%	4.6%	6.3%
	92%	1.1%	2.7%	4.4%	6.0%
	91%	1.0%	2.6%	4.2%	5.8%
	90%	0.9%	2.5%	4.0%	5.5%
	89%	0.9%	2.3%	3.8%	5.2%
	88%	0.8%	2.2%	3.6%	5.0%
	87%	0.7%	2.1%	3.4%	4.7%
	86%	0.7%	1.9%	3.2%	4.5%
	85%	0.6%	1.8%	3.0%	4.2%
	84%	0.5%	1.7%	2.8%	3.9%
	83%	0.5%	1.5%	2.6%	3.7%
	82%	0.4%	1.4%	2.4%	3.4%
	81%	0.3%	1.3%	2.2%	3.1%
	80%	0.3%	1.1%	2.0%	2.9%
	79%	0.2%	1.0%	1.8%	2.6%
	78%	0.1%	0.9%	1.6%	2.3%
	77%	0.1%	0.7%	1.4%	2.1%
	76%	0.0%	0.6%	1.2%	1.8%
	75%	-0.1%	0.5%	1.0%	1.6%
	74%	-0.1%	0.3%	0.8%	1.3%
	73%	-0.2%	0.2%	0.6%	1.0%
	72%	-0.3%	0.1%	0.4%	0.8%
	71%	-0.3%	0.0%	0.2%	0.5%
	70%	-0.4%	-0.2%	0.0%	0.2%

D'n (WM2 for Terrestric ecotoxicity)					
		"X" [years]			
		1	2	3	4
δ [%]	*100%*	-0.1%	3.9%	7.9%	11.9%
	99%	-0.1%	3.8%	7.7%	11.7%
	98%	-0.2%	3.7%	7.6%	11.5%
	97%	-0.2%	3.6%	7.5%	11.3%
	96%	-0.3%	3.5%	7.3%	11.1%
	95%	-0.3%	3.4%	7.2%	10.9%
	94%	-0.4%	3.3%	7.0%	10.7%
	93%	-0.4%	3.2%	6.9%	10.5%
	92%	-0.5%	3.1%	6.7%	10.3%
	91%	-0.5%	3.0%	6.6%	10.1%
	90%	-0.6%	2.9%	6.4%	10.0%
	89%	-0.6%	2.8%	6.3%	9.8%
	88%	-0.7%	2.8%	6.2%	9.6%
	87%	-0.7%	2.7%	6.0%	9.4%
	86%	-0.7%	2.6%	5.9%	9.2%
	85%	-0.8%	2.5%	5.7%	9.0%
	84%	-0.8%	2.4%	5.6%	8.8%
	83%	-0.9%	2.3%	5.4%	8.6%
	82%	-0.9%	2.2%	5.3%	8.4%
	81%	-1.0%	2.1%	5.2%	8.2%
	80%	-1.0%	2.0%	5.0%	8.0%
	79%	-1.1%	1.9%	4.9%	7.8%
	78%	-1.1%	1.8%	4.7%	7.7%
	77%	-1.2%	1.7%	4.6%	7.5%
	76%	-1.2%	1.6%	4.4%	7.3%
	75%	-1.3%	1.5%	4.3%	7.1%
	74%	-1.3%	1.4%	4.1%	6.9%
	73%	-1.4%	1.3%	4.0%	6.7%
	72%	-1.4%	1.2%	3.9%	6.5%
	71%	-1.5%	1.1%	3.7%	6.3%
	70%	-1.5%	1.0%	3.6%	6.1%

D'n (WM2 for Ab. Depl. El.)					
		"X" [years]			
		1	2	3	4
δ [%]	*100%*	-1.2%	7.4%	16.1%	24.7%
	99%	-1.2%	7.4%	16.1%	24.7%
	98%	-1.2%	7.4%	16.1%	24.7%
	97%	-1.2%	7.4%	16.1%	24.7%
	96%	-1.2%	7.4%	16.1%	24.7%
	95%	-1.2%	7.4%	16.1%	24.7%
	94%	-1.2%	7.4%	16.1%	24.7%
	93%	-1.2%	7.4%	16.1%	24.7%
	92%	-1.2%	7.4%	16.1%	24.7%
	91%	-1.2%	7.4%	16.0%	24.7%
	90%	-1.2%	7.4%	16.0%	24.7%
	89%	-1.2%	7.4%	16.0%	24.7%
	88%	-1.2%	7.4%	16.0%	24.7%
	87%	-1.2%	7.4%	16.0%	24.7%
	86%	-1.2%	7.4%	16.0%	24.7%
	85%	-1.2%	7.4%	16.0%	24.6%
	84%	-1.2%	7.4%	16.0%	24.6%
	83%	-1.2%	7.4%	16.0%	24.6%
	82%	-1.2%	7.4%	16.0%	24.6%
	81%	-1.2%	7.4%	16.0%	24.6%
	80%	-1.2%	7.4%	16.0%	24.6%
	79%	-1.2%	7.4%	16.0%	24.6%
	78%	-1.2%	7.4%	16.0%	24.6%
	77%	-1.2%	7.4%	16.0%	24.6%
	76%	-1.2%	7.4%	16.0%	24.6%
	75%	-1.2%	7.4%	16.0%	24.6%
	74%	-1.2%	7.4%	16.0%	24.6%
	73%	-1.2%	7.4%	16.0%	24.6%
	72%	-1.2%	7.4%	16.0%	24.6%
	71%	-1.2%	7.4%	16.0%	24.6%
	70%	-1.2%	7.4%	16.0%	24.6%

Table A1.3 Simplified Durability index (D'_n) for Washing Machine 1 (WM1), calculated for different values “δ” of the efficiency of the substituting product and different values “X” of the extended operative time environmental impact categories (high repairing scenario – HRS).

D'n (WM1 for GWP)					
		"X" [years]			
		1	2	3	4
δ [%]	*100%*	0.7%	2.2%	3.8%	5.3%
	99%	0.6%	2.1%	3.6%	5.0%
	98%	0.6%	2.0%	3.3%	4.7%
	97%	0.5%	1.8%	3.1%	4.5%
	96%	0.4%	1.7%	2.9%	4.2%
	95%	0.3%	1.5%	2.7%	3.9%
	94%	0.3%	1.4%	2.5%	3.6%
	93%	0.2%	1.2%	2.3%	3.3%
	92%	0.1%	1.1%	2.0%	3.0%
	91%	0.0%	0.9%	1.8%	2.7%
	90%	0.0%	0.8%	1.6%	2.4%
	89%	-0.1%	0.6%	1.4%	2.1%
	88%	-0.2%	0.5%	1.2%	1.9%
	87%	-0.2%	0.4%	1.0%	1.6%
	86%	-0.3%	0.2%	0.7%	1.3%
	85%	-0.4%	0.1%	0.5%	1.0%
	84%	-0.5%	-0.1%	0.3%	0.7%
	83%	-0.5%	-0.2%	0.1%	0.4%
	82%	-0.6%	-0.4%	-0.1%	0.1%
	81%	-0.7%	-0.5%	-0.3%	-0.2%
	80%	-0.7%	-0.7%	-0.6%	-0.5%
	79%	-0.8%	-0.8%	-0.8%	-0.8%
	78%	-0.9%	-0.9%	-1.0%	-1.0%
	77%	-1.0%	-1.1%	-1.2%	-1.3%
	76%	-1.0%	-1.2%	-1.4%	-1.6%
	75%	-1.1%	-1.4%	-1.6%	-1.9%
	74%	-1.2%	-1.5%	-1.9%	-2.2%
	73%	-1.3%	-1.7%	-2.1%	-2.5%
	72%	-1.3%	-1.8%	-2.3%	-2.8%
	71%	-1.4%	-2.0%	-2.5%	-3.1%
	70%	-1.5%	-2.1%	-2.7%	-3.4%

D'n (WM1 for Terrestric ecotoxicity)					
		"X" [years]			
		1	2	3	4
δ [%]	*100%*	-5.5%	-0.4%	4.7%	9.7%
	99%	-5.5%	-0.5%	4.5%	9.6%
	98%	-5.6%	-0.6%	4.4%	9.4%
	97%	-5.6%	-0.6%	4.3%	9.3%
	96%	-5.6%	-0.7%	4.2%	9.1%
	95%	-5.7%	-0.8%	4.1%	9.0%
	94%	-5.7%	-0.9%	4.0%	8.8%
	93%	-5.7%	-0.9%	3.9%	8.7%
	92%	-5.8%	-1.0%	3.8%	8.5%
	91%	-5.8%	-1.1%	3.6%	8.4%
	90%	-5.8%	-1.2%	3.5%	8.2%
	89%	-5.9%	-1.2%	3.4%	8.1%
	88%	-5.9%	-1.3%	3.3%	7.9%
	87%	-6.0%	-1.4%	3.2%	7.8%
	86%	-6.0%	-1.5%	3.1%	7.6%
	85%	-6.0%	-1.5%	3.0%	7.5%
	84%	-6.1%	-1.6%	2.9%	7.3%
	83%	-6.1%	-1.7%	2.8%	7.2%
	82%	-6.1%	-1.7%	2.6%	7.0%
	81%	-6.2%	-1.8%	2.5%	6.9%
	80%	-6.2%	-1.9%	2.4%	6.7%
	79%	-6.3%	-2.0%	2.3%	6.6%
	78%	-6.3%	-2.0%	2.2%	6.5%
	77%	-6.3%	-2.1%	2.1%	6.3%
	76%	-6.4%	-2.2%	2.0%	6.2%
	75%	-6.4%	-2.3%	1.9%	6.0%
	74%	-6.4%	-2.3%	1.8%	5.9%
	73%	-6.5%	-2.4%	1.6%	5.7%
	72%	-6.5%	-2.5%	1.5%	5.6%
	71%	-6.6%	-2.6%	1.4%	5.4%
	70%	-6.6%	-2.6%	1.3%	5.3%

D'n (WM1 for Ab. Depl. El.)					
		"X" [years]			
		1	2	3	4
δ [%]	*100%*	-20.3%	-11.9%	-3.5%	4.9%
	99%	-20.3%	-11.9%	-3.5%	4.9%
	98%	-20.3%	-11.9%	-3.5%	4.9%
	97%	-20.4%	-12.0%	-3.5%	4.9%
	96%	-20.4%	-12.0%	-3.6%	4.8%
	95%	-20.4%	-12.0%	-3.6%	4.8%
	94%	-20.4%	-12.0%	-3.6%	4.8%
	93%	-20.4%	-12.0%	-3.6%	4.8%
	92%	-20.4%	-12.0%	-3.6%	4.8%
	91%	-20.4%	-12.0%	-3.6%	4.8%
	90%	-20.4%	-12.0%	-3.6%	4.8%
	89%	-20.4%	-12.0%	-3.6%	4.7%
	88%	-20.4%	-12.0%	-3.6%	4.7%
	87%	-20.4%	-12.0%	-3.7%	4.7%
	86%	-20.4%	-12.0%	-3.7%	4.7%
	85%	-20.4%	-12.0%	-3.7%	4.7%
	84%	-20.4%	-12.0%	-3.7%	4.7%
	83%	-20.4%	-12.1%	-3.7%	4.6%
	82%	-20.4%	-12.1%	-3.7%	4.6%
	81%	-20.4%	-12.1%	-3.7%	4.6%
	80%	-20.4%	-12.1%	-3.7%	4.6%
	79%	-20.4%	-12.1%	-3.7%	4.6%
	78%	-20.4%	-12.1%	-3.8%	4.6%
	77%	-20.4%	-12.1%	-3.8%	4.6%
	76%	-20.4%	-12.1%	-3.8%	4.5%
	75%	-20.4%	-12.1%	-3.8%	4.5%
	74%	-20.4%	-12.1%	-3.8%	4.5%
	73%	-20.4%	-12.1%	-3.8%	4.5%
	72%	-20.4%	-12.1%	-3.8%	4.5%
	71%	-20.4%	-12.1%	-3.8%	4.5%
	70%	-20.4%	-12.1%	-3.8%	4.5%

Table A1.4 Simplified Durability index (D'_n) for Washing Machine 2 (WM2), calculated for different values "δ" of the efficiency of the substituting product, different values "X" of the extended operative time and different environmental impact categories (high repairing scenario – HRS).

D'n (WM2 for GWP)					
		"X" [years]			
		1	2	3	4
δ [%]	*100%*	1.0%	3.2%	5.4%	7.5%
	99%	0.9%	3.0%	5.2%	7.3%
	98%	0.9%	2.9%	5.0%	7.0%
	97%	0.8%	2.8%	4.8%	6.8%
	96%	0.7%	2.6%	4.6%	6.5%
	95%	0.7%	2.5%	4.4%	6.2%
	94%	0.6%	2.4%	4.2%	6.0%
	93%	0.5%	2.2%	4.0%	5.7%
	92%	0.5%	2.1%	3.8%	5.4%
	91%	0.4%	2.0%	3.6%	5.2%
	90%	0.3%	1.9%	3.4%	4.9%
	89%	0.3%	1.7%	3.2%	4.6%
	88%	0.2%	1.6%	3.0%	4.4%
	87%	0.1%	1.5%	2.8%	4.1%
	86%	0.1%	1.3%	2.6%	3.9%
	85%	0.0%	1.2%	2.4%	3.6%
	84%	-0.1%	1.1%	2.2%	3.3%
	83%	-0.1%	0.9%	2.0%	3.1%
	82%	-0.2%	0.8%	1.8%	2.8%
	81%	-0.3%	0.7%	1.6%	2.5%
	80%	-0.3%	0.5%	1.4%	2.3%
	79%	-0.4%	0.4%	1.2%	2.0%
	78%	-0.5%	0.3%	1.0%	1.7%
	77%	-0.5%	0.1%	0.8%	1.5%
	76%	-0.6%	0.0%	0.6%	1.2%
	75%	-0.7%	-0.1%	0.4%	1.0%
	74%	-0.7%	-0.3%	0.2%	0.7%
	73%	-0.8%	-0.4%	0.0%	0.4%
	72%	-0.9%	-0.5%	-0.2%	0.2%
	71%	-0.9%	-0.6%	-0.4%	-0.1%
	70%	-1.0%	-0.8%	-0.6%	-0.4%

D'n (WM2 for Terrestric ecotoxicity)					
		"X" [years]			
		1	2	3	4
δ [%]	*100%*	-4.1%	-0.2%	3.8%	7.8%
	99%	-4.2%	-0.3%	3.7%	7.6%
	98%	-4.2%	-0.3%	3.5%	7.4%
	97%	-4.3%	-0.4%	3.4%	7.2%
	96%	-4.3%	-0.5%	3.3%	7.0%
	95%	-4.4%	-0.6%	3.1%	6.8%
	94%	-4.4%	-0.7%	3.0%	6.7%
	93%	-4.5%	-0.8%	2.8%	6.5%
	92%	-4.5%	-0.9%	2.7%	6.3%
	91%	-4.6%	-1.0%	2.5%	6.1%
	90%	-4.6%	-1.1%	2.4%	5.9%
	89%	-4.7%	-1.2%	2.2%	5.7%
	88%	-4.7%	-1.3%	2.1%	5.5%
	87%	-4.8%	-1.4%	2.0%	5.3%
	86%	-4.8%	-1.5%	1.8%	5.1%
	85%	-4.9%	-1.6%	1.7%	4.9%
	84%	-4.9%	-1.7%	1.5%	4.7%
	83%	-5.0%	-1.8%	1.4%	4.5%
	82%	-5.0%	-1.9%	1.2%	4.4%
	81%	-5.0%	-2.0%	1.1%	4.2%
	80%	-5.1%	-2.1%	1.0%	4.0%
	79%	-5.1%	-2.2%	0.8%	3.8%
	78%	-5.2%	-2.3%	0.7%	3.6%
	77%	-5.2%	-2.4%	0.5%	3.4%
	76%	-5.3%	-2.5%	0.4%	3.2%
	75%	-5.3%	-2.6%	0.2%	3.0%
	74%	-5.4%	-2.6%	0.1%	2.8%
	73%	-5.4%	-2.7%	-0.1%	2.6%
	72%	-5.5%	-2.8%	-0.2%	2.4%
	71%	-5.5%	-2.9%	-0.3%	2.3%
	70%	-5.6%	-3.0%	-0.5%	2.1%

D'n (WM2 for Ab. Depl. El.)					
		"X" [years]			
		1	2	3	4
δ [%]	*100%*	-20.9%	-12.3%	-3.6%	5.0%
	99%	-20.9%	-12.3%	-3.6%	5.0%
	98%	-20.9%	-12.3%	-3.6%	5.0%
	97%	-20.9%	-12.3%	-3.6%	5.0%
	96%	-20.9%	-12.3%	-3.6%	5.0%
	95%	-20.9%	-12.3%	-3.6%	5.0%
	94%	-20.9%	-12.3%	-3.6%	5.0%
	93%	-20.9%	-12.3%	-3.7%	5.0%
	92%	-20.9%	-12.3%	-3.7%	5.0%
	91%	-20.9%	-12.3%	-3.7%	5.0%
	90%	-20.9%	-12.3%	-3.7%	5.0%
	89%	-20.9%	-12.3%	-3.7%	5.0%
	88%	-20.9%	-12.3%	-3.7%	5.0%
	87%	-20.9%	-12.3%	-3.7%	5.0%
	86%	-20.9%	-12.3%	-3.7%	4.9%
	85%	-20.9%	-12.3%	-3.7%	4.9%
	84%	-20.9%	-12.3%	-3.7%	4.9%
	83%	-20.9%	-12.3%	-3.7%	4.9%
	82%	-20.9%	-12.3%	-3.7%	4.9%
	81%	-20.9%	-12.3%	-3.7%	4.9%
	80%	-20.9%	-12.3%	-3.7%	4.9%
	79%	-20.9%	-12.3%	-3.7%	4.9%
	78%	-20.9%	-12.3%	-3.7%	4.9%
	77%	-20.9%	-12.3%	-3.7%	4.9%
	76%	-20.9%	-12.3%	-3.7%	4.9%
	75%	-20.9%	-12.3%	-3.7%	4.9%
	74%	-20.9%	-12.3%	-3.7%	4.9%
	73%	-20.9%	-12.3%	-3.7%	4.9%
	72%	-20.9%	-12.3%	-3.7%	4.9%
	71%	-21.0%	-12.3%	-3.7%	4.9%
	70%	-21.0%	-12.3%	-3.7%	4.9%

European Commission
EUR EN – Joint Research Centre – Institute for Environment and Sustainability

Analysis of Durability. European Commission. Joint Research Centre. Institute for Environment and Sustainability. Report n° 1 of the project "Integration of resource efficiency and waste management criteria in European product policies – Second phase. September 2012

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Abstract:
The present report aims at: 1) identifying key issues concerning the durability of products; 2) analysing methods and standards for the assessment of durability; 3) identifying potential product's policy criteria for durability. The report is subdivided in 3 Chapters:

Chapter 1 analyses scientific publications and standards to identify potential methods for the assessment of the durability of products. Also potential approaches to extend the operating time of products have been illustrated.

Chapter 2 applies the method for the environmental assessment of durability to two exemplary washing machines.

Chapter 3 illustrates hot spots for durability of washing machines, meaning those key components/parts that are functionally critical for the lifetime of the product. The analysis has been based on researches published in scientific literature and feedback from stakeholders. Potential environmental benefits for the washing machine product group due to extension of product's lifetime have been also estimated

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