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INTRODUCTION

Background

The Directive 2009/125/EC on Ecodesign establishes a framework for EU Ecodesign requirements for energy-related products with a significant potential for reduction of energy consumption. The implementation of such requirements would contribute to reach the target of saving 20% of primary energy by 2020 as identified in the Commission's Communications on Energy 2020 (European Commission 2010) and on the Energy Efficiency Plan 2011 (European Commission 2011a). Ecodesign measures may be reinforced also through the Directive 2010/30/EU on the indication by labelling and standard product information of the consumption of energy and other resources by energy-related products.

The European Commission has launched the revision of the Ecodesign and Energy-/Resource label implementing measures for the product group 'household dishwashers (DW)'. The revision study is coordinated by the European Commission's DG of the Environment and DG Energy, and is undertaken by the Commission´s Joint Research Centre (JRC) with technical support from Oeko-Institut and the University of Bonn. The methodology of the revision follows the Commission's Methodology for the Evaluation of Energy related Products (MEErP) (COWI and VHK 2011), consisting of the following steps:

- Task 1 – Scope definition, standard methods and legislation
- Task 2 – Market analysis
- Task 3 – Analysis of user behaviour and system aspects
- Task 4 – Analysis of technologies
- Task 5 – Environmental and economic assessment of base cases
- Task 6 – Assessment of design options
- Task 7 – Assessment of policy scenarios

The comprehensive analysis of the product group following the steps above will feed as research evidence basis into the revision of the existing Energy Label Regulation (EC) 1059/2010 (European Commission 2010) and the Ecodesign Regulation (EC) 1016/2010 on household dishwashers (European Commission 2010).

The research is based on available scientific information and data, uses a life-cycle thinking approach, and is engaging stakeholder experts in order to discuss on key issues and to develop wide consensus.

A set of information of interest has been already collected. Starting from the initial preparatory study (So-called 'ENER Lot 14') prepared in 2007 (ENEA/ISIS 2007a) and the resulting Regulations listed above on Energy Label and Ecodesign for domestic dishwashers and washing machines, a generic review of the fitness of these policies took place as part of the DG ENER project "Omnibus" (VHK et al. 2014). The Omnibus study identified a number of issues of these Regulations where revision is advisable.

Against this background, information is being revised, updated and integrated to reflect the current state of play, following the MEErP methodology.

As final result, the JRC will produce an updated preparatory study including a comprehensive techno-economic and environmental assessment for this product group. This will provide policy makers with an evidence basis for assessing whether and how to revise the existing Regulations.

A Technical Working Group (TWG) has been created in order to support the JRC along the study. This Technical Working Group is composed of experts from Member States, industry, NGOs and academia who have voluntarily requested to be registered as stakeholders of the study through the project website (http://susproc.jrc.ec.europa.eu/Dishwashers/index.html).

The TWG is contributing to the study with data, information and written feedback to questionnaires and working documents. Interaction with stakeholders is also taking place through two meetings organised by JRC:

- 1st Technical Working Group (TWG): 23 June 2015, in Seville.
- 2nd Technical Working Group (TWG): 17 November 2015, in Brussels.

Objectives and structure of this report

The preparatory study on household dishwashers builds on existing knowledge as far as possible. However, additional and complementary investigation is required to achieve the goals of the study. With this respect, the objective of this report is to:

- Summarise the background information so far gathered for household dishwashers.
- Identify areas which need to be revised, updated and integrated to reflect the current state of play and to align with the MEErP methodology.

The present document is prepared as input for the first TWG meeting (23 June 2015, in Seville).
This document is structured in the following chapters, following Tasks 1 to 4 of MEErP:

- Chapter 1 - Scope, defining the products and presenting relevant standards and legislation;
- Chapter 2 - Markets, presenting economic and market data of dishwashers at the EU28 level;
- Chapter 3 – Users and system aspects, describing user behaviour, key aspects influencing such practices and system aspects related to dishwashers;
- Chapter 4 - Technologies, analysing products from a technical point of view with a special focus on design, technology and innovation.

A summary and a list of key discussion points for the revision of the Regulations are presented at the end of each chapter. Where necessary, stakeholders are also informed where key decisions must be taken and where a gap of information must be filled with their support.
Once the necessary data has been collected, this background document will be enlarged to address all sections prescribed in MEErP, including:

- an environmental and economic assessment of base-cases;
- an analysis of the improvement potential achievable for this product group through the implementation of best available technologies and best not available technologies;
- a streamlined impact assessment of different policy options.

A first questionnaire to stakeholders has been sent in March 2015 to collect preliminary information for the study (JRC IPTS 2015a). Feedback received has been reported in this document to the extent possible. Additional questionnaires may also be sent in the coming months to fill any gaps of information needed to complete the study.

Stakeholder written feedback

Stakeholders are asked to carefully study the information presented in the individual chapters of this report, and to point out potential modifications and additions they deem necessary.
Please note that the written commenting of this report requires firstly registration as stakeholder through the project website (http://susproc.jrc.ec.europa.eu/Dishwashers/index.html), and takes place using the on-line platform BATIS (further information on access to BATIS is provided upon registration).

Experts not able to participate in the stakeholder meeting are also welcome to provide written comments, once registered as stakeholders.

1 TASK 1: SCOPE

The aim of Task 1 is to analyse scope, definitions, standards and assessment methods and other legislation of relevance for the product group and to assess their suitability for the existing Ecodesign and Energy Label Regulations.

1.1 Product Scope

The following sections first provide an analysis of existing definitions of household dishwashers as used for example in European statistics, legislations, standards and other voluntary initiatives such as ecolabels; followed by stakeholder feedback regarding the existing scope and definitions of the current EU ecodesign and energy label Regulations.
Based on this information and further research and evidence, a preliminary revised scope and revised definitions are proposed.

1.1.1 Existing definitions

The following section provides an overview of existing definitions of dishwashersrs given in key standards and legislation.

1.1.1.1 European statistics

The European statistical database for manufactured goods PRODCOM (Eurostat n.d.), classifies dishwashers under the following NACE Rev.2 code:

2751.12.00 – Household dishwashing machines

In the Preparatory Study for Ecodesign Requirements of Energy-using Products, Lot 14: Domestic Dishwashers & Washing Machines of 2007 (ENEA/ISIS 2007a), the former NACE Rev. 1.1 code "2971.12.00 – Household dishwashing machines" was used, but from 1 January 2008 NACE Rev 2 is to be used, in general, for statistics referring to economic activities.

1.1.1.2 Commission Regulations EC/1016/2010 and EC/1059/2010

The Regulation (EC) No 1016/2010 with regard to ecodesign requirements for household dishwashers (European Commission 2010) and Regulation (EC) No 1059/2010 with regard to energy labelling of household dishwashers (European Commission 2010) apply to

'Electric mains-operated household dishwashers and electric mains-operated household dishwashers that can also be powered by batteries, including those sold for non-household use and built-in household dishwashers'.

For household dishwashers, the following definitions are given

'Household dishwasher' means a machine which cleans, rinses, and dries dishware, glassware, cutlery and cooking utensils by chemical, mechanical, thermal, and electric means and which is designed to be used principally for non-professional purposes.

'Built-in household dishwasher' means a household dishwasher intended to be installed in a cabinet, a prepared recess in a wall or a similar location, requiring furniture finishing.

Specific ecodesign requirements for household dishwashers are further differentiated by capacity (number of place settings 'ps') and/or size:

- Requirements regarding Energy Efficiency Index (EEI) (c.f. equation 1-1) for:
  - Household dishwashers with a rated capacity equal to or higher than 11 ps and household dishwashers with a rated capacity of 10 ps and a width higher than 45 cm;

  - Household dishwashers with a rated capacity of 10 ps and a width equal or less than 45 cm;
  - Household dishwashers with a rated capacity of 8 and 9 ps.
- Requirements regarding Drying Efficiency for:
  - Household dishwashers with a rated capacity equal to or higher than 8 ps;
  - Household dishwashers with a rated capacity equal to or less than 7 ps.

Within the methods for calculating the EEI household dishwashers are also differentiated by capacity and/or size:

- Calculation of the Standard Annual Energy Consumption (SAEc) (c.f. equation 1-1) for:
  - Household dishwashers with a rated capacity equal to or higher than 10 ps and a width higher than 50 cm;
  - Household dishwashers with a rated capacity equal to or less than 9 ps and household dishwashers with a rated capacity higher than 9 ps and a width equal or less than 50 cm.

1.1.1.3 Standards IEC 60436 and EN50242:2008

The standards IEC 60436 (edition 3.2 consolidated with amendments 1&2, published on 19 April 2012), and EN50242:2008 'Electric dishwashers for household use – Methods for measuring the performance' apply to '*electric dishwashers for household use that are supplied with hot and/or cold water*.' The object is to state and define the principal performance characteristics of electric dishwashers for household use and to describe the standard methods of measuring these characteristics. The standard defines household dishwashers as follows:

> *Dishwasher: machine which cleans, rinses, and dries dishware, glassware, cutlery, and, in some cases, cooking utensils by chemical, mechanical, thermal, and electric means. A dishwasher may or may not have a specific drying operation at the end of the program.*

1.1.1.4 European Ecolabels

The scope of the German Ecolabel Blue Angel RAL-UZ 152 for Household Dishwashers (Ral gGmbH 2013) is given as follows – a further definition of 'electric dishwashers for household use' is not provided:

> *These Basic Criteria apply to electric dishwashers for household use. Excluded from the scope are dishwashers for semi-professional and professional use which feature special cleaning programmes for non-household use, e.g. medical offices, kindergartens etc..*

Specific requirements on energy efficiency, water consumption and noise emissions of household dishwashers are further differentiated by size:

- Dishwashers > 45 cm wide
- Dishwashers ≤ 45 cm wide

1.1.1.5 US Energy Star

The US Energy Star Program Requirements Version 5.2 for Residential Dishwashers provides definitions for "Dishwashers" and the following sub-categories:

- 'Dishwasher': A cabinet-like appliance which with the aid of water and detergent, washes, rinses, and dries (when a drying process is included) dishware, glassware, eating utensils, and most

cooking utensils by chemical, mechanical and/or electrical means and discharges to the plumbing drainage system.

-
- 'Compact Dishwasher': A dishwasher that has a capacity of less than eight ps plus six serving pieces as specified in ANSI/AHAM DW-1-2010 (incorporated by reference; see § 430.3), using the test load specified in section 2.7 of 10 CFR 430, Subpart B, Appendix C1.
- 'Standard Dishwasher': A dishwasher that has a capacity equal to or greater than eight ps plus six serving pieces as specified in ANSI/AHAM DW-1-2010 (incorporated by reference; see § 430.3), using the test load specified in section 2.7 of 10 CFR 430, Subpart B, Appendix C1.
- 'Portable Dishwasher': A dishwasher which is not permanently connected to the household water and electric supply lines. It can be mounted on wheels and easily moved from one place to another in normal use. This definition includes dishwashers intended to be used on a countertop or table.

Further, the scope of the US ENERGY STAR Program Requirements for Residential Dishwashers – Eligibility Criteria 5.2 (Revised April 2013) covers following products:

A. Included Products: Products that meet the definition of a dishwasher as specified above and a consumer product as specified in 10 CFR § 430.2 are eligible for ENERGY STAR qualification under this specification.

B. Excluded Products: Product types not specifically identified in the definitions given above are not eligible for ENERGY STAR qualification under this specification. Products that are covered under other ENERGY STAR product specifications (e.g., Commercial Dishwashers) are not eligible for qualification under this specification.

The cited Code of Federal Regulations (CFR), Title 10 / Part 430 ('Energy Conversation Program for Consumer Products'), § 430.2 provides the following definition of "Consumer products" (U.S. Government 2014):

Consumer product means any article (other than an automobile, as defined in Section 501(1) of the Motor Vehicle Information and Cost Savings Act): (1) Of a type (i) Which in operation consumes, or is designed to consume, energy or, with respect to showerheads, faucets, water closets, and urinals, water; and (ii) Which, to any significant extent, is distributed in commerce for personal use or consumption by individuals; (2) Without regard to whether such article of such type is in fact distributed in commerce for personal use or consumption by an individual.

The US ENERGY STAR Program Requirements for Residential Dishwashers – Eligibility Criteria 5.2 are under revision. According to Draft 2 Version 6.0 from 17 June 2014, there are no changes in the product definitions of dishwashers. Deviating from Version 5.2, however, Draft 2 Version 6.0 provides an explicit definition of a "consumer product":

Consumer product means any product (other than an automobile, as defined in Section 501(1) of the Motor Vehicle Information Cost Savings Act) which: (1) in operation consumes, or is designed to consume, energy and water (2) to any significant extent, is distributed in commerce for personal use or consumption by individuals.

1.1.1.6 Ecodesign Preparatory study Lot 24

The Preparatory study for Ecodesign Requirements of Energy-using Products, Lot 24: Professional Washing Machines, Dryers and Dishwashers, Part Dishwashers, Task 1 (Scope), defines professional dishwashers as follows (Rüdenauer et al. 2011a):

'Professional dishwasher' means a machine which cleans, rinses, and dries wash ware like dishware, glassware, cutlery, and other utensils connected to the preparation, cooking, arrangement or serving of food (including drinks) by chemical, mechanical, and thermal means;

which is connected to electric mains and which is designed to be used principally for commercial and industrial purposes as stated by the manufacturer in the Declaration of Conformity (DoC).

The delimitation between professional dishwashers and household dishwashers is defined through the Machinery Directive (European Parliament 2006) which explicitly excludes dishwashers intended for household use and which defines essential health and safety requirements for dishwashers which are intended for professional use. According to the Machinery Directive, manufacturers have to determine the 'intended use' (domestic or commercial / industrial use) and state this in the product information or the so called Declaration of Conformity.

The following Table 1.1 summarises and structures the different existing definitions for household dishwashers according to their function, intended use, design format, capacity or dimensions, power supply and other criteria.

Table 1.1: Systematic of existing definitions for household dishwashers

EU Ecodesign / Energy label Regulations	IEC / EN standards	EU Prodcom statistics	German Blue Angel ecolabel	US Energy Star label
Function				
"Machine which cleans, rinses, and dries dishware, glassware, cutlery and cooking utensils by chemical, mechanical, thermal, and electric means"	"Machine which cleans, rinses, and dries dishware, glassware, cutlery, and, in some cases, cooking utensils by chemical, mechanical, thermal, and electric means. A dishwasher may or may not have a specific drying operation at the end of the program."	---	---	"Appliance which with the aid of water and detergent, washes, rinses, and dries (when a drying process is included) dishware, glassware, eating utensils, and most cooking utensils by chemical, mechanical and/or electrical means and discharges to the plumbing drainage system."
Intended use				
"Household dishwasher", including "those sold for non-household use"	"Household use"	"Household"	"Household use". "Excluded from the scope are dishwashers for semi-professional and professional use which feature special cleaning programmes for non-household use, e.g. medical offices, kindergartens etc."	"Residential dishwasher"; "Consumer product: means any product which … to any significant extent, is distributed in commerce for personal use or consumption by individuals."
Design format				
Including "Built-in, i.e. intended to be installed in a cabinet, a prepared recess in a wall or a similar location, requiring furniture	---	---		"Cabinet-like"; "Standard"; "Compact"; "Portable: not permanently connected to the

EU Ecodesign / Energy label Regulations	IEC / EN standards	EU Prodcom statistics	German Blue Angel ecolabel	US Energy Star label
finishing"				household water and electric supply lines. It can be mounted on wheels and easily moved from one place to another in normal use. This definition includes dishwashers intended to be used on a countertop or table."
Capacity and/or dimensions				
EEI requirements: ≥ 11 ps 10 ps and > 45 cm width 10 ps and ≤ 45 cm width 8 and 9 ps Drying Efficiency Index requirements: ≥ 8 ps ≤ 7 ps SAE_C calculation: ps ≥ 10 and > 50 cm width ps ≤ 9 ps > 9 and ≤ 50 cm width	---	---	> 45 cm width ≤ 45 cm width	< 8 ps plus 6 serving pieces ("compact") ≥ 8 ps plus 6 serving pieces ("standard")
Power supply				
"Electric mains-operated" and "Electric mains-operated that can also be powered by batteries"	---	---	--	---
<u>Others</u>				
---	supplied with hot and/or cold water	---	---	---

1.1.2 Feedback from stakeholders with regard to the existing scope

In March 2015, a questionnaire has been circulated by the study team to gather input and opinions from stakeholders for use in the revision of the ecodesign and energy/resource label requirements of household dishwashers (JRC IPTS 2015a) . Regarding the scope and definitions in the current Regulations, stakeholders were asked

- if the existing definitions are comprehensive and clear or should be modified,

- if the existing functional definition of dishwashers is exhaustive and coherent, or if additional functional parameters are of relevance,
- if devices that can also be powered by batteries should still be listed separately in the scope,
- if there is still a need to list built-in household dishwashers as a separate category,
- if there are any examples of niche or special purpose types of household dishwashers which should be included or excluded from the scope, and
- if semi-professional dishwashers should be excluded from the scope.

The following answers and recommendation were provided by stakeholder feedback:

1.1.2.1 Clarity of the existing definitions

Some of the answering stakeholders consider the existing definitions as comprehensive and clear at all.

1.1.2.1.1 Functional parameters

The given main functions (cleaning, rinsing, and drying) are still seen as most important parameters by one stakeholder. Two stakeholders differ between

- Primary function: Cleaning and rinsing
- Secondary function: Drying, which is an important function for consumers but the drying function is not included in all programmes.

Another stakeholder proposes as secondary function the capability to remotely control the dishwasher.

1.1.2.1.2 Built-in appliances

Most stakeholders answered that a separation of standalone and built-in appliances is not needed. The same requirements should be applied for both of them – a separate category is only needed if the requirements differ for built-in and freestanding machines. One stakeholder explains that a differentiation is not needed as there is no difference between built-in and standalone machines in terms of covered efficiency and performance criteria. Also, it is clearly described in the existing standards how to measure the different appliances. “Built-in” was in the past one of the separation criteria for professional appliances. Another stakeholder notes that the differentiation is mainly needed for the noise measurements and declarations, as noise emissions are lower, when the appliance is built into a cabinet. One stakeholder does not see the need for separate categories as all dishwashers should be covered by possibly identical requirements; he argues that the best / most energy saving models should be promoted in a technology-neutral way; and informs that for dishwashers, many more built-in models reach A+++ than freestanding models.

1.1.2.1.3 Battery-powered dishwashers

The picture of those stakeholders answering on this topic is rather indifferent.
On the one hand, some stakeholders inform that so far no such appliances exist or the market relevance of this kind of machines is very low. Also, there is not enough data available as products are not yet present in the market, thus they should be excluded from the scope. One stakeholder recommends leaving them either out or extending the standards accordingly, as the current test standard does not explicitly describe the test procedure for battery powered appliances.
On the other hand, some stakeholders argue that it might become relevant, if battery powered appliances would need a different amount of energy in case of battery usage as compared to being operated by electric mains. These products should be considered separately as they may not reach the same performance levels as traditional machines. Another stakeholder, however, means that all dishwashers should be covered by possibly identical requirements, i.e. that the best / most energy saving models should be promoted in a technology-neutral way.

Also, some of the answering stakeholders still see the need to keep this sub-category listed separately in the scope as it might become useful in the framework of smart grids and demand response. Machines operated by batteries or working in continuous current could become more relevant in the future, as energy from renewable sources becomes more relevant. Against this speaks another stakeholder who would not expect electrical energy storages in dishwashers in the future to make use of renewable energy.

1.1.2.1.4 Niche or special purpose products

One stakeholder means that the definition of "household dishwasher" in general includes all types of possible niche products like table-top dishwashers, transportable dishwasher or even battery powered dishwashers. He informs that smart appliances shortly will be no niche anymore and proposed that they should not be separated. According to his opinion, energy efficiency of WLAN modules must be evaluated / rated separately for instance in relation to network standby.
Another stakeholder proposes adding definitions for "hot fill", "solar heated" or "renewable energy heated", "integrated power management system" etc., as a system approach is needed to identify additional energy saving potential beyond those within the appliance.

1.1.2.1.5 Semi-professional appliances

The existing distinction between household dishwashers and semi-professional dishwashers (undercounter water-change dishwashers) is seen as still clear enough and sufficient as it is in principle for non-professional purposes according to its definition. If there is too much doubt, one stakeholder proposes that the wording "including those sold for non-household use" could be added as it has been done for refrigerators.
Most of the answering stakeholders agree excluding semi-professional dishwashers from the scope of the ecodesign and energy labelling Regulations for household dishwashers. Arguments of stakeholders:

- The intended use might be different or the very different way the product is used;
- They cannot be compared with household dishwashers: Semi-professional dishwashers either need higher voltage (400 V) or have different safety requirements (e.g. related to 16 A).
- In addition, due to the higher reliability requirements, the appliances are often built with higher material masses. This may have an impact on measured energy and water consumption since more material mass is heated up during the cleaning and drying processes. Therefore they should be considered separately.
- Semi-professional dishwashers could have the same requirements as the professional ones.

One stakeholder agrees with the exclusion in the ecodesign Regulation but would welcome an inclusion in the energy label Regulation. Also another stakeholder argues that they should be included into the energy labelling Regulation as information on energy efficiency and consumption would be important information for bars / restaurants purchasing a dishwasher – due to the intense use even more so than for households. However, other stakeholders argue that semi-professional dishwashers should go together with professional dishwashers, whether in ecodesign or energy labelling.

1.2 Legislation and standards for ecodesign, energy efficiency and performance

In the following sections of chapter 1.2, the European legislation (section 1.2.1), test standards (section 1.2.2) and ecolabels (section 1.2.3) with regard to ecodesign, energy efficiency and performance criteria are described, followed by a compilation of international and third-country legislation and standards (section 1.2.4).

1.2.1 European legislation on ecodesign, energy efficiency and performance

Table 1.2 provides an overview of the European legislation discussed in this section.

Table 1.2: Overview of the European legislation on ecodesign, energy efficiency and performance

European legislation	
Ecodesing Regulations	Ecodesign Regulation (EC) No 1016/2010 for household dishwashers
	Ecodesign Regulation (EC) 1275/2008 for standby and off mode
	Ecodesign Regulation (EC) No 801/2013 on networked standby
	Ecodesign Regulation (EC) No 640/2009 for electric motors
	Ecodesign preparatory study on smart appliances (ENER Lot 33, ongoing)
Energy efficiency and performance	Energy Labelling Regulation (EC) No 1059/2010 for household dishwashers
	Low Voltage Directive (LVD) 2014/35/EU
	Electromagnetic Compatibility Directive (ECD) 2014/30/EU

1.2.1.1 Ecodesign Regulations relevant for dishwashers

1.2.1.1.1 Ecodesign Regulation (EC) No 1016/2010 for household dishwashers

Based on Directive 2009/125/EU with regard to ecodesign requirements for energy-related products, the Regulation (EC) No1016/2010 with regard to ecodesign requirements for household dishwashers established general and specific requirements that all appliances need to fulfil to be distributed on the European market. General requirements include

- the availability of a standard test programme,
- the application of this programme for the determination of energy and water consumption and performance values and
- the provision of obligatory information in the booklet.

The standard programme shall be clearly recognisable on the user interface; additionally it is to be used as the default cycle, where an automatic programme selection is available. Information to be included in the instructions shall clearly indicate that the standard programme is suitable for normally soiled tableware and that it is the most efficient programme in terms of its combined energy and water consumption for this kind of tableware. Energy consumption values for off-mode and left-on mode, and information on most relevant programmes shall be provided.
The specific requirements prescribe the minimum limits for energy efficiency (Table 1.3), cleaning and drying performance (Table 1.4) for appliances of different sizes and load capacities with the associated dates of entry into force.

Table 1.3: Specific ecodesign requirements in Regulation (EC) 1016/2010, related to the Energy Efficiency Index (EEI)

Due date	Specific requirement	Affected type of dishwasher
01/12/11	EEI < 71	All dishwashers except dishwashers for 10 ps with a width of 45 cm or less
	EEI < 80	Dishwashers for 10 ps with a width of 45 cm or less
01/12/13	EEI < 63	Dishwashers for 11 ps and more, and dishwashers for 10 ps with a width higher than 45 cm
	EEI < 71	Dishwashers for 10 ps with a width of 45 cm or less
01/12/16	EEI < 63	Dishwashers for 8 and 9 ps, and dishwashers for 10 ps with a width of 45 cm or less

Table 1.4: Specific ecodesign requirements in Regulation 1016/2010, related to cleaning performance index (I_C) and drying performance index (I_D)

Due date	Specific requirement	Affected type of dishwasher
01/12/11	$I_C > 1,12$	All dishwashers
01/12/13	$I_D > 1,08$	Dishwashers for 8 ps or more
	$I_D > 0,86$	Dishwashers for 7 ps or less

Regulation (EC) No 1016/2010 also prescribes formulas for the calculation of EEI and annual consumptions of energy. For the determination and calculation of cleaning and drying efficiency indices assessment tables and formulas are shown. These equations and tables are taken over in the Energy label Regulation (EC) No 1059/2010.
Additionally for the verification process tolerances for all measurement values are given, as well as reference values of the most efficient appliances of different capacities available on the market at that time.
This Regulation all in all led to restrictions concerning the distribution of household dishwashers in the EU market. From 01.12.2011 only appliances with energy efficiency class A (cf. Table 1.5) and cleaning efficiency class A may be placed on the market. In December 2012 the availability and declaration of the "Eco" programme became obligatory. In December 2013 energy efficiency class A^+ (for a load capacity of 11 ps or more), respectively A for small dishwashers (10 ps or less) and drying efficiency class A, became a minimum requirement. The classification of energy efficiency is outlined in Table 1.5.

1.2.1.1.2 Ecodesign Regulation (EC) 1275/2008 for standby and off mode

Regulation (EC) No 1275/2008 is implementing the Directive 2005/32/EC with regard to ecodesign requirements for standby and off mode electric power consumption of electrical and electronic household and office equipment (European Commission 2008). According to Annex I of the Regulation, dishwashing machines as household appliances are falling under the scope of this Regulation.
Currently, stage 2 is applicable for products placed on the market from 7 January 2013, with the following requirements regarding power consumption for standby- and off-mode, as well as power management or similar functions:

- Power consumption in 'standby mode(s)':
  - The power consumption of equipment in any condition providing only a reactivation function, or providing only a reactivation function and a mere indication of enabled reactivation function, shall not exceed 0.50 W.
  - The power consumption of equipment in any condition providing only information or status display, or providing only a combination of reactivation function and information or status display shall not exceed 1.00 W.

Dishwashers usually have a “left-on mode” and might have a “delayed start” function. According to the ecodesign Regulation (EC) No 1016/2010 for dishwashers, ‘left-on mode’ means the lowest power consumption mode that may persist for an *indefinite* time after completion of the programme and unloading of the machine without any further intervention of the end-user. A definition for "delayed start" mode is not provided by Regulation (EC) No 1016/2010. According to stakeholder feedback, both "left-on" mode and "delayed start" mode do not fall under the definition of a standby-mode under Regulation (EC) No 1275/2008. A “delayed start” function is not to be considered as standby because it does not last for an indefinite time. Also, since the introduction of power management in 2013 (see below), left-on mode does not fall under the definition of a standby-mode under Regulation (EC) No 1275/2008 anymore, as it is switched into off-mode after a certain time. This means that currently the requirements of Regulation (EC) No 1275/2008 with regard to power consumption in standby modes do not apply to household dishwashers. Nevertheless, the time and power in left-on mode has to be measured according to the ecodesign and energy label Regulations (EC) No 1016/2010 and 1059/2010 to determine the annual energy consumption (AE_C) being the basis for the EEI.

- Power consumption in ‘off mode’:
  - Power consumption of equipment in any off-mode condition shall not exceed 0.50 W.
- Availability of off mode and/or standby mode: Equipment shall, except where this is inappropriate for the intended use, provide off mode and/or standby mode, and/or another condition which does not exceed the applicable power consumption requirements for off mode and/or standby mode when the equipment is connected to the mains power source.
- Power management: When equipment is not providing the main function, or when other energy-using product(s) are not dependent on its functions, equipment shall, unless inappropriate for the intended use, offer a power management function, or a similar function, that switches equipment after the shortest possible period of time appropriate for the intended use of the equipment, automatically into:
  - standby mode, or
  - off mode, or
  - another condition which does not exceed the applicable power consumption requirements for off mode and/or standby mode when the equipment is connected to the mains power source. The power management function shall be activated before delivery.

For dishwashers, this means that all dishwashers placed on the market after January 2013 have a power management system requiring the appliances to automatically switch from left-on-mode into off-mode (not exceeding 0.50 W) after each cycle after a certain time. The timeframe has not been further specified; according to stakeholder feedback, this is for example realised after 30 minutes. The power management for networked appliances switches the equipment automatically into a condition providing networked standby within 20 minutes, cf. next section.

1.2.1.1.3 Ecodesign Regulation (EC) No 801/2013 on networked standby

The Regulation (EC) No 801/2013 (European Commission 2013) establishes ecodesign requirements related to standby and off mode, and networked standby, electric power consumption for the placing on the market of electrical and electronic household and office equipment. In this context, “networked standby” means a condition in which the equipment is able to resume a function by way of a remotely initiated trigger from a network connection, i.e. a signal that comes from outside the equipment via a network. Thus, the Regulation applies to all dishwashers being connected to a network (“smart dishwashers”).

While Ecodesign Regulation 1275/2008 for standby and off mode requires a power management for all equipment other than networked equipment since 2013 (see section above), as of 1 January 2015 the following requirements apply to networked equipment (i.e. equipment that can connect to a network and has one or more network ports):

- Possibility of deactivating wireless network connection(s): Any networked equipment that can be connected to a wireless network shall offer the user the possibility to deactivate the wireless network connection(s). This requirement does not apply to products which rely on a single wireless network connection for intended use and have no wired network connection.
- Power management for networked equipment: Equipment shall, unless inappropriate for the intended use, offer a power management function or a similar function. When equipment is not providing a main function, and other energy-using product(s) are not dependent on its functions, the power management function shall switch equipment after the shortest possible period of time appropriate for the intended use of the equipment, automatically into a condition having networked standby. In a condition providing networked standby, the power management function may switch equipment automatically into standby mode or off mode or another condition which does not exceed the applicable power consumption requirements for standby and/or off mode as specified in Regulation (EC) 1275/2008. The power management function, or a similar function, shall be available for all network ports of the networked equipment. The power management function, or a similar function, shall be activated, unless all network ports are deactivated. In that latter case the power management function, or a similar function, shall be activated if any of the network ports is activated. The default period of time after which the power management function, or a similar function, switches the equipment automatically into a condition providing networked standby shall not exceed 20 minutes.

- Networked equipment that has one or more standby modes shall comply with the requirements for these standby mode(s)
  - when all network ports are deactivated (since 1 January 2015)
  - when all wired network ports are disconnected and when all wireless network ports are deactivated (from 1 January 2017).

- Networked equipment other than HiNA equipment shall comply with the provisions of 'power management for all equipment other than networked equipment'
  - when all network ports are deactivated (since 1 January 2015)
  - when all wired network ports are disconnected and when all wireless network ports are deactivated (from 1 January 2017).

- The power consumption of 'other' networked equipment (i.e. not HiNA equipment or equipment with HiNA functionality) in a condition providing networked standby into which the equipment is switched by the power management function, or a similar function,
  - shall not exceed 6.00 W (since 1 January 2015);
  - shall not exceed 3.00 W (from 1 January 2017);
  - shall not exceed 2.00 W (from 1 January 2019).

1.2.1.1.4 Ecodesign Regulation (EC) No 640/2009 for electric motors

Regulation (EC) No 640/2009 (European Commission 2009) sets ecodesign requirements for electric motors including where integrated in other products. The Regulation (EC) No 640/2009, however, does not cover all motor types being on the market. Therefore, preparatory study Lot 30 (Almeida et al. 2014),

finished in 2014 aimed at identifying the environmental improvement potential of products outside the scope of Regulation (EC) No 640/2009 on electric motors, such as:

- motors below 750 W and above 375 kW;
- special-purpose inverter duty motors (such as asynchronous servo motors);
- permanent magnet motors;
- motors cooled by their load (fans),
- drives, such as soft starters, torque or variable speed drives (VSD) from 200W–1 000kW.

Motors are also integral part of household dishwashers. With the extension of the Ecodesign Regulation 640/2009 to motors below 750 W, asynchronous inverter motors and permanent magnet motors, household dishwashers would indirectly also be affected (cf. also section 4.1.4.2).
On 29 April 2015, an Ecodesign horizontal matters consultation forum meeting took place in Brussels. A discussion paper on Ecodesign for energy-related products integrated into other energy-related products was released pointed out the situation that faces electric motors which either may be sold as "stand alone" products, or integrated in other energy-related products such as dishwashers. The discussion paper informs that

> *It has been claimed by some manufacturers of final products incorporating other energy-related products that setting minimum requirements for components might have a negative impact on the lifecycle cost (LCC) of the final products and that it is necessary to allow manufacturers flexibility in deciding the best combination of 'measures' to meet the Ecodesign requirements for the final product (or to achieve a higher energy efficiency class).*
>
> *It has to be noted that from a technical point of view, so far no evidence has been presented showing that the use of more efficient components leads to a lower energy efficiency of the final product. In reality, most of the time very efficient products are combinations of very efficient components put together in an appropriate way.*
>
> *In fact, ecodesign requirements only remove the worst performing products from the market, leaving enough choice for final equipment manufacturers to integrate components allowing them to meet their design requirements including the minimum energy efficiency requirements set by a specific ecodesign measure.*
>
> *The results of a LCC analysis depend on the underlying assumptions regarding production costs, energy use, cost and hours of operation. If the assumptions regarding these parameters are set appropriately, the use of a more efficient component 'automatically' leads to a more efficient final product. Nevertheless, as "base cases" are abstractions of reality, not all the specific uses of equipment can be captured. For instance, the assumptions regarding the use of small motors need to reflect the "typical" use of a motor in different products (ranging from domestic washing machines and fridges to commercial chillers or industrial machine tools), the operating hours of which are all different .Moreover, the same applies to the different ways in which a final consumer may operate a (fairly homogeneous) product such as a washing machine, resulting in different LCC in reality. As an example, the preparatory study on the review of the motor Regulation assumed 400 running hours per year for small single phase motors which is line with the assumptions usually made regarding the use of domestic appliances. In reality, these running hours may differ for certain products and use patterns.*

The discussion paper concludes that

> *It may also lead to higher cost of the final product but if the requirements are correctly set, they will still be at the point of least LCC. Manufacturers may have less flexibility to decide what design measures to take.*

1.2.1.1.5 Ecodesign preparatory study on smart appliances (ENER Lot 33, ongoing)

This study (Vito NV 2015) will provide the European Commission with an analysis of all technical, economic, environmental, market and societal aspects that are relevant for a broad market introduction of smart appliances. The study started effectively in the autumn of 2014 and is expected to be finished in September 2016. A first discussion note has been published, presented and discussed at the first stakeholder meeting in March 2015. Initial information on the expected scope of the study, standardisation activities at EU level (cf. section 1.2.2.6), interoperability (i.e. the link between the individual appliance and the supply side) and options to reduce the interoperability gaps have been presented.

According to (VITO et al. 2015), the overall idea of a smart grid with smart appliances is to achieve a better balancing of energy supply and energy demand while accommodating more renewable energy and reducing peak load power generation. Flexibility of the energy demand is obtained through smart appliances for which the energy consumption load patterns can be shifted with acceptable user impact. The load shifting can take place when needed – typically at power peaks and times with renewable energy power surplus – and in accordance with the agreements with the consumers. (VITO et al. 2015) informs that the shifting of the energy consumption load patterns typically takes place through:

- Control signals from the power system as direct appliance control (start, stop, modulate load etc.) after an agreement with the consumer.
- Price signals that the appliance can react on according to consumer settings.
- Appliances with internal voltage and/or frequency measurement and control, where the appliances switch on/off or modulate the consumption in function of those measurements and according to consumer settings.

One of the use case examples chosen in the preparatory study Lot 33 is a variable pricing support by a washing machine. According to (VITO et al. 2015), in this use case, the user has an electricity contract based on variable prices, e.g., prices based on the day ahead energy market. Those prices are directly downloaded to the washing machine, which has a communication interface that supports the used pricing scheme and which is equipped with dynamic pricing scheduling logic. When the user configures the machine, he/she sets a deadline when the laundry should be finished the latest, and the washing machine then automatically starts the washing programme such, that the total energy price for the programme is cheapest, while the laundry is still finished in time. The washing machine may also give indications via its user interface to the user on when the cheapest and/or highest prices occur, such that the user can take this into account during configuration.

The same principle might also apply to household dishwashers. For further details, please refer to the dedicated website http://www.eco-smartappliances.eu.

1.2.1.2 Energy efficiency and performance legislations for dishwashers

1.2.1.2.1 Energy Labelling Regulation (EC) No 1059/2010 for household dishwashers

Based on Directive 2010/30/EU with regard to labelling of energy-related products, the Regulation (EC) No 1059/2010 with regard to energy labelling of household dishwashers came into force in 2011. It describes the uniform design and content of the new energy label that shall be used for the declaration of performance characteristics from 20.12.2011 on. Thereby Directive 97/17/EC implementing Council Directive 92/75/EEC with regard to energy labelling of household dishwashers, which was the basis for the design and content of the former energy label, is repealed. Regulation (EC) No 1059/2010 states that all declared values need to be determined by reliable, accurate and reproducible measurement methods under consideration of the state of the art and technological progress.

The current energy label has a multilingual design, displays energy efficiency classes from A^{+++} to D, the annual energy consumption, annual water consumption, drying efficiency class, load capacity and noise emission. The energy efficiency classes E, F, and G, which were displayed on the label until 2011, are omitted. The cleaning efficiency is not declared on the label and consumption values of a single cycle are

replaced by annual consumption values. Sizes and colours for all elements and declarations are prescribed in detail, as well as formulas to calculate annual consumptions, efficiency indices and tables that indicate minimum and maximum values for efficiency classes of energy and drying.
The allocation of individual machines to the efficiency classes A^{+++} to D is done in accordance with the given scheme (Table 1.5).

Table 1.5: Energy efficiency classes for household dishwashers (European Commission 2010)

Energy efficiency class	Energy Efficiency Index (EEI)
A^{+++}	EEI < 50
A^{++}	50 ≤ EEI < 56
A^{+}	56 ≤ EEI < 63
A	63 ≤ EEI < 71
B	71 ≤ EEI < 80
C	80 ≤ EEI < 90
D	EEI ≥ 90

In order to classify an appliance, the Energy Efficiency Index (EEI) is calculated according to equation 1-1:

$$EEI = \frac{AE_C}{SAE_C} \times 100$$ **Equation 1-1**

where: AE_C = annual energy consumption of the household dishwasher
SAE_C = standard annual energy consumption of the household dishwasher
As shown in Equation 1-2, AE_C results from the energy consumption of the standard test programme plus the power consumption of left-on mode and off mode, each of them taken into account to 50% percent, where no power management is present. A usage frequency of 280 cycles per year is assumed for the calculation of EEI and annual consumption of energy and water.

$$AE_C = E_t \times 280 + \frac{\left[P_o \times \frac{525600 - (T_t \times 280)}{2} + P_l \times \frac{525600 - (T_t \times 280)}{2}\right]}{60 \times 1000}$$ **Equation 1-2**

Where
E_t = energy consumption for the standard cycle, in kWh and rounded to three decimal places
P_l = power in 'left-on mode' for the standard cleaning cycle, in W and rounded to two decimal places
P_o = power in 'off mode' for the standard cleaning cycle, in W and rounded to two decimal places
T_t = programme time for the standard cleaning cycle, in minutes and rounded to the nearest minute
Since January 2013, according to the second tier of the Regulation (EC) No1275/2008 for standby and off-mode, all household dishwashers have to be equipped with a power management system, with the household dishwasher reverting automatically to 'off-mode' after the end of the programme. Therefore, another equation, established in Regulation (EC) No 1059/2010, is applied for calculating the AE_c, taking into consideration the effective duration of 'left-on mode'.

$$AE_C = E_t \times 280 + \frac{\{P_l \times T_l \times 280 + P_o \times [525600 - (T_t \times 280) - (T_l \times 280)]\}}{60 \times 1000}$$ **Equation 1-3**

Where
T_l = measured time in 'left-on mode' for the standard cleaning cycle, in minutes and rounded to the nearest minute.

Exemplary calculation of annual standby and off-mode consumption

T_l = 30 minutes before automatically reverting into off-mode by the power management system, assumed as maximum scenario
Tt = 180 minutes programme time for the standard cleaning cycle
P_l = 0.5 to 5 W, the latter assumed as maximum scenario
P_0 = 0.1 to 0.5 W, the latter being the maximum value according to Regulation (EC) No 1275/2008
Assuming the values above, the annual energy consumption of only the standby- and off-mode would sum up to 0.85 kWh/year to maximum 4.6 kWh/year.

The SAE_C is indicated in kWh/ year and depends on the rated capacity and the width of the dishwasher. For dishwashers with a rated capacity of 10 ps or more and a width of more than 50 cm:

$$SAE_C = 7{,}0 \times ps + 378 \qquad \textbf{Equation 1-4}$$

For dishwashers with a rated capacity of 9 ps or less and a width of 50 cm or less:

$$SAE_C = 25{,}2 \times ps + 126 \qquad \textbf{Equation 1-5}$$

The annual water consumption (AW_C) is given by the water consumption of the standard cleaning cycle (W_t) and the usage frequency of 280 cycles per year:

$$AW_C = W_t \times 280 \qquad \textbf{Equation 1-6}$$

Tolerances for all measurement parameters are given, to define to what extent declared values are allowed to deviate from values from the verification tests (Table 1.6). (Please note: further standardisation activities on tolerances and resulting recommendations are provided in sections 1.2.2.6 and 1.4)

Table 1.6: Verification tolerances for household dishwashers (European Commission 2010)

Measured Parameter	Verification tolerances
Annual energy consumption	The measured value shall not be greater than the rated value(*) of AE_C by more than 10%
Water consumption	The measured value shall not be greater than the rated value(*) of W_t by more than 10%
Drying efficiency index	The measured value shall not be greater than the rated value(*) of I_D by more than 10%
Energy consumption	The measured value shall not be greater than the rated value(*) of E_t by more than 10%
Programme time	The measured value shall not be greater than the rated value(*) of T_t by more than 10%
Power consumption in off-mode and left-on mode	The measured value of power consumption P_o and P_l of more than 1.00 W shall not be greater than the rated value by more than 10%. The measured value of power consumption P_o and P_l of less than 1.00 W shall not be greater than the rated value by more than 0.10 W.
Duration of left-on mode	The value measured shall not be longer than the rated value of T_l by more than 10%
Airborne acoustical noise	The measured value shall meet the rated value.
(*) 'Rated value' means a value declared by the supplier.	

Further annexes prescribe obligatory information for product fiche, technical documentation, distribution and marketing.

1.2.1.2.2 Low Voltage Directive (LVD) 2014/35/EU

The purpose of this LVD Directive (European Parliament 2014) is to ensure that electrical equipment on the market fulfils the requirements providing for a high level of protection of health and safety of persons, and of domestic animals and property, while guaranteeing the functioning of the internal market. The Directive applies to electrical equipment designed for use with a voltage rating of between 50 and 1,000 V for alternating current and between 75 and 1,500 V for direct current, which is new to the Union market when it is placed on the market, i.e. it is either new electrical equipment made by a manufacturer established in the Union or electrical equipment, whether new or second-hand, imported from a third country. Also for household appliances, inter alia dishwashers, the Directive covers all health and safety risks related to low voltage electricity use, thus ensuring that these appliances will be used safely and in applications for which they were made.

Manufacturers of electrical equipment covered by the Directive are obliged to carry out the conformity assessment procedure. The CE marking, indicating the conformity of electrical equipment, is the visible consequence of a whole process comprising conformity assessment.

The new requirements under LVD 2014/35/EU will be applicable from 20 April 2016 and replace the former LVD 2006/95/EC.

1.2.1.2.3 Electromagnetic Compatibility Directive (ECD) 2014/30/EU

ECD 2014/30/EU (European Parliament 2014) aims to ensure the functioning of the internal market by requiring equipment to comply with an adequate level of electromagnetic compatibility, i.e. the ability of equipment to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to other equipment in that environment.

Equipment shall be so designed and manufactured, having regard to the state of the art, as to ensure that:

- the electromagnetic disturbance generated does not exceed the level above which radio and telecommunications equipment or other equipment cannot operate as intended;
- it has a level of immunity to the electromagnetic disturbance to be expected in its intended use which allows it to operate without unacceptable degradation of its intended use.

Manufacturers of equipment covered by the Directive are obliged to carry out the conformity assessment procedure. The CE marking, indicating the conformity of apparatus, is the visible consequence of a whole process comprising conformity assessment. Apparatus shall be accompanied by information on any specific precautions that must be taken when the apparatus is assembled, installed, maintained or used, in order to ensure that, when put into service, the apparatus is in conformity with the essential requirements set out in the Directive.

The new requirements under EMC 2014/30/EU will be applicable from 20 April 2016 and replace the former EMC Directive 2004/108/EU.

1.2.2 European standards, basis for ecodesign and energy efficiency legislation

The following table provides an overview of the European standards discussed in this section

Table 1.7: Overview of the European standards, basis for ecodesign and energy efficiency legislation

	European and international standards
Performance	EN 50242/EN 60436 "Electric dishwashers for household use – Methods for measuring the performance
	Future development for EN 50242/ EN 60436 Electric dishwashers for household use – Methods for measuring the performance
Standby	EN 50564:2011
Safety	EN 60335-1:2012 'Household and similar electrical appliances - Safety - Part 1: General requirements'
	EN 60335-2-5:2013 'Household and similar electrical appliances - Safety - Part 2-5: Particular requirements for dishwashers'
	EN 61770:2010: 'Electric appliances connected to the water mains - Avoidance of back-siphonage and failure of hose-sets'
Noise	EN 60704-1:2010+A11:2012. Household and similar electrical appliances. Test code for the determination of airborne noise. General requirements
	EN 60704-2-3:2002, IEC 60704-2-3:2001. Household and similar electrical appliances. Test code for the determination of airborne acoustical noise. Particular requirements for dishwashers
	EN 60704-3:2006. Household and similar electrical appliances. Test code for the determination of airborne acoustical noise. Procedure for determining and verifying declared noise emission values

1.2.2.1 Performance

1.2.2.1.1 EN 50242/EN 60436 "Electric dishwashers for household use – Methods for measuring the performance"

In 2008 the third edition of the European Standard EN 50242/EN 60436 "Electric dishwashers for household use – Methods for measuring the performance" was published, based on the text of the international standard IEC 60436:2004 for performance measurements on dishwashers, with common modifications prepared by the Technical Committee CENELEC TC 59X to address requirements of EU Directives. Double numbering was used as Directive 97/17/EC makes explicit reference to EN 50242 as measurement standard, while CENELEC rules require to use the number of the respective IEC standard when an international standard is harmonised for Europe.

These common modifications have been introduced to prescribe the test procedure more detailed and reduce flexibility that is given for tests according to IEC 60436. Modifications include:

- Use of hot water supply is not allowed
- Use of soft water is not allowed
- Use of US-style load is not allowed
- Detailed description of conditioning and re-conditioning procedure for test load
- Soils supplied by certain manufacturers
- Soiled dishes shall not be dried by the air drying method
- Cleaning performance rating for score 3 allows less soil residue
- Test machine disconnected from power supply at the end of a drying performance run

The EN 50242: 2008 and EN 50242:2008/A11:2012 are the harmonised standards to test the conformity of household dishwashers with the ecodesign requirements in Regulation (EU) No 1059/2010 (European Commission 2010). Measurements of energy and water consumption and performance values are conducted in accordance to EN 50242/ EN 60436 with the standard test programme that shall be declared "Eco". Cleaning performance, energy and water consumption are determined in tests, where tableware items of a specific shape, material and amount for reference and test machines are soiled according to the prescribed procedure with seven different foods (spinach, oat flakes, margarine, egg yolk, tea, milk and minced meat) and dried for 2 h at 80°C. The reference and test machines are run with these soiled and dried items and a defined amount of reference detergent. Simultaneously consumption values are monitored. The temperature, pressure and composition of the water inlet are defined in the standard as well as the ambient conditions and power supply. After the end of the programme each item is assessed and graded at defined luminescence in accordance with a given scheme with scores from 5 (clean) to 0 (dirty). From the means of consumption values and performance scores of five to eight cycles of reference and test machines the indices for energy efficiency and cleaning performance may be determined.
The drying index is the result from separate test cycles of reference and test machine with clean tableware items that are washed with reference detergent and assessed for water residue 30 minutes after the end of the programme, where the machine is disconnected from the power supply. The assessment and grading is conducted in accordance with a scheme of scores from 2 (dry) to 0 (two or more water drops, or extensive water residue).
In 2009 a new reference machine type 2, the G 1222, has been introduced and an alternate microwave oven (HMT 742C) has been established in IEC 60436:2004 by Amendment 1, and was established in EN 50242 by a Corrigendum. Additionally the fruit bowl by Arzberg was replaced by a dessert bowl "Corning" by Corelle. (IEC, 2009)
A Round Robin test (RRT) in 2009 revealed several inaccuracies in the standard that contributed to differing test conditions and results in the participating labs. The cleaning and drying efficiency classes varied in the 19 labs, the water inlet temperature of the machines scattered with three labs lying outside of the prescribed range. (Brückner & Stamminger 2011)
These findings were considered for the elaboration of an amendment. It is clarified that water from a bypass shall be decanted prior to starting the test run. For the porridge soiling a more detailed description was incorporated in the amendment, emphasising that continuous stirring of the porridge and the application of hot porridge is essential. The expanded uncertainties in the new, informative Annex Z2 were also derived from the test results of the Round Robin test. For verification purposes only the tolerances listed in Annex III of Regulation (EC) No. 1016/2010 are mandatory. Via Amendment A11 further changes were introduced in 2012: As a standard test programme the "Eco" programme shall be used, which has to be declared on the user panel. The cutlery for testing from series "Berlin" is replaced by the series "Signum" and the knife from "Gastro". The measurement of standby power consumptions are prescribed in the new, normative Annex O "Additional aspects of energy consumption of dishwashers".
A test template in Annex Z1 provides a basis for the documentation of test results und contains all parameters that shall be measured to be compliant with Regulation (EC) No. 1059/2010, Regulation (EC) No. 1016/2010 and Regulation (EC) No. 1275/2008.

1.2.2.1.2 Future development for EN 50242/ EN 60436 Electric dishwashers for household use – Methods for measuring the performance"

The future 4th Edition of IEC 60436 is the basis for the next edition of EN 50242/ EN 60436. By adopting the new test load, described in 1.2.5.1, with a higher variety of shapes and materials, the combined assessment procedure for cleaning and drying performance, the new reference detergent, test procedures for automatic programmes, rinsing performance and other relevant changes of the international standard in Europe, the European Standard can take a big step forward towards consumer convenience and household relevance. Direct comparison of results before and after these modifications should be evaluated with care.

1.2.2.2 Standby

By Mandate 481 it is requested to include methods in the test standards for the determination of low power modes, where the appliance is not fulfilling its main function.

The standby consumption of household electrical appliances is measured according to the European standard EN 50564:2011 including the common modification agreed at European level to the international standard IEC 62301:2011, prepared by Technical Committee CENELEC TC59X.

EN 50564 specifies methods of measurement of electrical power consumption in standby mode. It is applicable to mains powered electrical household appliances or equipment and to the mains powered parts of appliances that use other fuels such as gas or oil. It does not specify minimum performance requirements nor does it set maximum limits on power or energy consumption. The objective of the standard is to provide a method of test to determine the power consumption of a range of appliances and equipment in standby mode (generally where the product is not performing its main function). The test method is also applicable to other low power modes where the mode is steady state or providing a background or secondary function (e.g. monitoring or display). In this case, the relevant low power modes (in addition to standby mode) to which the test procedure is applied should be defined by performance standards of appropriate appliances. The power consumption is determined by recording the instrument power reading where the power value is stable or by averaging the instrument power readings over a specified period or by recording the energy consumption over a specified period and dividing by the time where the power value is not stable. The time period is not less than 5 minutes, except if there is an operating cycle. The general conditions for measurement (including test room description, power supply, supply voltage waveform, power measurement accuracy) the selection and preparation of the appliance, the measurement procedure where the power value is stable and the test report (including appliance details, test parameters, measured data, test and laboratory details) are described. General conditions about test conditions and equipment are applied unless otherwise specified.

Annex A about 'Guidance on modes and functions for selected appliance types' is void. The standard does not define these modes, as these definitions are part of the individual Regulations and performance standards for dishwashers, washing machines and washer-dryers.
Annex B (informative) provides some guidance regarding the measurement of low power modes. The Crest Factor and its influence on the measurements are explained and the specifications and setup of measurement instrumentation are described.
Annex C (informative) provides some guidance regarding the conversion of power measurements determined under the standard to energy consumption values. To convert power to energy (e.g. an annual energy consumption), the number of hours of operation in each mode must be assumed for a given period and the average power for each mode must also be known. As most appliances can operate in a number of modes and the usage patterns and profiles may vary considerably between countries, converting power values determined under this standard to energy values is potentially fraught with difficulty.
Finally, Annex D provides information on the determination of uncertainty of measurement. To be meaningful, the uncertainty statement must have an associated confidence level: i.e. it is necessary to state the probability that the true value lies within the range given. A 95 % confidence level was chosen in the standard.

1.2.2.2.1 Standby for Dishwasher

The sequence and approach of the measurements for off mode and left-on mode power are given by Annex O "Additional aspects of energy consumption of dishwashers" in EN 50242/EN 60436, which was established in 2012 via Amendment 11. For the determination of left-on mode power the door of the appliance is opened within 5 min after the end of the programme without switching off the appliance, and the power measurement is started.
The power consumption is recorded for 30 min for dishwashers without a power management system. However, since January 2013 a power management system is mandatory for all household dishwashers according to Regulation (EC) No 1275/2008 (cf. section 1.2.1.1). Thus, for appliances that are reverted to

off-mode automatically by a power management system, the power consumption is recorded for the period between opening the door and switching to off mode. The result is indicated as the mean value of the measured data gained during one test run..
Off mode power is measured, after the measurement of left on mode power (Figure 1.1). The appliance is switched off manually or automatically and the power consumption is recorded for 10 min. The result is indicated as mean value of the measured data. (3.1, EN 50424/ EN 60436 Edition 2012)

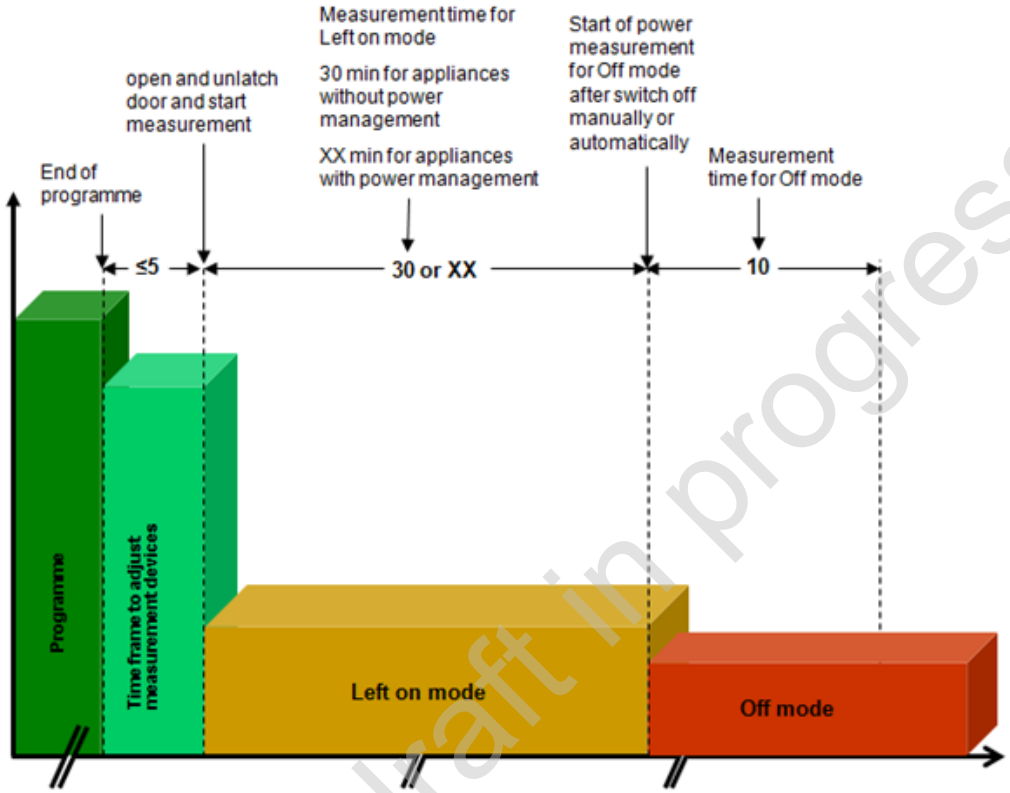

Figure 1.1: Measurement procedure for the low power modes (left on mode and off mode)

1.2.2.3 Safety

Safety for dishwashing appliances is mainly dealt with by the following standards:

- The general part EN 60335-1:2012 'Household and similar electrical appliances - Safety - Part 1: General requirements' that is common to all the electric motor appliances and a set of Part 2 documents addressing the different specific products;
- For dishwashers, EN 60335-2-5:2013 'Household and similar electrical appliances - Safety - Part 2-5: Particular requirements for dishwashers' applies;
- EN 61770:2010: 'Electric appliances connected to the water mains - Avoidance of back-siphonage and failure of hose-sets' as far as the connection with the water supply is concerned.

The mentioned standards address and implement an internationally accepted level of protection against hazards (such as electrical, mechanical, thermal, fire and radiation) when appliances are operated as in normal use, taking into account the manufacturer's instructions. The same standards cover also protection against further hazards deriving from abnormal situations that can be expected to happen during normal use.

It has been assumed in the drafting of these international standards that the execution of its provisions is entrusted to appropriately qualified and experienced persons.

The standards take into account the requirements of IEC 60364 'Low-voltage electrical installations – Part 1: Fundamental principles, assessment of general characteristics' as far as possible so that there is compatibility with the wiring rules when the appliance is connected to the supply mains. However, national wiring rules may differ.

Individual countries may wish to consider the application of the standard, as far as is reasonable, to appliances not mentioned in a part 2, and to appliances designed on new principles.

An appliance that complies with the text of this standard will not necessarily be considered to comply with the safety principles of the standard if, when examined and tested, it is found to have other features which impair the level of safety covered by these requirements.

An appliance employing materials or having forms of construction differing from those detailed in the requirements of this standard may be examined and tested according to the intent of the requirements and, if found to be substantially equivalent, may be considered to comply with the standard.

The principal objectives of the Low Voltage Directive, 2006/95/EC, are covered by these standards. The essential safety requirements of the following directives, which can be applicable to some household and similar appliances, have also been taken into account:

- 2006/42/EC – Machinery directive;
- 89/106/EEC – Construction products directive;
- 97/23/EC – Pressure equipment directive.

The Essential Health and Safety Requirements (EHSR) of the Directive 2006/42/EC are covered by Annex ZE. The application of EN 60335-1 alone does not give presumption of conformity for a product. This is achieved by complying with the requirements of EN 60335-1 and the relevant Part 2.

1.2.2.4 Noise

1.2.2.4.1 General requirements for noise measurement

In general, noise is measured according to the specifications prepared by IEC TC59 and transferred to Europe between IEC and CENELEC. For noise measurements on dishwasher the relevant standards are

EN 60704-1:2010+A11:2012. 'Household and similar electrical appliances. Test code for the de-termination of airborne noise. General requirements'', prepared by CENELEC technical committee TC59X.

EN 60704-2-3:2002, IEC 60704-2-3:2001. 'Household and similar electrical appliances. Test code for the determination of airborne acoustical noise. Particular requirements for dishwashers'. This part 2 addresses the specific test conditions for dishwashers.

Part 3 as EN 60704-3:2006. 'Household and similar electrical appliances. Test code for the determination of airborne acoustical noise. Procedure for determining and verifying declared noise emission values' describes the procedure for verification of any noise declaration and gives values of standard deviations of reproducibility for different categories of appliances.

EN 60704-1 permits the use of "special reverberation test rooms", "hard-walled test rooms" and "free field conditions over reflecting plane" for the measurement of the sound power level of the appliance based on acoustic measuring methods described in ISO 3743-1, ISO 3743-2 and ISO 3744. Within the measuring uncertainty specific to the three possible methods described in the standard, the results from the determination under free-field conditions over a reflecting plane are equal to those obtained in reverberant fields. This standard is concerned with airborne noise only, while in some cases, structure-borne noise may be of importance, e.g. transmitted to the adjoining room or from valves and water pipes not recorded in a test according to EN 60704-2-3.

A classification of different types of noise is given in ISO 12001. The methods specified in the mentioned ISO standards are suitable for all types of noise, except for sources of impulsive noise consisting of short duration noise bursts, taken into account in Parts 2.
Part 1 of EN 60704 applies to electric appliances (including their accessories or components) for household and similar use, supplied from mains or from batteries. By 'similar use' is understood the use in similar conditions as in households, for example in inns, coffee-houses, tea-rooms, hotels, barber or hairdresser shops, launderettes, etc., if not otherwise specified in Part 2. It does not apply to appliances, equipment or machines designed exclusively for industrial or professional purposes, appliances which are integrated parts of a building or its installations, such as equipment for air conditioning, heating and ventilating (with some exceptions) oil burners for central heating, pumps for water supply and for sewage systems, separate motors or generators and appliances for outdoor use.
Generally, the determination of noise levels is only part of a comprehensive testing procedure covering many aspects of the properties and performances of the appliance. When preparing the standard it was therefore considered important to keep at a modest level the requirements for noise measurements such as test environment, instrumentation, and amount of labour involved; this resulted in Part 1 methods with an "engineering accuracy" (or "grade 2" according to ISO 12001).
The resulting airborne acoustical noise is measured as sound power levels (L_W), expressed in decibels (dB) with reference to a sound power of one picowatt (1 pW), within the specified frequency range of interest (generally including the octave bands with centre frequencies from 125 Hz to 8,000 Hz), and for prescribed operating conditions of the appliance to be measured.
The estimated values of the standard deviations of reproducibility of sound power levels determined according to Part 1 are given in ISO 3743-1, ISO 3743-2, and in ISO 3744.

1.2.2.4.2 Specific requirements for dishwashers IEC (EN) 60704-2-3, Edition 2.1 (including Amendment 1)

Household and similar electrical appliances - Test code for the determination of airborne acoustical noise - Part 2-3: Particular requirements for dishwashers", has been published in August 2001 and amended in 2005.
These particular requirements apply to single-unit electric dishwashers for household and similar use, with or without automatic programme control, for cold and/or hot water supply, for detachable or permanent connection to water supply or sewage systems, intended for placing on the floor against a wall, for building-in or placing under a counter, a kitchen worktop or under a sink, for wall-mounting or on a counter.
The measuring conditions specified in this Part 2-3 provide sufficient accuracy in determining the noise emitted, and in comparing the results of measurements taken by different laboratories, whilst simulating as far as possible the practical use of dishwashers. In practice, to avoid unsteadiness caused by foaming, the tests are carried out with unsoiled loads and without detergents or rinsing aids. Compared to the first edition (1987) of this Part 2, this second edition additionally considers the noise of water supply, drainage, pre-wash and intermediate rinse.

1.2.2.4.3 Future development for IEC (EN) 60704-2-3, 3rd edition

Mandate 481 from 2011 and Regulation (EC) No. 1059/2010 request a method for the determination of airborne acoustical noise emissions. Corresponding to the requirements for performance measurements, the method shall be designed in a way that does not enable the test machine to detect the running of a test cycle and to adjust the programme course accordingly. (EN M/481 2011)
To be in line with the requirements of the Mandate, a new test procedure was elaborated and revised to be incorporated in the 3rd committee draft of IEC (EN) 60704-2-3 in 2014. The standard test programme for noise measurements is the same programme as used for measuring the cleaning performance, the drying performance and energy and water consumption, according to IEC 60436.
The standard test load for noise measurements is the load according IEC 60436. It consists of the whole number of complete ps plus the corresponding serving pieces, which together comprise the manufacturer's rated capacity. The standard test load includes one glass filled with frozen artificial soil. Apart from this glass the standard test load shall be unsoiled.

The artificial soil shall be prepared from UHT (ultra heat treated) milk with a fat content of 3.5 %. Glasses shall be filled with 200 ml artificial soil and frozen for at least 48 h in a four-star froze compartment according to IEC 62552-1. The intention behind the application of ballast soil is to simulate a soiled load and to have an effect on potential turbidity sensors. Detergent shall not be dosed; the containers for salt and rinse aid are filled and the dosage is adjusted to the setting with the smallest amount.
Compared to the second edition (2001) of this Part 2-3, the third edition does not contain the description of an appropriate test enclosure which has been incorporated in Part 1. The description of the test enclosure, which shall be installed as housing for built-in and integrated dishwashers, is included as normative annex in IEC 60436. Furthermore the values of standard deviations of sound power levels determined according to this part are given.

1.2.2.5 Uncertainty, tolerance, repeatability and reproducibility

To encourage the efficient use of energy and other resources, the European Parliament and Commission have issued regulations, which mandate the provision of information to consumers or sets up essential requirements. This information is conveyed by label obligations according EU Label Directive 2010/30/EU and Ecodesign requirements according EU Energy Related Products Directive (2009/125/EC). According this regulation the information has to be provided at point of sale or in the manuals by manufacturers. EU Mandates may be issued in order to cover these obligations.

Methods for measuring of resource consumptions and performance characteristics must be of sufficient accuracy to provide confidence to governments, consumers and manufacturers. The accuracy of a test method is expressed in terms of bias and precision. Precision, when evaluating test methods, is expressed in terms of two measurement concepts: repeatability (intra-laboratory variability) and reproducibility (inter-laboratory variability). Therefore, standard procedures are required for determining the repeatability and the reproducibility of test methods developed by technical committee and its subcommittees. The repeatability of a test method must be sufficiently accurate for comparative testing. The reproducibility of a test method must be sufficiently accurate for the determination of values which are declared and for checking these declared values.

Uncertainty reporting is essential to ensure measured data are interpreted in a correct way. Especially when data of measurements are to be compared between laboratories or when normative requirements are set up, it is necessary to know the uncertainty with which data can be measured. Measurement uncertainty is unavoidable always a combination of the variance of the product itself and the measurement method applied. This is subject of the measurement standard only. It should not be confused with production variation which in contrast is the very own responsibility of the manufacturer.

The Market Surveillance Authorities have the responsibility for verifying the information given at the point of sale or requested by eco-design measures and they do this by carrying out an independent set of measurements with other test sample(s). Both sets of measurements are subject to the uncontrollable factors described above. In addition to the product to product variation these uncontrollable factors will contribute to possible differences between the measurement result and what was declared by the manufacturer. Verification tolerances given in the regulations are supposed to consider these possible differences to ensure correct judgement of the compliance of the product under verification. A false judgement of non-compliance could have severe consequences (withdraw from market, fines, etc) for the manufacturer.

1.2.2.6 Additional standardisation activities

1.2.2.6.1 Avoiding test cycle recognition

Via Mandate 481 CEN, CENELEC and ETSI are requested to provide methods for the measurement of energy and water consumption, programme time, low power mode power consumption and noise emission. For this purpose accurate definitions shall be specified.
The described methods shall be designed in a way that does not allow the appliance to react to certain events during the test cycle and adjust the programme course accordingly. For the design of testing

procedures, both technical progress and actual consumer habits shall be taken into account. (EN M/481 2011)
In response to Mandate 481 a new test procedure is under development by combining the cleaning performance tests with the drying performance tests, corresponding to the situation in the households (named CCD – combined cleaning and drying). Based on the current method, the test procedure is modified in a way enabling the determination of cleaning performance, drying performance and energy and water consumption values within the same test cycle. The test procedures are combined by incorporating a period of 30 min after the completion of the programme, which is part of the current drying performance tests, in the method for measuring energy and water consumption values and cleaning performance.
With this new method the tableware items are soiled according to the standard and cleaned in the test programme, while consumption values are monitored. After the end of the programme the machine is disconnected from the supply and left undisturbed for 30 min. After these 30 min the drying performance of each item is assessed carefully, without relocating or removing soil residue. When the drying performance assessment is completed, the cleaning performance assessment can commence. The procedure is also part of the future IEC 60436. (IEC 60436 4th Edition, FDIS 2015)
With this method the requirements of the Regulation (EC) No 1059/2010 and Mandate 481 are fulfilled and the behaviour of the users in households is reflected in a better way as outlined in section 1.2.5.1 and 3.1.
The implementation of the new procedure is still ongoing. The target date for vote to approve the future edition of EN 50242/ EN 60436 is 30th January 2016 (CENELEC 2015). Additionally a combined CENELEC and CECED Round Robin Test (RRT) is performed with 20 labs from all over Europe, comparing the current method to the prospective procedure. (CECED 2014)

1.2.2.6.2 Uncertainty and tolerances

CENELEC TC59X WG16 "Uncertainty and tolerances" has taken up the initiative of IEC 59D and elaborated an internal document TC59X/(Sec.)0554/INF "Household and similar appliances – Method for calculation of uncertainty of measurements" for all working groups under CLC TC59X "Household and similar Appliances" asking for the reporting of expanded uncertainty values for all measurements defined in their standards.
However, assessing the expanded uncertainty will, in many cases, only be possible after a RRT. The analysis of these results provides data for the determination of the repeatability and reproducibility of the relevant measurement. How to perform such a RRT is also described in a technical report (CLC/TR 50619:2013 "Guidance on how to conduct Round Robin Tests"). Another informative document of CLC 59X (TC59X/ (Sec)0597/INF "Application of measurement uncertainty in setting verification tolerances") has been released in May 2014, where the relation of the expanded uncertainties, as a characteristic value of the measurement to the political issue of how tolerances are set, is explained.

1.2.2.6.3 Demand response appliances (smart appliances): overview on standardisation activities in Europe

In order to promote European Smart Grid deployment, several measures have been taken by the European Commission. In 2011, the EC issued the Standardisation Mandate 490 to European Standardisation Organizations (ESOs) to support European Smart Grid deployment. To accomplish this task, a Joint Working Group (SG-CG) has been created by the three ESOs: CEN CENELEC and ETSI. The aim was a set of consistent standards which will support the information exchange and the integration of all users into the electric system operation. The mandate's reports were finalised by the end of 2014.
Currently, the Preparatory Study on Smart Appliances (VITO, 2015) is carried out for DG Energy under framework contract ENER.C3.2012-418-lot 1. The preparatory study analyses all technical, economic, environmental, market and societal aspects that are relevant for a broad market introduction of smart appliances (cf. section 1.2.1.1).
In the following paragraphs, the most relevant standardisation activities in view of demand response appliances will be summarised:
SG-CG developed a generic functional architecture for the flexibility use cases, which is represented in Figure 1.2.

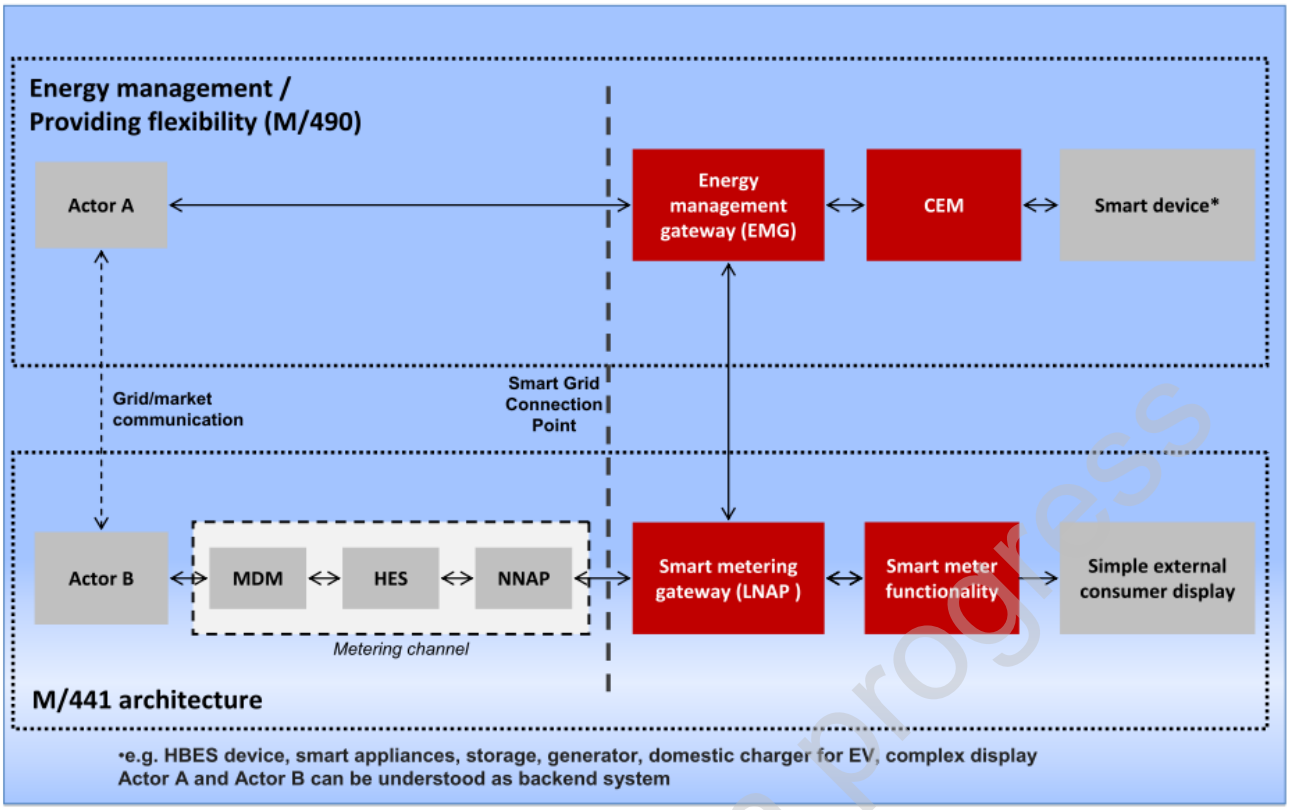

Figure 1.2 Flexibility functional architecture (CENELEC 2012)

In this architecture, the Customer Energy Manager (CEM) provides the flexibility of connected smart devices, through the Energy Management Gateway (EMG). The EMG communicates with the metering channel and the smart meter functionality through the Smart Metering Gateway. The gateways in this architecture split different networks and may be integrated with other functional entities. As the actors of this architecture are functional/logical entities, some of them may be part of the same physical device.

Standardisation aspects concerning smart meter interface are currently handled by IEC/TC 13 "Equipment for electrical energy measurement and load control", CEN/TC 294 "Communication systems for meters and remote reading of meters", CLC/TC 205 "Home and Building Electronic Systems (HBES)" and IEC/TC 57 "Power systems management and associated information exchange". The most relevant standards developed in this field are the IEC 62056 series covering the exchange of consumption information registered in the electricity meter and the transfer of demand response related data (e.g. tariff information, power limitation, prepayment settings). EN 13757 series are the corresponding standards with focus on non-electricity meters (e.g. gas, water and heat). IEC 62056-7-5 standard covers the unidirectional data transfer from a meter to an external device (e.g. consumer display). prEN 50491-11 concerns Smart Metering - Application Specifications in view of simple external consumer display, prEN 50491-12 Smart grid - Application specification concerning interface and framework for customer.

Standardisation activities related to smart appliances and smart home interoperability are handled by IEC/TC 57 WG 21 "Interfaces and protocol profiles relevant for systems connected to the electrical grid", IEC/TC 59 WG 15 "Connection of household appliances to smart grids and appliances interaction" and CLC/TC 59x WG 7 "Smart household appliances". Data definitions for demand response and functionalities (Use Cases) are provided in IEC TR 62746. In IEC TR 62476-2, use cases and requirements for Smart Grid/Smart Home are listed covering for example the provision of energy consumption information, controlling smart appliances, charging of electric vehicles, battery management and consumer offering flexibility. The focus of IEC/TS 62950 "Household and similar electrical appliances - Specifying and testing smart capabilities of smart appliances – General aspects" is on the development of a common architecture that applies to different appliance types and use cases. Moreover, general aspects of measuring smart performance within the context of the common architecture are addressed. prEn 50631

"Home network and smart grid connectivity" deals with the improvement of functionalities of domestic appliances through the use of network communication (e.g. smart grid, smart home or home network).

1.2.3 European and national ecolabels – focus energy and performance criteria

Note: This section only presents the energy and performance criteria of existing European and national ecolabels for dishwashers. Resource related criteria are presented separately in section 1.3.2.

In the preparatory study for ecodesign requirements Lot 14 on domestic dishwashers and washing machines, Task 1 on definitions (ENEA/ISIS 2007a), the following European policy instruments and measures were described:

Table 1.8: Overview of the European and national Ecolabels of relevance for dishwashers

Scheme	Still valid?	Comments
Voluntary Industry Commitment on Reducing Energy Consumption of Household Dishwashers	No, valid until 2004	
EU Ecolabel for dishwashers	No, valid until 2007	
Nordic Swan (for washing machines only)	yes	cf. section 1.2.3.1
Czech Environmentally Friendly Products label for dishwashers	no	
Swedish "Environmental Product Declaration (EPD) scheme for washing machines and dishwashers for household use"	No, until September 2004	cf. http://epdsystem.it/en/PCR/Detail/?Pcr=5656).
UK Energy Saving Trust Recommended described in Lot 14 (ENEA/ISIS 2007a)		UK-based labelling and certification scheme for energy efficient products. The logo could be used by manufacturers, retailers and suppliers to signpost consumers to best-in-class energy efficient products. Today, the Energy Saving Trust no longer awards a "Recommended" certification. Nowadays, for dishwashers, eight models of two manufacturers are currently listed as "verified", i.e. "Verified by Energy Saving Trust" (manufacturers can enhance the credibility of their claims concerning the energy efficiency of their products with a product verification service) (Energy Saving Trust n.d.)
Blue Angel Environmental Label for Household Dishwashers (RAL-UZ 152)	Yes, valid until Dec 2016	cf. section 1.2.3.2

On 12 March 2015, however, the EPD secretariat has launched a call for product category rules (PCR) moderators with interest to update these expired product category rules (cf. http://www.environdec.com/en/News-archive/).

1.2.3.1 Nordic countries: Nordic ecolabelling of white goods

In September 2014, version 5.0 of the Nordic Ecolabelling requirements for white goods (refrigerators and freezers, dishwashers, washing machines and tumble dryers) has been published, valid from 20 June

2013 to 30 June 2017. Gas-powered appliances are not in the scope of this criteria document. (Nordic Ecolabelling 2014)
Criteria are referring to the manufacture and to the operation of the white goods. Further, there are specific product requirements for each of the product categories, and criteria on customer information as well as quality and regulatory requirements. The following energy efficiency and performance criteria apply to dishwashers:

Table 1.9: Nordic ecolabelling: performance-related criteria for dishwashers; source: (Nordic Ecolabelling 2014)

Criteria category	Requirements
Operation requirements for dishwashers	
Energy efficiency	Dishwashers must achieve energy efficiency class A+++ or better in accordance with the applicable Energy Labelling Regulation.
Noise	Maximum limit for airborne noise of dishwashers: 44 dB(A)
Specific product requirements for dishwashers	
Water consumption	Maximum of 1.0 litre of water per ps
Cleaning performance	Meet the requirements for cleaning performance stated in Regulation 1016/2010
Drying performance	Meet the requirements for drying performance stated in Regulation 1016/2010
Requirements on customer information for dishwashers	
Installation and user instructions for dishwashers	Inter alia Information on the dishwasher's consumption of energy and water at different temperatures and with different load sizes, so that the consumer can select the appropriate programme for minimum energy and water consumption. It is to be made clear that the Nordic Ecolabelling requirements are fulfilled by the recommended normal programme. Information on how long the different programmes take.

1.2.3.2 Germany: Blue Angel Environmental Label for Household Dishwashers (RAL-UZ 152)

In February 2013, basic criteria for award of the German environmental label "Blue Angel" have been published for household dishwashers, being valid until December 2016. (Ral gGmbH 2013)
According to the Blue Angel ecolabel for dishwashers may be awarded to appliances with the following environmental properties: low energy and water consumption, use of time-variable power supply, low noise emissions, long-lived and recyclable design, and avoidance of harmful substances. Besides consumption criteria (energy and water), the Blue Angel Ecolabel further sets performance criteria on drying efficiency and noise emissions, requirements on materials (prohibition of certain hazardous substances and biocidal silver, requirements for insulation materials), and finally criteria facilitating repairs (spare parts) and recycling.
The detailed energy efficiency and performance criteria are as follows (Ral gGmbH 2013):
Energy Efficiency
The appliances shall at least meet the following energy efficiency ratings in accordance with Regulation (EC) No 1059/2010 relating to household dishwashers:

- Dishwashers > 45 cm wide: Energy efficiency class „A+++" (EEI < 50)
- Dishwashers ≤ 45 cm wide: Energy efficiency class „A++" (EEI < 56)

Power Consumption in "Left-On", "Delay Start" and "Off" Mode

- In "Left-on" (end-of-cycle) mode, the power consumption of the appliance shall not exceed 0.5 watts. If the device comes with a display the power consumption in "Left-on (end-of-cycle) mode shall not exceed 1.00 W.
- In "Delay Start" mode, the power consumption of the appliance shall not exceed 4 W.
- In "Off" mode, the power consumption shall not exceed 0.2 W.

Water Consumption

Water consumption for the standard cleaning cycle calculated according to Regulation (EC) No 1059/2010 relating to household dishwashers shall not exceed the following limits:

- Dishwashers > 45 cm wide: maximum consumption: 2,800 litres per year
- Dishwashers ≤ 45 cm wide: maximum consumption: 2,520 litres per year.

AquaStop

The appliance shall come with an aquastop system. The applicant shall provide warranty on the proper functioning of the system for the entire life of at least 2,800 standard cleaning cycles of the dishwasher, if properly installed. The product manual shall include the corresponding warranty information.

Drying Efficiency

The drying efficiency index (I_D) shall be rated as follows in accordance with Regulation (EC) No 1016/2010:

- I_D: > 1.08 - corresponding to drying efficiency class „A".

Noise Emissions

The evaluation of the noise emissions shall be based on the sound power levels in dB(A) rounded up to the integer L_{Cn}. Dishwashers shall not exceed the following sound power levels L_C:

- 44 dB(A) for appliances ≤ 45 cm wide;
- 42 dB(A) for appliances > 45 cm wide.

The product manual shall list the sound power level.

Delay Start/ Interconnectivity

The appliance shall feature a delay start option (delay timer) that allows the user to delay the start of the wash cycle for at least 8 hours. From 1January 2015, the appliances shall additionally be equipped with an interface enabling communication and control (interconnectivity) via the grid.

Consumer Information with regard to energy efficiency and performance

The energy, water and detergent consumption of dishwashers greatly depends on the user behaviour (above all, by the user's way of loading and cleaning programme selection). The operating instructions/product manual as well as manufacturer's website shall at least include the following basic user information/instructions:

- Information on the appliance's water and energy consumption for the individual programmes as well as for the selectable additional functions (presented in a table, if possible);
- Information on the offers for using time-variable power supply;
- Note stating that most of the energy required running a dishwasher is used to heat the water. An appliance with hot-water-connection can help reduce this energy consumption. The use of a hot-water connection (maximum 60°C) is recommended if hot water can be provided by solar panels,

district heating, a modern gas or oil heating system or by a suitable gas-fired instantaneous water heater and if the inlet hose to the appliance is short and properly thermally insulated. No more than 1.5 litres of cold water should drain off before hot water actually flows;

- Recommendation not to use the dishwasher until it is fully loaded (pictures showing the proper loading of the dishwasher would be useful);
- Reference to the website „Forum Waschen", providing information on proper dishwashing: http://www.forum-waschen.de/abwaschen-geschirrspuelen.html

1.2.4 European consumer associations tests and other consumer information portals

The Energy Label gives valuable information at the point of sale. Before purchasing white goods, many consumers inform themselves about latest state of the art in technologies, consumptions and relevant product factors that have to be considered. Therefore, they read users advice online and or recommendations of independent consumer organisations, e.g. German "Stiftung Warentest" (STIWA, www.test.de), British "Which?" (www.which.co.uk), French "Que Choisir" (www.quechoisir.org) or Spanish "OCU" (www.ocu.org). Those consumer associations periodically perform dishwasher tests and publish the results in their magazines and on their webpages, together with useful information about automatic dishwashing in general, e.g. best practices and new technologies and features.
Consumer associations and their magazines can be considered as driving forces for the market. Knowing how consumer associations actually test dishwashers, which categories are assessed and how they contribute to the final test judgement promises insight in consumer relevant aspects and market trends.

1.2.4.1 Stiftung Warentest (STIWA)

Testing methods change with time. For example, STIWA tests according to EN 50242/EN 60436:2008, with slight modifications, such as additional persistently soiled items when testing the Intensive programme. Until 2004, STIWA tested the Intensive programme and the standard ("eco") programme of the test machine. In 2004, the automatic programme was additionally tested for the first time. The constellation of tested programmes was changed to the Eco programme, the automatic programme and the rapid programme (for normally soiled dishes, water temperatures about 50 °C in the main cleaning phase and duration of about 60 minutes) in 2010. Since 2013, the Eco programme and the rapid programme are tested with additional plastic load items to assess the drying performance on diverse materials. They also aim to cover aspects which are not declared on the Energy Label but influence product quality, such as ease of use and the finishing quality. In addition, those consumer associations get feedback from their readers and users. Thereby, they get valuable insights in consumer relevant information and reflect consumer expectation and market trends related to dishwashers. Compared with official test standards, consumer associations are able to focus on new or more consumer-relevant aspects (Brückner 2013)
The latest dishwasher testing was published in 05/2014. Every dishwasher model tested gets a final test score ("test-Qualitätsurteil") following a school grade system (grades 1 to 6). The final test score is calculated out of the weighted results from six major testing categories: the performance of the Eco (Label) programme, the rapid programme and the automatic programme, usability, safety and noise emission.
The rapid programme and the Eco programme are tested following the EN 50242/EN 60436:2008+ EN 50242:2008/A11:2012, with additional plastic items. The cleaning and drying performance are assessed, and programme durations and energy and water consumptions are measured. The Automatic programme is tested following the EN 50242/EN 60436:2008+ EN 50242:2008/A11:2012, with 100 % soiling and with 150 % soiling in order to assess the ability of the sensors to adapt to different soil levels. The cleaning performance is evaluated; energy, water consumption and the duration are measured.
Usability assesses the practicability in everyday use, e.g. cleaning the sieve system, operating of the dishwasher, refilling rinse aid and salt, ease of operation of baskets. It also includes the comprehensibility of the manual and the ability to integrate the dishwasher into the kitchen. Safety assesses the mechanical

safety, the finishing of the dishwasher, e.g. the risk of injury by sharp edges, and the protection against water damages. Noise emission is measured according to DIN EN 60704-2-3:2006_2.
Each of the performances in the tested programmes (Eco, automatic, rapid) contributes 20% to the final test score, from which 10 % is related to cleaning and drying performance and the duration of the programme, and 10% to energy and water consumption. By this the performance values of the most important programmes have the highest impact (60%) on the final score. Usability has a share of 20%; safety and noise emission each contribute 10% to the final assessment.
Test results are published in the magazine "test" and on the STIWA webpage (fee-based). They are embedded in articles about automatic dishwashing, dealing with current trends, developments and best practice tips. E.g. it is explained the sorptive drying system with zeolith, the characteristics of different dishwashing programmes (Eco, automatic, rapid, intensive, pre-rinse) and why Eco programmes show high performances at low energy consumptions and long durations.
Test results are presented in a table form, using a schematic presentation of results instead of concrete test values. The table also indicates further relevant information about the dishwasher model that did not influence the final test score:

- Average price (in €)
- Operating costs on a ten years basis
- Technical details and equipment features: energy efficiency class, capacity (in ps), number of provided dishwashing programmes, concrete consumption values and names of the tested programmes, possible height-adjustments

The operating costs on a ten years basis are calculated using a "user profile". The user profile assumes that 280 dishwashing cycles are run per household and year in a dishwasher model with a capacity of 13 ps, 90 cycles of 280 are done in the Eco programme, 75 in the automatic programme with normal soiling (100 % soil level), 25 with heavy soiling (150 % soil level) and 90 cycles are done using the rapid programme. The number of dishwashing cycles is adjusted for dishwashers with 9, 10, 12 and 14 ps. As monetary costs per cycle, one multi-tab is calculated with 0.10 €, energy consumption is calculated with 0.28 €/kWh and water consumption with 3.85 €/m³.

1.2.4.2 Which?

The UK consumer association Which? continuously tests dishwasher models in their own test laboratories. Basic assessment categories are cleaning and drying, energy and water use, usability ("How easy it is to use") and noise emission.

Every dishwasher model is tested in the corresponding main programme that cleans normally soiled dishware with water temperatures about 55-65 °C, i.e. the normal Eco (label) programme. If a main programme is not available, the automatic programme is tested. The testing method is assumed to follow EN 50242/EN 60436:2008:

> *"[…] we dirty dishes with milk, tea, minced meat, eggs, oat flakes, spinach and margarine, baking on these substances in a heated cabinet to ensure we give dishwashers a tough realistic test. […] We load dishwashers with a typical load of dishes, including dinner plates, soup plates, dessert plates, cups, saucers, knives, forks, soup spoons, tea spoons, platters, serving bowls, a serving fork, a ladle […]." (Fletcher 2015)*

Additionally, the test load includes a saucepan, a glass jug and plastic lunch boxes. It is also accomplished with clean dishes, as indicators for redeposition of soilings during a dishwashing cycle.
Cleaning performance, drying performance, energy and water consumption of the tested programme are assessed. As reference base for consumption values, the energy and water consumption of the Eco programme are measured.
Usability describes the ease of everyday use: how easy is it to fill or empty the dishwasher up to capacity and is the manual to understand, how complicate is it to programme the dishwasher, to refill salt and

rinse aid. Noise emission is measured by a standard measurement method and by subjective assessment of test persons, identifying any loud or particularly irritating noises.
Each of the categories contributes part way to making up the total test score: cleaning and drying with 60%, energy and water use with 20%, usability with 15% and noise emission with 5%. The total score of a dishwasher model is expressed as percentage of the maximum test score, which is 100% if the dishwasher model performs full score in each category. Full size dishwasher models need to have a total score of 75%, compact dishwashers of 65% to be signed as "Best Buy" recommendation. Dishwashers scoring 40% or less are declared as "Don't Buy"-models.
Test results are published as "product review" on the webpage (fee-based). In addition to the test results, the product reviews contain further information about technical specifications such as type, dimensions, size, capacity (in ps), main programme duration, the presence of certain features (display, time remaining indicator, delay timer, child lock, half load wash, sensor wash, anti-flood technology), energy efficiency class, annual energy costs and water use.
Results of selected dishwashers are periodically summarized in "test lab"-articles for dishwashers in the Which?-magazine. The latest published article about dishwashers was found in the October version of the magazine in 2014. Test results are embedded in information about why manual dishwashing is less efficient than automatic dishwashing and explanations about efficient dishwashing programmes that help to safe money (Eco, automatic). Besides the short profiles of each test machine, test results are summarized in table-form. The table includes additional information such as main programme duration, delay start timer: yes/no, capacity, type and price of a dishwasher model.
In dishwasher testing, both consumer associations focus on performance and consumptions of the tested dishwasher model, but their results are not directly comparable. However, whereas STIWA weighs both factors as equally important, Which? primarily focusses on performance (60%) and then on energy and water consumption (20%). Whereas STIWA includes programme durations in its assessment category, Which? indicates programme durations as additional information, not influencing the final test score.

1.2.4.3 EU and several Member States: Topten web portal for best products of Europe (www.topten.eu)

Topten is a web portal guiding consumers to the most energy efficient appliances and cars in Europe. Altogether 19 national Topten websites present up-to-date, consumer-oriented information on the most energy-efficient models in a number of product groups, e.g. domestic appliances, cooling and lighting equipment, consumer electronics, and vehicles. The information is built on independent market surveys selecting the best available technologies (BATs) amongst the product categories. Participating Member States with national Topten websites are Austria, Belgium, Croatia, Czech Republic, Finland, France, Germany, Greece, Italy, Lithuania, Luxemburg, Norway, Poland, Portugal, Romania, Spain, Sweden, Switzerland, and UK.
The selection of the most energy-efficient models is based on specific selection criteria for each of the product categories. Household dishwashers are presented on the Topten website in two different categories: Freestanding dishwashers and built-in dishwashers. In order to qualify for topten.eu, dishwashers must meet the following criteria:

- Energy efficiency
  - Freestanding dishwashers: energy class A++ or A+++ according to the EU energy label
  - Built-in dishwashers: energy class A+++ according to the EU energy label
- Drying efficiency
  - Class A according to the EU energy label
- Maximum water consumption
  - 2,800 litres per year, according to the Energy Label
- Hot water supply being possible

- Water/flood protection

In order to qualify for the national Topten websites, dishwashers must meet the country-specific criteria mentioned in Table 1.10.

Table 1.10: Country-specific criteria for dishwashers to be placed on the national Topten websites

Countries	Listed product sub-categories	Topten Dishwasher criteria in different EU countries	National Topten websites
Austria	Freestanding 60 cm Semi-integrated 60 cm Fully integrated 60 cm	Freestanding: Gold: A+++ / ≤ 44 dB Silver: A++ / ≤ 44 dB Semi/fully integrated: Gold: A+++ / ≤ 42 dB Silver: A+++ / ≤ 44 dB	www.topprodukte.at
Belgium	Free-standing Built in	A++ (45 cm) or A+++ (60 cm) A for drying ≤ 0.92 kWh/cycle ≤ 11 litres/cycle ≤ 47 dB	www.topten.be
Croatia	No details available	A++	---
Czech Republic	Freestanding 45 cm / 60 cm Built-in 45 cm / 60 cm	60 cm: A+++ 45 cm: A-20% / A++ Both: ≤ 2800 litres/year	www.uspornespotrebice.cz
Finland	Same as Topten.eu	Same as topten.eu	www.topten-suomi.fi
France	Freestanding 45 cm / 60 cm Built-in 45 cm / 60 cm	A+ (45 cm) or A+++ (60 cm), A for drying ≤ 0.92 kWh/cycle ≤ 11 litres/cycle ≤ 47 dB	www.guidetopten.fr
Germany	45 cm 60 cm	A++ (45 cm) or A+++ (60 cm) A for drying ≤ 10 litres/cycle ≤ 44 dB (60 cm) or ≤ 46 dB (45 cm) Water/flood protection 60 cm: Load sensor or half-load programme; 45 cm: programme for light-soiled dishes	www.ecotopten.de
Italy	6-8 ps 9-12 ps > 12 ps	6-8 ps: A+ / 9-12 ps: A++ / > 12 ps: A+++	www.eurotopten.it
Lithuania	No details available	No details available	http://top-10.lt
Luxembourg	Freestanding 45 cm / 60 cm Built-in 45 cm / 60 cm	A+++ A for drying ≤ 48 dB	www.oekotopten.lu
Norway	---	A+++	www.besteprodukter.no

Poland	Freestanding Built-in	A++ (freestanding) or A+++ (built-in) A for drying ≤ 10 litres/cycle Water/flood protection Hot water supply possible	www.topten.info.pl
Portugal	Freestanding ≤ 13 ps / > 13 ps Built-in ≤ 13 ps / > 13 ps	A+++ A for drying	http://www.topten.pt
Romania	Freestanding < 45 cm / 45-60 cm Built-in	A+ to A+++ A for drying ≤ 11 litres/cycle (< 9 ps) and ≤ 13 litres/cycle (> 9 ps)	www.topten.info.ro
Spain	Freestanding Built-in	A+++ A for drying ≤ 11 litres/cycle (≤ 9 ps) ≤ 12 litres/cycle (> 9 ps)	www.topten.wwf.es
Sweden	---	---	www.toptensverige.se
Switzerland	Freestanding Built-in (60 cm) Built-in (55 cm; Swiss norm SMS) Compact (45 cm and/or ≤ 9 ps)	A+++ (built-in 60 cm) or A++ (freestanding; built-in 55 cm and compact dishwashers) A for drying Water/flood protection Hot water supply possible	www.topten.ch
United Kingdom	Freestanding Built-in	A+++ A for drying ≤ 10 litres/cycle	www.top10energyefficiency.org.uk/
Europe	Freestanding Built-in	A++ or A+++ (freestanding) A+++ (Built-in) A for drying ≤ 2800 litres/year Hot water supply possible Water/flood protection	www.topten.eu

1.2.5 International legislation and standards

1.2.5.1 International

1.2.5.1.1 IEC 60436:2004 3rd Edition "Electric Dishwashers for Household use"

IEC 60436 3rd Edition, February 2004 "Electric dishwashers for household use – Methods for measuring the performance" has been prepared by SC 59A of TC 59. The major changes introduced into the 3rd edition include:

- changes made to the soils used in the standard;
- the use of an oven and microwave oven to dry the soils;
- the alternate 15 to 18 h air dry method to dry the soils;

- the addition of a reference dishwasher;
- the recognition of alternate supply voltages and frequencies;
- the recognition of a cold or hot water supply to the dishwasher;
- the detergent and rinse aid compositions have been updated to reflect current technology;
- the addition of the US-style load;
- the evaluation of the filter systems;

The third edition has been amended in 2009 and 2012 to incorporate further changes:

- The addition of a second type of reference machine (Miele G 1222);
- The addition of an alternate model of the microwave oven;
- An illustration for the through-circulation thermal cabinet (Figure 1.3) to indicate the position of temperature sensors and a new position for the basket to prevent partial blockage of the inlet air path which will improve the consistency of the Oven Drying results. Furthermore an improved calibration procedure of the oven temperatures is included. It applies to annex G.

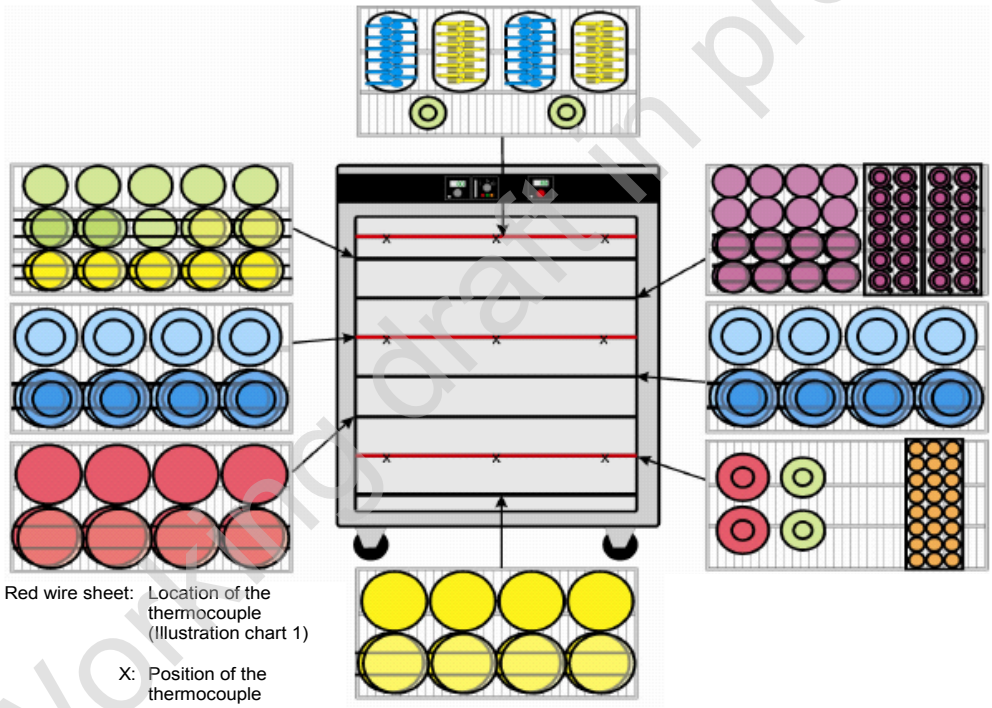

Figure 1.3: Loading scheme of the thermal cabinet for 24 ps

- Revised small bowl specification; throughout the standard the names "small serving bowl" and the "fruit bowl" have been changed to "dessert bowl". It applies to Clause 6, Annex A and Annex B;
- The inclusion of standby power to cover the relevant low power modes for dishwashers as a new Annex O which references IEC 62301 for the measurement method;
- A more detailed description how to calibrate and work with the new microwave oven introduced with IEC 60436-A1;
- Alternative replacement cutlery items for Annex A

The performance of the tested machines is measured by comparison with a reference machine (Miele G590, Miele G595, and Miele G1222). Two alternative loads are defined and described, the reference machine to be always loaded with the load set in Annex A (the non-US style load).
Performance tests must be generally carried out on a new machine, with a reference machine running parallel with the machine(s) under test, i.e., at the same time under the same conditions using soil prepared at the same time from the same batch. The reference machine is always installed as a free standing machine independent of the type of machine under test. Dishwashers are tested as free standing except where they are designated as built–in or integrated. Before conducting the performance tests, the dishwasher is operated for at least three complete cycles using a clean load with reference detergent and without rinse agent. The following cycle(s) can be a noise test according to Clause 9. No additional cycles are carried out on the machine under test between the sequential steps specified in the following procedure.
The tests are performed in the following order: cleaning performance then drying performance. The determination of energy, water and cycle/programme time is done in conjunction with the cleaning performance test. The first programme to be tested is the one recommended by the manufacturer for a normally soiled load. In some countries the manufacturer has to declare the programme to be used, for the purpose of energy labelling which may not be for a normally soiled load, in which case this programme is the one tested first. The same programme is used for measuring the cleaning performance, the drying performance, the energy and water consumption and time and the noise, if tested. The test conditions are specified:

- Voltage and frequency;
- Ambient conditions;
- Water supply pressure, hardness and temperature both cold (at 15 ± 2 °C) and hot (at 60 ± 2 °C) water inlet;
- The reference detergent is used, the quantity as recommended by the manufacturer but no more than 15.0 g + 1.25 g per ps. If no recommendation is given by the manufacturer, use 12.0 g + 1.0 g per ps;
- The reference rinse agent is used, the type (acidic or neutral) is used according to the water hardness;
- The reference salt is used;
- The following soiling agents are required: milk, tea, minced meat, egg, oat flakes, spinach, margarine. All food products, at the time they are used for the preparation of soiling agents for the standard, must be within the “use-by” date or before their expiry date stated on the product. The remains of newly opened packets of tea and oat flakes may be used for subsequent tests for a period of up to 60 days after opening, if the contents are stored in a sealed container. Specific directions are provided for storage and re-use of spinach after defrosting. The preparation and application of each soiling agent on the tableware is described. Then the soiled tableware are dried in an oven or air dried.

The standard provides descriptions for the following measurements:

- The cleaning performance (Clause 6): the purpose of this test is to measure how well the appliance cleans normally soiled ps and serving pieces. The tests are carried out in parallel with the reference machine; soiling of the test loads for the test machine(s) and the reference machine are prepared in parallel. One person must prepare each soil type for all loads and one person must apply each soil type for all loads. Perform at least five cleaning test cycles of the test programme without cleaning the dishwasher filters between the measurements; if necessary increase the number of cleaning test cycles until an acceptable defined standard deviation is fulfilled, to a

maximum of eight cleaning test cycles. Any soil residue is assessed and the score noted according to the following score system in Table 1.11

Table 1.11: Scoring scheme for the cleaning performance assessment

Number of small dot shaped soil particles	Total soiled area mm^2	Score
$N = 0$	$A = 0$	5
$0 < n \leq 4$	$0 < A \leq 4$	4
$4 < n \leq 10$	$4 < A \leq 20$	3
$10 < n$	$20 < A \leq 50$	2
Not applicable	$50 < A \leq 200$	1
Not applicable	$200 < A$	0
Each load item shall be awarded a score from the table according to the category of soil area or number of discrete soil particles adhering to the item. If the requirements for more than one score are met, the lowest applicable score shall be awarded.		

The type of soil and total number of relevant items is noted and the cleaning index is calculated by comparing the results of the test and the reference machines as the average of the indexes of the run cycles;

- Drying performance (Clause 7): to measure how well the dishwasher dries the load. The drying performance measurement is not determined in conjunction with the measurement of the cleaning performance and is undertaken using clean ps and serving pieces. Drying effect is evaluated by visual inspection and judged to be "dry", "intermediate" or "wet". Inspection of the items in the machine under test and the reference machine are carried out by the same person.

  "Dry" is defined as an article being completely free of moisture. In this case, the article shall be given a score of 2; "Intermediate" is defined as an article having one or two drops of water, or one wet streak (run), the article shall be given a score of 1; "Wet" is defined as an article having more than two drops of water, or one drop and one streak, or two streaks, or water in glass or cup cavity, the article shall be given a score of 0. The single drying index, approximated to two decimal places, for the test and the reference machine is calculated as the average of the scores of the single item types. The final drying index is calculated by comparing the results of the test and the reference machines as the average of the indexes of the run cycles;
- Energy, water consumption and time (Clause 8): to determine the electrical energy, the energy contained in the hot water if an external source of hot water is used, and the quantity of hot and/or cold water consumed by the dishwasher and the time it takes to complete a particular programme used for measuring the cleaning performance. Total energy consumption is the sum of the electrical, cold water correction (if any), and hot water energy (if any). The arithmetic mean of the five or more cycles for the test machine is given: the energy consumption is measured in kWh to three decimal places, water consumption in litres, to one decimal place, and time to the nearest minute. The energy and water consumption are not determined during a drying test;
- Airborne acoustical noise (Clause 9), determined according to IEC 60704-2-3.

Fifteen annexes are included in the standard:

- Annex A (normative) defines the ps and serving piece specifications to be used in the test machines according to its capacity in terms of ps.

- Annex B (normative) defines an alternative load, the US style load, to be used for dishwashers not using load described in Annex A, such as U.S. style machines. Tableware and serving piece specifications are given according to the test dishwasher capacity, along with a table of concordance with load items.
- Annex C (informative) illustrates the soil distribution, i.e. the number of each item type soiled for a 12-ps, a 9-ps and a 6-ps dishwasher.
- Annex D (normative) specifies the characteristics of test materials: the detergents (two detergents are possible), the rinse agents (with two formulas, "acidic" and "neutral" type) and the salt.
- Annex E (normative) describes the characteristics of the reference machine type 1, the reference programme (Universal 65 °C), the installation and the calibration of the machine and the load.
- Annex F (informative) gives a list of possible suppliers of the materials and reference equipment used in the standard.
- Annex G (normative) specifies the characteristics of the microwave oven and through-circulation thermal cabinet to be used for the drying of the soiled tableware.
- Annex H (informative) suggests that testing laboratories develop their own internal guidelines for the evaluation of soil and cleaning, to ensure that repeatable results are obtained. An example of guidelines for assessing cleaning performance taken from the Australian/New Zealand standard is also included in the annex.
- Annex I (normative) describes the test enclosure for built-in models.
- Annex J (informative) presents a flow chart with the test sequence of the entire standard.
- Annex K (normative) specifies the shade numbers for various colours to be used to assess the washing performance.
- Annex L (informative) gives an example of the test report format
- Annex M (informative) provides guidance on how to adjust the water consumption of the reference dishwasher in order to achieve the target water consumption of 27.8 litres.
- Annex N (normative) describes the characteristics of the reference machine type 2, the reference programme, the installation and the calibration of the machine and the load.
- Annex O (normative) describes procedures for the measurement of low power modes that are relevant for dishwashers, e.g. left- on mode and off mode.

1.2.5.1.2 New 4th Edition of IEC 60436

A new edition of the international standard has been elaborated by subcommittee 59A: Electric dishwashers, of IEC technical committee 59: Performance of household electrical appliances.
This edition constitutes a technical revision and includes the following significant technical changes with respect to the previous edition:

- IEC 60436 edition 3 Amendment A1 and A2 content. Previous amendment revisions are included in edition 4. Primary amendment content includes: Specification of reference dishwasher G1222, an additional microwave oven 752C, inclusion of standby / low power modes, and updated cutlery and tableware items.
- Combined Cleaning and Drying. Combining the cleaning and drying performance evaluations into one test, along with the energy and water consumption evaluation, prevents an opportunity for circumvention if tests were performed separately. A dishwasher might detect whether soil is present or not and adjust the cycle to favour performance on cleaning and energy consumption or drying (without measurement of energy consumption) depending on what kind of test is

conducted; combining the tests in a combined cleaning and drying assessment avoids this possibility.

- New dish load items. New dish load items were incorporated which reflect consumer use. New items are: stainless pots, coffee mugs, melamine plastic items, and glass bowl. The new load items provide different shapes which challenge a dishwasher water spray patterns and provide additional surfaces for soil removal assessment.
- A new detergent D is specified which mirrors current tablet formulations available on the market. Detergent type D is phosphate free, with percarbonate instead of perborate bleach and more active enzymes.
- Repeatability and reproducibility improvements.
- Informative annexes. Annexes were added for evaluation of soil sensing programmes, rinsing performance, and dishwasher filtration. An annex is provided for inlet water temperature influence on energy consumption.

The fourth edition is being prepared to proceed to FDIS status in spring or summer of 2015. A RRT has been planned and will be carried out in 2015/ 16 using edition 4. Results from the RRT will be available after the edition 4 is published. Edition 4 updates, if needed, will be incorporated into edition 4 Amendment 1.

1.2.5.1.3 Current activities of IEC SC 59A

The last, current and future editions of the international standard have been developed by Working Group 2 of Subcommittee 59A. During the last meeting of SC 59A in October 2014 it has been decided to launch certain advisory and working groups in addition to maintenance team 2, which was been working as working group 2 for the last decades. A new structure of SC 59A (Table 1.12) has been established, to enable more targeted collaboration and to call for experts in these new fields of work. By this the selected subjects can be discussed and worked on by delegated experts and more in detail.
The target of the new working groups is the elaboration of a new test standard or technical specification. The new advisory groups are requested to do preliminary work for the present standard, while the maintenance team is responsible for maintaining the present standard.

Table 1.12: New structure of SC 59A

Label	Title
Advisory Group 1 (AG 1)	Standard detergent and standard rinse agent
Maintenance Team 2 (MT 2)	Dishwasher tests
Working Group 3 (WG 3)	Measurement of microbiological properties
Working Group 4 (WG 4)	Uncertainty assessment
Advisory Group 5 (AG 5)	Reference equipment and test material
Advisory Group 6 (AG 6)	Global application of test methods for dishwashing appliances

The first meetings of WG 3, WG 4 and AG 5 took place in March 2015, where the individual tasks were defined and first discussions were held.
The task of WG 3 is to develop a technical specification on measuring of hygienic properties in dishwashers for household use during the dishwashing process, firstly looking at the dish items to be cleaned, secondly looking at the dishwasher itself.
WG 4 shall use appropriate methods for assessing the uncertainty of the measurement of performance and consumption values for dishwashers, as defined in the standards under SC59A and propose ways to reduce the uncertainty.

AG 5 shall work on the task that the items referenced or intended to be used in the standard (reference machine, cutlery, dishes, cookware, microwave appliance, thermal cabinet, soiling materials) are precisely defined, globally available, and stable for long term. Strategies have to be developed to ensure long term, consistent and global supply of test materials needed for the standard

1.2.5.2 United States

1.2.5.2.1 US Federal Energy Efficiency Standard for Residential Dishwashers

In a direct final rule published on May 30, 2012, the U.S. Department of Energy (DOE) prescribed the current energy conservation standards for residential dishwashers manufactured on or after May 30, 2013 as shown in the following table:

Table 1.13: Current US Federal Energy Efficiency Standards for Residential Dishwashers valid since May 2013 (US EERE 2014)

Product class	Maximum annual energy use (based on 215 cycles per year)	Maximum per-cycle water consumption
Standard (≥8 ps plus 6 serving pieces)	307 kWh/year	5.0 gallons (18.9 litres) per cycle
Compact (<8 ps plus 6 serving pieces)	222 kWh/year	3.5 gallons (13.3 litres) per cycle

On December 19, 2014, the DOE published a notice of proposed rulemaking (NOPR) which is proposing energy conservation standards for residential dishwashers. The comment period for the NOPR pertaining to the energy conservation standards for residential dishwasher products ended February 17, 2015. DOE was reopening the comment period for comments related to the analysis that estimates the potential economic impacts and energy savings that could result from an energy conservation standard for residential dishwashers by March 25, 2015.
DOE proposes amended energy conservation standards for residential dishwashers. The proposed standards, which are the maximum annual energy use and maximum per-cycle water consumption for each product class, are shown in the table below.

Table 1.14: Proposed New US Federal Energy Conservation Standards for Residential Dishwashers (US EERE 2014)

Product class	Maximum annual energy use	Maximum per-cycle water consumption
Standard (≥8 ps plus 6 serving pieces)	234 kWh/year	3.1 gallons (11.7 litres) per cycle
Compact (<8 ps plus 6 serving pieces)	203 kWh/year	3.1 gallons (11.7 litres) per cycle

These proposed standards, if adopted, would apply to all products listed in the table and manufactured in, or imported into, the United States on or after the date 3 years after the publication of any final rule for this rulemaking. For purposes of the analysis conducted in support of this proposed rule, DOE used 2016 as the expected year of publication of any final standards.

1.2.5.2.2 US Energy Guide

According to (US EPA [n.d.]b), major home appliances such as dishwashers must meet the 'Appliance Standards Program' set by the DOE. Manufacturers must use standard test procedures developed by DOE to prove the energy use and efficiency of their products. Test results are printed on a yellow EnergyGuide label, which manufacturers are required to display on their appliances according to the Appliance Labeling

Rule of the Federal Trade Commission (FTC). This label estimates how much energy the appliance uses, compares energy use of similar products, and lists approximate annual operating costs. The exact costs will depend on local utility rates and the type and source of energy. Appliances which are ENERGY STAR qualified (cf. next section) must carry the EnergyGuide label.
For dishwashers, the EnergyGuide label shall provide the following information (FTC 2012):

- Models for which the EnergyGuide label applies
- Capacity
- Estimated Yearly Energy Cost (US Dollar), when used with an electric water heater.
- Cost range of similar models; capacity on which the cost range is based.
- Estimated yearly electricity use (kWh).
- Estimated Yearly Energy Cost (US Dollar), when used with a natural gas water heater.
- US Energy Star logo if applicable for the EnergyGuide labelled appliance.

The estimated energy cost is based on four wash loads a week and a national average electricity cost of 12 cUS$/ kWh and natural gas cost of $1.09 per therm.

1.2.5.2.3 US Energy Star for Residential Dishwashers

Since January 2012, the ENERGY STAR Residential Dishwasher specification version 5.2 is in effect. However, compact dishwashers may no longer be Energy Star certified since January 2014. Qualification criteria for standard dishwashers include energy and water performance. The following energy and water performance requirements must be fulfilled by standard dishwashers (defined as dishwashers with a capacity equal to or greater than 8 ps plus 6 serving pieces) (US EPA [n.d.]a)

- Annual Energy Consumption: ≤ 295 kWh per year
- Water Consumption: ≤ 4.25 gallons per cycle (i.e. 16.09 litres per cycle)

Recently, the Energy Star specification for residential dishwashers has been under revision and it is expected to take effect on January 29, 2016. This update is version 6.0 while currently version 5.2 is in place. The proposed US standards (see above) will apply from 2019 earliest so another update after version 6.0 of the Energy Star will be needed to avoid mismatches between the new US Standards and the Energy Star requirements.
In version 6.0, it is proposed that the criteria for compact dishwashers are slightly relaxed to allow efficiency criteria being achievable by more than one technology (dish-drawer and countertop models). The criteria will reduce the energy use of compact dishwashers by 9% and the water use by 11% relative to a compact dishwasher that just meets the US Federal standard. Further, the proposal includes the incorporation of a cleaning performance reporting requirement based on an Energy Star test method for determining residential dishwasher cleaning performance.
Finally, version 6.0 includes clarifications and exemptions to the optional connected criteria. The energy and water consumption and cleaning performance of certain dishwasher cycle selections may be impacted as a result of responding to a temporary appliance load reduction signal. Compact dishwashers are exempted from the optional connected criteria.
The Energy Star Product Specification version 6.0 for Residential Dishwashers proposed following certification criteria (US EPA 2014):

- Proposed Energy Performance Requirements:
The Annual Energy Consumption (AEC) shall be less than or equal to Maximum Annual Energy Consumption (AEC_{MAX}), as calculated per following equation.

$$AEC_{MAX} = AEC_{BASE} + AEC_{AdderConnected}$$

AEC_{BASE} is the annual energy consumption base allowance (kWh/year),

- Standard dishwashers: 270 kWh/year
- Compact dishwashers: 203 kWh/year

$AEC_{AdderConnected}$ is the annual energy connected allowance for standard dishwashers only: 0.05 x AEC_{BASE}

- Proposed Water Performance Requirements:

- Standard dishwashers: ≤ 3.5 gallons per cycle (i.e. 13.25 litres/cycle)
- Compact dishwashers: ≤ 3.1 gallons per cycle (i.e. 11.73 litres/cycle)

Further, it proposed following optional cleaning performance reporting in order to achieve energy savings without sacrifice in performance (US EPA 2014):

> *Applicants for Energy Star are encouraged, i.e. not mandatory, to provide a complete set of cleaning performance data for each Energy Star certified product. The per-cycle Cleaning Index (CI) as defined in the ENERGY STAR Test Method for Determining Residential Cleaning Performance may be reported for each ENERGY STAR basic model. For those basic models for which the manufacturer wishes to submit voluntary cleaning performance data, the per-cycle CI should be calculated as the average of the units in the sample for each test cycle (heavy, medium, and light).*

Finally, the Energy Star Product Specification version 6.0 for Residential Dishwashers proposed following optional connected criteria (US EPA 2014):

> *A connected dishwasher system shall include the base appliance plus all elements (hardware, software) required to enable communications in response to consumer-authorized energy related commands. The specific design and implementation of the connected dishwasher system is interoperable with other devices via open communications protocol and enables economical consumer-authorized third party access to the functionalities "Energy consumption reporting", "Operational Status, User Settings & Messages" and "Demand Response". The connected dishwasher system might exchange data with energy management devices or applications such as smart meters, internet or cloud applications, hubs or gateways or other devices or applications.*

(US EPA 2014) defines the communication standards and the communications hardware architecture. Further, to allow transmission, reception and interpretation of the information an interface specification, Application Programming Interface (API) or similar documentation shall be made available to interested parties. Also, the product shall be capable of receiving and responding to consumer authorized remote requests (remote management), via a communication link, similar to consumer controllable functions on the product. The product is not required to respond to remote requests that would compromise performance and/or product safety as determined by the product manufacturer. Finally, if additional modules, devices, services and/or infrastructure are part of the configuration required to activate the product's communications capabilities, prominent labels or other forms of consumer notifications with instructions shall be displayed at the point of purchase and in the product literature including information to consumers how to activate these capabilities.
The functionalities of a connected dishwasher system are given as follows (US EPA 2014):

- Energy consumption reporting: In order to enable simple, actionable energy use feedback to consumers and consumer authorized energy use reporting to 3rd parties, the product shall be capable of transmitting energy consumption data via a communication link to energy management systems and other consumer authorized devices, services, or applications. This data shall be representative of the product's interval energy consumption. According to the US Energy Star specifications, it is recommended that representative data shall be reported in watt-hours for intervals of 15 minutes or less, however, they may also be reported in alternate units and intervals. The product may also provide energy use feedback to the consumer on the product

itself. On-product feedback, if provided, may be in units and format chosen by the manufacturer (e.g., $/month).

- Operational status, user settings and messages: The product shall be capable of providing the following information to energy management systems and other consumer authorized devices, services or applications via a communication link:
  - Operational / Demand Response status (e.g., off/standby, cycle in process, delay appliance load, temporary appliance load reduction).
  - At least two types of messages relevant to the energy consumption of the product. For example, messages for dishwashers might address performance issues or report of energy consumption that is outside the product's normal range. This information might also be provided on the product itself.
- Demand response: A connected dishwasher system shall have the capability to receive, interpret and act upon consumer-authorized signals by automatically adjusting its operation depending on both the signal's contents and settings from consumers. At a minimum, the product shall be capable of providing the following capabilities in all operational modes:
  - Delay Appliance Load Capability: The capability of the product to respond to a signal in accordance with consumer settings, by delaying the start of an operating cycle beyond the delay period.
  - Temporary Appliance Load Reduction Capability: The capability of the product to respond to a signal by providing load reduction for a short time period, typically 10 minutes. Upon receipt of signal and in accordance with consumer settings, the product shall restrict its average power draw during the load reduction period to no more than 50% relative to the baseline average power draw defined in the Test Method to Validate Demand Response.

  The US Energy Star specifications further define default settings for demand response as well as exemptions and possibilities for consumers to override the automatic demand response functionalities.

1.2.5.3 Asia

1.2.5.3.1 China – Hong Kong

The Hong Kong Green Label Scheme (HKGLS)

According to (Hong Kong Green Council 2010), the Hong Kong Green Label Scheme (HKGLS) is an independent and voluntary scheme, which aims to identify products that are, based on life cycle analysis consideration, more environmentally preferable than other similar products with the same function. The Scheme is organized by the Green Council (GC) with contributions from the HKGLS Advisory Committee and a number of supporting organizations. Product environmental criteria have been established for a wide variety of consumer products, inter alia washing machines and dishwashers.

The aim of the environmental criteria developed for dishwashers is to: Reduce energy consumption and promote energy-saving dishwashers; reduce water consumption and promote water-saving dishwashers; reduce noise emission and the use of the environmentally harmful substances; reduce detergent consumption; minimize waste production by reducing the amount of primary packaging and promoting its reusability and/or recyclability. This product environmental criteria apply to domestic dishwashers who are either floor-mounted or worktop models and are intended for use either freestanding or built in.

The product environmental criteria for dishwashers are the following (Hong Kong Green Council 2010):

- Energy Efficiency Index, EEI (%):

  - Dishwasher with 10 or more ps: lower than 76%.
  - Dishwasher with less than 10 ps: lower than 88%.
- Water consumption of not more than 25 litres per normal cycle
- Noise Emission: Airborne noise emission from the appliance, measured as sound power level, shall not exceed 57 dB (A) on freestanding models and 51 dB (A) on built-in models.
- Plastic parts shall have no lead or cadmium added by the manufacturer and plastic parts weighing over 25 g shall not contain flame retardants containing polybrominated biphenyls (PBBs), polybrominated diphenylethers (PBDEs) and chloroparaffins with 10-13 carbon atoms per molecule and chlorine content of greater than 50% by weight.
- Surface Treatment: Paints shall not contain pigments or additives based on cadmium, lead, chromium, mercury or their compounds. Metals shall not be coated with cadmium, chromium, nickel or their compounds.
- The product shall have clear volumetric markings on the detergent dispenser to allow adjustment according to degree of soiling.
- Packing requirements: Packaging materials shall not contain chlorine-based plastics. General packaging requirements according to the Hong Kong labelling criteria for packaging materials.

1.2.5.3.2 Korea Ecolabel

The Korea Ecolabel has been implemented since 1992. Inter alia, they have certification criteria for dishwashers.

The scope of the Korea Ecolabel for Dishwashers (Korea Environmental Industry & Technology Institute KEITI 2005) applies to electric dishwashers (hereinafter referred to as "dishwasher") which wash trays or utensils, limited to 20 or less person-capacity batch dishwashers and 2,000 tray/h capacity continuous dishwashers. The criteria document includes requirements with regard to

- Batch system general type washers
  - Allowance of grade index for energy consumption efficiency
  - Water saving rating (water consumption per functional unit)
- Batch system ultrasonic washers
  - Power consumption; water consumption; water saving ratings
- Continuous washers
  - Power consumption; water consumption; water saving ratings
- Cleansing and drying performance
- Use of chemicals (detergents dosage) and discharge of contaminants (batch system washers and continuous washers only)
- Noise during the operation of the product (Batch general type washer / Batch ultrasonic washer)
- Restriction of certain hazardous substances
- Recycling capability of product during the recycling or disposal stage of production process: Marking of separable plastic parts; material requirements for shock-absorbing materials in packaging.
- Consumer information

1.2.5.3.3 Singapore

The Singapore Green Labelling Scheme (SGLS) was launched in May 1992 to endorse consumer products and services that have less undesirable effects on our environment. This is administered by the Singapore Environment Council (SEC). The SGLS is also recognised as a member of the international Global Ecolabelling Network (GEN), allowing certification by mutual recognition of SGLS endorsed products by other members of the network (http://www.sec.org.sg/sgls/). For the Singapore Green Label Scheme (SGLS) for dishwashers (last updated in 2012), there is no access to the criteria documents.

1.2.5.4 Australia & New Zealand

The Equipment Energy Efficiency (E3) programme aims to increase the energy efficiency of lighting, appliances and equipment used in the residential, commercial and manufacturing sectors in Australia and New Zealand. This is achieved through the delivery of an energy efficiency standards and labelling programme which apply (Minimum Energy Performance Standards [MEPS] and High Efficiency Performance Standards [HEPS]) and comparative energy rating labelling. The Australian labelling programme is based on a star system, rated from one to ten. (International Energy Agency IEA 2014)

1.2.5.4.1 Energy

Minimum Energy Performance Standards (MEPS)

MEPS specify the minimum level of energy performance that appliances, lighting and electrical equipment must meet or exceed before they can be offered for sale or used for commercial purposes. MEPS are not mandatory for dishwashers.

However, the Greenhouse and Energy Minimum Standards Determination 2012 for dishwashers defines labelling and communication requirements and other requirements on performance. (Australian Government 2012):

- The Determination covers dishwashers that are ordinarily supplied and used for personal, domestic or household purposes irrespective of the context in which they are used. For example, the Determination applies to household dishwashers used in a commercial context.
- Labelling and communication requirements, as well as the product performance requirements (Rated capacity; Washing Index; Water Consumption; Drying Index; and Water Pressure) refer to the requirements stated in the Australian standard AS/NZS 2040.2:2005 (see further below, section “Performance Standard AS/NZS 2007:2005”).

Energy Rating Label

The Energy Rating Label, or ERL, is a mandatory comparative energy label that provides consumers with product energy performance information at point-of-sale on a range of appliances. Attached to each appliance, it allows comparison between similar appliance models through a star rating of between one and six stars (the greater the number of stars, the higher the efficiency) shown in half star increments and the annual energy consumption in kWh per year, cf. sample label in the figure below.

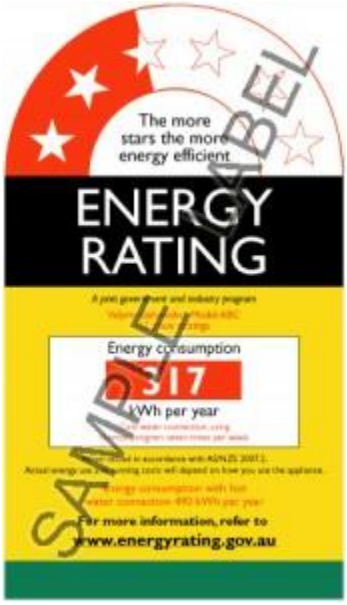

Figure 1.4: Australia's Energy Rating Label for dishwashers; source (Australian, State and Territory and New Zealand Governments 2014c)

Various "algorithms" or equations have been developed to rate the least efficient products at around 1 star. The Base Energy Consumption (BEC) defines the "1 star" line for particular products. An additional star is awarded when the so called Comparative Energy Consumption (CEC) of the model is reduced by a defined percentage from the BEC.

For dishwashers, the Base Energy Consumption is defined as BEC = 48 x number of ps. The energy reduction factor per star is 0.30, i.e. 30%. For example, a model that had a CEC that was 0.70 of the BEC or less would achieve 2 stars. Similar, a CEC of 0.49 (0.70 x 0.70) of the BEC or less would achieve 3 stars and so on. The Comparative Energy Consumption of a dishwasher is measured under conditions specified in an Australian and New Zealand Standard (see next section). Over a year, it is assumed that the dishwasher is used 7 times per week (365 times per year). (Energy Efficient Strategies (EES) 2010); (Australian, State and Territory and New Zealand Governments 2014b)

Performance Standard AS/NZS 2007:2005

Dishwashers in Australia and New Zealand are measured according to the standard AS/NZS 2007:2005 "Performance of household electrical appliances - Dishwashers". The overall objective of the AS/NZS 2007 series is to promote high levels of performance, energy efficiency and water efficiency in electric dishwashers.

The dishwasher standard AS/NZS 2007:2005"Performance of household electrical appliances - Dishwashers" was prepared by the Joint Standards Australia/Standards New Zealand Committee EL-015, Quality and Performance of Household Electrical Appliances, to supersede the former standard AS/NZS 2007.1:2003. The AS/NZS 2007 series comprises two parts:

- AS/NZS 2007.1 Part 1: Methods for measuring performance, energy and water consumption, which includes performance test procedures and minimum performance criteria for dishwashers;
- AS/NZD 2007.2 Part 2: Energy efficiency labelling requirements, which includes algorithms for the calculation of the energy efficiency star rating and projected energy usage, performance requirements, details of the energy label and requirements for the valid application for registration for energy efficiency labelling. It also includes the application form for registration for water efficiency labelling. It has been structured to be suitable for reference in regulatory legislation and to be used in conjunction with Part 1.

AS/NZS 2007.1 standard includes a number of requirements derived from the 3rd Edition of IEC 60436: 2004, which will bring it closer to the IEC standard. It also incorporates the following significant changes in comparison to earlier editions:

- Test methods have generally been made more repeatable and reproducible by adding definitions, indicating measurement accuracies and making descriptions more precise;
- A “test program” has been defined and it has been clarified that any programme can be tested to this standard, but the performance requirements in Section 4 of the standard only apply to the programme recommended for a normally soiled load. The programme for a normally soiled load is the programme mandated for energy efficiency labelling in AS/NZS 2007 – Part 2;
- Definitions in this standard are now generally aligned with IEC definitions;
- Programme time and cycle time have been added to the definitions;
- Power measurements on a number of standby modes are now required. Standby modes have been added to the definitions and examples of the types of standby modes have been added in Appendix M (the impact of communication by appliances over a network is under consideration);
- There are improved instructions regarding the use of the reference machine;
- A recommendation to purchase all test materials from the same sources has been added to minimize variations in test results. These materials will be used for check testing.
- A number of performance requirements must be met by dishwashers during a test for energy consumption. These include:
  - Washing index: the washing index of the test machine must exceed the specified value measured on the reference machine which is tested in parallel. The reference machine is a dishwasher which specially constructed and calibrated for this purpose;
  - Drying index: the drying index of the test machine must exceed 50% (this is conducted as a separate test);
  - Rated capacity: all specified load items shall be supported;
  - Water consumption: shall not exceed 110% of the value stated by the manufacturer.
  - Water pressure: machine shall be capable of operating at the maximum and minimum water pressure stated by the manufacturer;
  - Energy consumption is determined on the programme recommended by the manufacturer for energy labelling that is capable of meeting the above mentioned requirements. From April 2004, all dishwashers are to be re-labelled using the "normal" programme when tested to the 2003 Edition of AS/NZS 2007.1;
- The ambient air temperature is 20°C ± 2°C and the humidity is 60% ± 5%. All tests are undertaken with a power supply of 240 V and 50 Hz.

The Australian/ New Zealand Standard of 2005 is broadly based on the former, second edition of the international standard IEC 60436:1981 and on the revised test method published in IEC 60436, Edition 3, February 2004. Still there are differences between the AU/NZS and the IEC 60436 Ed.3, which can be summarised as:

The current, third edition of IEC uses the “universal 65°C” as the reference programme to determine a relative performance index for declaration by the manufacturer. The reference programme on the reference machine used in the AU/NZS standard is “gentle 45°C” which is used to set a pass/fail for wash performance, rather than a manufacturer declaration of wash performance. The IEC standard also uses the reference machine to assess drying performance whereas it is not used for assessing drying performance in Australia/ New Zealand;

AS/NZS 2007:2005 currently allows the use of an IEC load (without serving items) or the original AS/NZS load as an alternative. IEC also allows an AHAM (US-style) load as an alternative to the European-style load. The AS/NZS load was to be phased out by December 2007;

There are slight differences in the ambient humidity requirements between AS/NZS (60%) and IEC (55% or 65% dependent on the soil drying method);

The food items used for soiling the load in AS/NZS are more similar to the soiling of the second edition of IEC 60436. AS/NZS uses tomato juice while the IEC 60436, Edition 3 uses milk treated in a microwave as well as minced meat. Some soiling agents are slightly different (e.g. tinned spinach versus frozen spinach) and the preparation of some items and the allocation of soils to the load itself are also slightly different;

The AS/NZS cold water supply temperature is 20°C while IEC is 15°C;

The AS/NZS water hardness is soft (45 ppm) while the IEC standard specifies both soft (≤ 70 ppm) and hard (250 ppm) water; water pressure is 320 kPa in AS/NZS while it is 240 kPa in the IEC;

The AS/NZS reference detergent is based on the old IEC type A (phosphate based with chlorine bleach), while IEC specifies type C detergent (phosphate based with oxygen bleach and enzymes). IEC also have new rinse agent formulations (types III and IV);

AS/NZS requires the manufacturer to specify the amount of detergent to be used, whereas IEC specifies a default detergent quantity where an amount is not specified by the manufacturer. AS/NZS and IEC both specify maximum detergent quantities, which may be used for testing;

In AS/NZS the water softener of the reference machine is de-activated while in IEC it is allowed to operate normally. Most dishwashers in Australia and New Zealand do not have a water softener;

AS/NZS use the reference machine only for assessing the washing performance while IEC use it for assessing washing and drying performance;

IEC allows the use of either oven drying or air drying of the soiled load prior to washing while AS/NZS only allow air drying;

AS/NZS and IEC now specify the lighting conditions for cleaning and drying evaluations. The viewing cabinet, which previously had been mandatory in AS/NZS, has been moved to an informative Appendix L;

AS/NZS and IEC scoring scheme for the assessment are now aligned;

AS/NZS requires filter cleaning between test runs while IEC specify that filters are not cleaned between runs. IEC classifies filters into three main categories and require a minimum of 5 tests (but could be as many as 10 tests) on each dishwasher, depending on variability and performance without filter cleaning;

AS/NZS now requires standby power measurements on a number of modes;

IEC requires that the load be pre-conditioned in a dishwasher with IEC rinse aid prior to use in a performance test. AS/NZS does not specify any particular requirements except a clean load prior to use.

Energy Star Australia

The US Energy Star has been adopted by several countries, also by Australia. The Energy Star mark is awarded to the top 25% most energy efficient products; inter alia to dishwashers. (Australian, State and Territory and New Zealand Governments 2014a)

1.2.5.4.2 Water

Water Efficiency Labelling and Standards (WELS) scheme

WELS is Australia's water efficiency labelling scheme that requires certain products to be registered and labelled with their water efficiency in accordance with the standard set under the national Water

Efficiency Labelling and Standards Act 2005. The WELS label replaces a prior voluntary water conservation rating 'AAAAA' label endorsed by the Water Services Association of Australia. The water-using WELS products are inter alia dishwashers. (Australian, State and Territory Governments 2014b)
The standard that sets out the criteria for rating the water efficiency is AS/NZS6400:2005 "Water-efficient products – Rating and labelling" being displayed on the WELS label.
Testing of dishwashers: The average total water consumption for dishwashers is determined by testing three models on the programme (including all associated settings) recommended for a soiled load equal to the maximum number of ps that the machine can carry. The water efficiency rating is determined by using a formula derived from the total water consumption. Washing and drying effectiveness are also tested. These tests have performance thresholds which must be met in order for the product to be registered and labelled. (Australian, State and Territory Governments 2014a)

1.2.5.5 Other world regions and/or countries

(Ecofys 2014) has conducted a comprehensive study gathering considerable detailed information on equipment energy efficiency standards and labelling programmes in place in forty eight countries outside the EU. According to this study, for dishwashers, following countries have Minimum Energy Performance Standards or comparative labelling schemes, besides those listed in the sections before:

Table 1.15: Third-country legislation (Minimum Energy Performance Standards or comparative labels) for dishwashers; source: (Ecofys 2014)

Country	Minimum Energy Performance Standards	Comparative Labels
Jordan	Mandatory Minimum Energy Performance Standards for dishwashers; status: under development (2014)	Mandatory Comparative Label for dishwashers; status: development completed - pending implementation (2013)
Russia	Voluntary Minimum Energy Performance Standards for dishwashers; status: entered into force - no activity (1987)	Mandatory Comparative Label for dishwashers; status: entered into force - no activity – (2011)
South Africa*	Mandatory Minimum Energy Performance Standard; status: under development	Voluntary Comparative Label for dishwashers; status: adopted (2012)
Turkey	Mandatory Minimum Energy Performance Standards for dishwashers; status: entered into force – no activity – (2012)	Mandatory Comparative Label for dishwashers; status: entered into force – no activity – (2012)
*Voluntary energy labels for clothes washers, washer dryers, and dishwashers		

1.3 Legislation, standards and related activities with regard to substances, material and resource efficiency and end-of-life

In Annex I, Part 1.3 the Ecodesign Directive 2009/125/EC defines parameters which must be used, as appropriate, and supplemented by others, where necessary, for evaluating the potential for improving the environmental aspects of products. According to the Directive 2009/125/EC (European Parliament 2009), this includes:

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

Incorporation of used components;

Avoidance of technical solutions detrimental to reuse and recycling of components and whole appliances;

The following sections identify and provide an overview of legislation, standards, and labels in the EU, Member States and at third-country level for the products in scope with focus on resources use and material efficiency.

1.3.1 Legislation

Table 1.16 shows an overview of the European Directives and Regulation discussed in this section

Table 1.16: Overview of the European directives and regulation related to use of substances, material and resource efficiency

European Directive or regulation	
RoHS 2 Directive	Directive 2011/65/EU of the European Parliament and of the Council of 8 June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment
WEEE Directive	Directive 2012/19/EU of the European Parliament and of the Council of 4 July 2012 on waste electrical and electronic equipment (WEEE) (recast)
REACH Regulation	Regulation (EC) No 1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), establishing a European Chemicals Agency, amending Directive 1999/45/EC and repealing Council Regulation (EEC) No 793/93 and Commission Regulation (EC) No 1488/94 as well as Council Directive 76/769/EEC and Commission Directives 91/155/EEC, 93/67/EEC, 93/105/EC and 2000/21/EC
CLP Regulation	Regulation (EC) No 1272/2008 of the European Parliament and of the Council of 16 December 2008 on classification, labelling and packaging of substances and mixtures, amending and repealing Directives 67/548/EEC and 1999/45/EC, and amending Regulation (EC) No 1907/2006
F-Gas Regulation	Regulation (EU) No 517/2014 of the European Parliament and of the Council of 16 April 2014 on fluorinated greenhouse gases and repealing Regulation (EC) No 842/2006
Detergent Regulation	Regulation (EC) No 648/2004 of the European Parliament and of the Council of 31 March 2004 on detergents Regulation (EU) No 259/2012 of the European Parliament and of the Council of 14 March 2012 amending Regulation (EC) No 648/2004 as regards the use of phosphates, other phosphorus compounds in laundry and dishwasher detergents

1.3.1.1 EU RoHS Directive 2011/65/EU

The Directive 2011/65/EU on the restriction of the use of certain hazardous substances in electrical and electronic equipment (commonly referred to as RoHS 2) restricts the use of certain hazardous substances in electrical and electronic equipment to be sold in the EU and repeals Directive 2002/95/EC from 3rd of January 2013. (European Parliament 2011)

The RoHS-Directive restricts the presence of the substances listed in Annex II of the Directive, currently including the following substances: lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls (PBB) and polybrominated diphenyl ether (PDBE).

The RoHS-Directive limits the presence of these substances in electrical and electronic equipment to be placed on the Union market, to concentrations not exceeding 0.1% by weight of homogenous material. For cadmium the threshold level is at 0.01%.

Exemptions from these provisions are only possible, provided that the availability of an exemption does not weaken the environmental and health protection afforded by Regulation (EC) No 1907/2006/EC (commonly referred to as REACH, cf. section 1.3.1.3), and that at least one of the following conditions is fulfilled:

- Substitution is not possible from a scientific and technical point of view;
- The reliability of substitutes is not ensured;

- The negative environmental, health and consumer safety impacts caused by substitution are likely to outweigh the benefits;

Decisions on exemptions and on their duration may also take into consideration the following aspects, though it is understood that these do not suffice on their own to justify an exemption:

- The availability of substitutes;
- Socio-economic impacts of substitution;
- Impacts on innovation; and
- Life-cycle thinking on the overall impact of an exemption;

Applications for granting, renewing or revoking exemptions have to be submitted to the European Commission in accordance with Annex V of the Directive, and are required to include among others a justification including comprehensive information on the substance-application and possible substitutes. All applications undergo a technical analysis as well as a stakeholder consultation.
In general, applications exempted from the restriction are listed in Annex III of the RoHS Directive. As most of the exemptions are very specific, it is not possible to generalise certain topics for household appliances. Possible exemptions might be for example lead in various alloys (steal, copper, aluminium) probably being relevant for housings, though depending on the applied housing materials, as well as other components for which such alloys are in use. Theoretically, another example of exemptions might be CFL backlight systems if still being used in displays of dishwashers, although it is assumed that most displays have been shifted to LED backlight systems.
During the preparation of RoHS 2, an amendment of the list of restricted substances in Annex II was discussed. Preparatory studies, in particular the review of restricted substances under RoHS (Groß et al. 2008), revealed that further relevant hazardous substances are used in EEE. According to Recital 10 of RoHS 2 in particular the risks to human health and the environment arising from the use of the following substances were to be considered as a priority for the first review:

- Hexabromocyclododecane (HBCDD)
- Bis (2- ethylhexyl) phthalate (DEHP)
- Butyl benzyl phthalate (BBP)
- Dibutyl phthalate (DBP)

RoHS 2 sets the rules for amending the list of restricted substances in Article 6(1). A review and amendment of Annex II was performed and considered by the Commission in July 2014, and is to be considered periodically thereafter. In preparation of the 2014 review, the Austrian Umweltbundesamt GmbH (AUBA) conducted a first study in 2012-2014. Among others, the outcomes of this study included a 24 entry priority substance list (see Table 1.17), and detailed dossiers for the four substances prioritised already in RoHS 2, Recital 10. Further details can be found under this link: http://www.umweltbundesamt.at/rohs2.

Table 1.17: Substances with priority as indicated by the Austrian Umweltbundesamt GmbH (excluding the four substances listed in Directive 2011/65/EU, Recital 10)

Substances	CAS-No	EC-No
Highest priority		
Diisobutylphthalate (DIBP)*	84-69-5	201-553-2
Tris(2-chloroethyl) phosphate (TCEP)	115-96-8	204-118-5
Dibromo-neopentyl-glycol	3296-90-0	221-967-7
2,3-dibromo-1-propanol (Dibromo-propanol)	96-13-9	202-480-9
Second highest priority		
Antimontrioxid	1309-64-4	215-175-0
Diethyl phthalate (DEP)	84-66-2	201-550-6
Tetrabromobisphenol A	79-94-7	201-236-9
MCCP (medium chained chlorinated paraffins), C14 – C17: alkanes, C14-17, chloro;	85535-85-9	287-477-0
Third highest priority		
Polyvinylchloride (PVC)	9002-86-2	-
Fourth highest priority		
Nickel sulphate	7786-81-4	232-104-9
Nickel bis(sulfamidate); Nickel sulfamate	13770-89-3	237-396-1
Beryllium metal	7440-41-7	231-150-7
Beryllium oxide (BeO)	1304-56-9	215-133-1
Indium phosphide	22398-80-7	244-959-5
Fifth highest priority		
Di-arsenic pentoxide; (i.e. Arsenic pentoxide; Arsenic oxide)	1303-28-2	215-116-9
Di-arsenic trioxide	1327-53-3	215-481-4
Cobalt dichloride	7646-79-9	231-589-4
Cobalt sulphate	10124-43-3	233-334-2
Sixth highest priority		
Cobalt metal	7440-48-4	231-158-0
4-Nonylphenol (branched and linear)	84852-15-3 25154-52-3	284-325-5 246-672-0
* This substance was reviewed by Öko-Institut; for more information, please refer to the Substance specific Dossier compiled by (Gensch et al. 2014).		

AUBA recommended adding HBCDD (brominated flame retardant), DEHP, BBP and DBP (three phthalate plasticisers), to Annex II of RoHS. The study also showed that in some cases a selective ban of a substance from a larger substance group might drive industry towards the use of a problematic alternative from the very same group (e.g. substituting one phthalate plasticiser for another). An assessment of the phthalate diisobutylphthalat (DIBP) was thus carried out by Öko-Institut (Gensch et al. 2014), recommending its addition to Annex II consequence to the addition of the three phthalates. Decisions as to the addition of these five substances to Annex II of RoHS 2 are still pending. The 24 entry priority substance list prepared by AUBA (excluding the 5 substances listed above) has also been developed by Öko-Institut to include quantitative usage data and is understood to provide a further basis for the European Commission to assess the need to amend the substances listed in Annex II in the future.

Once new substances are added to Annex II of RoHS, it is assumed that a transition period shall be provided for stakeholders to establish compliance of their products and components with the consequential new RoHS substance restrictions. Where substitutes are available, this shall mean that such alternatives are to be implemented in the redesign and manufacture of EEE to be made available on the Union market by the end of the transition period. Where substitutes are not sufficiently developed, exemptions may be applied for, on the basis of the criteria listed above.
(Dalhammar et al. 2014) see interlinkages between RoHS and the Ecodesign Directive; the latter might complement the rules in the RoHS Directive through setting additional rules for chemicals for certain product groups when this would be required to stimulate recycling and contribute to cleaner materials streams. However, Dalhammer et al. also state that this might probably require first developing methodologies within the MEErP.

1.3.1.2 EU WEEE Directive 2012/19/EU

The Directive 2012/19/EU (European Parliament 2012) on waste electrical and electronic equipment (commonly referred to as WEEE-Directive) regulates the separate collection, treatment and recycling of end-of-life electrical and electronic equipment. The Directive 2012/19/EU replaces Directive 2002/96/EC of 27 January 2003, which entered into force on 1st of July 2006. Amongst others, Directive 2012/19/EU requires member states to achieve quantitative collection targets (e.g. 65% of the average weight of EEE placed on the market in the three preceding years). It also requires Member States to ensure that producers provide for the financing of the collection, treatment, recovery and environmentally sound disposal of WEEE (Article 12).
The WEEE-Directive classifies EEE in various categories. In this system, household dishwashers are classified under category 1 "Large household appliances". Nevertheless, this classification is under transition and will follow a new system from the 15th of August 2018 onwards. Under this new system, dishwashers might not be classified in one single category, but instead fall under the following out of the six new categories:

- Category 4: Large equipment (any external dimension more than 50 cm); this category will mainly apply to household dishwashers;
- Category 5: Small equipment (no external dimension more than 50 cm); this category might apply to few very small table top dishwashers;
- Category 1: Temperature exchange equipment; this category might apply to dishwashers with heat pumps;
- Category 2: Screens, monitors, and equipment containing screens having a surface greater than 100 cm^2; this category might apply to dishwashers in case of having a large control panel.

Annex V of the Directive also contains minimum targets for recovery and recycling. For the initial category 1 equipment (large household appliances), these targets are 80% for recovery and 75% for recycling until 14th August 2015. From 15th of August 2015, these targets will be raised to 85% for recovery and 80% for recycling. From 15th August 2018, the targets are split to the new categories: 85% recovery and 80% recycling for categories 1 and 4; 80% recovery and 70% recycling for category 2, and 75% recovery and 55% recycling for category 5.
Furthermore, Annex VII of the Directive specifies substances, mixtures and components that have to be removed from any collected WEEE for selective treatment. However, different interpretations by recyclers can be found: removal before or after shredding. Regarding household dishwashers, the following components might be of relevance:
As a minimum the following substances, mixtures and components have to be removed from any separately collected WEEE:

- Dishwashers and appliances < 20 years old:

  - Printed circuit boards of devices if the surface of the printed circuit board is greater than 10 square centimetres
  - Plastic containing brominated flame retardants: enclosures of power electronics, and electronic components like casting compound of transformers, capacitors and PCBs contain brominated flame retardants (e.g. Tetrabrombisphenyl A, TBBA).
  - Gas discharge lamps: these might be in backlight units of LCD control panels, if not realized with LED
  - External electric cables
  - Components containing refractory ceramic fibres as described in Directive 97/69/EC adapting to technical progress for the 23rd time Directive 67/548/EEC on the approximation of the laws, Regulations and administrative provisions relating to the classification, packaging and labelling of dangerous substances (CLP Regulation).Theoretically, these might be in insulation materials of large household appliances; in general, however, they are made of bitumen sheets.

- Future appliances:
  - Chlorofluorocarbons (CFC), hydrochlorofluorocarbons (HCFC) or hydrofluorocarbons (HFC), hydrocarbons (HC): dishwashers with heat pump
  - Liquid crystal displays (together with their casing where appropriate) of a surface greater than 100 square centimetres and all those back-lighted with gas discharge lamps: today's control panel displays are slightly smaller than 100 cm^2
- Possibly in historical dishwashers > 20 years old:
  - Polychlorinated biphenyls (PCB) containing capacitors in accordance with Directive 96/59/EC on the disposal of polychlorinated biphenyls and polychlorinated terphenyls (PCB/PCT): might be found in capacitors of motors
  - Mercury containing components, such as switches or backlighting lamps: might be found in fill level switches
  - Asbestos waste and components which contain asbestos: might be in the ducts of heating elements
  - Electrolyte capacitors containing substances of concern (height > 25 mm, diameter > 25 mm or proportionately similar volume): might be found in capacitors of motors

(Dalhammar et al. 2014) saw interlinkages between WEEE and the Ecodesign Directive; the latter might complement the horizontal rules in the WEEE Directive through implementing measures for a design of products that better enables recycling of certain components and materials.

1.3.1.3 EU REACH Regulation 1907/2006/EC

The REACH Regulation (European Parliament 2006) entered into force on 1st of June 2007. Under the REACH Regulation, certain substances that may have serious and often irreversible effects on human health and the environment can be identified as Substances of Very High Concern (SVHCs). If identified, the substance is added to the Candidate List, which includes candidate substances for possible inclusion in the Authorisation List (Annex XIV). Those SVHC which are included in Annex XIV become finally subject to authorisation. By this procedure REACH aims at ensuring that the risks resulting from the use of SVHCs are controlled and that the substances are replaced where possible.
In this regard, REACH also introduced new obligations concerning general information requirements on substances in articles. Producers and importers of articles that contain SVHC included in the candidate list,

will be required to notify these to the European Chemicals Agency (ECHA) if both of the following conditions are met:

- The substance is present in those articles in quantities totalling over 1 t/y per producer or importer;
- The substance is present in those articles above a concentration of 0.1% weight by weight (w/w).

Notification will not be required in case the SVHC has already been registered for this use by any other registrant (Article 7(6)), or exposure to humans or environment can be excluded (Article 7(3)).
In addition, Article 33(1) requires producers and importers of articles containing more than 0.1% w/w of an SVHC included in the candidate list, to provide sufficient information to allow safe handling and use of the article to its recipients. As a minimum, the name of the substance is to be communicated.
The provisions of Article 33(1) apply regardless of the total amount of the SVHC used by that actor (no tonnage threshold) and regardless of a registration of that use. Furthermore, this information has to be communicated to consumers, on request, free of charge and within 45 days (Article 33(2)).
The above mentioned Candidate list is updated regularly (two to three times a year). At present (April 2015), 161 substances are on the list. Several of these substances can be present in dishwashers, e.g. plasticisers in seals.
(Dalhammar et al. 2014) see interlinkages between REACH and the Ecodesign Directive: Recyclers are not included as stakeholders that have a right to information about chemicals in articles in REACH Art. 33. As both the WEEE and REACH rules are sometimes considered inadequate in providing the information on toxic components to recyclers needed for improved recycling. This could be for example identification of chemicals that can be a barrier to recycling. Ecodesign implementing measures could, when possible, address such chemicals through banning or setting limits for their content. Another option would be to mandate information about the content through implementing measures; this information might then be used e.g. in public purchasing schemes to reward front-runners, or by recyclers in some cases. (Dalhammar et al. 2014)

1.3.1.4 EU CLP Regulation 1272/2008/EC

The CLP Regulation (European Parliament 2008) entered into force on 20 January 2009. The purpose of the CLP Regulation is to identify hazardous chemicals and to inform their users about particular threats with the help of standard symbols and phrases on the packaging labels and through safety data sheets. The purpose of the globally harmonised system (UN-GHS) is to make the level of protection of human health and the environment more uniform, transparent and comparable as well as to simplify free movement of chemical substances, mixtures and certain specific articles within the European Union.
Substances had to be classified until 1 December 2010 pursuant to Directive 67/548/EEC and mixtures until 1 June 2015 pursuant to Directive 1999/45/EC. Differing from this provision, the classification, labelling and packaging of substances and preparation may already be used before 1 December 2010 and 1 June 2015 in accordance with the provisions of the CLP/GHS-Regulation. After these dates the provisions of the CLP-Regulation are mandatory. The REACH-Regulation (cf. section1.3.1.3) is complemented by the CLP-Regulation.

1.3.1.5 EU F-Gas Regulation 517/2014/EU

The revised F-Gas Regulation (EU) No 517/2014 (European Parliament 2014) repeals the 2006 F-Gas Regulation and applies since 2015. The objective of this Regulation is to protect the environment by reducing emissions of fluorinated greenhouse gases. This Regulation applies to dishwashers using a heat pump system based on fluorinated hydrocarbons like the frequently applied refrigerant R134a. Accordingly, this Regulation:

- establishes rules on containment, use, recovery and destruction of fluorinated greenhouse gases, and on related ancillary measures;
- imposes conditions on the placing on the market of specific products and equipment that contain, or whose functioning relies upon, fluorinated greenhouse gases;

- imposes conditions on specific uses of fluorinated greenhouse gases; and
- establishes quantitative limits for the placing on the market of hydrofluorocarbons.

Inter alia, there is a requirement that products and equipment that contain, or whose functioning relies upon, fluorinated greenhouse gases shall not be placed on the market unless they are labelled. The label required shall indicate the following information:

- a reference that the product or equipment contains fluorinated greenhouse gases or that its functioning relies upon such gases;
- the accepted industry designation for the fluorinated greenhouse gases concerned or, if no such designation is available, the chemical name;
- from 1 January 2017, the quantity expressed in weight and in CO_2-equivalent of fluorinated greenhouse gases contained in the product or equipment, or the quantity of fluorinated greenhouse gases for which the equipment is designed, and the global warming potential of those gases.

Further, the Regulation specifies certain types of equipment to be banned from being placed on the EU market from certain dates. Dishwasher appliances with heat pump technology applied are not listed under the prohibited products. Further, according to (AREA 2014), bans will not apply to Ecodesign equipment that has less lifecycle CO_2-equivalent emissions than equivalent equipment that meets Ecodesign requirements and does not contain HFCs. The conditions for such an exception would be as follows (AREA 2014):

- The equipment falls under Ecodesign requirements, i.e. an Ecodesign measure has been adopted for the equipment in question.
- It is explicitly established in the Ecodesign that the equipment, due to higher energy efficiency, has lifecycle CO_2-equivalent emissions lower than equivalent equipment which meets all relevant Ecodesign requirements and does not contain HFCs. However, currently none of the adopted ecodesign standards contain such statement.

The new Regulation also includes a phase-down scheme according to which the quantity of hydrofluorocrabonates (HFCs) placed on the EU market will gradually decrease between 2015 and 2030. Although the new Regulation does not name the alternative refrigerants, ammonia (NH_3), carbone dioxide (CO_2), hydrocarbons (HCs) and hydrofluoroolefine (HFOs) are the main fluids affected. It is expected that the combination of the phase-down and the planned bans will result in an increase in use of alternative refrigerants and technologies to HFCs.

1.3.1.6 EU Detergents Regulation 648/2004/EC

The Detergents Regulation 648/2004 (European Parliament 2004) stipulates the biodegradability of surfactants in detergents and restricts the use of not readily biodegradable surfactants. The Regulation introduced harmonized labelling requirements of detergents: the labelling comprises a labelling scheme on the packaging that includes the labelling of fragrance allergens. Besides, a detailed ingredient list has to be published on internet. Manufacturers must hold additional information on the detergents such as ingredient datasheet and safety tests at the disposal of the Member States' competent authorities and medical personnel in cases of accidents.

The REACH Regulation, (cf. section 1.3.1.3) stipulates the registration and evaluation of the substances in the detergents. Under REACH, manufacturers have to inform how the substance can be safely used, and they must communicate the risk management measures along the supply chain. The final detergents are considered mixtures under REACH. Also the CLP Regulation (cf. section 1.3.1.4) is applicable for detergents and their ingredients. The CLP Regulation ensures that the hazards presented by chemicals are clearly

communicated to workers and consumers in the European Union through classification and labelling of chemicals.
The latest amendment of Regulation (EC) No 648/2004, Regulation (EC) No 259/2012 (European Parliament 2012), concerned the limitations on the content of phosphorus compounds in consumer automatic dishwasher detergents. The total phosphorous content limit is set at 0.3 grams phosphorous per standard dose, being applicable by 1 January 2017.This restriction will not allow the use of phosphates in the consumer dishwasher detergents, as these compounds cause algae to grow at the expense of other aquatic life (eutrophication).

The European Commission stated in its press release that "*for consumer automatic dishwasher detergents more research and innovation is still needed to develop adequate alternatives to phosphates without reducing the efficacy of detergents*." (European Commission 2011b) The Regulation 259/2012 foresees that the Commission will re-assess the situation for automatic dishwasher detergents by 31 December 2014 to verify whether compliance with the phosphate limitation is economically and technically feasible taking into account cost, availability, cleaning efficiency and the impact on waste water treatment.
Phosphate acts as water-softeners and thereby prevents the deposition of lime scale; it dissolves grease and keeps it suspended in the washing water. Phosphate-free dishwasher detergents instead use other compounds e.g. sodium citrate and sodium disilicate (Groß et al. 2010). Also additional polycarboxylates are used as water softener. A market overview for Germany, for example, shows that most consumer automatic dishwasher detergents on the market still contain phosphate. (Stiftung Warentest 2014)

In September 2014, the study "Evaluation of the use of phosphates in consumer automatic dishwasher detergents (CADD)" (Bio by Deloitte 2014) has been published aiming at collecting information on the content of phosphates and alternatives in CADD. The availability of the alternatives that could potentially replace phosphorus compounds and reduce the phosphorus pollution of the waterways in the EU were identified with a particular focus on the cleaning efficiency, cost efficiency and impact on wastewater treatment process. The study provides an extensive overview about existing national and international policies and voluntary agreements limiting the content of phosphorus in CADD, describes the phosphate use in CADD and the availability, technical feasibility and performance of phosphates-free alternatives.
Regarding the performance of phosphate-free alternatives, consumer associations from various Member States have performed tests comparing performance of phosphates-free and phosphates-containing CADD. (Bio by Deloitte 2014) summarised their results as follows: *Overall, phosphates-free CADD and phosphates-containing CADD fall into similar performance range based on their cleaning efficiency. While a large number of high performing CADDs are generally phosphates-containing, some phosphates-free CADD are able to achieve similar level of performance.* The tests show that the use of phosphates is not the only factor influencing performance. Further, stakeholders being asked within the study remarked that the performance of CADD relies on many factors (formulation, product position, raw material prices variations and new technology development) that remain true whether or not phosphates were used. According to (Bio by Deloitte 2014), many stakeholders confirmed that phosphates-free CADD perform as well as the phosphate-containing CADD. A few noted that it is possible to have phosphates-free CADD that performs better than average phosphates-containing CADD, but that it comes at a higher cost. Only three stakeholders maintain that phosphates-free CADD do not perform as well as the phosphates-containing CADD.
In case of generally lower performing dishwashing detergents, this might have an overall impact if for example leading to compensation efforts realised by the dishwashing machines (e.g. higher energy and/or water consumption).

1.3.2 Ecolabels and other voluntary schemes – focus resource criteria

Note: This section only presents resource related criteria of existing European and national ecolabels for dishwashers. Energy and performance related criteria are presented separately in section 1.2.3.

1.3.2.1 Nordic countries: Nordic ecolabelling of white goods

In September 2014, version 5.0 of the Nordic Ecolabelling requirements for white goods (refrigerators and freezers, dishwashers, washing machines and tumble dryers) was published, valid from 20 June 2013 to 30 June 2017. (Nordic Ecolabelling 2014)
The following resource related criteria apply to dishwashers:

Table 1.18: Nordic ecolabelling: resource-related criteria for dishwashers; source: (Nordic Ecolabelling 2014)

Criteria category	Requirements
Manufacture – product requirements for dishwashers	
Description of manufacturing process and materials	Summary of all parts (type, materials); manufacturing process including different stages, including production technology, cleaning technology for surface treatment and metal plating of parts; name and location of factories for final assembly of core components (e.g. drum, pipework etc.); subcontractors for production of core components and for surface treatment and metal plating
Chemical products, classification	List of chemicals used in final assembly; safety data sheets for the chemical products
Chemical substances	Certain substances prohibited to be actively added to the chemical products named in the criterion above (such as cleaning products, paints, lacquers, adhesives, sealants used in final assembly and surface treatment)
Metal plating of parts	Metals may not be plated with cadmium, chromium, nickel, zinc or alloys of these. Exceptional cases are described as well as plating processes ensuring the greatest possible recovery of the chemical products.
Marking of plastic parts	Plastic parts that weight 50 grams or more must be marking in accordance with ISO 11469. (Cables and plastic parts with a smooth surface of less than 200 mm^2 are excluded from the requirement).
Flame retardants in plastic and rubber parts	Certain halogenated organic flame retardants and other flame retardants with certain risk phrases are not allowed to be added. An exemption from the latter requirement may be given for halogenated flame retardants in cases where these are required for electrical or fire safety reasons under the Low Voltage Directive 73/23/EEC or standard EN 60335-1; printed circuit boards PCBs; plastic and rubber parts weighing < 25 grams that are integral to electronic parts
Phthalates	Certain phthalates listed in the criteria document must not be added to plastic or rubber materials. The following are exempted from the requirement: Printed circuit boards PCBs; plastic and rubber parts weighing < 25 g that are integral to electronic parts
Antibacterial properties	Chemicals or additives (including nano materials such as silver ions, nano silver, nano gold and nano copper) that are added to create an antibacterial or disinfectant surface, in or on the product or to be released during the use of the product, must not be used.
Packaging	It must be possible to recycle or reuse the materials in the packaging and transport protection. Chlorine based plastics and biocide treated/impregnated timber must not be used in the packaging.
Waste	The manufacturer must sort different types of waste that arise from the production of the white good, for example glass waste, plastics and metals. A waste plan is to be included, listing waste fractions and a description of how the waste will be handled (e.g. recycling, landfill and incineration) and who will deal with the waste.
Requirements on customer information for dishwashers	
Installation and user instructions for dishwashers	Inter alia, Information on the addition/dosing of rinse aid and salt including adaptions necessary with regard to the water hardness, type of items, size and soiling of load
Warranties	The manufacturer has to provide a warranty that the dishwasher will work for at least two years. The warranty is to apply from the day that the machine is delivered to the customer.

Criteria category	Requirements
Replacement parts	The availability of replacement parts shall be guaranteed for 10 years from the time that production ceases.
Quality and regulatory requirements for dishwashers (excerpt)	
Quality of the white good	The licensee must guarantee that the quality of the Nordic Ecolabelled dishwasher is maintained throughout the validity period of the licence. Verification: Procedures for collating and, where necessary, dealing with claims and complaints regarding the quality of the Nordic Ecolabelled white goods.

1.3.2.2 Germany: Blue Angel Environmental Label for Household Dishwashers (RAL-UZ 152)

In February 2013, basic criteria for award of the German environmental label "Blue Angel" were published for household dishwashers, being valid until December 2016. The detailed resource related criteria are as follows (Ral gGmbH 2013):

Table 1.19: Blue angel: resource-related criteria for dishwashers

Criteria category	Requirements
Energy Consumption	
Energy Efficiency	The appliances shall at least meet the following energy efficiency ratings in accordance with Regulation (EU) 1059/2010 relating to household dishwashers: -Dishwashers > 45 cm wide: Energy efficiency class „A+++" (EEI < 50) -Dishwashers ≤ 45 cm wide: Energy efficiency class „A++" (EEI < 56)
Power Consumption in Left-On, Delay Start and Off Mode	In „Left-on" (end-of-cycle) mode, the power consumption of the appliance shall not exceed 0.5W. If the device comes with a display the power consumption in "Left-on" (end-of-cycle) mode shall not exceed 1.00 watt. In "Delay Start" mode, the power consumption of the appliance shall not exceed 4 watts. In "Off" mode, the power consumption shall not exceed 0.2 watts.
Water Consumption	
Water Consumption	Water consumption for the standard cleaning cycle calculated according to Regulation (EU) 1059/2010 relating to household dishwashers shall not exceed the following limits: -Dishwashers > 45 cm wide: maximum consumption: 2800 litres per year -Dishwashers ≤ 45 cm wide: maximum consumption: 2520 litres per year
AquaStop	The appliance shall come with an aquastop system. The applicant shall provide warranty on the proper functioning of the system for the entire life of at least 2800 standard cleaning cycles of the dishwasher, if properly installed. The product manual shall include the corresponding warranty information
Spare Parts Provision	
Spare Parts Provision	The applicant undertakes to make sure that the provision of spare parts for appliance repair is guaranteed for at least 10 years following the termination of production and that the customer is informed about this guaranteed availability of spare parts, e.g. by means of corresponding notes in the product manual. Spare parts are those parts which, typically, may break down within the scope of the ordinary use of a product - whereas those parts which normally exceed the average life of the product (aesthetic parts) are not to be considered as spare parts. Also, the applicant undertakes to provide after-sales services or hire a company to perform on-site repair work at customer's premises

Criteria category	Requirements
Materials	
Material Requirements for the Plastics used in Housing and Housing Parts	The plastics must not contain as constituents any substances classified as a) carcinogenic in category 1 or 2 according to Table 3.2 of Annex VI to Regulation (EC) No 1272/20089, b) mutagenic in category 1 or 2 according to Table 3.2 of Annex VI to Regulation (EC) No 1272/2008 c) toxic to reproduction in category 1 or 2 according to Table 3.2 of Annex VI to Regulation (EC) No 1272/2008 d) being of very high concern for other reasons according to the criteria of Annex XIII to the REACH Regulation, provided that they have been included in the Candidate List set up in accordance with REACH, Article 59, paragraph 1. Halogenated polymers shall not be permitted. Nor may halogenated organic compounds be added as flame retardants. Moreover, no flame retardants may be added which are classified pursuant to Table 3.1 or 3.2 in Annex VI to Regulation (EC) 1272/2008 as very toxic to aquatic organisms with long-term adverse effect and assigned the Hazard Statement H 410 or Risk Statement R 50/53. The following shall be exempt from this rule: -process-related, technically unavoidable impurities; -fluoroorganic additives (as, for example, anti-dripping agents) used to improve the physical properties of plastics, provided that they do not exceed 0.5 weight percent; -plastic parts less than 25 grams in mass.
Insulation Materials	If fibrous insulation materials are used, such as mineral, glass or rock wool, the applicant shall present a test report showing that the carcinogenicity index (CI) of the products concerned is ≥ 40 and, hence, the material need not be classified as carcinogenic or suspected of causing cancer in accordance with the classification scheme of TRGS 905. Ceramic mineral fibres, i.e. glassy (silicate) fibres with an alkali metal oxide and earth alkali metal oxide content (Na2O + K2O+ CaO + MgO + BaO) of less than or equal to 18 % wt may not be used.
Design requirements	
Systems using Biocidal Silver	The use of systems using biocidal silver shall not be permitted.
Recyclable and Easy-to-Maintain Design	The appliance shall be so designed as to allow quick and easy disassembly with a view to facilitating repair and separation of valuable components and materials. This means that: -it must be possible to separate the connections concerned by the use of ordinary tools and the joints must be easily accessible, -plastics should consist of only one polymer or plastic parts greater than 25 g in mass must be marked according to ISO 11469 to allow for a sorting of plastics by type and -disassembly instructions must be made available to end-of-life recyclers or treatment facilities in order to recover as many valuable resources as possible
Information	
Consumer Information	The energy, water and detergent consumption of dishwashers greatly depends on the user behaviour (above all, by the user's way of loading and cleaning program selection). The operating instructions/product manual as well as manufacturer's website shall at least include the following basic user information/instructions: 1. Recommendation to adjust the amount of detergent to the level of soiling and a note stating that energy and water-saving cycles usually suffice for daily use; 2. Recommendation to adjust the salt usage to the hardness of the local water; 3. Note stating that there is no need to rinse the dishes before placing them in the dishwasher; 4. Information on the 10-year provision of spare parts as well as a contact

1.3.2.3 Ecolabels and other voluntary schemes regarding the use of detergents

1.3.2.3.1 Ecolabel for detergents

The EU Ecolabel criteria for detergents for dishwashers were adopted in 2011 (Commission Decision 2011/263/EU). The aim of these criteria documents was to promote dishwasher detergents that corresponded to the best 10-20 % of the products available on the Community market in terms of environmental performance considering the whole life-cycle of production, use and disposal. These criteria are due to expire in 2016. Currently, these criteria are under review (for more details, cf. http://susproc.jrc.ec.europa.eu/detergents/index.html).

1.3.2.3.2 The A.I.S.E. Charter for Sustainable Cleaning

This voluntary initiative of the European cleaning and maintenance products industry established since 2005 sets high level standard to drive sustainable progress and standard in the detergent industry. More than 200 companies have joined the project, representing over 95% of the total production output for Europe. The Charter stipulates a set of Charter Sustainability Procedures for companies to implement in their management systems. It also defines a set of key performance indicators (KPIs) linked to the sustainability procedures and covering the whole lifecycle. Companies signed up to the Charter must report annually on these KPIs to measure their progress towards sustainable cleaning. The data collected is independently verified by an international audit firm.

Since 2010, the Charter also incorporates a product dimension, enabling companies to offer sustainability assurance for individual products, by complying with Charter Advanced Sustainability Profiles (ASPs). The Advanced Sustainability Profiles cover following aspects: Ingredient's safety (if applicable), product formulation, packaging weight and recycled content as well as end-user information.

Products which meet the requirements of these ASPs may then use a differentiated 'ASP' logo on pack which signifies not only that the manufacturer is committed to certain sustainability processes at the manufacturing level, but also that the product itself meets certain advanced sustainability criteria. ASPs are specific to product categories. The following criteria for automatic dishwashing detergents exist

Criteria for household Automatic Dishwashing (ADW) Detergents

The following requirements in each of these domains (i.e. product formulation, packaging and end-use information) should be fulfilled in order to reach ASP status (A.I.S.E. 2012):

Table 1.20: Advanced Sustainability Profile (ASP) requirements for household automatic dishwashing (ADW) detergents; source (A.I.S.E. 2012)

Criteria category	Powders and unit doses (e.g. tabs, gel sachets, liquid sachets) with rinse function	Powders and unit doses (e.g. tabs, gel sachets, liquid sachets) without rinse function	Automatic dishwashing detergents: liquids
Product formulation	Pass successfully Environmental Safety Check (ESC) on all ingredients AND Dosage g/job (1 dish wash cycle, normal soil, excluding free water from liquid / gel unit doses): ≤ 25 g	Pass successfully Environmental Safety Check (ESC) on all ingredients AND Dosage g/job (1 dish wash cycle, normal soil, excluding free water from liquid / gel unit doses): ≤ 20 g	Pass successfully Environmental Safety Check (ESC) on all ingredients AND Dosage ml/job (1 dish wash cycle, normal soil): ≤ 35 ml
Packaging weight per job	Total (primary + secondary but excluding tertiary) packaging g/job: ≤ 3.5 g		Total (primary + secondary but excluding tertiary) packaging g/job: Mono chamber style ≤ 4.5 g Multi chamber style ≤ 6 g
Board	Minimum requirement: ≥ 60 %		

Criteria category	Powders and unit doses (e.g. tabs, gel sachets, liquid sachets) with rinse function	Powders and unit doses (e.g. tabs, gel sachets, liquid sachets) without rinse function	Automatic dishwashing detergents: liquids
packaging – recycled content	OR Where 100% of the board used is certified made from fibre sourced from sustainable forests under an endorsed certification standard such as FSC, SFI or PEFC: no minimum.		
Materials other than board – recycled content	No minimum, but any recycled plastic content may be excluded from the calculation of overall packaging weight per job		
End user information	Safe use tips AND Autodish Cleanright Panel on-pack		
Performance	Evidence has to be provided (in case of external verification organised by A.I.S.E.) that the product has been performance tested and reached a level acceptable to consumers consistent with claims made.		

The products also carry on a voluntary basis some best use advice to promote the sustainable use of detergents (dosage, low temperature washing, filling of the machine etc.) whether laundry or automatic dishwashing detergents, which are featured on all packs of products.

1.3.3 Test standards for resource efficiency, durability and recyclability

In the following, an overview of existing test standards and measurement methods for resource efficiency with regard to the aspects durability (maintenance, repair, re-use) and recyclability is given. Table 1.21 shows an overview of the standards discussed in this section.

Table 1.21: Overview of the standards for resource efficiency, durability and recyclability

	Standards for resource efficiency, durability and recyclability
Durability	Austrian standard ONR 192102:2014 on durable, repair-friendly designed electrical and electronic appliances
	British PAS 141 re-use standard
	Durability test standards and measurement methods applied in EU Ecodesign and Ecolabel Regulations International IEC 60068-1 ed7.0 Environmental testing
	Safety standards for products and components, indirectly addressing durability
Recyclability and end-of-life of EEE	EN 50574: Collection, logistics and treatment requirements for end-of-life household appliances containing volatile fluorocarbons of volatile hydrocarbons
	TS 50574-2: Collection, logistics & treatment requirements for end-of-life household appliances containing volatile fluorocarbons or volatile hydrocarbons - Part 2: Specification for de-pollution
	European Commission's Mandate M/518 for standardisation in the field of Waste Electrical and Electronic Equipment (WEEE)
	EN 50625 standard series: Collection, logistics & treatment requirements for WEEE
	EN 50614 (under preparation): Requirements for the preparation for re-use of waste electrical and electronic equipment
	European Commission's draft Mandate M/529 with regard to ecodesign requirements on material efficiency
	IEC/TR 62635: Guidelines for end-of-life information provided by manufacturers and recyclers and for

	Standards for resource efficiency, durability and recyclability
	recyclability rate calculation of electrical and electronic equipment
	IEC/TC 111 PT 62824: Guidance on consideration and evaluation on material efficiency of electrical and electronic products in environmentally conscious design. ISO 11469: Plastics - Generic identification and marking of plastics products
	British standard BS 8887: Design for Manufacture, assembly, disassembly and end-of-life processing

1.3.3.1 Durability

According to stakeholder feedback from the questionnaire (JRC IPTS 2015a), there exist only few standards originally designed for durability purposes.

1.3.3.1.1 Austrian standard ONR 192102:2014 on durable, repair-friendly designed electrical and electronic appliances

ONR 192102:2014-10-01 with regard to a label of excellence for durable, repair-friendly designed electrical and electronic appliances replaces ONR 192102 from 2006.

Manufacturers of electrical and electronic equipment, who intend to mark their products with a label for repair-friendly designed appliances, have to test their products according to the requirements of ONR 192102 verifying compliance with a test report. According to (Ricardo-AEA 2014b), this standard suggests a labelling system with three levels of achievement (good, very good, excellent) based mostly upon reparability criteria. The standard includes white goods (such as dishwashers). The aim is to consider reparability to ensure products are not discarded sooner than is necessary as the result of a fault or inability to repair a fault.

The in total 40 criteria for white goods are split into mandatory criteria and other criteria for which a certain scoring can be achieved. To comply, products have to fulfil all mandatory requirements and achieve a minimum number of scores for common criteria and for service documentation.

The types of requirements include criteria such as accessibility of components, ease of disassembly, use of standard components, achievable service life (at least 10 years for white goods), availability of spare parts (at least 10 years after the last production batch), facilitation of regular maintenance, and further service information (inter alia free access for all repair facilities (not only authorized repairers) to repair-specific information). Each requirement is underpinned with some examples of realisation; however, no specific testing procedures and techniques are detailed.

1.3.3.1.2 British PAS 141 re-use standard

The PAS 141 specification has been developed by British Standards Institution (BSI) to increase the re-use of electrical and electronic equipment and to ensure that they are tested and repaired to a minimum level. The British non-for-profit company WRAP has developed a set of protocols based on industry experience highlighting tests and procedures to be carried out. The product protocols form a baseline for electrical product assessment and repair for re-use and can be used as a guideline to product assessment and testing (WRAP [n.d.]b).

The PAS 141 Protocol Product Guide for Dishwashers developed by WRAP describes a series of minimum tests that should be performed on domestic-use dishwashers when the product shall be considered functional or fit for re-use for auditing purposes. No specific testing procedures and techniques are described as the protocol shall be applied as widely as possible. (WRAP 2013b)

The following components of a dishwasher shall undergo a visual inspection, safety or function test:

Table 1.22: PAS 141 Protocol Product Guide for Dishwashers (Source: adapted (WRAP 2013b))

Component	Test
Hoses, trims, connector, seals	Visual inspection of condition and for damage
Door hinges and handles Detergent dispenser	Visual inspection of condition
Knobs, switches, internal racks and spray bars	Visual inspection of absence or damage

Component	Test
Cabinet and back panel	Visual inspection of condition
Feet	Visual inspection of absence or damage
Plug and lead cables	Safety test regarding condition and connection
Door locking mechanism	Function test
Hoses, connectors, seals	Function test for leakage
Programme control timer	Function test
Internal components	Function test
Thermostat and heating element	Function test
Wash and rinse phases, drain phase, dry phase	Function test
Outlet pipe, sump hose	Function test regarding damage or leaks
LED display (if applicable)	Function test

1.3.3.1.3 Durability test standards and measurement methods applied in EU Ecodesign and Ecolabel Regulations

In some existing EU Ecodesign Regulations requirements with regard to the durability of products or components are specified. The according test procedures are detailed in sections 5.1 to 5.3.

International IEC 60068-1 ed7.0 Environmental testing

The test procedures described in this IEC standard are used as reference in the draft EU Ecolabel criteria for "Personal, notebook and tablet computers" with regard to durability testing of portable computers (cf.section 1.3.2.3).

IEC 60068-1:2013 includes a series of methods for environmental testing along with their appropriate severities, and prescribes various atmospheric conditions for measurements and tests designed to assess the ability of specimens to perform under expected conditions of transportation, storage and all aspects of operational use. Although primarily intended for electro-technical products, this standard is not restricted to them and may be used in other fields where desired. The IEC 60068 series consists of:

- IEC 60068-1 – General and guidance, which deals with generalities;
- IEC 60068-2 – Tests – which publishes particular tests separately for different applications;
- IEC 60068-3 – Supporting documentation and guidance, which deals with background information on a family of tests. The families of tests comprising Part 2 of the IEC 60068 series are designated by the following upper-case letters:
  - A: Cold
  - B: Dry heat
  - C: Damp heat (steady-state)
  - D: Damp heat (cyclic)
  - E: Impact (for example shock and rough handling shocks)
  - F: Vibration
  - G: Acceleration (steady state)
  - H: (Awaiting allocation; originally allotted to storage tests)
  - J: Mould growth
  - K: Corrosive atmospheres (for example salt mist)

- L: Dust and sand
- M: Air pressure (high or low)
- N: Change of temperature
- P: (Awaiting allocation; originally allotted to "flammability")
- Q: Sealing (including panel sealing, container sealing and protection against ingress and leakage of fluid)
- R: Water (for example rain, dripping water)
- S: Radiation (for example solar, but excluding electromagnetic)
- T: Soldering (including resistance to heat from soldering)
- U: Robustness of terminations (of components)
- V: (Awaiting allocation; originally allocated to "acoustic noise" but "vibration, acoustically induced" will now be Test Fg, one of the "vibration" family of tests.
- W: (Awaiting allocation)
- Y: (Awaiting allocation)

1.3.3.1.4 Safety standards for products and components, indirectly addressing durability

There are some standards which are related to the safety of products and components and seem to address quality and/or durability of those components at least indirectly.
For example, EN 60335 addresses product safety; EN 60335 Part 1 defines general safety requirements on household and similar electrical appliances, whereas Part 2 is divided into specific sub-parts each containing appropriate appliance specific safety requirements inter alia for dishwashers:

Table 1.23: Examples of safety standards for household and similar electrical appliances and their indirect requirements for quality and durability of components to comply with product safety

Standard	Component	Requirement
Household and similar electrical appliances - Safety - Part 1: General requirements; EN 60335-1:2012/FprAD:2014, Annex C	Engine	Ageing-check for engines (in device-specific parts are modifications possible)
Household and similar electrical appliances - Safety - Part 1: General requirements; EN 60335-1:2012/FprAD:2014, section 25	Power supply and external cables	(In device-specific parts are modifications possible regarding the number of operating cycles)
Household and similar electrical appliances - Safety - Part 1: General requirements; EN 60335-1:2012/FprAD:2014; section 23	Inner cables	The flexible part is being moved with 30 bends per minute backwards and forwards, so that the conductor is bended by the feasible biggest angle, enabled with this construction. The number of bends accounts: 10,000 for conductors, which are bended during proper use 100 for conductors, which are bended during users-maintenance (In device-specific parts are modifications possible, concerning the number of bends)
Household and similar electrical	Components:	Number of operating cycles have to add up to at

Standard	Component	Requirement
appliances - Safety - Part 1: General requirements; EN 60335-1:2012/FprAD:2014, section 24; standard for switches: IEC 61058-1	Switches	least 10,000
Household and similar electrical appliances - Safety - Part 1: General requirements; EN 60335-1:2012/FprAD:2014, section 24; standard for Regulation- and control systems is IEC 60730-1	Components: Regulation and control systems	Minimum number of required operating cycles for example for temperature controllers: 10,000; for operating temperature limiter – 1,000 (In device-specific parts are modifications possible regarding the number of operating cycles)
Household and similar electrical appliances - Safety - Part 2-5: Particular requirements for dishwashers (IEC 61/4313/ CDV:2011); FprEN 60335-2-5:2011	Ageing-check for elastomer parts	Test to determine hardness and mass of elastomer parts before and after dipping in detergent and rinse-aid with increased temperature
ISO 6804:2009	Rubber and plastics inlet hoses and hose assemblies for dishwashers	Requirements for three types of rubber or plastics inlet hoses and hose assemblies for washing-machines and dishwashers connected to the domestic water supply at a pressure not exceeding 1 MPa (10 bar). It is applicable to the following types of hose: Type 1: rubber hoses for unheated water supply (maximum temperature 70 °C). Type 2: rubber hoses for heated water supply (maximum temperature 90 °C). Type 3: plastics hoses for unheated water supply (maximum temperature 60 °C). The standard foresees performance requirements for finished hoses, such as bending tests, flexing tests, resistance to kinking, resistance to hydrostatic pressure after ageing resistance to ozone or weathering, resistance to hydraulic-pressure impulse test, adhesion and mechanical resistance of thermoplastics coupling nuts.

According to stakeholder feedback, however, those existing safety and endurance / performance standards cannot directly be translated into durability standards. The standards are used by companies to test the safety of their appliances under endurance tests and extreme conditions to ensure consumers' safety during functioning of the appliance, but also in case of incident (stress tests to ensure that people do not get hurt). This is especially true for safety standards to measure components for failure. According to the stakeholders' feedback to the questionnaire (JRC IPTS 2015a), methods for testing failed components have no relation to component durability, although they might be a good starting point for standardisation organisations' investigations in starting up standardisation work for testing durability of appliances and/or components. In this context, the safety standards would have to be checked for details of the testing conditions to make sure that they are applicable for an alternative purpose.

(Ricardo-AEA 2014b) argued in the same direction, that the adoption of the EN 60335 test requirements into an ecodesign Regulation would not affect the durability performance of appliances since these requirements should already be achieved and declared for LVD compliance. However, they could be the basis of tests, potentially with higher minimum standard pass requirements.

(Ardente & Talens Peirò 2015) conducted a survey in the websites which revealed that several manufacturers of household dishwashers claim to perform durability tests on sample of devices before

putting them in the market. Tests are generally based on intensive use under pre-set conditions, in order to simulate the total number of washing cycles during lifetime. (Ardente & Talens Peirò 2015) propose these manufacturers' procedures to be potentially translated into standardised procedures.

1.3.3.2 Recyclability and end-of-life treatment of electrical and electronic equipment

1.3.3.2.1 EN 50574: Collection, logistics and treatment requirements for end-of-life household appliances containing volatile fluorocarbons of volatile hydrocarbons

This European standard was prepared by CENELEC's Technical Committee 111X / Working Group 04, "Environment - End of life requirements for household appliances containing volatile fluorinated substances or volatile hydrocarbons" and published in 2012. It defines requirements for the end of life handling, transportation, storage, sorting and treatment of WEEE household appliances containing volatile fluorocarbons, volatile hydrocarbons, or both; as well as requirements for monitoring and reporting. Furthermore, this European standard only applies to WEEE household appliances that use heat-transfer media other than water e.g. refrigerators, freezers, heat pump tumble dryers, de-humidifiers and portable air conditioners. Also dishwashers, if operated with heat pump, are covered by this standard. Discarded appliances covered by this European Standard will have to be deposited at a collection facility as domestic WEEE.

The standard describes requirements for the removal of volatile fluorocarbons and volatile hydrocarbons. These substances can be found as refrigerant in the refrigerating system (partly dissolved in the oil) and as blowing agent in the insulating foam of discarded household appliances.

Further, Annex D of the standard includes sorting requirements for heat pump tumble dryers based on instructions for identifying tumble dryers containing fluorinated refrigerants. According to the European F-gas Regulation (cf. section 1.3.1.5) and the WEEE Directive (cf. section 1.3.1.2), volatile fluorinated hydrocarbons (VFCs) have to be removed when recycling appliances. Special treatment plants are required to recycle appliances containing VFCs. To achieve the right treatment for heat pump tumble dryers with VFCs it is therefore necessary to ensure identification and correct sorting of these appliances. The following procedure should be used to facilitate this identification: Marking according to the requirements of the F-gas Regulation. The information is usually printed on a separate label, placed on the back of the machine with a text declaring that the appliance contains fluorinated gases that are covered by the Kyoto protocol. Or it could be included in the main rating plate. Other ways of identification, if the information is not provided via F-gas label or the main rating plate is the existence of a compressor and a heat exchanger which can be seen when opening the device.

Although these requirements have been exemplified for tumble dryers, they should also be applicable to other household appliances if operated with heat pumps, such as e.g. dishwashers with a heat pump.

1.3.3.2.2 TS 50574-2: Collection, logistics & treatment requirements for end-of-life household appliances containing volatile fluorocarbons or volatile hydrocarbons - Part 2: Specification for de-pollution

This Technical Specification, published in November 2014, is intended to support EN 50574:2012 (see above) by providing further normative requirements for the measurement of de-pollution for treatment of end-of-life household appliances containing volatile fluorocarbons or volatile hydrocarbons. Any characteristic numbers and target values within this technical specification are based on evidence gathered by technical experts over a time period of more than two years when performing test according to EN 50574:2012.

EN 50574:2012 gives the responsible take-back parties the task of defining target values (e.g. for treatment, and minimum masses of volatile fluorocarbons or volatile hydrocarbons to be recovered). This Technical Specification provides applicable target values, characteristic numbers, sampling and analysis procedures, as well as monitoring and reporting requirements. Furthermore the Technical Specification provides validation methodologies for tests and the daily business of the treatment plants as defined in EN 50574:2012.

1.3.3.2.3 European Commission's Mandate M/518 for standardisation in the field of Waste Electrical and Electronic Equipment (WEEE)

According to (CENELEC n.d.), mandates, also called standardization requests are the mechanism by which the European Commission and the EFTA Secretariat request the European Standards Organizations (ESOs) to develop and adopt European standards in support of European policies and legislation. This mechanism evolves through several steps: Sending a provisional draft mandate, a draft mandate and finally a

mandate for acceptance to CENELEC. The Technical Board Members are invited (not) to accept the given mandate, with or without restrictions, based on the Technical Body and CENELEC feedback. In case of acceptance of the mandate, the Technical Body is entrusted with the task of starting expected standardization work within CENELEC.
In January 2013, the European Commission has sent Mandate M/518 to the European standardisation organisations with the purpose to develop one or more European standard(s) for the treatment (including recovery, recycling and preparing for re-use) of waste electrical and electronic equipment, reflecting the state of the art. The European standard(s) requested by this mandate shall assist relevant treatment operators in fulfilling the requirements of the WEEE Directive. (European Commission 2013b)

1.3.3.2.4 EN 50625 standard series: Collection, logistics & treatment requirements for WEEE

CENELEC, through its Technical Committee 'Environment' (CLC/TC 111X), is leading the development of standards (and other deliverables) that will support the implementation of the EU Directive on Waste Electrical and Electronic Equipment. These standards, which are being developed in response to a request issued by the European Commission (EC M/518, see section above), cover various aspects of the treatment of electronic waste (including collection, treatment requirements, de-pollution and preparing for re-use). TC111X works on standards related to the environment and set up Working Group 6 for the EN 50625 series.
According to (SENS/Swico/SLRS 2014), the general standard EN 50625-1 (Collection, logistics & treatment requirements for WEEE - Part 1: General treatment requirements) came into force recently. On 20 December 2013 the voting of the European National Committees on the general WEEE treatment standard EN 50625 resulted in the acceptance of the standard which was finally published in March 2014. It establishes the basis for the standards to follow for individual categories of equipment, such as lamps, monitors and photovoltaic panels and other equipment containing volatile fluorocarbons or volatile hydrocarbons; the latter being also relevant for dishwashers with heat pumps. These more specific standards will contain references to the general standard, and together they will form the EN 50625 series. Additionally, an associated Technical Specification TS 50625-3-1 for de-pollution (general) has been developed in 2014.
The standard on general treatment requirements includes on the one hand administrative and organisational requirements for the treatment operator and the treatment facility such as management, infrastructural pre-conditions, training and monitoring. On the other hand, technical requirements regarding the handling of WEEE, the storage of WEEE prior to treatment, the de-pollution process, the determination of recycling and recovery targets and documentation requirements. The technical specification further details different methodologies for monitoring of de-pollution.
According to (SENS/Swico/SLRS 2014), the technical specifications are just as binding as the standards themselves, except that they contain limit values and target values as well as instructions for taking samples of material and specific details for performing tests.
Besides Part 1 on general treatment requirements, further parts are under development:

- EN 50625-2-1: Treatment requirements for lamps plus associated Technical Specification for de-pollution TS 50625-3-2
- EN 50625-2-2: Treatment requirements for WEEE containing CRTs and flat panel displays plus associated Technical Specification for de-pollution TS 50625-3-3
- EN 50625-2-3: Treatment requirements for WEEE containing volatile fluorocarbons or volatile hydrocarbons; according to stakeholder feedback, this standard has currently a draft status and is planned to replace EN 50574:2012. Also for this standard, an associated Technical Specification for de-pollution (TS 50625-3-4**)** will be developed. According to stakeholder feedback, the draft is not yet available, however, will replace TS 50574-2:2014 when adopted.
- EN 50625-2-4: Treatment requirements for WEEE for photovoltaic panels plus associated Technical Specification for de-pollution TS 50625-3-5.

Additionally to these 5 standards and corresponding Technical Specifications (TS), three further TS shall be developed covering horizontal matters:

- TS 50625-4: Specification for the collection and logistics associated with WEEE
- TS 50625-5: Specification for the end processing of WEEE fractions – copper and precious metals
- TS 50625-6: Report on the alignment between Directive 2012/19/EU and EN 50625 series standards

For household dishwashers, especially the standard and technical specification regarding the treatment of WEEE containing refrigerants would be applicable in case of appliances operated with heat pumps. If in future, appliances would be equipped with control panels greater than 100 cm^2, also EN 50625-2-2 and TS 50625-3-3 would apply. Precious metals, for which the technical specification TS 50625-5 is planned, can be found for example in PWBs, containing palladium, silver and gold, and in permanent magnet motors of dishwashers.
Whereas the standards and according technical specifications define requirements regarding the removal and further treatment of certain substances, mixtures and components such that they are contained as an identifiable stream or part of a stream by the end of the treatment process, they do not specify requirements for better identification or ease of dismantling of those components to facilitate the end-of-life treatment process itself.

1.3.3.2.5 EN 50614 (under preparation): Requirements for the preparation for re-use of waste electrical and electronic equipment

The Technical Committee CLC/TC 111X, Working Group 7 started the preparation of such a standard in March 2014 and is planned to be completed in December 2015.

1.3.3.2.6 European Commission's draft Mandate M/529 with regard to ecodesign requirements on material efficiency

The European Commission addressed a standardization request to the ESOs to develop generic methodologies related to material efficiency, such as durability, reusability, recyclability and recoverability. Related aspects, such as upgradeability, reversible disassembly time, end of life dismantling time, part mass or value, calculation of recycled and re-used content in products, or other relevant characteristics relevant for the product groups under consideration, were asked to be included if appropriate.. The request covered the following generic standards to be developed (European Commission 2015a):

Reusability / recyclability / recoverability (RRR) indexes by mass

Reusability / recyclability / recoverability (RRR) indexes by environmental impact

Durability of products or some of their key components

Measuring the time for the reversible disassembly, substitution and re-assembly of key components of products

Measuring the dismantling time of products (or of its components) at end-of-life

Reusability / recyclability / recoverability (RRR) indexes by mass, i.e. the amount of reusable, recyclable and recoverable (RRR) materials compared to the overall product mass. The standardization work shall include the definition of tables about recycling and recovery rates of some specific materials and components present in products in the scope of the Ecodesign Directive. The rates shall be based on literature references as well as field surveys at representative EU recycling plants. Further, guidance on how to build such representative and quality-assured tables shall be provided, including the development and calculation of sub-indexes targeted to the RRR indexes of certain substances or materials with an economic and/or environmental interest, such as for example critical raw materials.

Reusability / recyclability / recoverability (RRR) indexes by environmental impact: the environmental-based indicators shall be calculated upon mass-based indicators including life cycle impacts of materials and components, and related to the overall product life cycle impacts. The standardization work shall provide guidance for the identification of representative quality-assured Life Cycle Inventory data to be used for the calculations. Attention shall be paid to the likely evolution of recycling methods and techniques over time.
Durability of products or some of their key components, and/or their ease of maintenance and repair. The standardisation work shall include the identification of critical components within a product that influence its durability and the definition of a method to define acceptable performances of durability of products, integrating technical, environmental, economic and consumer aspects.
Measuring the time for the reversible disassembly, substitution and re-assembly of key components of products, i.e. during maintenance, for re-use or remanufacturing; as well as measuring the dismantling time of products (or of identified critical components) at end-of-life in order to improve resource/material efficiency. The standardised procedure (which might be product-specific) should include the definition of key aspects, such as the experience of workers performing the measurement, pre-conditions for the measurement, how to define the sequence of steps for the disassembly/substitution/re-assembly of key components, tools/machines to be used for the process, tools used for the measurement, tolerance of the measurement.
According to (ECOS, EE and UK SNS 2015), the standardisation organisations rejected the Commission's initial mandate on the grounds that it was too prescriptive on the requirements asked for and also the inability to fully develop the methods within the proposed timescale.
The European Commission will specify the standardization request accordingly and hand in the revised mandate to the ESOs again. However, once the request is made, the process of developing such standards could take up to three years or even more.
Further national and international standards with regard to end-of-life treatment and facilitating recyclability are listed in the following:

1.3.3.2.7 IEC/TR 62635: Guidelines for end-of-life information provided by manufacturers and recyclers and for recyclability rate calculation of electrical and electronic equipment

The Technical Report IEC/TR 62635:2012 ed1.0 (IEC 2012) provides a methodology for information exchange involving EEE manufacturers and recyclers, and for calculating the recyclability and recoverability rates to

- Provide information to recyclers to enable appropriate and optimized end-of-life treatment operations,
- Provide sufficient information to characterize activities at end-of-life treatment facilities in order to enable manufacturers to implement effective environmental conscious design (ECD),
- Evaluate the recyclability and recoverability rates based on product attributes and reflecting real end-of-life practices.

Furthermore this technical report includes:

- Criteria to describe EoL treatment scenarios;
- Criteria to determine product parts that might require removal before material separation and related information to be provided by manufacturers (location and material composition);
- A format for information describing EoL scenarios and the results of EoL treatment activities;
- A method for calculating the recyclability and recoverability rate of EEE. The calculation is limited to EoL treatment and does not cover collection. The recyclability rate is expressed as a percentage of the mass of the product that can be recycled or reused, whereas the recoverability rate in addition includes a portion derived from energy recovery. This technical report can be applied to all electrical and electronic equipment;

- Some example data corresponding to identified scenarios.

1.3.3.2.8 IEC/TC 111 PT 62824: Guidance on consideration and evaluation on material efficiency of electrical and electronic products in environmentally conscious design.

Further, under the IEC Technical Committee 111, Project Team 62824 has been established to provide guidance on consideration and evaluation on material efficiency of electrical and electronic products in environmentally conscious design.

1.3.3.2.9 ISO 11469: Plastics - Generic identification and marking of plastics products

This International Standard, published in 2000, specifies a system of uniform marking of products that have been fabricated from plastics materials. The marking system is intended to help identify plastics products for subsequent decisions concerning handling, waste recovery or disposal. Generic identification of the plastics is provided by the symbols and abbreviated terms given in ISO 1043, parts 1 to 4:

- ISO 1043-1, Plastics — Symbols and abbreviated terms — Part 1: Basic polymers and their special characteristics.
- ISO 1043-2, Plastics — Symbols and abbreviated terms — Part 2: Fillers and reinforcing materials.
- ISO 1043-3, Plastics — Symbols and abbreviated terms — Part 3: Plasticizers.
- ISO 1043-4, Plastics — Symbols and abbreviated terms — Part 4: Flame retardants.

The standard includes requirements on the marking system and the method of marking. The marking system is subdivided into marking of products, of single-constituent products, of polymer blends or alloys, and of compositions with special additives (fillers or reinforcing agents, plasticizers, flame retardants and products with two or more components difficult to separate).
The standard is often referred to in ecolabels containing requirements on resource efficiency and end-of-life treatment of appliances.

1.3.3.2.10 British standard BS 8887: Design for Manufacture, assembly, disassembly and end-of-life processing ("MADE")

The British Standards Institution has developed a design for manufacture standards series BS 8887 (Design for Manufacture, Assembly, Disassembly and End-of-life processing MADE) first in 2006. The series contains of following sub-standards:

- BS 8887-1: Design for manufacture, assembly, disassembly and end-of-life processing (MADE) – part 1: General concepts, process and requirements (01 February 2012, superseding BS 8887-1:2006)
- BS 8887-2: Design for manufacture, assembly, disassembly and end-of-life processing (MADE) – part 2: Terms and definitions (01 July 2014)
- BS 8887-211: Design for manufacture, assembly, disassembly and end-of-life processing (MADE) – part 211: Specification for reworking and remarketing of computing hardware (31 August 2012). This sector-specific standard focuses on the information and communication technology sector and created to provide the vocabulary and procedures for 'remarketed products', i.e. products that cannot be sold as new. It is planned to develop a generic remarketing standard for use by all sectors, using BS 8887-211 as a template (BSI Group n.d.).
- BS 8887-220: Design for manufacture, assembly, disassembly and end-of-life processing (MADE) – part 220: The process of remanufacture – specification. It outlines the steps required to change a used product into an 'as-new' product, with at least equivalent performance and warranty of a comparable new replacement product (BSI Group n.d.).
- BS 8887-240: Design for manufacture, assembly, disassembly and end-of-life processing (MADE) – part 240: Reconditioning (March 2011)

According to (BSI Group n.d.),

> *In 2012, BS 8887-1 was put forward to the ISO and it has been accepted onto the work programme of the ISO committee with responsibility for technical product documentation. A new working group is being set up, which will be led by the UK, and work to convert BS 8887-1 into an international standard.*

The international standard BS ISO 8887-1 Design for manufacture, assembly, disassembly and end-of-life processing (MADE) Part 1: General concepts, process and requirements is currently in development, by the BSI committee TDW/4 'Technical Product Realization' being responsible.

1.3.3.3 Test standards regarding the performance of detergents

According to (JRC IPTS 2014), in ecolabels the cleaning performance of dishwasher detergents is either tested according to a modified standard EN 50242 (cf. section 1.2.2.1), or according to a standard test developed by the Association of German Detergent Manufactures (IKW). A detailed description of the IKW test method can be found in (IKW 2006); however, according to (JRC IPTS 2014), for household dishwasher detergents the IKW test method is currently under revision.

Within the current EU Ecolabel for dishwasher detergents (under revision, cf. section 1.3.2.3), for example, tests shall be carried out to ensure that the product has a satisfactory wash performance at the recommended dosage according to the standard test developed by IKW or the modified standard EN 50242 as follows: The tests shall be carried out at 55 °C or at a lower temperature if the product claims to be efficient at this temperature. When applying for rinse aids in combination with dishwasher detergents, the rinse aid shall be used in the test instead of the reference rinse aid. For multifunctional products the applicant must submit documentation proving the effect of the claimed functions.

Modifications apply if the EN 50242:2008 test is to be used:

- The tests shall be carried out at 55 °C ± 2 °C (or at a lower temperature if the detergent claims to be efficient at a temperature below 55 °C) with cold pre-wash without detergent.
- The machine used in the test shall be connected to cold water and must hold 12 ps with a washing index of between 3.35 and 3.75.
- The machine's drying programme shall be used, but only the cleanliness of the dishes shall be assessed.
- A weak acidic rinsing agent in accordance with the standard (formula III) shall be used.
- The rinsing agent setting shall be between 2 and 3.
- The dosage of dishwasher detergent shall be as recommended by the manufacturer.
- Three attempts shall be carried out at water hardness in accordance with the standard.
- An attempt consists of five washes where the result is read after the fifth wash without the dishes being cleaned between the washes.
- The result shall be better than or identical to the reference detergent after the fifth wash.
- Recipe for the reference detergent (Detergent B IEC 436) and rinsing agent (formula III) see Appendix B in the standard EN 50242:2008 (the surfactants are to be stored in a cool place in watertight containers not exceeding 1 kg and are to be used within 3 months).

If rinse aid and salt functions are part of a multifunctional product the effect must be documented by test.

Within the Nordic Swan for dishwasher detergents, at the recommended dose, the dishwasher detergent must perform as well as, or better than, the reference detergent (IEC-D or IEC-B), with an average for each soil category (of minimum 3 cycles) at 50 °C in all 4 soil categories (bleachable, burnt-on, amylase-specific, protease-specific). Alternatively the product is considered as good as the reference if the average value for all 8 soil types (at a minimum of 3 dish cycles) is better than the reference detergent. A 95 %

confidence interval is to be used when evaluating the results. Cleaning performance is to be tested in accordance with the standard test for dishwasher detergents developed by IKW, with the following amendments:

- Wash temperature 50 °C for the test product and 55 °C for the reference
- Water hardness 6 °dH
- Reference detergent IEC-D or IEC-B is to be used at a dose of 20 g
- Reference rinsing agent (formula III) at dose setting of between 2 and 3

1.3.4 Other studies on material resource efficiency

1.3.4.1 Study "Ecodesign Directive version 2.0 – from energy efficiency to resource efficiency" by Bundgaard et al.

(Bundgaard et al. 2015) reviewed in their study "Ecodesign Directive version 2.0 – from energy efficiency to resource efficiency" in total 23 currently adopted implementing measures and voluntary agreements under the Ecodesign Directive, criteria for resource efficiency in voluntary instruments such as ecolabels and Green Public Procurement as well as recent Commission projects with regard to implementation of resource efficiency aspects into the ecodesign directive.
In the study, Bundgaard et al. generally subsume under "resource efficiency" following measures:

- Reducing materials and energy use in the entire life cycle of products (mining of materials, production / use / final disposal of the product)
- Improving possibilities for maintenance and repair (e.g. guidelines)
- Ensuring re-use or redistribution, i.e. multiple use cycles.
- Increasing the potential for remanufacturing or refurbishment of the product, i.e. multiple use cycles (e.g. improving reparability, access to spare parts)
- Improving recyclability of materials used in the product

The review of existing instruments revealed that resource efficiency is already widely applied in voluntary instruments covering energy related products. The instruments include following criteria which were also assessed by the study team with regard to their transferability to the Ecodesign Directive (Bundgaard et al. 2015):

<u>Declaration and threshold of RRR ratio (reusability, recyclability and recoverability)</u>
According to (Bundgaard et al. 2015), transferring declaration and threshold requirements with regard to RRR ratio to the implementing measures and voluntary agreements of the Ecodesign Directive first needs a common methodology to be developed on how to calculate the RRR ratio for products and materials to verify the requirements based on technical information provided by the producers.
However, setting requirements for the RRR ratio of the material or the product only reflects the theoretical potential and will not ensure that the materials or products are in fact reused, recycled or recovered which depends on the infrastructure for collection and treatment and the technologies available.
In case of future requirements to RRR ratio it is recommended to make them according to the waste hierarchy, by prioritising reuse before recycling, and recycling before recovery.

<u>Declaration and/or threshold of recycled content</u>
According to (Bundgaard et al. 2015), setting criteria for the threshold of recycled materials can help create a market for these materials. The environmental benefits of using recycled materials would depend on the type of material. However, before transferring these requirements to the Ecodesign Directive, it is important to assess if the manufacturers of recycled materials can handle the increase in demand that a

requirement would create. A possibility could be to begin by setting declaration requirements and then tightening them continuously by setting threshold requirements.
Setting criteria for recycled materials, however, first needs reliable technologies for an analytical assessment of the recycled content in the products to enable verification and market surveillance.

Bill of materials (BOMs)

BOMs are an important source of information to conduct LCAs, assess the product's recyclability, recoverability and recycled content and identify priority resources in the product to ensure their reuse and recycling; all of these activities are the basis for other requirements to improve resource efficiency.
However, (Bundgaard et al. 2015) conclude that due to the complexity of the supply chain of electronic and electrical equipment, a mandatory requirement on providing BOMs would be especially challenging to comply for small producers, as they might not have the ability to force these requirements on to their larger suppliers. Further, the implementation of such a requirement might first need the setup of a system that can ensure the companies' property rights, e.g. with regard to the use of rare metals.

Identification of plastic components

Marking of plastic components according to ISO 11469 shall help recyclers identifying different plastic types and parts to ensure correct handling during waste recovery or disposal, especially when the plastic parts are manually sorted. Also, the visual marking of plastics parts according to certain ISO standards might be quite easy to verify visually by market surveillance authorities when dismantling the product.
On the other hand, there are certain drawbacks shown by the literature research of (Bundgaard et al. 2015): A certain percentage of the labels were found to be incorrect and, mainly, for automatic sorting systems the ISO labels had no effect as these systems sort according to the plastic's mechanical, optical and electrostatic properties.
Thus, (Bundgaard et al. 2015) recommend that before setting criteria for visual marking of plastics in the Ecodesign Directive it should be further examined to what extent the waste is manually sorted for the product group in question, and how the future waste treatment of the product might look like. Furthermore, alternative marking methods should be examined, which could be applied for example in automatic sorting systems.

Contamination of materials / plastics

Requirements regarding contamination of materials are relevant for the recyclability, as the potential for recycling is reduced if incompatible materials are combined, e.g. painting, coating or metallizing large plastic parts making them not compatible with recycling. Depending on the specific requirement, it could be verified visually.

Mono-materials

Using compatible or a reduced number of plastics can improve the recyclability of e.g. thermoplastics, as a mixture of different polymers or a contamination of the plastic fractions can significantly decrease the plastics properties and thereby the use of the recycled materials.
(Bundgaard et al. 2015) recommend that setting these types of requirements should be supplemented with a dialogue with the stakeholders from the recycling industry to ensure the effectiveness of these types of requirements which depends on the recycling system that the products enter into.

Efficient use of materials during the use phase

For washing machines, the Ecodesign Regulation 1015/2010 sets specific ecodesign requirements with regard to the water consumption. For dishwashers, no such requirement is in place. According to (Bundgaard et al. 2015) an example of ecodesign requirements within this category could be to set a requirement to an automatic detergent dosing system for washing machines avoiding over-dosage and overconsumption of detergents.

Durability requirements (incl. extended warranty, upgradability and repair, spare parts, modularity)

All criteria strive to extend the lifetime of the product thereby preventing electronic waste. Durability is also related to the previous category disassembly, where criteria targeting easy disassembly for repair and upgradability were included.
The length of the warranty should be product specific and it is also strongly related to the availability of spare parts, which is also an issue for reparability. Determining how long spare parts should be available taking into account both economic and resource efficiency aspects: On one hand components should be available to enable repair, but on the other hand the risk is that a too large inventory of components will be out-dated and never utilized. Modular design and easy disassembly enable upgrading and repair and are thus prerequisites for lifetime extension. Upgradability can potentially reduce the frequency of replacement against the background of rapid technological product developments.
(Bundgaard et al. 2015) conclude that durability should be included as possible resource efficiency requirements in the Ecodesign Directive, also due to the requirements being possibly verifiable by market surveillance authorities. However, it is important to ensure that prolonging the lifetime of the product is the environmentally best solution in a life cycle perspective, e.g. that possible environmental benefits are not evened out by increased energy consumption of the older product compared to a new more energy efficient product.

Easy disassembly
Easy or manual disassembly can help improve reparability and upgradability of the product improving the durability of the product. Criteria might be detailed with regard to the components to be separated, the type of connections or the tools to be used.
Regarding end-of-life treatment, (Bundgaard et al. 2015) conclude that it is not possible based on the finding of their study to assess whether or not requirements for manual disassembly will improve the recyclability and recoverability of electrical and electronic equipment in the future. This is due to the reason that manual disassembly in the waste treatment process of electrical and electronic equipment (EEE) is increasingly being replaced by automatic or destructive disassembly in many developed countries which questions if requirements for easy or manual disassembly will improve the recyclability and recoverability of EEE if they are fed into an automatic or destructive disassembly system. However, manual disassembly is still performed when economically feasible, e.g. components or materials containing valuable resources, or when Regulations such as the WEEE Directive require it, e.g. for components containing hazardous substances. (Bundgaard et al. 2015) propose requirements in addition to manual disassembly which might target automatic or destructive disassembly, however, without further specifying this proposal.

Waste from manufacturing
By including requirements to the manufacturing, the scope would be expanded from a product focus towards a production focus which is applicable to the Ecodesign Directive which mainly sets requirements to the design of the product, however targeting the environmental performance of the entire product life cycle. Therefore, design requirements to the product that might improve the manufacturing process would be highly relevant. However, as many electronic products are produced outside Europe, it might be difficult to enforce these criteria. (Bundgaard et al. 2015)
Further requirements
Further requirements on hazardous substances, take-back schemes and packaging identified in voluntary instruments such as ecolabels are not recommended to be transferred to the Ecodesign Directive as there are rather large overlaps with existing legislations such as REACH and RoHS, WEEE and the European Directive on packaging and packaging waste.

Information requirements related to resource efficiency
With regard to information and specific requirements targeting resource efficiency in ecodesign, (Bundgaard et al. 2015) recommend in their study following:

- Information and specific requirements on durability (e.g. on lifetime of the product as for lamps, or for components, such as minimum loading cycles for batteries in computers)

  - Relevant for consumers to enable them selecting the most durable product

- Information requirements with regard to resource consumption in the use phase
  - Relevant for consumers: e.g. to stipulate consumers choosing the most efficient programmes in terms of energy and water consumption and the best suitable detergents.
- Information requirements on hazardous substances, precious metals or rare earths
  - Relevant for recyclers to a) avoid contamination of the materials when they are recycled or b) ensure a more optimal recovery of precious materials. As stated above, also for this information it is suggested to make it more easily available, by embedding it in the product in e.g. a RFID.
- Information relevant for disassembly, recycling or disposal at end-of-life:
  - Relevant for end-users to know how to correctly dispose the product at its end-of-life
  - Relevant for recyclers to know how to disassemble and recycle the products in the best possible way, for example to ensure that hazardous substances are removed and treated correctly. It is suggested that such information could be made more easily available, by embedding it in the product in e.g. a RFID to benefit the recyclers more compared to information provided on webpages or in user instructions. Furthermore, it could be specified in the Directive which type of information the recyclers may need. This could be done in close collaboration with the recyclers to ensure that the information is indeed relevant for their processes.
- Information and specific requirements on easy disassembly:
  - Relevant for consumers / repair facilities to help improving maintenance and repairs. Generic information requirements for non-destructive disassembly for maintenance could be supplemented by requirements for the producers to make repair and service manuals public. It may also be relevant to set specific requirements for easy disassembly of the product for maintenance purposes.
  - Relevant for recyclers to help improving end-of-life treatment, for example the removal of certain components which have to be treated separately in accordance with the WEEE Directive (batteries, heat pumps etc.).

1.3.4.2 Study "Material-efficiency Ecodesign Report and Module to the Methodology for the Ecodesign of Energy-related Products (MEErP)" by BIO Intelligence Service

(BIO Intelligence Service 2013) conducted a study to clarify the implications of material efficiency from the pragmatic perspective of its practical application for ecodesign purposes, and the elaboration of recommendations for the MEErP methodology (Part 1); and undertook an update of the MEErP methodology and its component EcoReport tool, to include the necessary means for better analysing material efficiency in MEErP (Part 2). Part 2 also contains a guidance document for analysing material efficiency in ErP; as well as an updated version of the EcoReport Tool and a report of the test of the updated methodology on two case studies.
The project identified from available evidence the most significant parameters regarding material efficiency that may be used in MEErP, in order to analyse the environmental impacts of ErP, and assessed their suitability and robustness for Ecodesign purposes, together with associated information parameters.
The parameters selected as most suitable were:

- Recyclability benefit ratio, describing the "potential output" for future recycling, based on a formula considering the recyclable mass per material and its recycling rate and a down-cycling

index. It implies that it is possible to assess the potential benefits of recyclable plastic parts in a product. However, due to data constraints only data on recyclability benefit rate for bulk and technical plastic is included.

- Recycled content, describing the "input" of materials with origin on waste, based on new data sets for materials. The dataset makes it possible to model products with recycled material as input material. However, again due to data constraints, only data on paper, PVC, PET and HDPE has been included in the EcoReport Tool.
- Lifetime, a mechanism to display impacts not only as a total over the whole lifespan, but also per year of use, allowing an easier comparison of products with different lifetimes or analysing the effect of lifetime extension. The product lifetime can refer to:
  - The technical lifetime is the time that a product is designed to last to fulfil its primary function (technical lifetime).
  - The actual time in service is the time the product is used by the consumer (service lifetime). The actual time in service is not a typical parameter in industry and depends more on the user than on the manufacturers of the product design.
- Critical raw materials, a tool to analyse products including critical raw materials to display differences between different product designs and improvement options.

A key end result of this project was that the new features within the MEErP, enabling further analyses of material efficiency aspects in products, are fully functional and ready to be used in future Ecodesign preparatory studies. However, (Bundgaard et al. 2015) conclude in their study:

> *The MEErP methodology has not been changed significantly. The alterations made to the EcoReport Tool are minor and to some extent updates of existing elements. Hence, despite the good intentions to include material efficiency into MEErP, the current update and expansion of MEErP will properly not be enough to ensure a focus on material efficiency in future implementing measures and voluntary agreements.*

1.3.4.3 Study "The durability of products" by Ricardo-AEA

Ricardo-AEA, in collaboration with Sustainability Management at Scuola Superiore Sant'Anna di Pisa (SuM) and Intertek, has been commissioned by the European Commission – DG Environment to conduct a study on the durability of products. The purpose of the study is to identify two priority products and develop a methodology for measuring their durability. The study also aims to estimate the benefits and costs of more durable products. The outputs from this work can then be used in relevant product policies. (Ricardo-AEA 2014a)

Within the durability study, the authors undertook a literature analysis to develop an appropriate definition of durability. For example, the Ecodesign Directive 2009/125/EC in Annex I, Part 1.3 defines parameters which must be used, as appropriate, and supplemented by others, where necessary, for evaluating the potential for improving the environmental aspects of products. According to (European Parliament 2009), this includes inter alia

> *"Extension of lifetime as expressed through: minimum guaranteed lifetime, minimum time for availability of spare parts, modularity, upgradeability, reparability."*

The following definition has been developed by (Ricardo-AEA 2014a) proposed to be potentially also applied to other policy interventions in Europe aimed at improved durability of products.

> *"Durability is the ability of a product to perform its function at the anticipated performance level over a given period (number of cycles – uses – hours in use), under the expected conditions of use and under foreseeable actions.*
>
> *Performing the recommended regular servicing, maintenance, and replacement activities as specified by the manufacturer will help to ensure that a product achieves its intended lifetime."*

The authors further discussed the possibility of creating an extended definition of durability that encompasses repair, design for repair and remanufacturing, and that such an extended definition of durability could be developed for inclusion within for example the EU Ecolabel and GPP criteria requirements.

> *"A product to maintain its functions over time and the degree to which it is repairable before it becomes obsolete."…. "In other words, a product should not cease to function after relatively little usage and its reparability should not be hindered by its design."*

It is thus worth considering that, within this context, extended durability is the aim to extend the life of a product past its first life by ensuring a product can be easily repaired, upgraded, remanufactured and, at end of life, dismantled and recycled.
Beyond the above definitions on durability, (Ardente et al. 2012) concluded their literature review, cited in (Ricardo-AEA 2014a), the following definitions for a number of relevant terms:

- 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 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.

Within the study of (Ricardo-AEA 2014a), domestic refrigerators and freezers, and ovens were selected for further analysis. The selection is based on the assumption, that they might also be applicable to other products with similar components. For dishwashers, the study results are expected to be transferable to a large extent as following components are similar:

- Outer casing
- Pumps
- Filters
- Heating elements
- Mechanical elements such as hinges and catches
- Electronics, including controls and displays

1.3.4.4 Study "Investigation into the repairability of Domestic Washing Machines, Dishwashers and Fridges" by RReuse

The Reuse and Recycling EU Social Enterprises network (RREUSE) is a European umbrella organisation for national and regional networks of social enterprises with re-use, repair and recycling activities. They cover 42,000 Full Time Equivalent (FTE) employees and over 200,000 volunteers working throughout 22 member organisations across 12 EU Member States.
In 2013, RReuse has conducted an investigation into some of the main obstacles its members encounter when repairing products, inter alia for dishwashers, to provide part of the basis for setting requirements within implementing measures to improve the reparability of products, and thus their material and resource efficiency. Based on a questionnaire sent out through their network, the findings are answers from 9 individual reuse and repair centres from four national networks of social enterprises namely AERESS (Spain), Repanet (Austria), Réseau Envie (France) and the Furniture Reuse Network (UK). (RReuse 2013)
The results of the study with regard to specific obstacles for repair and maintenance of dishwashers can be found in section 3.2.2. Examples of common causes of break downs as well as suggestions for product design to help improve reparability of domestic dishwashers are provided in section 4.2.6.

Based on the study results, the following horizontal measures within Ecodesign Implementing Measures are suggested by (RReuse 2013):

- Simplification of specific components and potential standardisation of certain components across different brands would significantly increase the efficiency of repair as it would allow greater interoperability of components across different machines
- Free of charge access to repair service documentation of the after sales service providers of the manufacturers for all reuse and repair centres, not only those of the after sales service providers, together with any relevant fault diagnostic software and hardware.
- The availability of replacement parts must be guaranteed for a minimum period of 10 years following the last product batch. Critical spare part components should be available at a reasonable price.
- The product should be able to be disassembled non-destructively into individual components and parts without the need for special proprietary tools to do this. If special tools are required however, these must be readily and freely available to all approved reuse and repair centres/networks (not just to the after sales service providers of the manufacturers).

1.3.4.5 "Study on Socioeconomic impacts of increased reparability" by BIO by Deloitte

Currently, DG Environment has commissioned a study to BIO by Deloitte to analyse the socioeconomic impacts of increased reparability. (Bio by Deloitte 2015)
With this study, DG Environment strives to gather information about the mechanisms of the solutions in order to increase reparability. To assess the viability of the requirements, they must be tested in order to measure the benefits of their impacts on economic growth, job creation and resource efficiency under the perspective of the Roadmap to a Resource Efficient Europe and the Green Employment Plan. Thus, within the study case studies on possible reparability requirements are performed on 4 product groups (domestic washing machine, dishwasher, coffee machine and vacuum cleaner) in order to get a global and complementary vision of the repair sector. These case studies enhance the mechanisms barriers and drivers in the perspective of their potential integration of generic or product-specific requirements in product policy instruments (either mandatory or voluntary). The operational objectives of the project are stated as follows:

- Perform case studies on four product groups;
- Review existing barriers and identify suitable reparability requirements;
- Quantify the job creation, economic and resource-savings potential of the selected reparability requirement policy scenario and its individual elements, including impact on SMEs;
- Describe the characteristics of possible job creation potential in terms of skills requirements, private/public, entrepreneurship and self-employment, entry to labour market and global mobility; and
- Describe mechanisms under which such a policy framework would develop in a scientifically sound way building on empirical studies, literature studies or economic modelling or others as best suited.

Each case study is performed in order to assess the job creation potential, the resource savings potential and the net cost and benefits for society. The results are compared in order to identify an EU policy scenario.
In April 2015 a first questionnaire has been sent out to stakeholders. For domestic dishwashers, (Bio by Deloitte 2015) ask about the importance of certain barriers to repair:

- Availability of service manuals, diagnosis software

- Availability of spare parts
- Cost of spare parts
- Labour cost
- Difficulty of disassembly and access to inner parts (e.g. heating resistors, access to inner parts in on-mode)
- Low consumer awareness about repair possibilities

Additionally, stakeholders are asked about their opinion regarding possible reparability requirements and their effectiveness to increase the repair of products by being voluntary or mandatory tools (Bio by Deloitte 2015):

- Provision of instructions for troubleshooting, diagnosis software, diagrams of the Printed Circuit Board
- Ensure accessibility in the switched on position for the purpose of troubleshooting during the repair work
- Ensure accessibility to inner parts (e.g. cable lengths, space for mounting, welding, screw orientation and size, scale of design)
- Ensure the possibility of breaking down the product (e.g. components can be tested separately)
- Provision of information relevant for disassembly (e.g. instructions, break down plan
- Avoidance of non-reversible adhesives
- Ensure the separation of the connections by ordinary tools
- Ensure the possibility to exchange or upgrade critical components (e.g. ball bearings, door hinges)
- Use of standardised designs to allow compatibility of spare parts
- Ensure the availability of compatible spare parts for a determined period of time
- Offer to consumers an optional extension of warranty time at purchase
- Provision of information to consumers about reparability in product Energy Labels, brochures, etc. (e.g. similar to Austrian rating Standard ONR 192102)

1.3.4.6 Study "Report on benefits and impacts/costs of options for different potential material efficiency requirements for dishwashers" by Ardente and Talens Peirò (JRC IES)

The objective of this report is supporting the European Commission for the integration in the European product policies of measures for the improvement of resource efficiency and was developed to be a direct input to the present policy process. In particular, the report analyses potential requirements for dishwashers which could be implemented within the framework of the Ecodesign directive. The analysis is based on the application of a certain method ("REAPro") developed by JRC IES, already applied to various product groups in the context of the EU ecodesign and EU Ecolabel, to the product group dishwashers for the following resource efficiency criteria: reusability / recyclability / recoverability, recycled content, use of hazardous substances and durability. A set of specific indicators are calculated to support the analysis, including the Recyclability benefits indicator as introduced in the revision of the MEErP and Ecoreport tool in 2013.

(Ardente & Talens Peirò 2015) conclude that the resource efficiency of dishwashers could significantly be improved by the manual extraction of key parts before shredding, and also by extending the lifetime of a dishwasher. Based on their results, the report proposes following potential ecodesign measures:

- The time for extraction of PCBs larger than 10cm^2, LCDs screens and pumps (circulation pump and drain pump) shall not exceed 300 seconds, performed by professional worker;
- The design for durability of the dishwasher based on:
  - The reparability of the following key components: pumps, printed circuit boards, heating system, thermostat, valves, filters, hoses, spray arms, door panels, seals and racks (including the availability of spare parts);
  - The setting of a minimum 2 years warranty for some key components (e.g. pumps, electronics, heating system and door panels).

1.3.4.7 Study "Addressing resource efficiency through the Ecodesign Directive. Case study on electric motors" by Dalhammar et al.

(Dalhammar et al. 2014) conducted a case study in 2012 on the potential inclusion of permanent magnet (PM) motors in the Ecodesign Regulation for electric motors (permanent magnet motors are also used in household dishwashers, cf. section 4.1.4.2). The objective was to see how the Ecodesign Directive could promote eco-innovation for resource use in PM motors, and to:

- Investigate what kind of requirements related to resource use of rare earth elements (REE) are of relevance for permanent magnet electric motors, and
- Obtain input from experts on the feasibility of outlined potential requirements, and the most important drivers for eco-innovations.

Against the background of increased demand for REE, combined with global supply imbalances and unavailable post-consumer recycling options for REE, their substitution in the magnets is currently being investigated in several pilot projects. Replacing REEs with other materials however can come with a performance loss in the PM motor (i.e. reduced energy efficiency due to a reduced energy density in the magnet and more material use). Therefore, increasing the recyclability of PMs is of interest, if technically and economically feasible at the point in time of interest, as it could provide a stable supply of REEs and thus, enhances their continued use to achieve more energy-efficient motors.
Based on interviews with material experts, (Dalhammar et al. 2014) outline potential implementing measures facilitating recycling of REE.

- Generic requirements that producers should show how they take design for recycling into account in the design process.
- Design for dismantling, e.g. modularisation; or preventing that permanent magnets are for instance covered by plastic, which would ease recycling practices.
- BOMs providing information about key materials and their positions to promote future recycling (when new technologies may allow for profitable recycling if the motors are easy to disassemble).
- Additional information to recyclers that are relevant for allowing cost-effective recycling.
- Take-back obligation; it might provide incentives to design a motor from which materials can more easily be recycled.

(Dalhammar et al. 2014) conclude that it appears as if a more developed set of requirements cannot be set under the Ecodesign Directive until pilot projects and ongoing research have provided more insights on the technical and economic viability of REE recycling. The long-time scales involved (i.e. time before the motors are at the EoL stage) however mean that future recycling options and associated costs and benefits are rather uncertain compared to products with shorter life spans, e.g. laptops or cell phones.

1.3.4.8 Further studies with regard to resource efficiency as possible Ecodesign measures

The following study will be analysed during the further course of the project:

- VHK study "Resource efficiency requirements in Ecodesign: Review of practical and legal implications". (2014).

1.4 Summary and discussion: scope, legislation and standardisation

1.4.1 Preliminary product scope and definitions

Based on the previous analysis of existing scopes and definitions, stakeholder feedback related to the scope as well as the analysis of market data and trends (cf. Task 2), the following preliminary product scope and definitions for the revision of the ecodesign and energy label Regulations for household dishwashers are proposed. These definitions and scope proposal shall be discussed at the first stakeholder meeting.

1.4.1.1 Proposal for a product scope

Current scope of the ecodesign Regulation (EC) No 1016/2010 for household dishwashers:

> *This Regulation establishes ecodesign requirements for the placing on the market of electric mains-operated household dishwashers and electric mains-operated household dishwashers that can also be powered by batteries, including those sold for non-household use and built-in household dishwashers.*

Proposal for a revised scope of the ecodesign Regulation for household dishwashers (to be discussed):

> *This Regulation establishes ecodesign requirements for the placing on the market of electric mains-operated household dishwashers.*

Rationale:

- It is proposed to delete the addition of 'electric mains-operated household dishwashers that can also be powered by batteries'. The market research reveals that these kinds of dishwashers do not have any market relevance. No battery-operated household dishwashers could be detected. Very small dishwashers with 5 or 4 ps, which might be possibly portable, have totally disappeared from the market since 2010/2011. Also for the coming years it is expected that battery powered household dishwashers will not enter the market. Theoretically, battery powered household appliances might work as capacity storage in a smart-grid network; however, it is assumed that such a power storage would rather be realised as a central storage system for the whole household with the single appliances still being electric-mains operated. (cf. section 0)
- It is proposed to delete the addition 'including built-in household dishwashers' from the scope. In general, this sub-type of appliances is already covered by the term 'household dishwasher'. According to stakeholder feedback, a separation of standalone and built-in appliances is not needed; also, the requirements do not differ between the categories.
- It is proposed to delete the addition 'including those sold for non-household use' which would cover household dishwashers being used in a professional context. The next section provides a definition of 'household dishwashers' clearly differentiating them from professional appliances according to the provisions of legislative framework (Low Voltage and Machinery Directives).
- It is proposed still not to include semi-professional dishwashers into the future revised scope of the ecodesign and energy label Regulations for household dishwashers. Although few stakeholders would welcome their inclusion into the energy label Regulation only, semi-professional machines clearly differ from household dishwashers with regard to several aspects which justify further exclusion from the scope of Regulations for household appliances (see Table 1.24).

Table 1.24: Main differences between household and semi-professional dishwashers

	Household dishwashers	Semi-professional dishwashers (category: undercounter water-change); source: (Rüdenauer et al. 2011b)
Number of operations	280 cycles per year	2–20 racks/h (depending on program)
Cycle times (depending on the chosen programme)	30-200 minutes	6–27 minutes
Safety requirements	Low Voltage Directive	Machinery Directive

Discussion point 1.1

Do you agree with the proposed revised scope? Why (not)?

1.4.1.2 Proposal for definitions

Current definitions of the ecodesign Regulation (EC) No 1016/2010 for household dishwashers:

(1) 'Household dishwasher' means a machine which cleans, rinses, and dries dishware, glassware, cut lery and cooking utensils by chemical, mechanical, thermal, and electric means and which is designed to be used principally for non-professional purposes.

(2) 'Built-in household dishwasher' means a household dishwasher intended to be installed in a cabinet, a prepared recess in a wall or a similar location, requiring furniture finishing.

Proposal for revised definitions of the ecodesign Regulation for household dishwashers (to be discussed):

'Household dishwasher' means a machine which cleans, rinses and dries dishware, glassware, cutlery and cooking utensils by chemical, mechanical, thermal, and electric means; which may or may not have a specific drying operation at the end of the programme; which is designed in a way principally intended for domestic use as stated by the manufacturer in the Declaration of Conformity (DoC).

Rationale:

- 'Built-in dishwashers': According to stakeholder feedback it seems not to be necessary to provide a separate definition for built-in appliances any more. Already within the current ecodesign and energy labelling Regulations, no further differentiation has been made regarding requirements for built-in and standalone appliances. The inclusion of such definitions is thus redundant for the purpose of these Regulations .Also in future, ecodesign and energy labelling requirements should be made in a technology neutral way as far as possible.
- According to stakeholder feedback, the drying operation is not seen as a primary function of a dishwasher, as some programmes have not included it. Thus it is proposed to align the definition to those of the EN/IEC standards for performance measurement of household dishwashers which include a sentence that the machines may or may not have a specific drying operation at the end of the programme.
- 'Household / sold for non-household use': The "Guidelines on the application of the Low Voltage (LVD) Directive 2006/95/EC" (European Commission 2007 / modif. 2012) clarify the borderline between the scope of the Machinery Directive and the LVD Directive in order to provide greater legal certainty for manufacturers. Whilst it is possible for a consumer to acquire an appliance intended for commercial use or for a commerce to use an appliance intended for consumers, the criterion to be taken into account for determining the intended use is the use intended and stated by the manufacturer of the appliance concerned in the Declaration of Conformity (DoC) and in the product information/instructions/advertising concerning the product. The statement from the manufacturer in the product information concerning the specific product is the criterion that has

to be considered to determine the intended use of the appliance in this case and which Directive (LVD Directive or Machinery Directive) applies. Evidently this must accurately reflect the reasonably foreseeable use of the product. The definitions provided by the guidelines are "Household appliances intended for domestic use" and a description of "domestic use". Thus, it is proposed to replace the current part of the scope "including those sold for non-household use" by the formal definition given in the LVD Directive and to align the definition of "household appliances" to that of the LVD Directive.

- If needed, a further definition of 'domestic use' could be added: appliances intended for use by private persons (consumers) in the home environment.
- Depending on the selection of base case improvement options and the proposal of certain policy measures, further definitions might be added during the course of the study (e.g. special purpose products, system approach like 'renewable energy heated', 'smart grid ready (SG ready)' or others.

Discussion point 1.2

Do you agree with the revised definitions? Why (not)?

1.4.2 Legislation and standardisation: energy efficiency and performance

Based on the analysis undertaken of existing legislation, standards and labels on ecodesign, energy efficiency and performance, the following discussion points on future standardisation activities have been identified, and are proposed for discussion at the first stakeholder meeting.

1.4.2.1 Adoption of IEC 60436 4th edition in Europe

The "Omnibus Report" (VHK et al. 2014) identified a number of gaps between real dishwasher use by consumers, and the currently tested performance parameters, as required in EN 50242 (section 1.2.2.1). This standard is currently under revision, possibly affecting the test load (introduction of plastic items and other types of cooking utensils and a different type of soiling). The foreseen changes are expected to affect the energy consumption per cycle and hence the calculation of the EEI, the cleaning and the drying performance. This will make the label program (currently called 'eco') a more suitable choice for the most common types of dishes used currently in Europe (including plastics, pots and pans), reflecting better current consumer behaviour.

Regulations EC 1016/2010 and EC 1059/2010 refer to standard EN 50242, linked to IEC 60436. As mentioned above, this standard for testing household dishwashers is being updated to better reflec consumer behaviour in terms of load items and detergent. The revised regulation will refer to the updated standard (4th ed. of IEC 60436). Results of tests according to EN 50242 will not be directly comparable to measurements according to this new standard. The introduction of the new IEC standard in Europe as a CEN/CENELEC standard will have to be carefully studied and communicated, and correlation tables/formulas prepared, to minimise confusion for consumers and manufacturers.

Modifications to this IEC standard as needed for European adaptation will likely be incorporated via the usual harmonization process of CENELEC.

Discussion point 1.3

How are the consumption and performance values influenced by the new updates of the standard? Reported updates include: - a higher variety of shapes and materials, - the combined assessment procedure for cleaning and drying performance, - the new reference detergent,

- test procedures for automatic programmes.

Please provide any available data to support your view (e.g. results of preliminary tests).

1.4.2.2 Improvement of consistency in Ecodesign and Labelling Regulation and test standard

Further analysis should address the inconsistency between the Energy Labelling and Ecodesign regulation regarding the threshold width of the machines, i.e. less than 45 cm (ecodesign) or 50 cm (labelling), and 12 or more ps.

1.4.2.3 Simplification of low power requirement

The exemplary calculation of the annual energy consumption of standby and off-mode only (cf. section 1.2.2.1) has shown that the low power energy consumption is a rather minor contribution to the annual energy consumption, especially since the implementation of a power management system has become mandatory for household dishwashers in 2013 according to Regulation (EC) No 1275/2008.

Additionally, the systematic measurement of this value as part of the measurement of performance is complicated and introduces a high burden to all testing laboratories as it needs special test set-ups to avoid failure rates beyond the measurement tolerances.

The mandatory prescriptions for stand-by in place since 2013 by Regulation (EC) No. 1275/2008) seem to have made to some extent obsolete the testing of some of the low power conditions in performance tests of dishwashers. Testing of low power modes may thus be excluded from the calculation of the EEI used for Ecodesign and the energy label.

An alternative is to include low power consumption requirements as Ecodesign requirement, (if not already included in Commission Regulation (EC) No. 1275/2008).

Discussion point 1.4

Do you agree that low power energy consumption barely contributes to the annual energy consumption of dishwashers?

Is there any risk in your view that this low-power energy consumption increases if not part of the Ecodesign/Energy Label regulations, given the need of following mandatorily the prescriptions for stand-by of Regulation (EC) No. 1275/2008)? For instance, the delay-start function does not fall under the Standby Regulation as 'delay start' is not defined as standby mode because it is not lasting for an indefinite time.

Should the energy consumption of the 'delay start' function be taken into account in the EEI calculation or be a separate ecodesign requirement??

Please provide the reasons for your statements.

1.4.3 Programme duration

Programme time is an important parameter for balancing the information on the energy efficiency of a dishwasher. The currently available models ion the market demonstrate in practice that it is possible to achieve outstanding low energy consumption by prolonging the programme time (extended drying time and increased mechanical action of water at lower temperature) to reach the targeted cleaning/drying performance.

To allow the customer at the point of sale to make a more informed purchase decision, an option could be to include the programme time of the standard programme as mandatory information on the Energy label. However, a total value in minutes on the label should always be accompanied by better information about the reasons for increased programme durations in connection with increased energy efficiency gains. Alternatively, an overall cap to the duration for the standard programme might be an option for generic ecodesign requirements. Both options will be discussed at the first stakeholder meeting together with other upcoming proposals.
Necessary preconditions, as well as possible implications and side effects will be analysed during the further course of the project.

Discussion point 1.5

How would you tackle the issue of an increasing time of the 'Eco' programme which could prevent the consumer from using the most efficient programme?

Please provide your opinion and any pros/cons of the following potential additional requirements:

- a limitation of the total washing time of the test associated to the labelling.

- a clear indication of the cycle time in the energy label.

- compulsory information to the consumer (e.g in the display) when the programme is chosen

1.4.3.1 Specification of consumption values per cycle

As the low power energy consumption has turned out to have quite a small contribution to the annual energy consumption (see above), there is no longer a need to calculate average energy and water consumption on an annual basis. For consumers, the value of the annual consumption has a similar representativeness as the specific consumption per cycle (perhaps a potential buyer can convert more easily yearly values to potential annual savings in EUR). The real consumption depends on the household size and washing habits, thus for individual households, the annual number of cleaning cycles might deviate from the 280 cleaning cycles taken as basis for the calculation of the annual energy consumption.

Therefore it is proposed to discuss if it is advisable to change the annual energy and water consumption reporting on the label to 'consumption per cycle' (i.e. back to the format before EC 1059/2010).

Discussion point 1.6

Are you in favour of providing information per cycle rather than per year? Why (not)?

1.4.3.2 Verification of the level of uncertainty of all measured values

As a step in the implementation of any new proposals of revision of the Ecodesign and energy label Regulations, it would be useful that round robin tests (RRT) are being carried out for all new measurement standards. A centralised office for organising and evaluating the round-robin test results may be needed. The results of the RRTs might also be used to establish expanded uncertainty values for all measurements required for energy labelling and ecodesign.

Discussion point 1.7

Could you provide any preliminary indications about the actual uncertainty associated with the measurement of the levels of performance for dishwashers, and how tolerances should be set to reflect such inherent uncertainties?

1.4.3.3 Test programme(s) for labelling purposes

Basically, the test programme is defined as a programme that is suitable to clean normally soiled tableware, and therefore may be used on a daily basis by consumers and should also be an efficient programme with regard to energy and water consumption. This test programme shall be named 'Eco' on the user interface of the dishwasher. (EN 50242/ EN 60436:2008+A11:2012)

A recently published article of the German consumer journal Stiftung Warentest points out that 24% of the participants never use the Eco programme. 43% indicate that they use the 'Eco' programme to save energy and water, while 47% use the automatic programme of their dishwasher to have an optimised input of energy, water and time (see section 1.2.4.1).

Previous studies indicated similar user behaviour (see 3.1.1.6) concerning the programme choice.

Therefore, the extension or modification of the test procedure to take into account real-life user behaviour is an issue to be discussed. The voluntary test procedure for sensing programmes, introduced into the new IEC 60436 4th Edition might be the basis for the development of the new standard test procedure.

STIWA is already performing tests with automatic programmes, according to their own procedure, using the basic conditions and procedures of EN 50242/ EN 60436. (Stiftung Warentest 2015)

Discussion point 1.8

How could the test procedure be modified or extended to better reflect real-life user behaviour? Should e.g. half-load cycles be included, automatic programmes, etc.?

How could automatic programmes be included in the test procedure?

1.4.3.4 Demand-response enabled appliances

Appliances which offer a demand-response function provide flexibility in the demand side to match the fluctuating energy production forecasted for the future due to the increasing number of wind and solar PV stations. However, this cannot work alone, and it is needed that the distribution system operator, or an aggregator of the smart grid, offers the consumer sufficient incentives to allow the use of the demand-response enabled power capacity. A sufficient large number of appliances need to be in the market before such a system can take off.

It could therefore be useful to support the introduction of demand-response enabled appliances. Requirements to the demand-response function itself can be set up either by standardization or be introduced in the ecodesign or energy label regulation.

Therefore, it is proposed for discussion if support to the demand-response enabled appliances should be introduced, and what is the best tool to set up the general requirements, e.g. user settings, information and capabilities.

Discussion point 1.9

Should any general requirements be set to handle the demand-response function (e.g. user settings, information requirements, capabilities, etc) ? Please explain which ones and why

1.4.3.5 Improvement of rounding methods

Industry operates globally. Thus, rounding has to follow international rules. IEC 59D and CLC 59X standards define rounding by using the methods described in the Rule B of the Annex B.3 of the ISO 80000-1:2009 'Quantities and units - Part 1: General'. These should be applied to the final result of any calculation. European standards and regulations should not differ more than necessary from international standards.

However, the methods described in the European standards and Regulations deviate from this target. Different rounding methods were found, e.g. for the water consumption of dishwashers where the annual water consumption of a household dishwasher is calculated in liters, rounded up to the nearest integer and after that multiplied by the total number of standard cleaning cycles per year (280) (cf Equation 1-6 and Regulation (EC) No1059/2010, clause 3 of Annex VII).

This method is different from ISO 80000-1, and implies double rounding , as a rounded-up value is multiplied by 280. Such deviations can lead to differences between the declared values and the values determined during the verification procedure.

Therefore, it is proposed to discuss if the method from ISO 80000-1 is to be prescribed, where rounding up is applied to the final value of any calculation.

Discussion point 1.10

Is the rounding of figures an issue of concern? Would a prescription of the method from ISO 80000-1 be a solution to that?

1.4.4 Noise verification procedure

For verification purposes it is mandatory to measure the performance of three additional appliances, if the first appliance under test deviates from the declared value by more than the given verification tolerance. The mean value of these additional appliances shall meet the requirements of Regulation (EC) No 1016/ 2010.

Currently this is not prescribed for noise measurements according to EN 60704-3 and verification tolerances for noise emissions are not described by a Regulation or directive. Therefore, it will be discussed if the procedure for noise emissions has to be aligned with the procedure for the remaining performance characteristics.

Discussion point 1.11

Should the procedure for noise emissions be aligned with the procedures for the remaining performance characteristics? Why (not)?

1.4.5 Legislation and standardisation: (material) resource efficiency

Research has shown an increasing number of examples of integration of resource efficiency matters (such as durability, and facilitating end-of-life management of products) into product policy instruments like mandatory ecodesign Regulations or voluntary ecolabels. While ecolabels such as EU Ecolabel, German Blue Angel or the Nordic Swan already have included a large range of resource-related criteria for quite a long time, the implementation of those criteria into mandatory product-specific Regulations has only started a few years ago (e.g. ecodesign for vacuum cleaners, lamps, displays), apart from general directives or Regulations such as RoHS, REACH or WEEE. This is accompanied by increasing importance of research on the feasibility of implementing resource efficiency aspects into product policies, as reflected in at least seven European research studies published within the past two years.

However, it seems that there is still a gap between the already implemented requirements/criteria in product policies, and the ongoing research in this field, which focuses on the effectiveness and impacts of increased product-related resource efficiency. One of the causes of this gap is the absence of sufficient standards which are applicable for testing and measuring resource-related criteria, that hinder a practicable implementation of the criteria (including procedures for verification and market surveillance).
Some stakeholders indicate additionally that any new resource efficiency requirements should be measurable, enforceable, relevant and should not hinder innovation and competitiveness. Any new requirements should have a proven environmental benefit and thus be based on robust data, methodologies and widely recognised standards that confirm this. Standards should be built on a solid foundation to ensure they reflect the technical reality (state of the art). Solid evidence for feasibility, proper measurability and environmental benefit should be taken into account when developing such standards. In the absence of these conditions, any shift from resources in use (energy, water, etc.) towards material efficiency should not be forced artificially.
Some stakeholders find it also confusing that material efficiency and end-of-life requirements, once (early 2000's) part of the same integrated product policy initiative although split in the final implementation (ecodesign and energy labelling on one side, RoHS, REACH and WEEE/ELV on the other) are again re-integrated.
There are currently a number of standards related to material efficiency (e.g. safety standards for durability, recycling standards for end-of-life management), but they are primarily developed for other purposes (product safety, management at recycling operations) and are not directly transferrable for increasing resource efficiency in the design phase . For example, the EN 50625 standard series cover various aspects of the treatment of electronic waste (including collection, treatment requirements, de-pollution and preparing for re-use). However, it only deals with the handling of existing (waste) products entering the recycling stream. The European Commission will issue a standardization request to ESO to develop, in an appropriate timeframe, European standards on material efficiency aspects for energy-related products. When available, such standards might be referenced normatively in product or product group related harmonised standards where implementing measures set ecodesign requirements for material efficiency aspects.
However absent harmonized standards for resource efficiency may be, it is still possible to explore resource efficiency aspects in the preparatory study. The ESO horizontal initiative above may if deemed necessary be combined with product-specific standards which could address requirements of design that facilitate end-of-life management and resource efficiency for specific product groups.

For household dishwashers, the presented examples are used as a basis for the discussions. Further research in the following sections (e.g. user behaviour, technical product lifetime, common causes of breakdown, end-of-life behaviour), and especially a more accurate picture of the end-of-life management situation in Europe will enable a better decision on the feasibility and value-added of proposing resource efficiency requirements in the ecodesign and energy label Regulations for household dishwashers.

Discussion point 1.12

Which kind of resource or end-of-life requirement do you see most/least feasible for dishwashers? Why?

2 TASK 2: MARKETS

2.1 Generic economic data

This section presents an economic analysis based on official European statistics provided by Eurostat concerning production and trade data. Based on these data, the apparent EU-28 consumption of household dishwashers is calculated in section 2.1.3.
It has to be noted, however, that the statistical data have to be interpreted with care as there are some data gaps, especially for the domestic production. However, the statistical analysis can very well complement the general market analysis which is presented in subsequent sections as they do represent the official source for EU policy.
Classification of household dishwashers in Eurostat statistics
Household dishwashers apply to the following classifications in the Prodcom database and the European trade statistics. In the EU-28 trade statistics, the so called Combined Nomenclature codes (CN8) are used.

- Prodcom database: Household dishwashers (Prodcom code 27511200)
- Trade database: Dishwashing machines of the household type: (CN code 84221100)

Further differentiation, e.g. regarding their way of installation (standalone, built-in) or capacity (number of ps), is not provided by the European statistics.

2.1.1 EU Production of household dishwashers

Volume of EU production of household dishwashers
The following table shows the unit volume of household dishwashers produced in EU Member States and EU28 totals in the years 2007 to 2013 according to (Eurostat 2015a).
The Prodcom data suggests that Poland, Germany and Italy are the main Member States producing household dishwashers with declining production volume by around two-thirds in Italy, and more than doubling the production in Poland between 2007 and 2013. However, it is important to note that data is missing for the Member states Czech Republic, France, Greece, Spain, Sweden and UK, as well as for Germany since 2011. This leads to a data gap of around 3.8 million units in 2013 of the listed production in single Member States and the EU 28 totals production volume.
In total, the Eurostat data indicate that the volume of produced household dishwashers in EU28 declined from 9.6 million units in 2007 by 15% to 8.2 million units produced in 2013.

Table 2.1: Volume (number of units) of household dishwashers produced in the EU28 between 2007 and 2013; source: (Eurostat 2015a)

Declarant	2007	2008	2009	2010	2011	2012	2013
Austria	0	0	0	0	0	0	0
Belgium	0	0	0	0	0	0	0
Bulgaria	0	0	0	0	0	0	0
Croatia	0	0	0	0	0	0	0
Cyprus	0	0	0	0	0	0	0
Czech Republic	:	:	:	:	:	:	:
Denmark	0	0	0	0	0	0	0
Estonia	0	0	0	0	0	0	0
Finland	0	0	0	0	0	0	0
France	:	:	:	:	:	:	:
Germany	3,426,495	3,177,512	2,804,282	3,023,716	:	:	:

Declarant	2007	2008	2009	2010	2011	2012	2013
Greece	31,074	:	:	:	:	:	:
Hungary	0	0	0	0	0	0	0
Ireland	0	0	0	0	0	0	0
Italy	2,920,533	2,800,827	2,058,367	1,828,785	1,554,872	1,205,681	896,619
Latvia	0	0	0	0	0	0	0
Lituania	0	0	0	0	0	0	0
Luxemburg	0	0	0	0	0	0	0
Malta	0	0	0	0	0	0	0
Netherlands	0	0	0	0	0	0	0
Poland	1,674,203	2,205,244	2,333,616	2,727,533	2,909,866	3,087,610	3,509,555
Portugal	0	0	0	0	0	0	0
Romania	0	0	0	0	0	0	0
Slovakia	0	0	0	0	0	0	0
Slovenia	0	0	0	0	0	0	:
Spain	:	:	:	:	:	:	:
Sweden	:	:	:	:	:	:	0
United Kingdom	:	:	:	:	:	0	0
EU28 TOTALS	**9,623,978**	**9,575,970**	**8,373,919**	**8,917,795**	**8,697,511**	**8,071,726**	**8,204,164**

":" means data not being available

Value of EU production of household dishwashers

The following table provides an overview of the value corresponding to the number of units produced in certain Member States and EU28 totals (cf. Table 2.1). It can be resumed that the total value of produced household dishwashers in EU28 declined from 2.5 billion Euros in 2007 by 20% to 2.0 billion Euros in 2013; i.e. according to the Eurostat data, the production value decreased more sharply than the production volume.

Table 2.2: Value (in thousand Euros) of household dishwashers produced in the EU28 between 2007 and 2013; source: (Eurostat 2015a)

Declarant	2007	2008	2009	2010	2011	2012	2013
Austria	0	0	0	0	0	0	0
Belgium	0	0	0	0	0	0	0
Bulgaria	0	0	0	0	0	0	0
Croatia	0	0	0	0	0	0	0
Cyprus	0	0	0	0	0	0	0
Czech Republic	:	:	:	:	:	:	:
Denmark	0	0	0	0	0	0	0
Estonia	0	0	0	0	0	0	0
Finland	0	0	0	0	0	0	0
France	:	:	:	:	:	:	:
Germany	1,145,011	1,086,789	992,436	1,139,032	:	:	:
Greece	2,614,696	:	:	:	:	:	:
Hungary	0	0	0	0	0	0	0

Declarant	2007	2008	2009	2010	2011	2012	2013
Ireland	0	0	0	0	0	0	0
Italy	640,890	608,146	438,164	397,321	348,245	275,685	189,020
Latvia	0	0	0	0	0	0	0
Lituania	0	0	0	0	0	0	0
Luxemburg	0	0	0	0	0	0	0
Malta	0	0	0	0	0	0	0
Netherlands	0	0	0	0	0	0	0
Poland	317,203	396,941	410,037	475,328	477,546	507,290	560,532
Portugal	0	0	0	0	0	0	0
Romania	0	0	0	0	0	0	0
Slovakia	0	0	0	0	0	0	0
Slovenia	0	0	0	0	0	0	:
Spain	:	:	:	:	:	:	:
Sweden	:	:	:	:	:	:	0
UK	:	:	:	:	:	0	0
EU28 TOTALS	2,510,033	2,411,758	2,123,188	2,326,347	2,295,381	2,199,558	2,000,000

":" means data not being available

2.1.2 EU exports and imports of household dishwashers

The following table provides an overview of exports and imports of household dishwashers by Member States for the year 2013. In terms of quantity, Poland, Netherlands and Germany appear to be the largest exporting countries of household dishwashers, followed by Italy, Spain and Sweden. On the other hand, France, Germany and UK are the most importing Member States, followed by Italy, Sweden and Netherlands.

Table 2.3: Quantity and value of exports and imports of household dishwashers in 2013; source: (Eurostat 2015a)

Declarant	Exports			Imports		
	Quantity (units)	Value (Euro)	Unit value (Euro)	Quantity (units)	Value (Euro)	Unit value (Euro)
Austria	14,620	4,867,070	333	254,203	64,116,790	252
Belgium	151,192	24,932,150	165	375,128	85,244,920	227
Bulgaria	2,491	567,990	228	36,237	7,047,360	194
Croatia	1,514	299,700	198	52,020	9,579,930	184
Cyprus	1	950	950	5,894	1,709,220	290
Czech Republic	164,069	50,077,230	305	157,043	33,858,940	216
Denmark	72,928	24,592,530	337	218,171	57,752,160	265
Estonia	2,858	808,700	283	15,577	3,667,580	235
Finland	1,222	473,580	388	150,824	33,674,210	223
France	71,133	11,664,450	164	4,279,703	319,741,390	75

Germany	2,414,396	720,767,960	299	1,720,592	300,985,030	175
Greece	3,843	1,662,780	433	66,368	13,920,790	210
Hungary	24,387	4,701,170	193	73,614	12,605,140	171
Ireland	6,987	1,518,570	217	95,994	17,472,510	182
Italy	827,980	182,995,830	221	806,292	134,884,390	167
Latvia	2,352	779,340	331	11,630	2,926,520	252
Lituania	21,896	5,334,850	244	29,086	6,839,780	235
Luxemburg	2,036	796,430	391	14,834	4,479,910	302
Malta	:	:	:	2,544	651,290	256
Netherlands	3,005,329	28,334,820	9	516,906	103,802,240	201
Poland	3,383,405	543,338,450	161	418,446	82,956,500	198
Portugal	4,477	1,289,930	288	117,238	20,116,620	172
Romania	1,169	203,420	174	32,119	5,709,950	178
Slovakia	22,071	5,669,820	257	50,364	10,968,770	218
Slovenia	90,052	22,572,580	251	95,565	18,349,490	192
Spain	493,479	108,608,680	220	467,351	76,465,990	164
Sweden	388,532	125,785,800	324	587,195	126,024,460	215
UK	68,121	12,643,960	186	1,223,779	210,630,800	172
EU27TOTALS	2,123,487	576,070,160	271	2,894,219	425,569,960	147
EU28TOTALS	2,095,955	570,560,950	272	2,917,393	429,233,590	147

2.1.3 Apparent consumption of household dishwashers

Apparent consumption of EU Member States as shown in the following table can be calculated as follows:

$$\text{Apparent consumption} = \text{Production} + \text{Imports} - \text{Exports} \qquad \textbf{Equation 2-1}$$

Note that for several EU Member States, import and export data have been reported in PRODCOM but production have been reported as zero or not at all (in which cases ":" is indicated in the table). These figures should thus be considered with caution, for example in cases where the apparent consumption results in negative data such as for Netherlands.
In total, for EU28 the volume of apparent consumption was around 9 million dishwashers in 2013, with highest volumes in Germany, Italy and Netherlands.

Table 2.4: Calculation of apparent consumption of household dishwashers between 2007 and 2013; source: own calculations based on (Eurostat 2015a)

Declarant	2007	2008	2009	2010	2011	2012	2013
Austria	207,183	205,395	206,157	226,655	239,990	248,227	239,583
Belgium	220,673	215,340	233,262	238,972	259,514	244,380	223,936
Bulgaria	47,824	50,759	32,178	34,785	25,741	30,288	33,746
Croatia	73,029	69,564	50,419	51,281	59,285	52,464	50,506
Cyprus	15,606	15,940	14,201	12,121	13,986	:	5,893
Czech Rep.	:	:	:	:	:	:	:
Denmark	211,065	190,044	179,117	164,968	158,614	138,243	145,243

Declarant	2007	2008	2009	2010	2011	2012	2013
Estonia	13,960	13,233	9,259	10,311	11,563	11,826	12,719
Finland	144,405	155,859	127,583	149,965	156,703	151,564	149,602
France	:	:	:	:	:	:	:
Germany	1,845,649	1,879,723	1,931,000	2,269,948	:	:	:
Greece	187,079	:	:	:	:	:	:
Hungary	112,990	97,939	103,805	132,967	90,178	52,749	49,227
Ireland	159,365	125,439	93,106	96,472	89,888	101,806	89,007
Italy	1,121,813	1,211,839	1,074,685	1,166,259	1,098,242	936,973	874,931
Latvia	14,607	11,813	5,728	5,182	5,620	7,283	9,278
Lituania	20,469	22,573	9,326	11,080	7,963	9,559	7,190
Luxemburg	12,395	12,410	13,131	13,376	12,261	13,182	12,798
Malta	:	:	2,783	:	:	:	:
Netherlands	380,961	367,615	433,505	349,291	-326,560	-2,102,256	-2,488,423
Poland	494,670	1,150,306	602,686	493,123	487,992	463,060	544,596
Portugal	181,352	195,583	159,536	172,349	138,330	104,295	112,761
Romania	17,994	32,774	18,178	28,601	28,826	37,682	30,950
Slovakia	33,717	52,555	825	64,864	34,316	27,324	28,293
Slovenia	28,401	32,993	26,860	28,398	30,354	26,888	:
Spain	:	:	:	:	:	:	:
Sweden	:	:	:	:	:	:	198,663
UK	:	:	:	:	:	1,034,736	1,155,658
EU27 totals	9,808,822	8,636,203	8,974,491	9,730,913	9,454,067	8,932,870	8,974,896
EU28 totals	9,890,377	8,711,658	9,027,803	9,782,384	9,510,501	8,987,157	9,025,602

":" means data not derivable as input data (mostly production data) not being available

2.1.4 EU sales and Intra/Extra-EU28 trade of household dishwashers

The following table shows the Intra- and Extra-EU trade of EU Member States in 2014 according to (Eurostat 2015b).

The trade data suggest that for nearly all Member States, the Intra-EU trade is greater than the Extra-EU trade. Germany and France have the largest number of imports from other EU Member States (Intra-EU imports), followed by Italy, UK and Sweden. The Netherlands, Poland and Germany, on the other hand, have the largest number of exports to other EU Member States (Intra-EU exports). Trade with countries outside Europe is mainly done by Germany, Poland and Italy (Extra-EU exports); the largest number of imports of household dishwashers from Extra-EU countries is reported for France, UK and Spain.

Table 2.5: Intra- and Extra-EU28 trade of Member States with household dishwashers in 2014; source: (Eurostat 2015b)

Partner	EU28 EXTRA (units)		EU28 INTRA (units)	
Reporter	**Imports**	**Exports**	**Imports**	**Exports**
Austria	17,638	6,535	252,351	8,457
Belgium	145,673	405	255,631	157,812
Bulgaria	15,904	1,026	25,305	1,694
Croatia	19,174	1,130	31,104	1,290
Cyprus	777	4	6,245	
Czech Republic	44,952	1,574	116,331	189,101
Denmark	16,849	14,733	189,339	32,553
Estonia	1,906	1,267	14,999	1,833
Finland	16,196	16	134,931	1,174
France	721,121	22,488	1,129,581	25,345
Germany	283,400	810,659	1,595,572	1,596,970
Greece	24,447	282	59,041	3,781
Hungary	33,867	1,454	56,648	21,772
Ireland	28,322	1,632	84,856	6,507
Italy	196,730	334,530	636,691	474,183
Latvia	12	274	95,061	2,402
Lithuania	2,057	19,825	21,305	1,926
Luxembourg		2	16,186	2,410
Malta	644		1,936	
Netherlands	219,024	1,521	399,036	4,188,650
Poland	136,576	552,141	250,961	3,183,836
Portugal	46,466	2,865	91,632	2,831
Romania	17,608	288	30,973	1,556
Slovakia	19,744	15	38,974	41,494
Slovenia	50,066	75,250	43,975	103,135
Spain	361,294	113,256	157,191	305,174
Sweden	95,702	163,868	583,100	183,592
UK	676,815	2,752	597,402	51,999

Comparing Table 2.5 with Table 2.3 shows that due to the different nature of the 2 databases and to some limitations existing in such statistics (e.g. precision, completeness), the presented data may contain some inherent inconsistencies. Nevertheless, this is only one of the sources considered for describing the market and further input from stakeholders is welcome.

2.2 Market, stock data and trends

The European Commission has identified a need to systematically monitor and report on the impact of Ecodesign, Energy Labelling, Energy Star and Tyre Labelling measures, including potentially new forthcoming actions, with a view to improve its understanding of the impacts over time as well as its

forecasting and reporting capacity. With contract No. ENER/C3/412-2010/FV575-012/12/SI2.657835 DG Energy has contracted Van Holsteijn en Kemna B.V. (VHK) to undertake this exercise. (VHK 2014)

The accounting method developed in this study (ECODESIGN IMPACT ACCOUNTING; Part 1 – status Nov. 2013) provides a practical tool to achieve those goals. The accounting covers projections for the period 2010-2050, with inputs going as far back as 1990 and earlier. Studies of 33 product groups (including Lot 14 on washing machine and dishwashers) with over 180 base case products were harmonised and complemented to fit the methodology. For the period up to 2025-2030, inputs were derived from the available studies. The period beyond 2025-2030 is an extrapolation of the existing trend without any new measures, i.e. it is not in the scope of the Impact Accounting study to develop new policies.

Projections use two scenarios: a 'business-as-usual' (BAU) scenario, which represents what was perceived to be the baseline without measures at the moment of the decision making, and an ECO scenario that is derived from the policy scenario in the studies which come closest to the measure taken. The BAU scenario is not a 'freeze' scenario; it is derived from extrapolating historical trends at the time of the preparatory study analysis, including possible ongoing trends in energy efficiency improvement and emission abatement The ECO scenario is the scenario with the impact of known Ecodesign, Energy Labelling, Energy Star, Tyre Label and voluntary agreements. Up to 2020-2030 it is derived from Impact Assessment (IA) and preparatory study scenarios for the selected/ proposed measures. Longer term scenarios are extrapolations of the trends, but do NOT assume that new measures will be introduced. All prices, rates and euro amounts are in 2010 euros, i.e. inflation corrected (at 2%) to 2010.

Regarding dishwashers this study reports about a continuous increase of sales of dishwashers in the European market with more than doubling the number of installed appliances from 2015 to 2050 (Figure 2.1) reaching almost 100% penetration in European households. For calculating the expected change in energy consumption and related greenhouse gas emissions the study makes some essential assumptions (Table 2.6). While the size of the dishwasher is seen as rather constant (in terms of rated capacity and used capacity measured as ps per cycle), the average temperature used for the cleaning cycle is assumed to drop by more than 6 Kelvin between 2015 and 2050.

Using the stock model as developed by VHK with the assumption of constant 15 years life time the energy used for a dishwasher on stock in all years can be calculated (Figure 2.2). This calculation prognoses a significant difference of the total amount of energy used per year for a dishwasher between the BAU (220 kWh) and the ECO (140 kWh) scenario in 2050. This is mainly caused by the improvement of dishwashers efficiencies up to year 2025 following the implementation of Regulation (EC) No 1059/2010. Following these calculations for the ECO scenario a total energy consumption for automatic dishwashing in the EU is estimated to be at 30 TWh elec. in 2050 causing 8 MtCO2 eq./a greenhouse gas emissions (Figure 2.3, Figure 2.4). Notably, this is twice as high as it is calculated for washing machines use. Not included in these calculations are the savings achieved in terms of energy, water and greenhouse gas emissions avoided by substituting manual dishwashing by automatic dishwashing. As it has been shown in (ENEA/ISIS 2007b) automatic dishwashing is using considerably less amount of energy and water and thus the total amount of greenhouse gases emitted is balanced by the reduced amount needed for manual dishwashing.

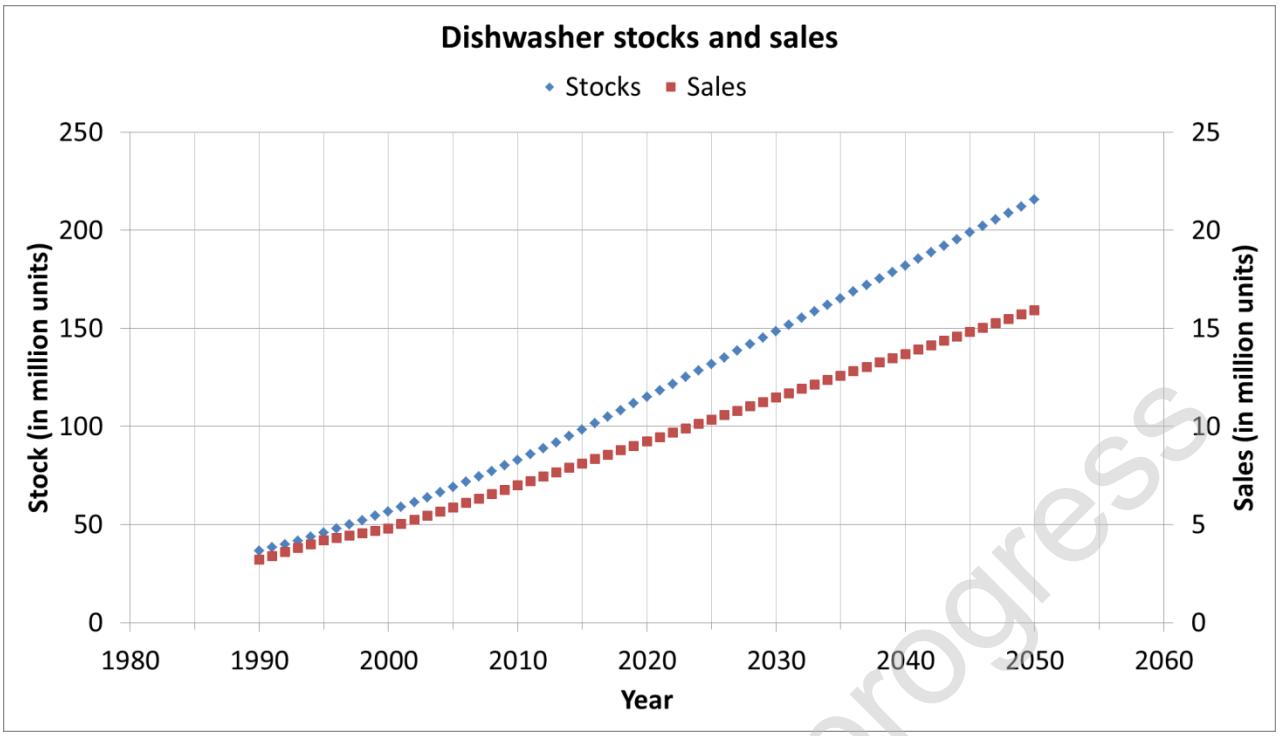

Figure 2.1: Sales and stock of dishwashers in the European market from 1990 to 2050 (data from (VHK 2014))

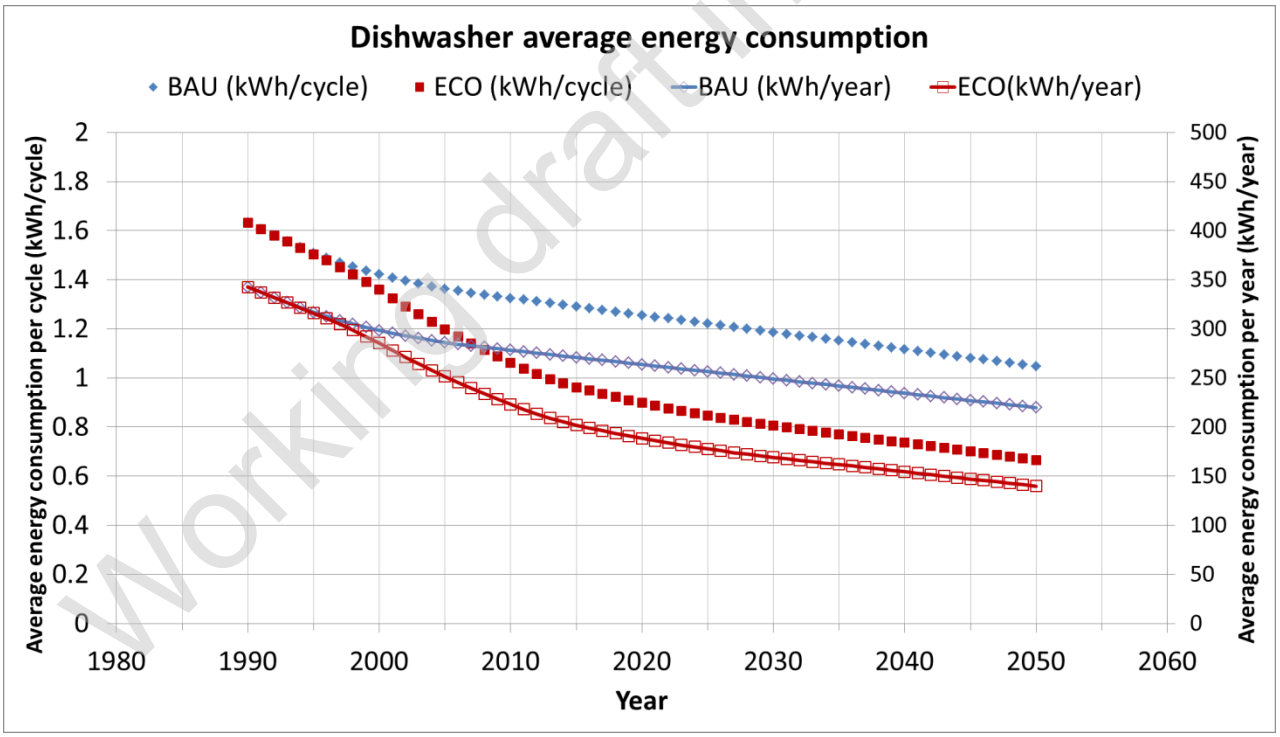

Figure 2.2: Average energy consumption of a dishwashers installed in the European market from 1990 to 2050 (data from (VHK 2014))

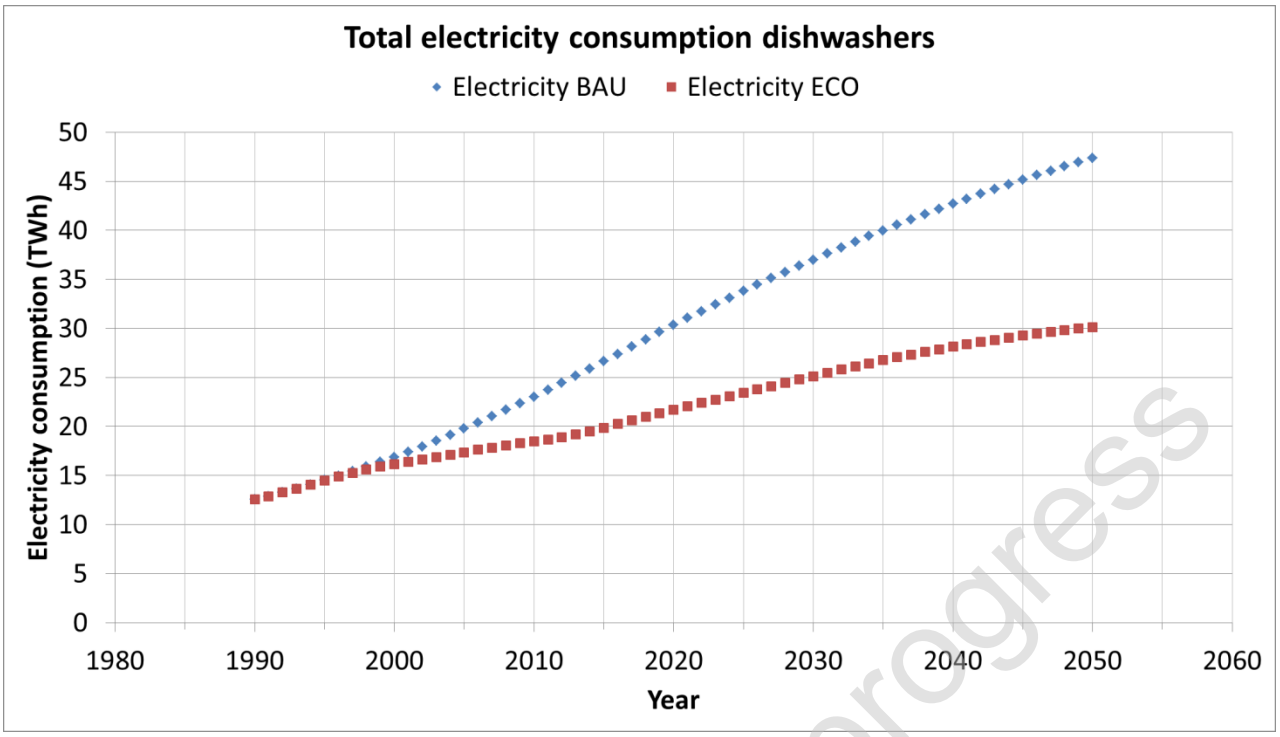

Figure 2.3: Total electricity consumption of installed dishwashers in the European market from 1990 to 2050 (data from (VHK 2014))

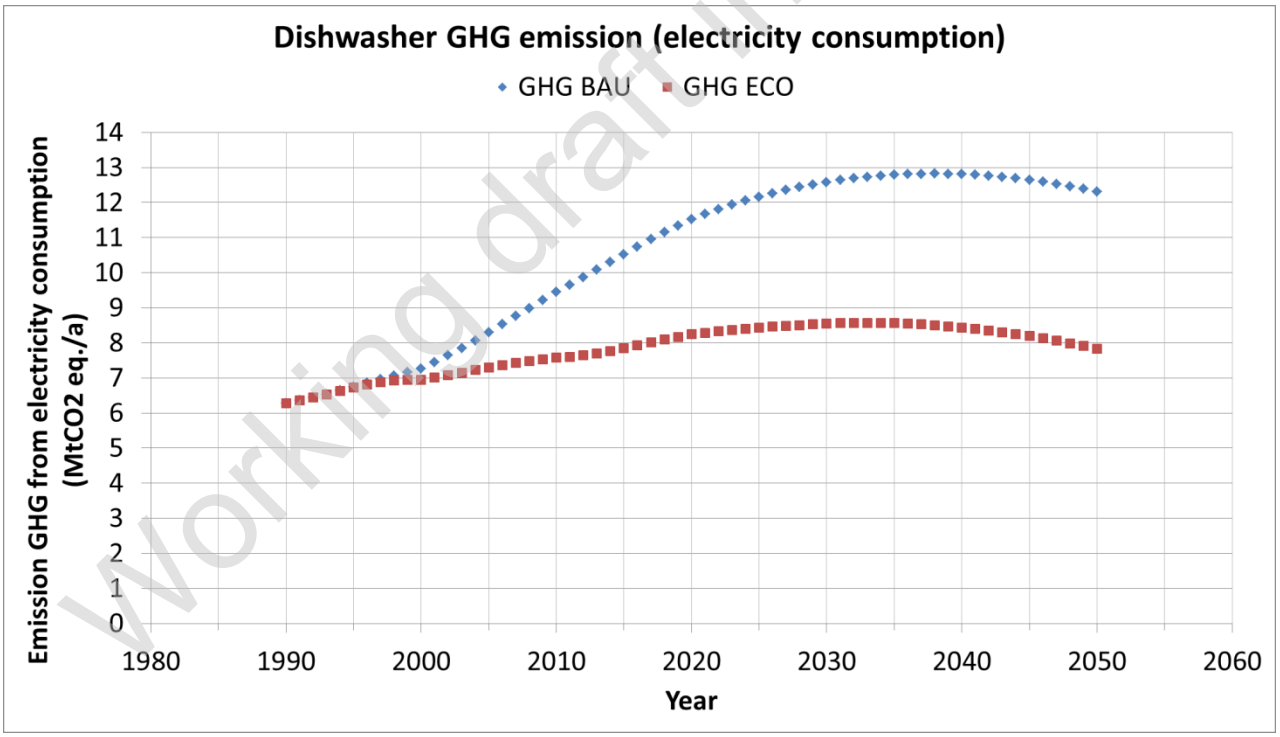

Figure 2.4: Total greenhouse gas emissions originating from the electricity use of dishwashers installed in the European market from 1990 to 2050 (data from (VHK 2014))

Table 2.6 Summary of data regarding dishwashers from ECODESIGN IMPACT ACCOUNTING (VHK 2014)

Data Dishwasher	unit	year									
		1990	2010	2015	2020	2025	2030	2035	2040	2045	2050
Stock	in units of million	36,633	82,799	98,345	115,036	131,797	148,553	165,303	182,047	198,790	215,532
Sales	in units of million	3,200	6,999	8,116	9,233	10,351	11,467	12,583	13,699	14,815	15,931
Real average programme temperature	°C	61.6	57.6	56.6	55.6	54.6	53.6	53	52	51	50
Rated capacity in place setting	ps/cycl	11.9	12.6	12.7	12.8	12.8	12.8	13	13	13	13
Real load in place settings	ps/cycl	6.7	8.8	9.1	9.3	9.3	9.3	9	9	9	9
Cycles/year per unit (estimated)	cyc/a	210	210	210	210	210	210	210	210	210	210
SAEc (EEI=100)	kWh/a	438	455	457	458	458	458	458	458	458	458
Place settings washed per year	bn	52	154	188	224	257	290	322	355	388	420
Sales energy/cycle BAU	kWh/cycle	1.48	1.28	1.25	1.21	1.18	1.14	1.1	1.07	1.03	1
Sales energy/year BAU	kWh/a	310	269	262	254	247	239	232	225	217	210
Sales energy/cycle ECO	kWh/cycle	1.48	0.94	0.87	0.83	0.79	0.76	0.72	0.69	0.65	0.62
Sales energy/year ECO	kWh/a	310	198	183	174	167	159	152	145	137	130
Stock energy/cycle BAU	kWh/cycle	1.63	1.33	1.29	1.26	1.22	1.19	1.15	1.12	1.08	1.05
Stock energy/year BAU	kWh/a	343	278	271	264	256	249	242	234	227	220
Stock energy/cycle ECO	kWh/cycle	1.63	1.06	0.96	0.9	0.85	0.81	1.0	0.74	0.7	0.67
Stock energy/year ECO	kWh/a	343	223	202	189	178	169	162	154	147	140
Electricity BAU	TWh elec	13	23	27	30	34	37	40	43	45	47
Electricity ECO	TWh elec	13	18	20	22	23	25	27	28	29	30
Emissions GHG BAU	MtCO2 eq./a	6	9	11	12	12	13	13	13	13	12
Emissions GHG ECO	MtCO2 eq./a	6	8	8	8	8	9	9	8	8	8
Unit price BAU	€ (2010)	541	541	541	541	541	541	541	541	541	541
Unit price ECO	€ (2010)	541	718	719	704	686	667	649	631	614	596
Revenue Wholesale BAU	m€ (2010)	52	114	132	150	168	186	204	222	240	259
Revenue Wholesale ECO	m€ (2010)	52	151	175	195	213	230	245	260	273	285
Revenue Industry BAU	m€ (2010)	698	1528	1771	2015	2259	2502	2746	2989	3233	3476
Revenue Industry ECO	m€ (2010)	698	2028	2353	2621	2862	3087	3296	3489	3668	3832

2.2.1 Market and sales data

2.2.1.1 Dishwasher penetration rates

Dishwashers have lower penetration rates than washing machines or refrigerators. In 2012, approximately 40% of households in EU-27 owned a dishwasher. However, penetration rates vary widely between the Member States. According to (JRC IPTS 2014), countries with the highest rate of dishwasher ownership in 2013 include Austria 82 %, Sweden 75 %, Germany 69 %, Ireland 67 % and Denmark 67 %. Countries with the lowest rate of dishwasher ownership include Latvia 4 %, Lithuania 5 %, Bulgaria 6 %, Romania 6 % and Slovakia 13 %. Although the ownership rate of dishwashers varies by country, across Europe the overall trend is a rise in ownership over the past five years.

According to stakeholder feedback to the questionnaire (JRC IPTS 2015a), market research across Europe done by a panel of about 500 consumers in 23 countries in October 2014 resulted in a penetration of dishwashers of 60% across Europe, ranging from 35% in Eastern Europe to 73% in Southern Europe.

2.2.1.2 Sales and stock data of dishwashers

According to (CLASP 2013) and(VHK 2014), sales and stock data of dishwashers continuously increase (Table 2.7).

Table 2.7: Sales and installed stock of dishwashers in the EU 27 countries (CLASP 2013) and (VHK 2014)

	2007	2008	2009	2010	2011
Sales (million units) (CLASP)	6.4	6.7	7.0	7.4	7.8
Stock (million units) (CLASP)	74.0	76.0	78.0	82.2	84.0
Sales (million units) (VHK)	:	:	:	6.9	:
Stock (million units (VHK)	:	:	:	82.8	:

Table 2.8 shows the sales and diffusion of dishwashers, population and - as a standardized comparative figure - the inhabitants per sold appliance of various European countries in 2014 (Scharf 2015).

Diffusion rates in Spain and Portugal are low; the level of inhabitants per sale is high, which means that few dishwashers were sold in 2014. This is a result of the economic crisis still inhibiting private households to make big purchases. In UK and Italy the diffusion rate are also low, but the level of inhabitants per sales is on midlevel. High penetration rates ≥ 60 % can be found for France, Denmark, Germany, Switzerland and the Netherlands. Those countries also hold the first position in "Inhabitants per sold appliance" ranking. From (Scharf 2015): "*Even without the recent statistical data, we can affirm with certainty that the situation is not different in Norway, Sweden and Finland.*"

Table 2.8: Sales and diffusion of dishwashers in various European countries in 2014 (Scharf 2015), database: National statistical bodies, trade associations, sector press

Nation	Sales (1,000 units)	Diffusion (%)	Population (Million)	Inhabitants per sold unit
Italy	900	45	60.0	67
France	1,450	60	65.8	45
Germany	2,250	68	81.8	36
Great Britain	1,020	42	64.1	63
Spain	576	47	47.1	82
Switzerland	215	68	8.2	38
Portugal	105	40	10.4	99

Nation	Sales (1,000 units)	Diffusion (%)	Population (Million)	Inhabitants per sold unit
Denmark	165	69	5.6	34
The Netherlands	410	69	16.6	40

Dishwasher markets in central and north Europe are nearly saturated. Mediterranean markets (Spain, Italy, and Portugal) are expected to show higher growth rates in future, when the economic situation is improved for private households. In the new European member states ("NM-12": Estonia, Hungary, Latvia, Lithuania, Poland, Czech Republic, Slovakia, Slovenia, Romania, Bulgaria, Cyprus and Malta) *"[…] market penetration so far only reached approximately 10%, […]."* (CLASP 2013)
In Eastern Europe *"[…] the dishwasher is a luxury item, prerogative of few wealthy people and its possession becomes a status symbol. "* (Scharf 2015)
There is a fast growth in dishwasher penetration in the NMS-12 market, "*[…] reaching an overall EU-27 average household ownership level of just above 60 % in 2030.*" (CLASP 2013)
Table 2.9 shows the estimates of future sales and total installed stock data of dishwashers.

Table 2.9: Projected Dishwasher sales and installed stock in EU-27 countries (CLASP 2013) and (VHK 2014)

	2015	2020	2025	2030
Sales (million units) (CLASP)	8.8	9.8	10.9	11.9
Stock (million units) (CLASP)	99.1	118.2	137.0	153.4
Sales (million units) (VHK)	8.1	9.2	10.4	11.5
Stock (million units) (VHK)	98.3	115.0	131.8	148.6

On the contrary, (JRC IPTS 2014) assume that the increase of single-person households in many EU countries will also have an impact on dishwasher sales. In the UK, for example, only 22 % of single-person households own a dishwasher. Currently, the number of single adult households across Europe ranges from 16% of households in Cyprus to 46% of households in Denmark. If these numbers were to increase further, it can be reasonably assumed that dishwasher ownership would stagnate.

2.2.1.3 Development of energy efficiency classes of total dishwasher sales

In compliance with the development of *available* dishwasher models of a certain energy efficiency class (cf. Figure 2.16 in section 2.2.2.4), the *sales data* of dishwashers belonging to a certain energy efficiency class has changed. Figure 2.5 shows the relative distribution of sales of dishwashers of a certain energy efficiency class from 2004 to 2012 in 14 European countries (AT, BE, DE, DK, ES, FI, FR, GB, GR, IE, IT, NL, PT, SE).
The share of sold dishwashers with an energy efficiency class A steadily increased up to 98 % in 2010. Since new energy efficiency classes were implemented in December 2011, the share of sold dishwashers with energy efficiency class A+, A++ and A+++ increased for about 25% (2011: 28%, 2012: 52.9%).

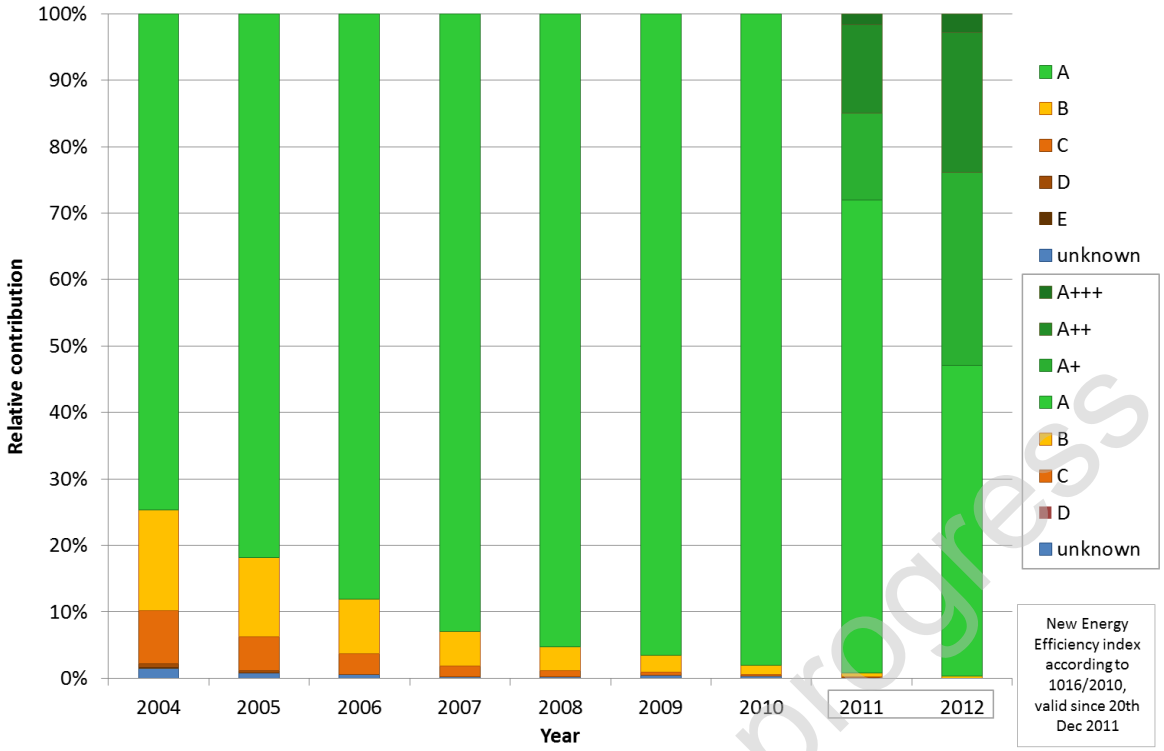

Figure 2.5: Relative distribution of energy efficiency classes on total dishwasher sales from 2004 – 2012 in 14 European countries (AT, BE, DE, DK, ES, FI, FR, GB, GR, IE, IT, NL, PT, SE), (data from GfK, personal communication)

Figure 2.6 visualizes the share of A++ and A+++-appliances (accumulated for washing machines, dishwashers, fridges and freezers) on sold units from January to February 2014 in 28 European countries. The highest share of energy efficient appliances was sold in Germany, Belgium and Austria, with a share of > 50%, followed by Denmark, the Netherlands, Sweden, Czech Republic and Slovakia (≥ 40%). Low shares (> 20%) can be seen in France, UK, Ireland and Eastern European countries like Hungary, Romania, Croatia, Serbia and Ukraine.

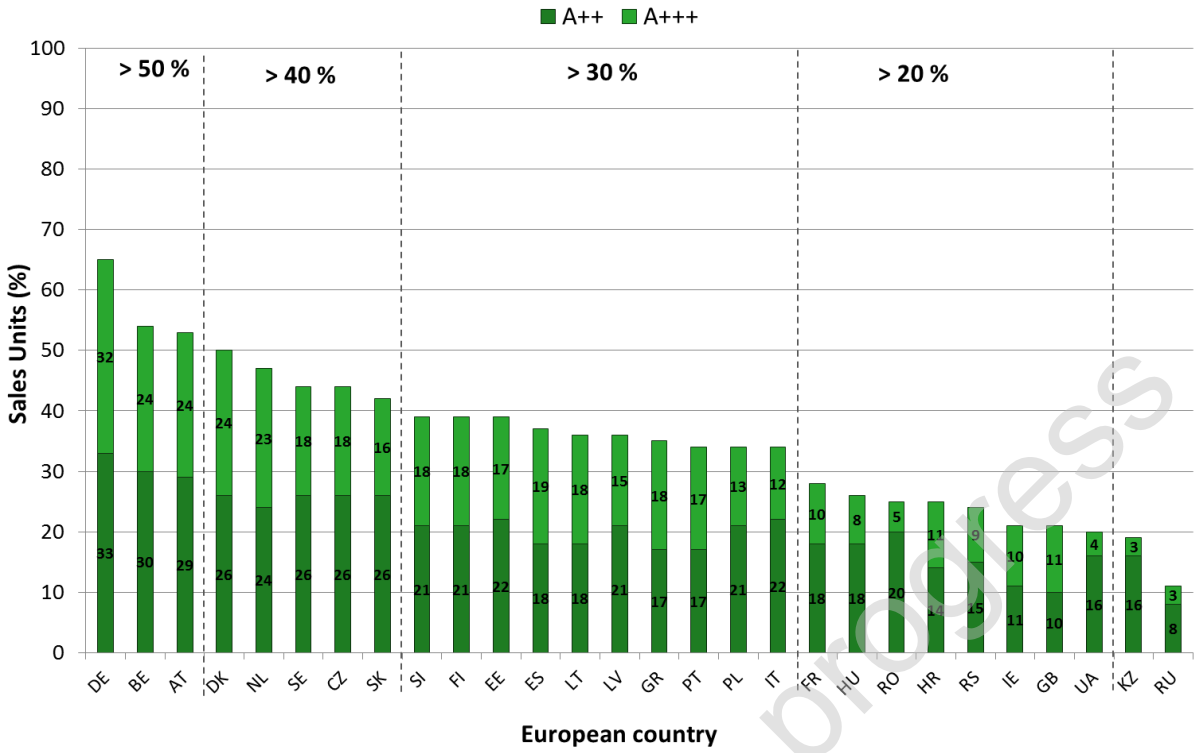

Figure 2.6: Share of A++ and A+++-appliances (accumulated for washing machines, dishwashers, fridges, freezers) on the total amount of sold units in January-February 2014 in 28 European countries (Stöckle 2014)

Replacing old dishwashers by new ones is a further way to decrease the energy consumption by dishwashers. Average life time expectancy of dishwashers can be assumed to be 15 years (Presutto et al. 2007). 15 years backwards from 2013, in 1998, no dishwasher available on the European market had energy efficiency class A (Figure 2.16). It is therefore highly likely that many older and inefficient dishwashers that have been bought until 1998 will be replaced by new high efficient appliances in the next years.

2.2.1.4 Market structure of the European white goods industry

The European white goods industry in 2012 was dominated by seven major players, as shown in Table 2.10. BSH is ranked European number one in terms of turnover, and global number 3. Electrolux is ranked number 2, both European and globally. Indesit is European number 3. Whirlpool is European number 4, followed by Samsung, LG and Miele. Globally, Whirlpool was number 1 player in 2012. Other important players are Haier, Amica and Fagor. (Capgemini Consulting 2012)

In 2004 Whirlpool took over Indesit which gives it an equal size as Electrolux in Europe (Livesey 2014).

Table 2.10: Major players in European white goods industry (Capgemini Consulting 2012)

Company	Main brands (non exhaustive)	Total turnover * in EU (2010, bln €)	European ranking	Total turnover* (2010, bln €)	Global ranking
BSH	Bosch, Siemens, Gaggenau, Neff	6.7	1	8.4	3
Electrolux**	Electrolux, AEG, Zanussi	4.8	2	11.5	2
Indesit	Hotpoint, Indesit, Scholtès	2.7	3	2.9	
Whirlpool**	Whirlpool, Bauknecht, Ignis, KitchenAid	2.2****	4	13.0	1

Company	Main brands (non exhaustive)	Total turnover * in EU (2010, bln €)	European ranking	Total turnover* (2010, bln €)	Global ranking
Samsung**	Samsung	1.7***		7.5	
LG**	LG	1.2***		6.1	
Miele	Miele	--		2.8	
* Not all turnover is white goods related. Figures most of the time concern the overall home appliance turnover, including small home appliances.					
** Converted to €, based on June 2010 currency rates.					
*** High level estimate, based on published European Turnover share for all product groups.					
**** EMEA figure, assuming that turnover in Middle East and Africa is small compared to Europe					

Leading manufacturers operate numerous production locations in different European countries, mainly in Italy, Poland, Germany, Spain, Hungary and Turkey. Each production location is specialized in one product group and supplies the whole of Europe.

Retail channels for white goods are diverse: there is a large number of smaller retailers specialized in white goods and household appliances, large grocery chains, kitchen manufacturers and resellers, mail-order companies and online shops. (Capgemini Consulting 2012) Data of the importance of e-commerce when purchasing dishwashers have not been found. Generally, the e-commerce of white goods (category "Electronics and Appliances") is supposed to differ widely throughout the European countries, as shown for the example of Germany and UK in 2012 (Figure 2.7). As in UK 42.3 % of Electronics and Appliances were bought online, in Germany only 25.5 % were sold by this purchase channel.

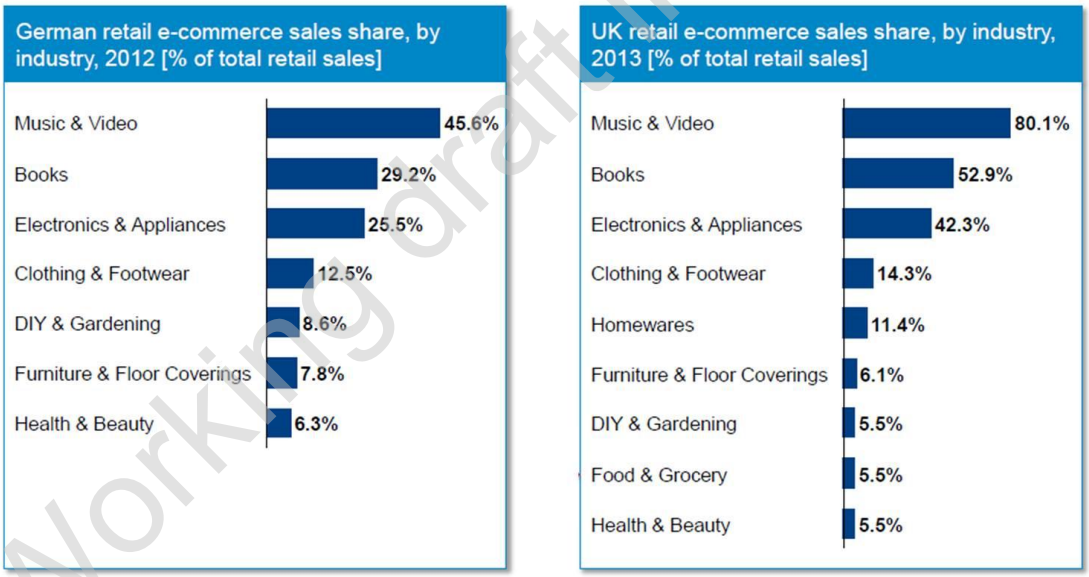

Figure 2.7: E-commerce with household Electronics and Appliances in 2012 (Bachl & Koll 2013)

2.2.2 Models offered on the market

The following analysis is based on the CECED database of all dishwasher models available on the European market from 1998 to 2013.

2.2.2.1 Total number of dishwasher models available on the market

Apart from sharp declines in 2006 and 2011, the general market trend shows an increase in the number of available dishwasher models (Figure 2.8). This trend can be ascribed to the continuously increasing market (chapter 2.2.1) with its need to offer a larger variety of models due to different consumer needs and preferences and the invention and implementation of new product features. The number of models does not necessarily correlate with the number of sold appliances in a certain year.

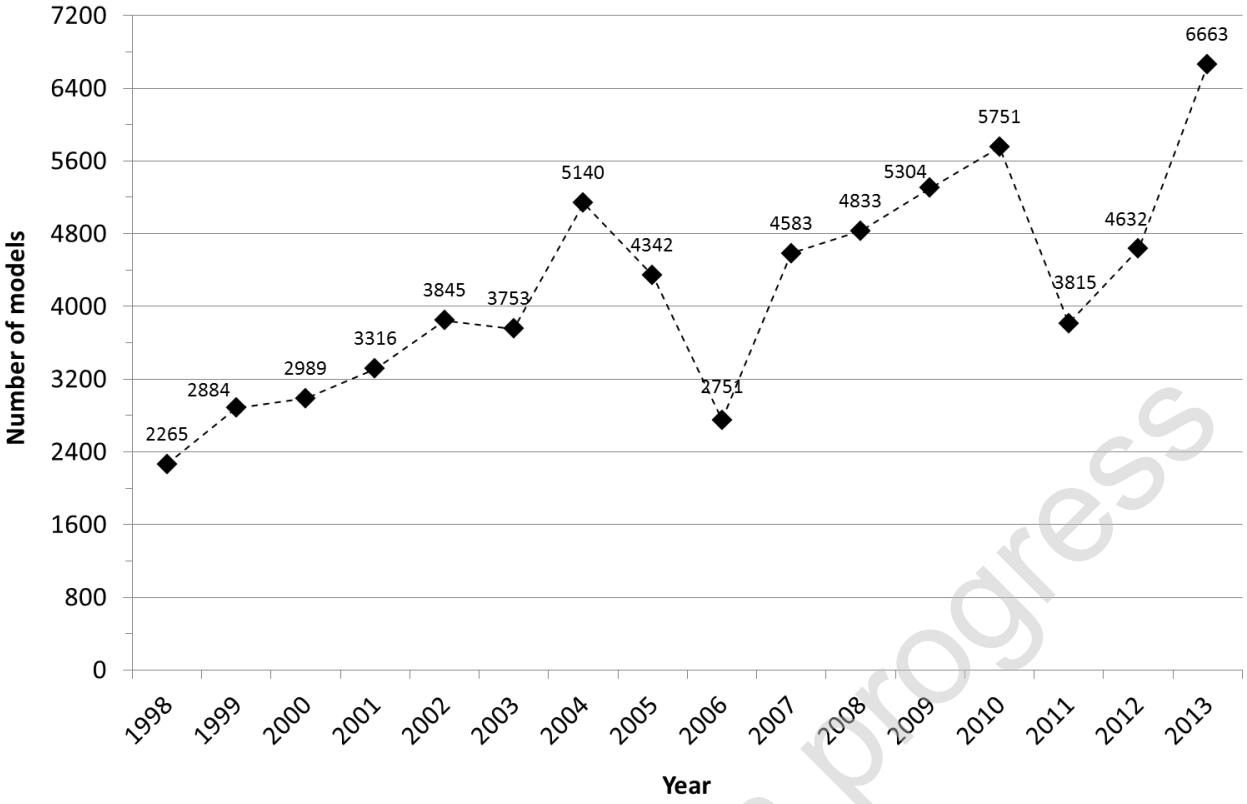

Figure 2.8: Development of number of dishwasher models available on the European market from 1998 to 2013 (data from CECED, personal communication)

2.2.2.2 Capacities of dishwasher models available on the market

The capacity of a dishwasher is indicated by the amount of ps that can be loaded into the baskets. In general, the market is mainly divided in two relevant dishwasher segments:

- Full size models (width: 60 cm, capacity: 12-15 ps) and
- Slim line models (width: 45 cm, capacity: 8-10 ps).

Further, there are few models with less than 8 ps on the market, the so-called countertop models.
The overall development of dishwasher capacities on the European market between 1998 and 2013 is shown in Table 2.11 and Figure 2.10.
The vast majority of dishwasher models on the European market are full size dishwashers (width: 60 cm). Today, the capacity of full size dishwashers ranges from 12 to 15 ps. The prevailing trend shows an increase in the market shares of dishwashers with a capacity > 12 ps. Since the beginning of this database in 1998, 12 ps models dominated the dishwasher market. Since 2005, their market share has continuously been decreasing (2005: 81.7 %; 2013: 40.1 %) in favour of dishwashers with a capacity of 13 ps (2005: 0 %; 2013: 31.1 %) and 14 ps (2005: 0.6 %; 2013: 10.9 %). Further, first full size models with a capacity of 15 ps entered the market in 2004 (1.6 %); their market share growed to 3.0 % in 2013.
Since 2001, the share of slim line models is on a constant level of (15 ± 3) %. The capacity of slim line models increases. By 2000, slim line models with a capacity of 8 ps held the majority in this market segment. Since 2001, the majority of slim line models have a capaicity of 9 ps. Also in 2001, slim line models with a capacity of 10 ps entered the market but did not push through (4.1% in 2013). In 2013, still the 9 ps slim line models dominated this market segment with 9% of all dishwasher models. Since 2009, finally, the shares of slim line models of a certain capacity on the total market are on a steady level: (4 ± 1) % for 10 ps-models, (8 ± 3) % for 9 ps-models and (0.5 ± 0.2) % for 8 ps-models.
Dishwashers with a capacity < 8 ps (so called countertop models) have a small but steady market share of 1% to 1.5%. Whereas for many years 4 and 5 ps were common, in 2002 models with 6 ps entered the market. In 2010, 4 ps models and in 2011, 5 ps models disappeared from the market.

Table 2.11: Development of dishwasher capacities on the European market from 1998 to 2013, relative shares (%) in ps = place settings (data from CECED, personal communication)

Capacity (in ps)	Year with number (n) of available dishwasher models on the European market															
	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
	n=2265	n=2884	n=2989	n=3316	n=3845	n=3753	n=5140	n=4342	n=2751	n=4583	n=4833	n=5304	n=5751	n=3815	n=4632	n=6663
4	0.4	0.2	0.2	0.2	0.4	0.5	0.7	0.6	0.0	0.4	0.4	0.3	0.0	0.0	0.0	0.0
5	0.5	0.3	0.4	0.4	0.4	0.5	0.3	0.2	0.5	0.1	0.1	0.1	0.1	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.4	0.4	0.6	0.4	1.2	0.5	0.5	1.3	1.3	1.5	1.5	1.5
8	10.2	6.2	5.6	4.8	3.2	2.7	1.0	0.4	0.5	0.6	0.7	0.7	0.3	0.4	0.4	0.4
9	2.2	5.8	6.1	11.0	11.5	9.0	12.2	12.2	10.9	13.5	10.0	8.9	8.0	11.4	8.2	9.0
10	0.0	0.1	0.0	0.4	0.8	0.5	0.4	1.5	4.2	2.5	2.7	4.2	4.7	3.7	4.0	4.1
11	0.3	0.7	0.7	0.6	0.6	0.5	0.4	0.0	0.6	0.7	0.4	0.5	0.5	0.5	0.3	0.0
12	85.0	84.3	84.2	79.5	78.5	83.5	82.1	81.7	77.1	78.2	71.9	55.1	51.4	48.2	46.6	40.1
13	0.0	0.0	0.0	1.0	1.7	1.3	0.8	0.0	0.0	0.1	8.0	17.2	19.6	24.3	28.9	31.1
14	1.3	2.4	2.7	2.0	2.5	1.0	0.0	0.6	0.3	1.1	3.2	9.1	11.4	8.8	9.5	10.9
15	0.0	0.0	0.0	0.0	0.0	0.0	1.6	2.4	4.7	2.1	2.0	2.7	2.6	1.3	0.7	3.0

The shift of market shares in favour of dishwasher models with a capacity of ≥ 13 place settings is also visualised in Figure 2.9.

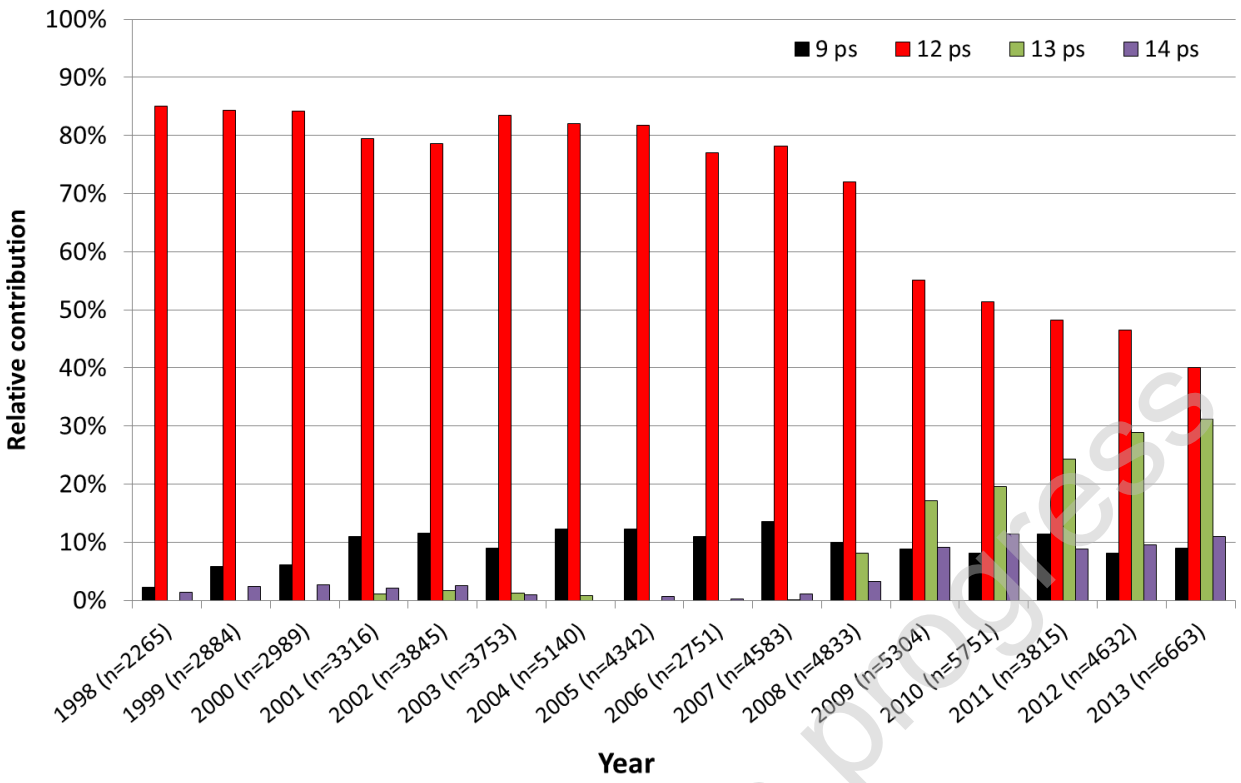

Figure 2.9: Shift of market shares of dishwasher capacities (in ps=place settings, n = number of dishwashing models available on the European market in a certain year) (data from CECED, personal communication)

2.2.2.3 Energy and water consumption of dishwasher models available on the market

Figure 2.10 (energy) and Figure 2.11 (water) visualize the average consumption values per cycle or per ps of a dishwasher model in a certain year. Average values are calculated from the consumption values of the Eco programme from all models of a respective year. Continuous technical advances and changes in programme courses lead to decreasing energy and water consumptions per cycle. In combination with increasing dishwasher capacities, this leads to decreased consumptions values per ps. That means: although the amount of table- and dishware that can be cleaned per cycle increases, the consumption of energy and water per cycle decreases. Both developments often go hand in hand: technical advances (e.g. improvements in filter design, pump motor efficiency, moving the heater from the tub to the water sump) offer more space for additional dishwasher load (iea-4e 2014).

Important technical developments to reduce energy consumption of a dishwasher during the observation period were temperature-time trade-off, sophisticated electronic process controls and electronic water and temperature controls. "*Further improvements with these design options are still possible, with the greatest potential to further reduce the energy consumption are temperature-time trade-off, sensors and innovative drying systems (e.g., the adsorption drying systems that were only recently introduced to the market*)." (CLASP 2013) For a detailed analysis of technical improvement options, please refer to section 4.1.4.

From 2004 to 2010, the energy consumption per cycle and ps (Figure 2.10) showed a significant decrease; the amount of realised energy savings per year decreased:

- 2002 to 2003: - 0.045 kWh per cycle and - 0.004 kWh per ps
- 2003 to 2004: - 0.024 kWh per cycle and - 0.002 kWh per ps
- 2004 to 2005: - 0.017 kWh per cycle and - 0.002 kWh per ps
- 2005 to 2006: - 0.011 kWh per cycle and - 0.001 kWh per ps

Since 2004, the vast majority of dishwasher models met the demands of energy efficiency class A according to the former Directive 97/17/EC on energy labelling. There was neither pressure nor incentive for manufacturers to further reduce the energy consumption values of their Eco programme. In 2010, the ecodesign Regulation (EC) No 1016/2010 for dishwashers implemented a revised energy efficiency index, introducing the new energy efficiency classes A+++, A++, A+, A and B. It also defines specific requirements of future dishwasher models that come into force on specific dates:

- December 2011: all dishwashers with a capacity of > 10 ps and a width of ≥ 45 cm need to fulfil the requirements of energy efficiency class A. Only dishwashers with a capacity of ≤ 10 ps and a width of < 45 cm may belong to energy efficiency class B.
- December 2013: all dishwashers with a capacity of ≥ 11 ps as well as dishwashers with a capacity of 10 ps and a width of ≥ 45 cm need to fulfil requirements of energy efficiency class A+. Energy efficiency lass A is only allowed for dishwashers with a width of ≤ 45 cm or a capacity of ≤ 9 ps.
- December 2016: all dishwasher models need to fulfil the requirements of energy efficiency class A+.

As a resulting effect, realised energy savings per cycle and ps per year again increased:

- 2011 to 2012: - 0.020 kWh per cycle and - 0.003 kWh per ps
- 2012 to 2013: - 0.020 kWh per cycle and - 0.002 kWh per ps

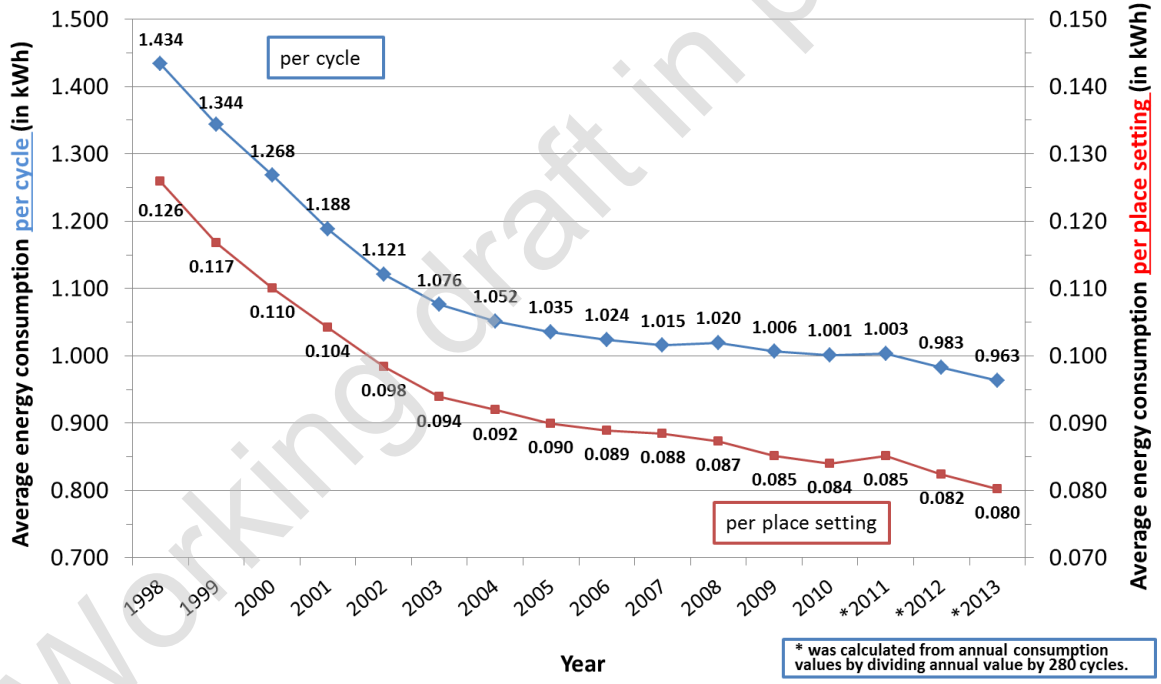

Figure 2.10: Development of average energy consumption per cycle or per ps. Note that before 2011 the data were declared as per cycle (data from CECED, personal communication)

Water consumptions per cycle and place setting have been reduced (Figure 2.11) by 46% from 1998 to 2013, while energy consumption per cycle and place setting has been reduced by 30% over the same time period (Figure 2.10). Besides technical advances (section 4.1.4), savings in water consumption are realised by variations in programme courses, e.g. omitting the pre-rinse phase or re-using final rinse water for the pre-rinse of the following dishwashing cycle.

According to (iea-4e 2014), the correlation between water and energy consumption suggests to implement *"[...] minimum standards for water consumption and achieve a double benefit of reduced water and energy use. However, [...] as manufacturers could for example increase temperatures to reduce*

washing times [...] it is important that any water regulations are introduced in conjunction with energy regulations."

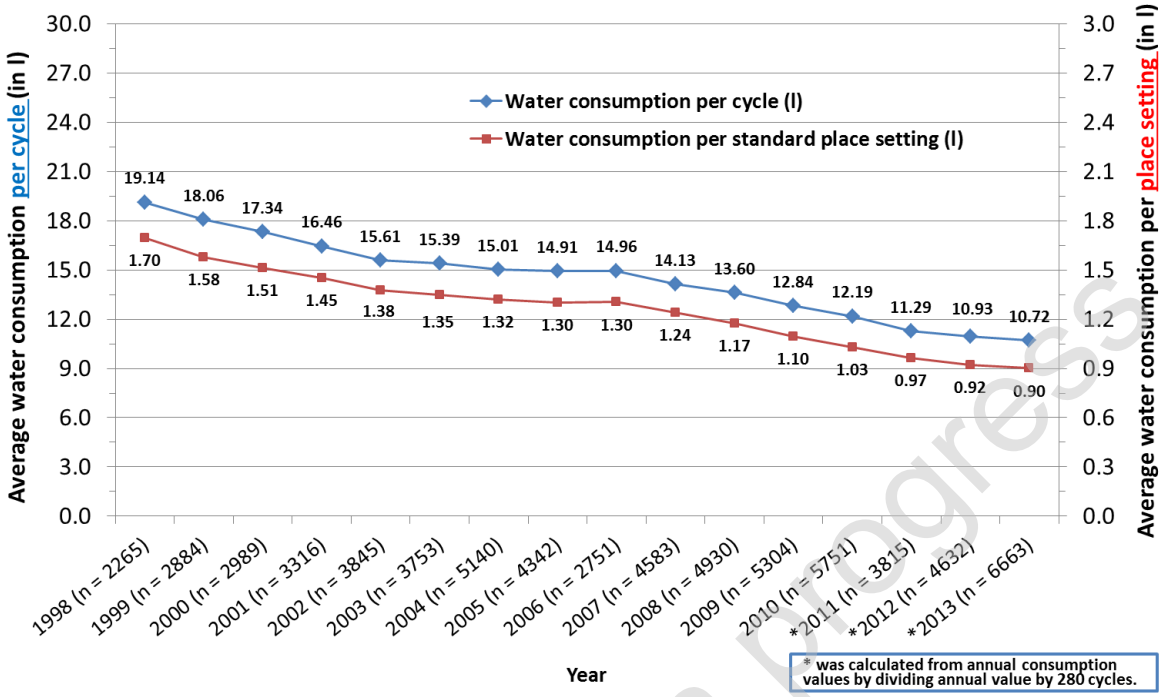

Figure 2.11: Development of average water consumption per cycle or per ps (data from CECED, personal communication)

2.2.2.3.1 Development of energy and water consumption per cycle

Figure 2.12 (energy) and Figure 2.13 (water) visualizes the development of average consumption values for energy and water per cycle in 9 and 12 ps-models from 1998 to 2013. Average values are calculated out of the consumption values of the Eco programme of all dishwasher models with a capacity of 9 respectively 12 ps on the European market in the corresponding year. Per cycle, slim line dishwashers with a capacity of 9 ps use less water and energy than full size 12 ps-models.

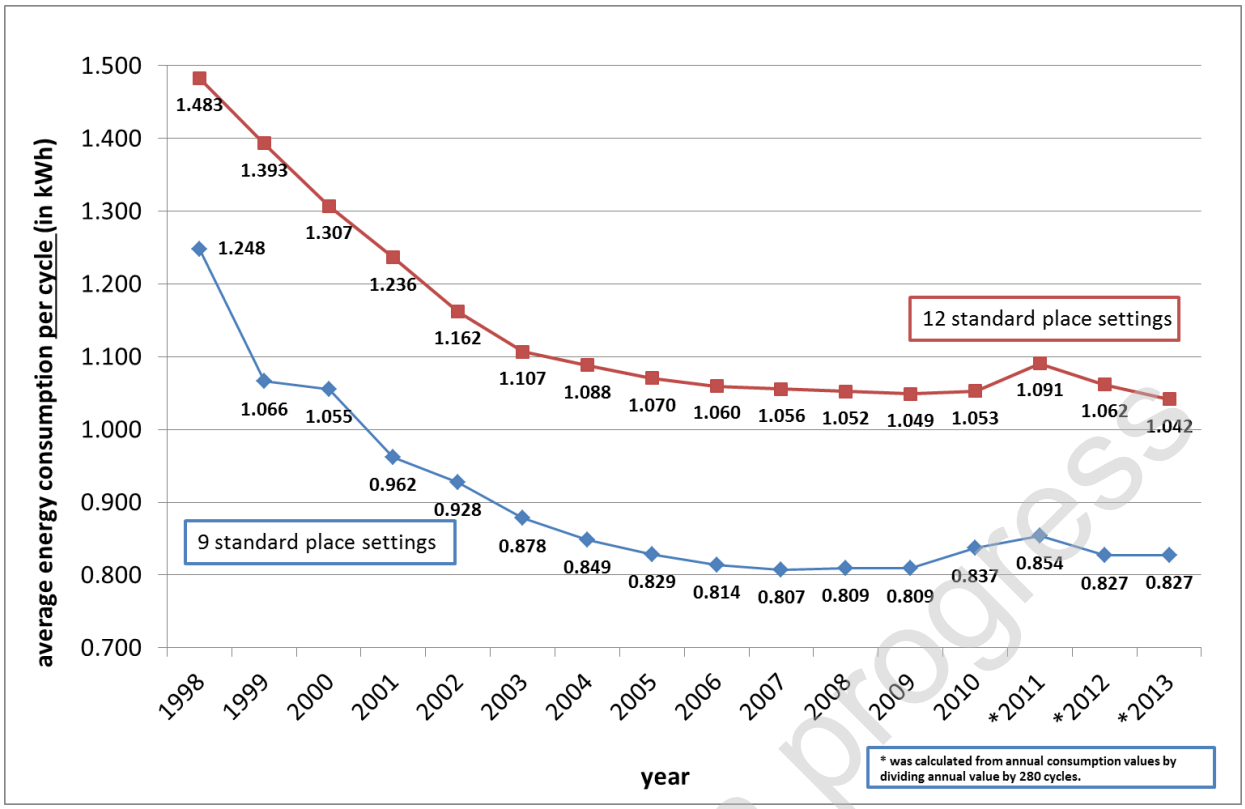

Figure 2.12: Development of average energy consumptions per cycle for 9 and 12 ps-models on the European market (data from CECED, personal communication)

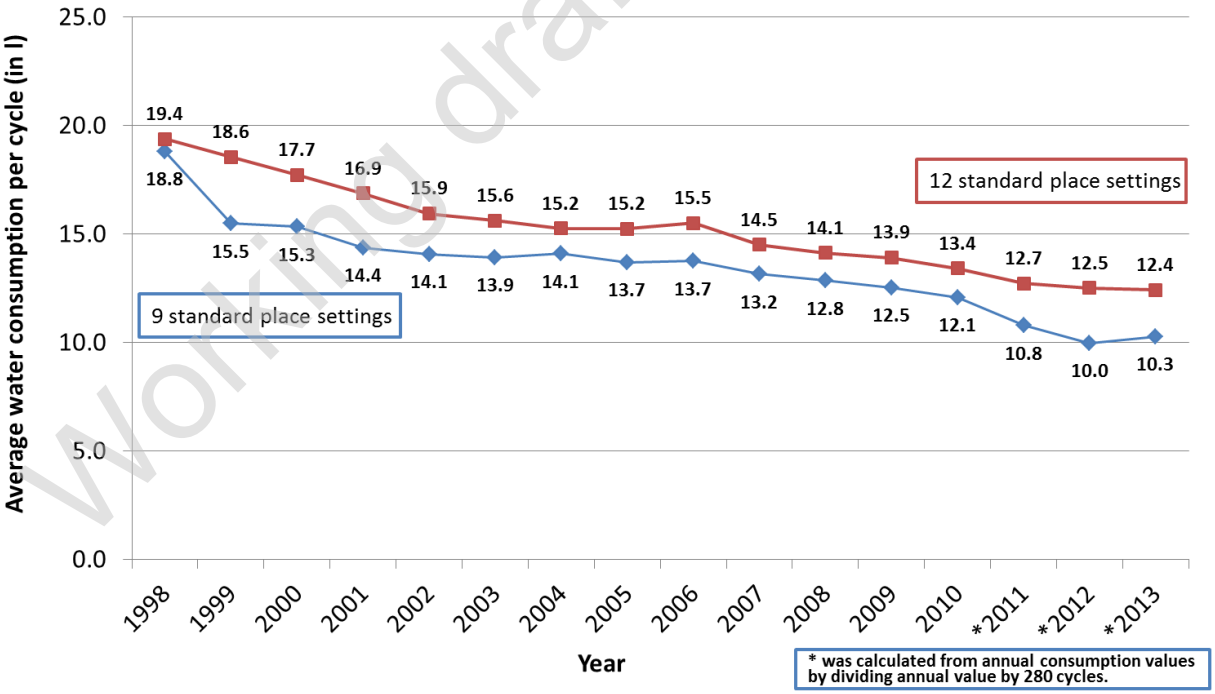

Figure 2.13: Development of average water consumptions per cycle for 9 and 12 ps-models on the European market (data from CECED, personal communication)

2.2.2.3.2 Development of energy and water consumption per place setting

With regard to the estimated increase in the number of European single households and the increasing costs for resources like water and energy one may suggest promoting the distribution of slim line dishwasher models. But full size models show their superior efficiency when consumption values are related to the overall capacity. Figure 2.14 and Figure 2.15 show that per ps, dishwashers with a capacity of 12 ps use less water and energy than 9 ps-models.

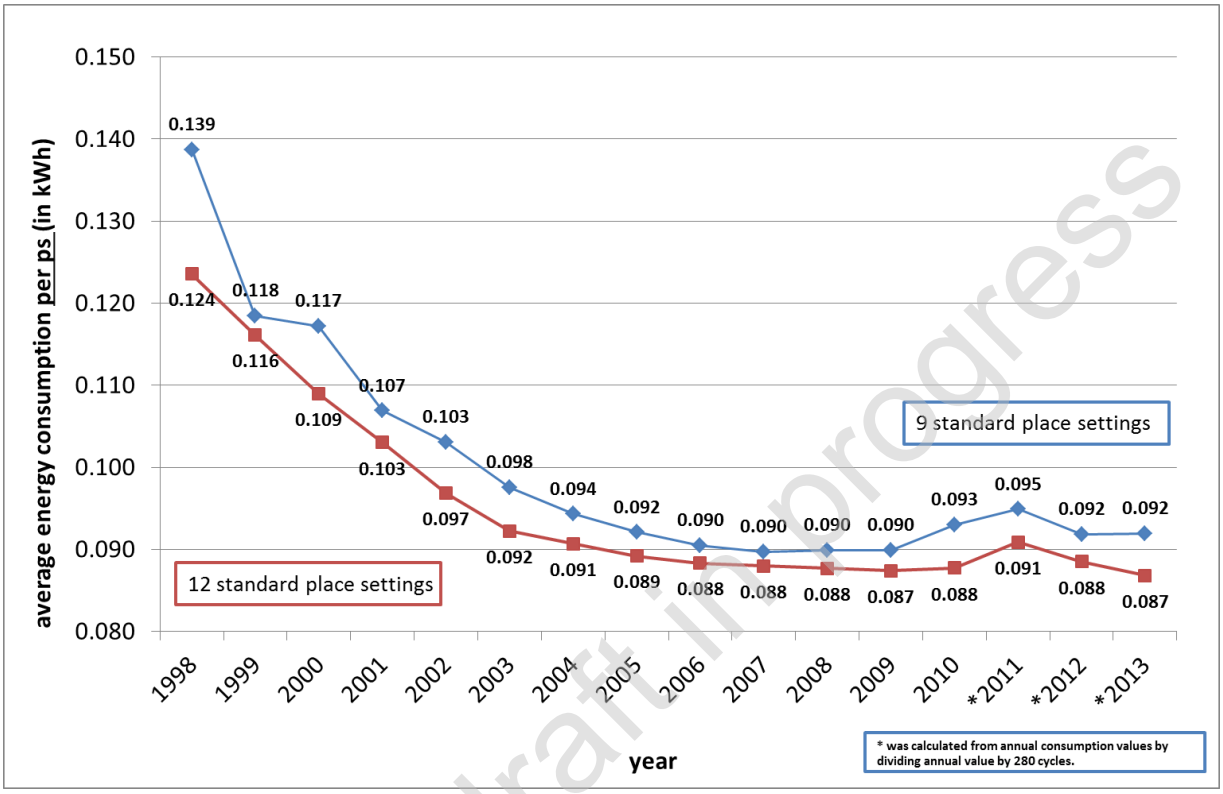

Figure 2.14: Development of average energy consumptions per ps for 9 and 12 ps-models on the European market (data from CECED, personal communication)

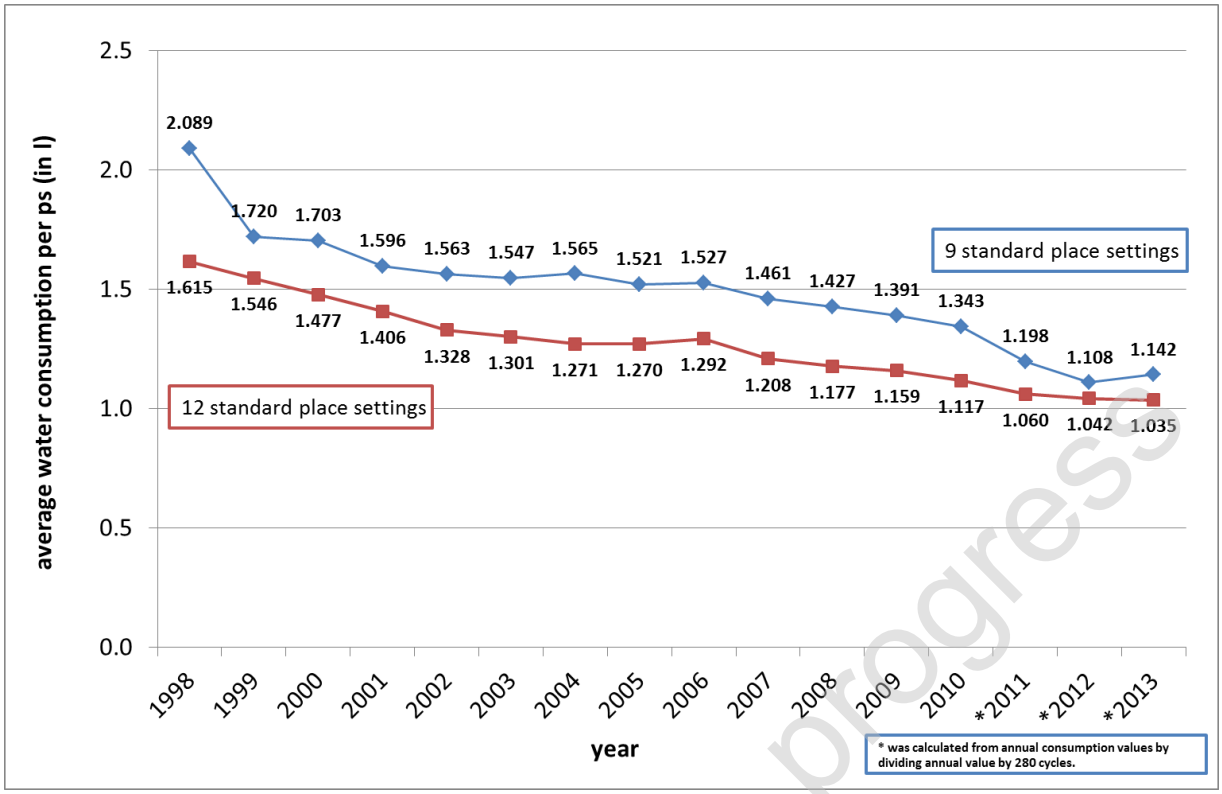

Figure 2.15: Development of average water consumptions per ps for 9 and 12 ps-models on the European market (data from CECED, personal communication)

Table 2.11 provides a breakdown of the energy and water consumption of 2013 models available on the market with regard to different capacities. It shows that the energy and water consumption per place setting of larger appliances is generally lower compared to small sized dishwashers.

Table 2.12: Energy and water consumption of different dishwasher capacities in 2013 (data from CECED, personal communication)

Number of ps	Annual energy consumption (kWh/year)	Energy consumption per cycle (kWh/cycle)	Energy consumption per standard ps (kWh/cycle/ps)	Annual water consumption (l/year)	Water consumption per cycle (l/cycle)	Water consumption per standard ps (l/cycle/ps)
4	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
5	227.0	0.8	0.16	2,800	10.0	2.00
6	179.1	0.6	0.11	2,112	7.5	1.26
8	205.0	0.7	0.09	2,450	8.8	1.09
9	231.7	0.8	0.09	2,878	10.3	1.14
10	238.5	0.9	0.09	3,035	10.8	1.08
11	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
12	291.6	1.0	0.09	3,479	12.4	1.04
13	263.8	0.9	0.07	2,522	9.0	0.69
14	259.4	0.9	0.07	2,832	10.1	0.72
15	284.1	1.0	0.07	3,019	10.8	0.72

2.2.2.4 Development of energy efficiency classes of dishwasher models available on the market

Since the Ecodesign Regulation (EC) No 1016/2010 came into force, the relative contribution of dishwasher models to certain energy efficiency classes changed (Figure 2.16) from 2010 to 2011. Manufacturers hurried ahead: Although the Regulation requires all dishwasher models to fulfil requirements of energy efficiency class A only from December 2016 on, already in 2011 nearly all dishwashers on the European market have been at least classified as energy efficiency class A (except 4 models out of 6,663, see Figure 2.18). As expected, the share of dishwasher models with higher energy efficiency classes (A+++, A++ and A+) increased from 61% in 2010 to 82% in 2013.

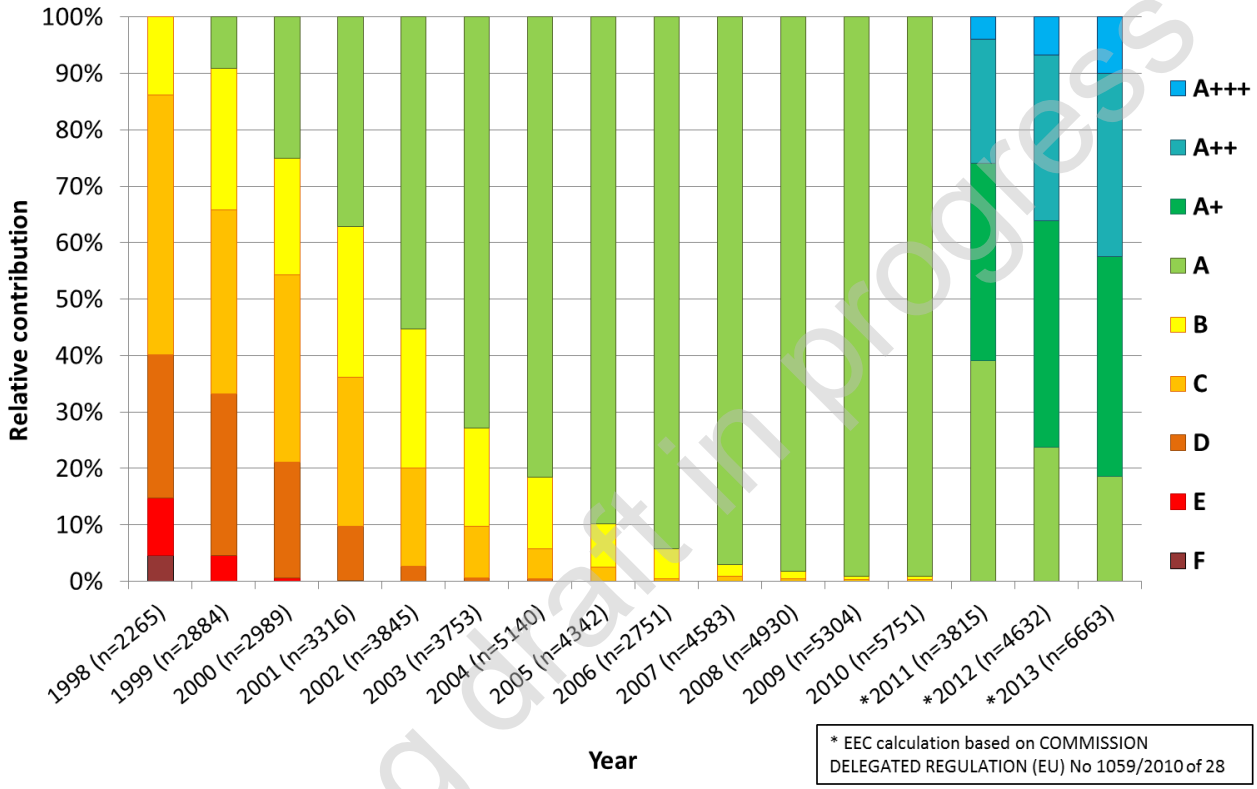

Figure 2.16: Development of the distribution of dishwasher models of a certain energy efficiency class on the European market (data from CECED, personal communication)

Differentiating the energy efficiency classes according to the capacities of the models, the following spread can be observed for 2013 (Figure 2.17):
Dishwashers with a capacity of 6 ps (countertop models) only were energy efficiency class A and A+, slim-line models with 8 to 10 ps already were 16% class A++ and 1% A+++; for full-size models with 12 ps or more 36% achieved A++ and 10% A+++. After 2013 a market shift is assumed as Tier 2 of the Ecodesign Regulation (EC) No 1016/2010 applied in December 2013 allowing class A only for models with ps ≤ 9 or width <45 cm any more. From December 2016, class A will be banned for all models (Tier 3).

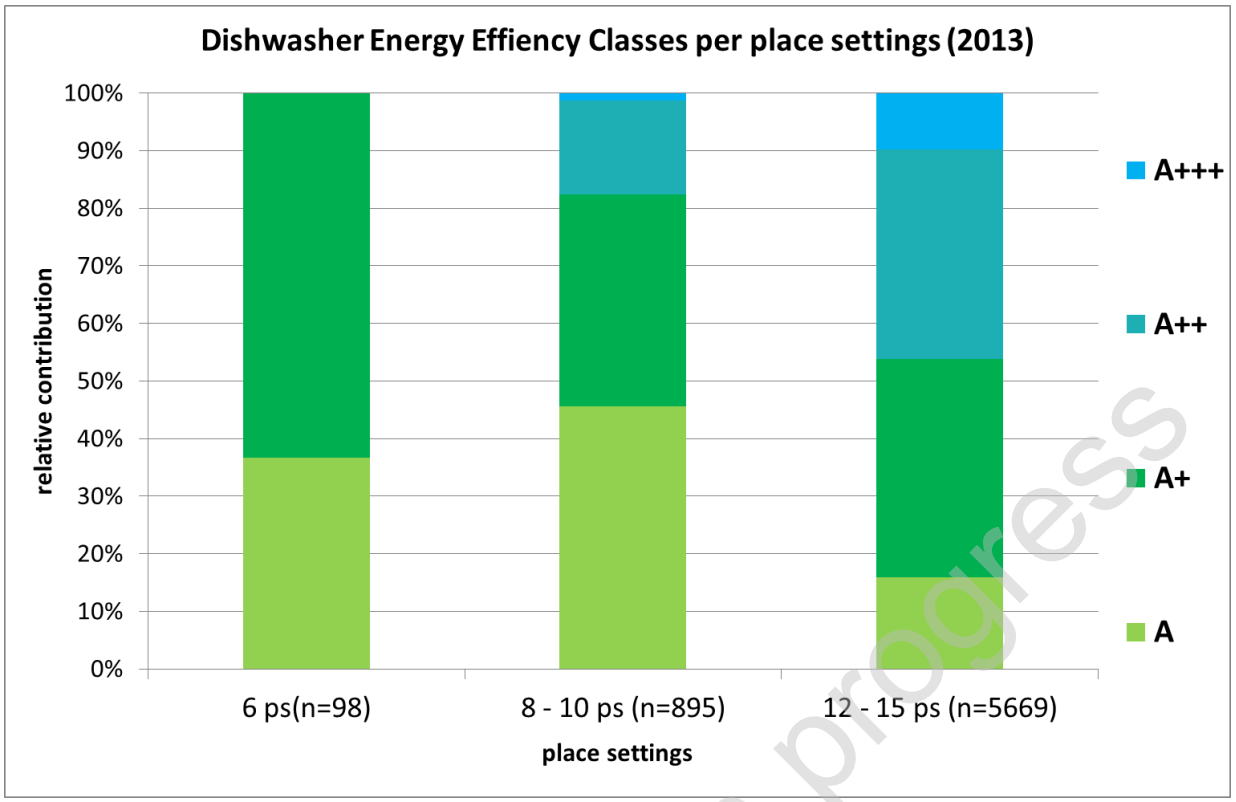

Figure 2.17: Distribution of different dishwasher capacities to certain energy efficiency classes on the European market (2013) (data from CECED, personal communication)

In 2013, 6,663 dishwasher models were offered on the European market. Figure 2.18 illustrates the distribution of dishwasher models in terms of their EEI. The majority of models have an EEI that complies with the lower limitation of the corresponding energy efficiency class. E.g., 2,241 dishwasher models had an EEI of just below 63, which is the lower limit of energy efficiency class A (56 ≤ EEI < 63). The same effect can be observed for the other energy efficiency classes.

Since manufacturers seem to adjust the energy performance of the Eco label programme to the minimum requirements of a desired energy efficiency class, there seems to be further potential to decrease the energy consumption of automatic dishwashers.

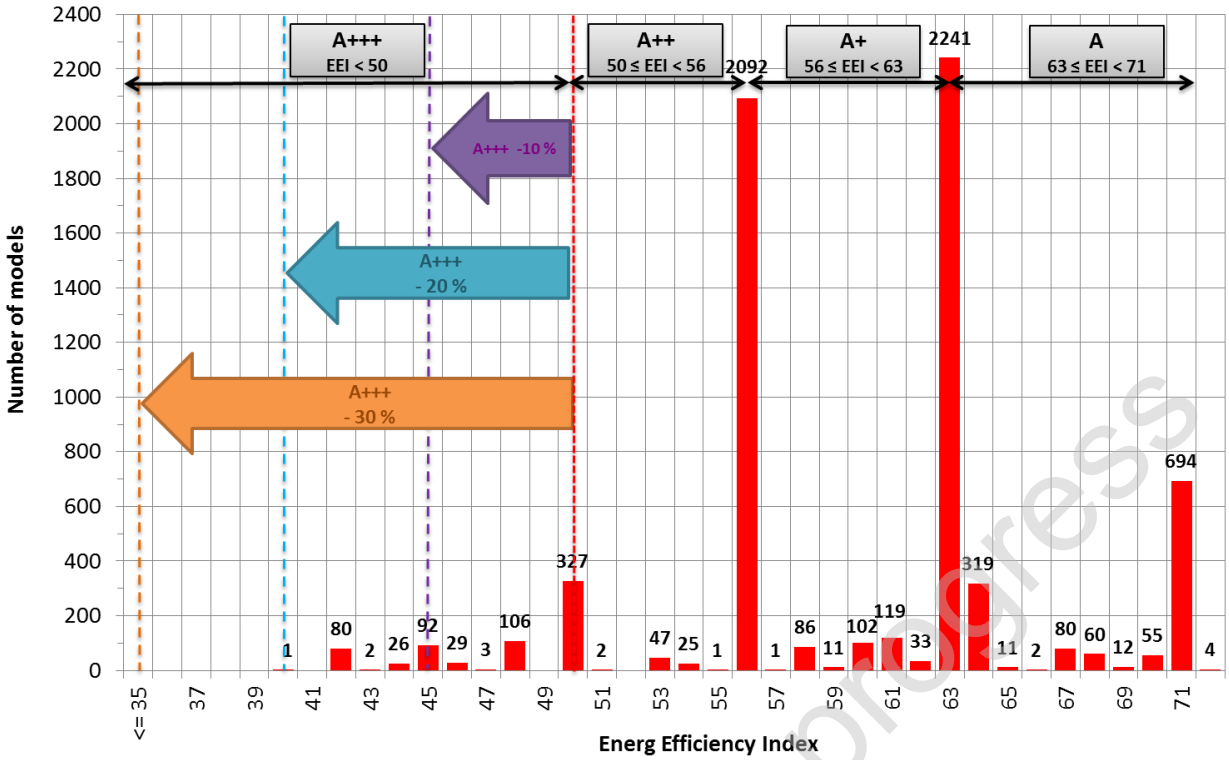

Figure 2.18: Distribution of dishwasher models of a certain energy efficiency index on the European market in 2013 (data from CECED, personal communication)

2.2.2.5 Development of the cleaning and drying performance of dishwasher models available on the market

Savings in energy and water consumption have been realised without negative implications on the cleaning and drying performance of dishwashers. They even could be increased, as shown in Figure 2.19 (cleaning performance) and Figure 2.20 (drying performance).

Since 1999, the share of dishwasher models reaching cleaning performance class A steadily increased to 99 % in 2010. According to the requirements of ecodesign Regulation (EC) No. 1016/2010, *all* dishwasher models on the European market have to meet cleaning performance class A from December 2011. As this was realised already *in* 2011, and as the cleaning performance class is no longer declared on the new energy label for dishwashers, database entries end with 2010.

Also the share of dishwasher models with a drying performance class A continually increased. In 2013, 98.5 % of the dishwasher models on the European market fulfilled the expected requirements. Since 2007, no dishwasher models with a drying performance class < C were offered. In 2013 only 0.1 % (which equals an amount of seven dishwasher models) still met drying performance class C, and only a few percent class B. Ecodesign Regulation (EC) No 1016/2010 requires that from December 2013 on, *all* dishwasher models have to meet a drying performance class of A. This will be noticeable within 2014 statistics.

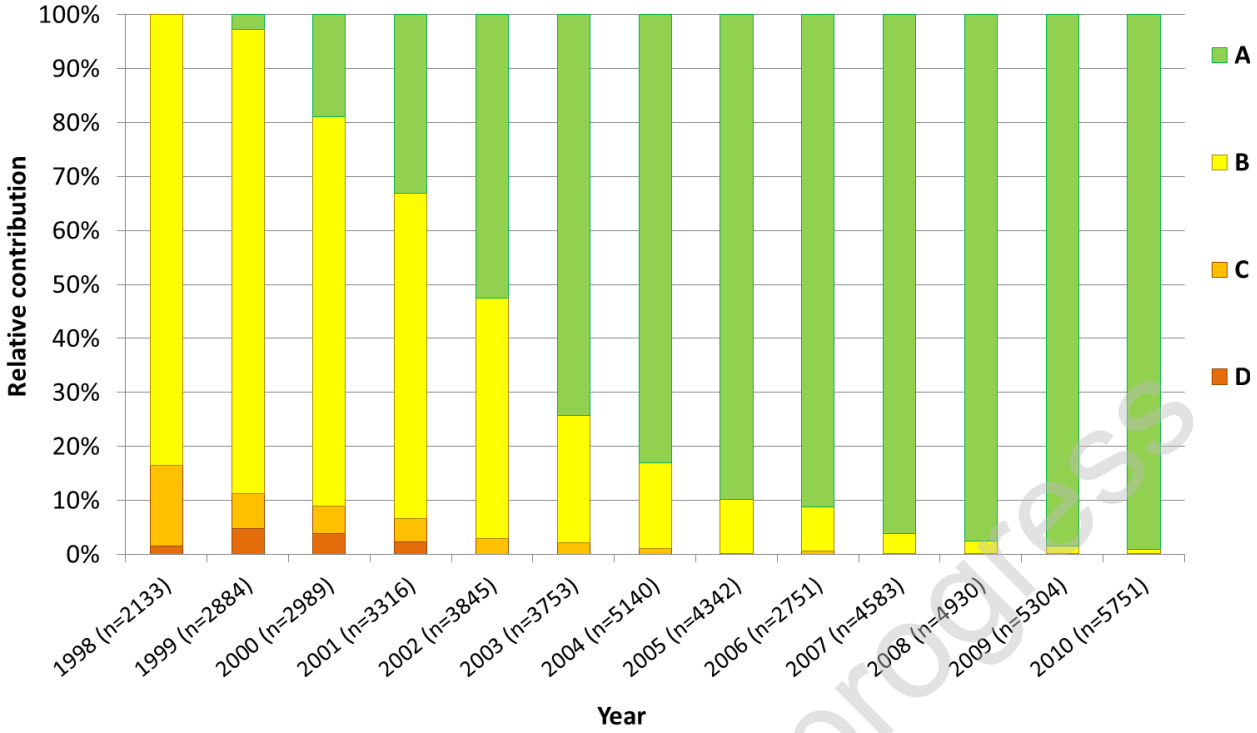

Figure 2.19: Development of the distribution of dishwasher models of a certain cleaning performance class (data from CECED, personal communication)

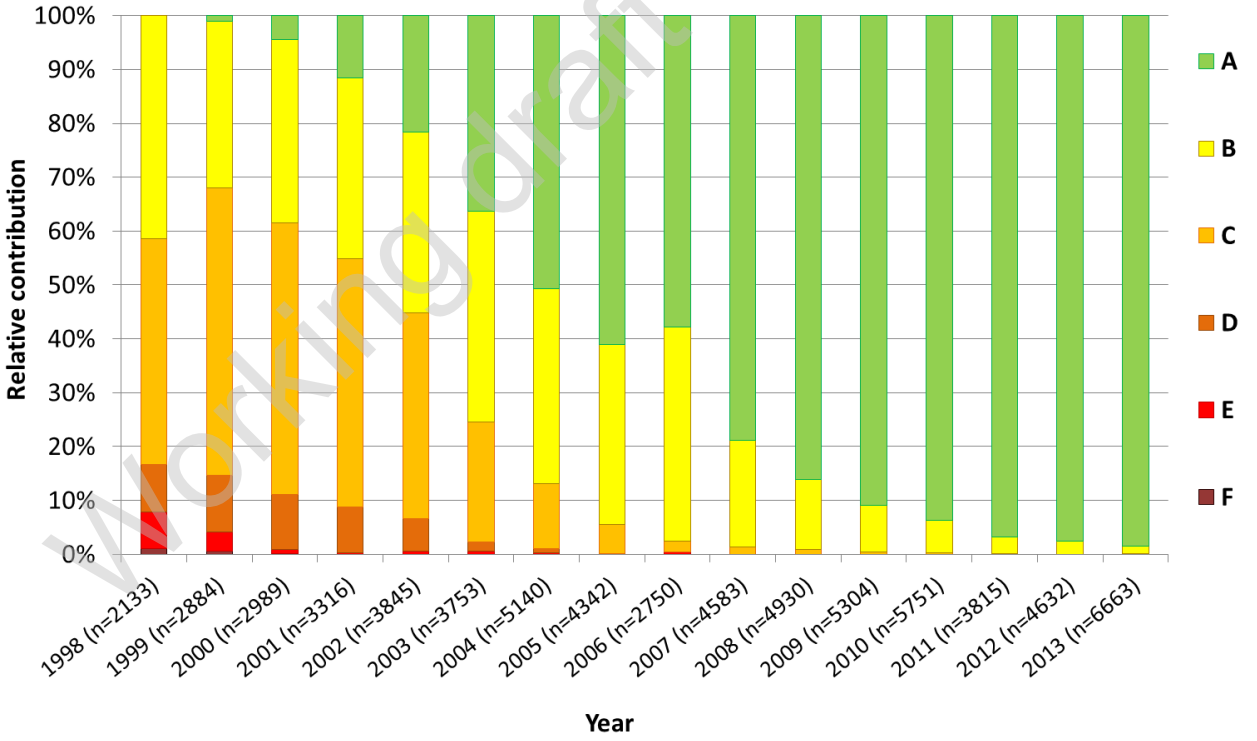

Figure 2.20: Development of the distribution of dishwasher models of a certain drying performance class (data from CECED, personal communication)

According to (Benchmarking study 2014), improvements in cleaning performances at lower consumption values are based on technical advances, such as *"[...] more effective mechanical action (improved pump/motor efficiency, spraying technology and electronic controls), more and or better detergents [...]".* Since 2010, they are primarily based on changes in the programme course of the Eco. According to the contexts of the Sinner circle (cf. section 4.1.1.1), the same cleaning performance can be obtained with reduced water temperatures (which relates to lower energy consumptions) if the duration of the cleaning phase is prolonged. With longer programme durations, the dirt is able to soak for a longer time, the exposure time of the automatic dishwashing detergent is extended and the exposure time of the mechanical forces of the water jets is prolonged (see chapter 2.2.3).
Technical improvements (increased ventilation, sorptive drying methods, auto open function etc.), as well as reduced water temperatures in the hot rinse with a contemporary prolongation of the drying phase of a dishwasher programme reduced the energy demand of the drying process at improved drying performances. For further details on the technical improvement options of household dishwashers, please refer to section 4.1.4.

2.2.3 Market trends with regard to product design and features of dishwashers

2.2.3.1 Trends to increasing programme duration of household dishwashers

Besides technical improvement options (cf. section 4.1.4), savings in resource consumption of a dishwashing programme can be realised by modifications of the dishwashing programme course, e.g. cutting the amount of water that has to be heated up and by reducing water temperatures at prolonged programme durations.
Reducing water temperatures in the cleaning and/or in the hot rinse phase of a dishwashing programme and compensating this by increasing the respective phase durations (low temperature automatic dishwashing) is the latest trend in realising energy savings of dishwashing programmes, and in particular for Eco programmes.
Eco programmes are designed to use little energy and deliver high cleaning and drying performances, in order to maintain high energy efficiency classes and high performance classes on the Energy Label. Especially since the implementation of the new energy efficiency classes in 2010, manufacturers apply the low temperature automatic dishwashing strategy to realise energy savings needed to meet the requirements of the highest energy efficiency class possible. This tendency is also reported in current studies:

> *"[...] it seems that in Europe [...] the programme cycle times for dishwashers under test have increased enormously since 1996. In Denmark, for example, it is estimated that cycle time has gone up by more than 200% in that period."* (iea-4e 2014)
>
> *The evaluation of dishwasher test results from STIWA from 2010 to 2015 provides an insight on this topic as well. Figure 2.21 shows the arithmetic mean values of all dishwasher models tested in a certain year for (a) the average energy consumption and (b) the programme durations of popular dishwashing programmes: Eco programme, automatic programme, rapid programme.*

While the energy consumption of the Eco programmes decreased, programme durations increased. The range of programme duration of Eco programmes is large: in 2015, the minimum programme duration of the eco programme for dishwashers of energy efficiency class A++ was 179 minutes (2 h 59 min) (Beko DIN 5930, Amica EGSP 14386 V), whereas the maximum duration was 252 minutes (4 h 12 min) (Bauknecht GSX 81454). (Stiftung Warentest 2015)
On the contrary programme durations of the rapid and the automatic programme are shorter and they do not show an increasing trend over the observation period.

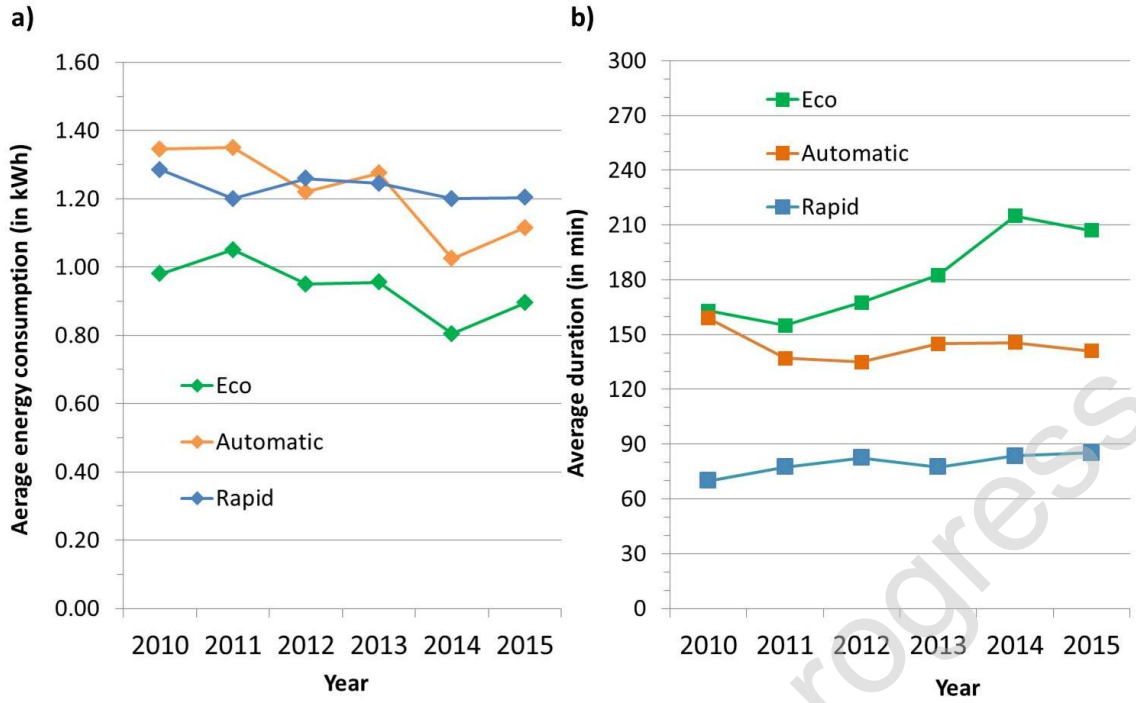

Figure 2.21: Development of the average a) energy consumption and b) programme durations of the Eco, Rapid and Automatic programme, full size models (12-15 ps); calculation by Uni Bonn from data published by Stiftung Warentest from 2010 to 2015

As a result, Eco programmes show lower consumption values than other dishwashing programmes designed for cleaning „normally soiled tableware". The respective dishwasher model is declared high energy efficiency on the Energy Label, which is a purchasing incentive for consumers. In practice, many consumers avoid using the Eco programme because of its long running times and many consumers do not know the context of the Sinner circle. They believe that long programme durations end in higher energy consumption values. Also, many consumers use other available dishwashing programmes of their dishwasher model, e.g. the automatic programme or the rapid programme (cf. section 3.1.6). Thereby, the energy saving potential of high energy efficient dishwasher models is not exploited to its full extend.
Figure 2.22 gives an *impression* of the impact of consumers choosing other programmes than the Eco programme. It shows the relative height of energy and water consumption as well as the duration of popular dishwashing programmes (automatic programme, normal programme and rapid programme) in relation to the respective data for the Eco programme as a basis (= 100 %). Data is not representative. It is based on the consumption values of twelve dishwasher models that were offered on the European market since 2010 (Table 2.13).

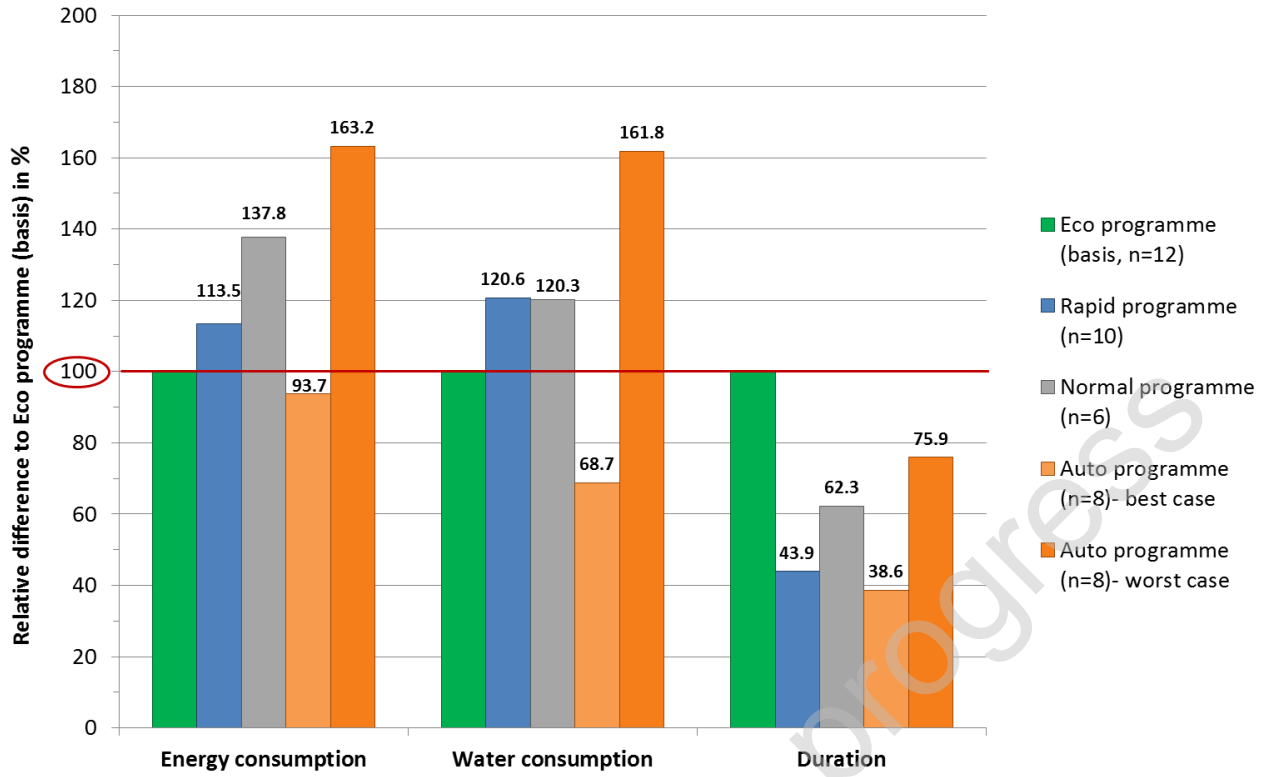

Figure 2.22: Relative heights of consumption values and programme durations of popular dishwashing programmes in relation to the Eco programme as a basis

Table 2.13: Dishwasher models used for calculating relative height of consumption values and durations compared to the Eco programme

Brand	**White Knight**	**OK.**	**Whirlpool**	**Gorenje**	**Zanussi**	**Beko**	**Gaggenau**	**Indesit**	**V-ZUG**	**Bauknecht**	**Miele**	**AEG**
Model	DW0945IA	ODW 450-BI	ADG 6999 FD	GV61224	ZDT15001 - FA	DIN 6831 FX	DF 261163	DIF04 Integrated	Adora 60 SL GS60SLdi	GSI 102303 A 3+TR PT	G 4920 SCU	F66709 VIOP
Capacity	9	10	12	12	12	12	12	13	13	13	14	15
EEC	A+	A	A+	A+	A+	A++	A++	A+	A+++	A+++	A++	A++

The manuals of those dishwasher models were researched for the consumption values and duration of the automatic programme, the rapid programme and the normal programme. Corresponding values for the Eco programme were taken from the product data sheet. Six of twelve dishwashers have a normal programme (n=6), eight dishwashers have an automatic programme (n=8) and ten dishwashers have a rapid programme (n=10).

For the automatic programme two scenarios were assumed: a best case scenario, calculating with the lower limits of the indicated consumption value range and a worst case scenario, calculating with the upper limits. For each programme (and scenario), the differences of the energy consumption, the water consumption and the duration were calculated as relative difference from the corresponding value of the Eco programme as a basis. For each category (e.g. relative difference of water consumption of rapid

programme compared to the Eco programme) the average value was calculated out of the single values of the twelve dishwasher models. Those average values are depicted in Figure 2.22.
Figure 2.22 shows that all researched programmes have shorter programme durations than the Eco programme. Even the automatic programme in the worst case scenario, which relates to heavily soiled dishware, is on average 24.1 % shorter than the Eco programme, meant for cleaning normally soiled dishware. The only programme using less energy and water than the Eco programme is the automatic programme when performing in the best case scenario, which relates to slightly soiled dishware. All other programme options use at least 13.5 % more energy (rapid programme) or 20.3 % more water (normal programme) on average.
"*Particularly in the EU therefore, regulators should be aware that any energy benefits associated with these longer programme cycles will not be reaped if consumers are using faster wash cycles than those used in the test.*" (iea-4e 2014)

2.2.3.2 Trends to increasing convenience of household dishwashers

Besides efforts to improve performance and/or reduce consumption values, manufacturers focus on improving the design (e.g. coloured illumination of the dishwasher inside) and the consumer convenience of their dishwasher models. These are sales appeals for consumers that tend to buy high efficient products highly equipped with design and convenience features (CLASP 2013) (Stöckle 2014).
Trends to increase convenience are for example (CLASP 2013):

- The further refinement of adjustable baskets to load e.g. long stemmed wine glasses, vases or ladles etc.,
- To improve an easy operation of the baskets and of the dishwasher itself (intuitive handling such as knock2open and comfort close, both by Miele) and
- To increase the number of special dishwashing programmes (e.g. hygienic programmes to clean baby bottles; special programmes for certain kinds of glasses or pots).

2.2.3.3 Trends to lower noise emissions of household dishwashers

Also noise emission of dishwashers is in focus of manufacturers. The trend of open kitchens that are integrated to the living room is growing. Dishwashers shall perform silently to avoid noise pollution. Extra silent dishwashing programmes enter the market, named ExtraSilent, Super Silence Plus, etc. Some of them are designed and recommended especially for nocturnal use of the dishwasher, with minimum noise emission levels of 37 dB (A).
Current Eco programmes perform with noise emission of ≥ 41 dB (A). Since 2012, declaration of noise emission values of dishwasher models is mandatory data on the Energy Label. Therefore, it is assumed that manufacturers will further reduce noise emission in future.

2.2.4 Market data and trends with regard to detergents

According to (BIO by Deloitte, 2014), the automatic dishwashing detergent market for the EU 28 is gradually growing (Figure 2.23), with an increase of 8% by 2013 compared to 2008. "*The five countries with the largest market share in 2013 are, in decreasing order of volume, Germany, France, UK, Italy and Spain […]. The majority of remaining [member states] only has small market shares, on an average around three percent or less.*" (BIO by Deloitte, 2014)
In the EU 28 (except Romania, Croatia and Bulgaria), the average consumption of automatic dishwashing detergents per capita was 0.864 kg/year in 2006 (BIO by Deloitte, 2014). With regard to the expected increase of dishwasher penetration in the European Union (chapter 2.2.1), an increase of detergent consumption per capita is also to be expected.

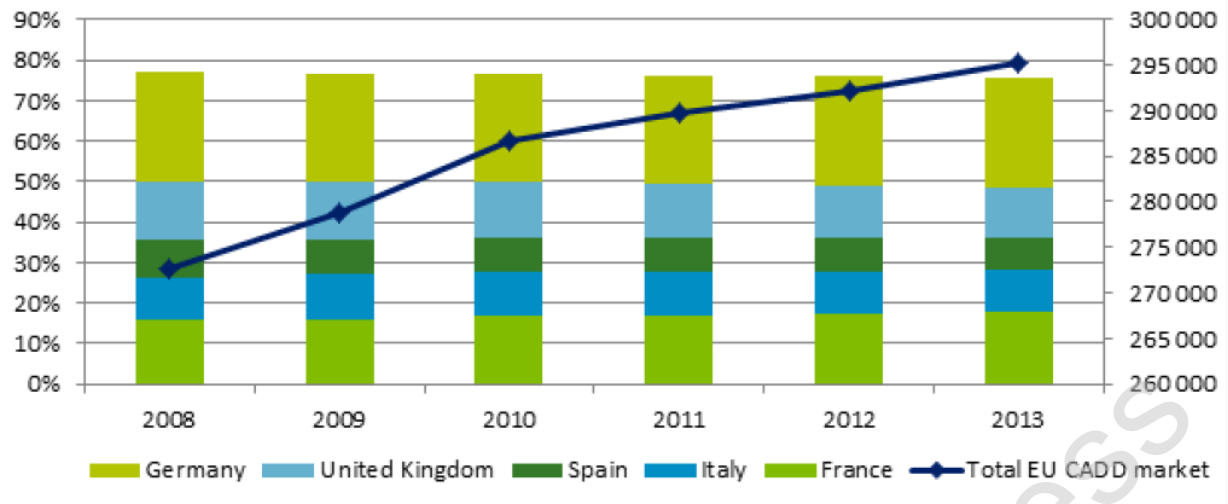

Figure 2.23: Development of automatic dishwashing detergent market (retail volume of powders, liquids and tablets, in tonnes) in EU including percentage shares of the five countries with biggest market share, database: Eurostat (BIO by Deloitte, 2014)

According to a market analysis done within the EU Ecolabel revision for dishwasher detergents, the dishwasher detergent products on the European market can be broadly categorised into four different product types (JRC IPTS 2014):

1. Dishwasher detergents, consisting of:
   - Powdered detergents – made up of granules which are poured into the dishwasher dispenser.
   - Gel/liquid detergents – to be poured into the dishwasher dispenser.
   - Tablet detergents – a compact amount of detergent in a premeasured tablet. These are most commonly in powdered form, but gel tablets are becoming more widely seen.
2. Other dishwasher additives – including water hardness regulators.
3. Rinse aids – used to improve cleaning (particularly for reducing smearing on glasses) and to aid drying.
4. Combined products – for example dishwasher detergents combined with rinse aids or other dishwasher additives. Often, these products come in tablet form.

According to (JRC IPTS 2014), in the past few years, the largest dishwasher detergent manufacturers have primarily been focused on promoting sales of tablet detergents, the most recent innovation in the dishwasher detergents market. The biggest incentive for consumers to switch to these tablets detergents is convenience; the tablets provide an easy to use single dose measure, which often contains both detergent and other additives such as rinse aid (i.e. a combined product).

(JRC IPTS 2014) summarise the market trends of dishwasher detergents as follows:

- Detergent tablets – these have an estimated market share of 83% in Europe, based on sales values (ranging from 52% in Denmark to 92% in the UK). These products are commonly seen as convenient and are increasingly likely to also contain dishwasher additives. However, they are typically more expensive and do not allow the consumer to control dosing of the product. Detergent tablets have seen a steady increase in sales value since 2007 and this increase is expected to continue.
- Powder detergents – this type of product has an estimated market share of 9% in Europe, based on sales values (ranging from 25% in Denmark to 4% in Italy). Across Europe, sales of powder dishwashing detergents remain flat. This means that as the detergent market grows, powdered detergents are losing market share.

- Liquid detergents – this type of product has the lowest market share in Europe, with estimated 8%, based on sales values (ranging from 25% in Italy to 1% in Germany). Sales of liquid dishwasher detergents have seen an increase in the past five years, although this increase has levelled since 2011 and is slight compared to the increase in sales value seen in the detergent tablet market.

Market data by Euromonitor International with regard to the European market of dishwasher detergents provided via stakeholder feedback slightly deviates from above data on market shares, namely a still larger market share of powder detergents (23%) and accordingly lower share of detergent tablets (71%).

Table 2.14: EU Market sizes of automatic dishwasher detergents; retail volume in million litres / kg; source: Euromonitor International via Stakeholder feedback

Categories	2012	2013	2014
Automatic Dishwashing Liquids	17.6	18.9	20.2 (=6.8%)
Automatic Dishwashing Powders	70.2	68.3	66.8 (=22.5%)
Automatic Dishwashing Tablets	204.1	206.2	209.7 (=70.7%)
(Automatic) Dishwashing Additives (includes all rinsing agents, salts, water softeners, and deodorisers used in dishwashing machines in addition to dishwashing detergents. Also includes products that clean the inside of dishwashers and remove limescale.)	not avalaible	not avalaible	not avalaible

Dishwasher detergents, in general, have followed a trend of offering multi-functional products, often including rinse aids and salts in the product. Due to their ability to function as 'multi-purpose', detergent tablets and gels have the potential to cannibalise sales of dishwashing additives – these will now be combined in a detergent tablet/gel and so additives on their own may be considered redundant. However, sales of ancillary products still remain reasonably strong in Europe which suggests that consumers are still willing to buy these products separately, perhaps alongside cheaper dishwasher detergent. In the UK, for example, around 50 % of shoppers who bought dishwasher detergents also bought rinse aids. (JRC IPTS 2014)

According to (JRC IPTS 2014), the Detergents Regulation which takes effect from 2017 for dishwasher detergents (cf. section 1.3.1.6) will catalyse the move to phosphate-free dishwasher detergents which use zeolites instead. The move to zeolite-based detergents will reduce phosphorus loading in the environment and, in doing so, reduce problems of eutrophication. In 2010, 40 % of new automatic dishwasher detergent products introduced in Europe were phosphate-free compared to 2007 (13%).

2.3 Consumer expenditure base data

In the EcoTopTen-Report for dishwashers of 2006 (Öko-Institut e.V., 2006) absolute and relative annual costs of household dishwashers are shown (Table 2.15), assuming an average purchase price of 600 €, a life cycle of 12 years, and a washing frequency of 200 cycles per year, given that 0.196 €/ kWh, 4 €/ m^3 of water, and 0.11 € per tablet of detergent are fixed and 14 l of water and 1.05 kWh of energy are used per cycle.

Table 2.15: Total annual costs of household dishwashers (efficiency class A), (Öko-Institut, 2006)

	Annual costs for				Total costs
Absolute	**Acquisition**	**Power**	**Water**	**Detergent**	
Average appliance	50 €	41 €	11 €	22 €	125 €
free-standing	36 €	41 €	11 €	22 €	110 €
built-in	54 €	41 €	11 €	22 €	129 €

	Annual costs for				Total costs
Relative					
Average appliance	40%	33%	9%	18%	100%
free-standing	32%	37%	10%	20%	100%
built-in	42%	32%	9%	17%	100%

2.3.1 Average unit value of household dishwashers produced in EU28

According to the Ecodesign Impact Accounting study by (VHK 2014), the price of a household dishwasher (Figure 2.24) is assumed to be constant at 541 € (in 2010 prices) for the assumed BAU scenario, while for the ECO scenario the cost increase estimated by the introduction of the Energy labelling requirements according to EU 1059/2010 and Ecodesign requirement according to EU 1016/2010, is predicted to be 178 € in maximum but is reduced continuously after 2015 and will end up with additional price of 55 € for the dishwasher following the ECO scenario compared to the BAU scenario. For further details regarding the ECO and BAU scenarios, please refer to section 2.2.

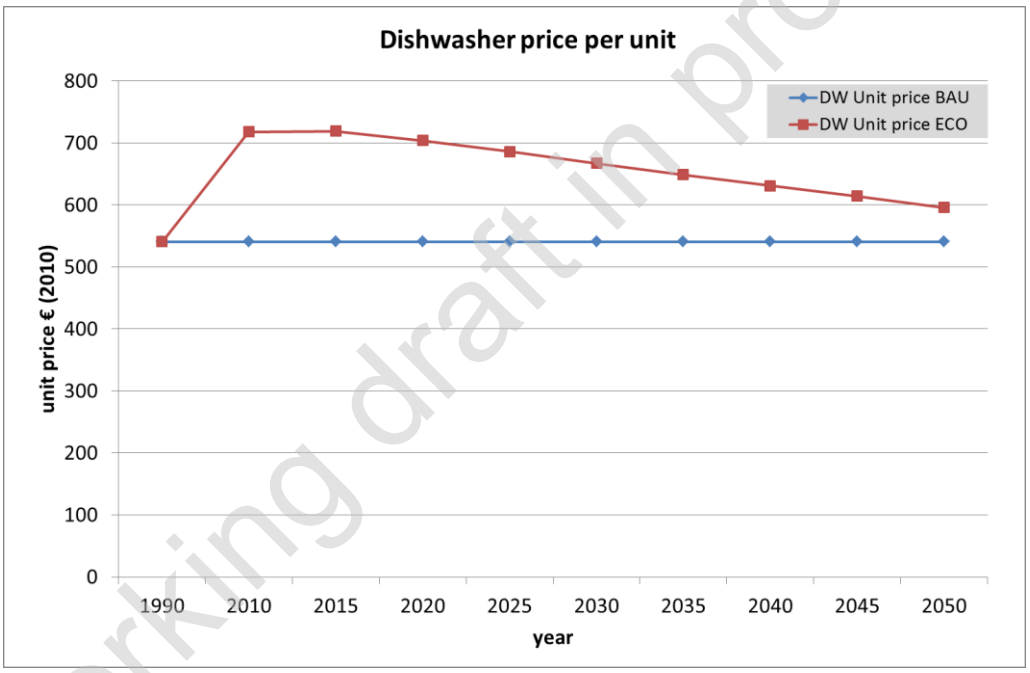

Figure 2.24 Average price in € (basis 2010) for a dishwasher in the European market from 1990 to 2050 (VHK 2014)

Additional to these data, Table 2.16 shows the calculated average unit values of household dishwashers produced in EU28 and certain Member States as reported by (Eurostat 2015a) for those Member States where information is available. The unit values have been calculated by dividing the value data by the volume data of the EU production units (cf. section 2.1.1). It can be seen that household dishwashers produced in Germany achieve higher unit values compared to Italy, Poland and the EU28 average, which moreover have been increasing between 2007 and 2010. Compared to the above data, the calculated average unit values are significantly lower compared to the average price estimated by (VHK 2014) above. However, it has to be noted that Prodcom values data relate to the manufacturer selling price, not to the end consumer price and data might not reflect real prices due to data gaps in the statistics.

Table 2.16: Calculated average unit value (in Euro) of household dishwashers produced in the EU28 between 2007 and 2013; source: own calculation based on (Eurostat 2015a)

Declarant	2007	2008	2009	2010	2011	2012	2013
Germany	334	342	354	377	:	:	:
Italy	219	217	213	217	224	229	211
Poland	189	180	176	174	164	164	160
EU28 TOTALS	261	252	254	261	264	273	244

":" means data not being available

2.3.2 Consumer prices of consumables

According to a market research at major players' websites done in 2014 by (Bio by Deloitte 2014), all over Europe a variety of multifunctional dishwashing tablets is available for 0.08 € to 0.33 € per tablet. Tablets that are free from phosphate can be purchased for 0.11 € to 0.22 € per wash (in 2014 euros), tablets containing phosphate have similar prices between 0.08 € and 0.24€. With the estimated 280 cycles per year, which are the basis for determining the energy efficiency according to Regulation (EC) No. 1059/2010, consumers would spend between 22.4 € and 67.2 € per year for dishwasher detergents when using tablets only.

A consumer study in 2007 revealed, that about half of the consumers in Germany (55%), France (64%), UK (50%) and USA (40%) choose environmental-friendly dishwashing detergents (Userneeds 2009)

In 2010 extensive tests had been performed to compare monofunctional and multifunctional tablets and tablets with and without phosphate by STIWA (Table 2.17). In 2010, more than 30 dishwasher detergents were investigated. Another recently published article also compares multifunctional tablets with and without phosphate. The data indicate that there is no remarkable difference between prices for tablets with and without phosphate. (Stiftung Warentest, 2010a, Stiftung Warentest, 2010b, Stiftung Warentest, 2013, Stiftung Warentest, 2015b, Stiftung Warentest, 2014).

Table 2.17: Prices per tablets (incl. VAT) in Germany 2010-2015

		Products tested	Without phosphate		With phosphate	
			Min.	Max.	Min.	Max.
Mono-Tabs	2010a	7	-	-	0.05	0.14
	2010b	9	0.10 €	0.26 €	-	-
Multi-Tabs (*:powder)	2010a	18	-	-	0.07 €	0.23 €
	2010b	8	0.10 €	0.12 €	0.10 €	0.24 €
	2013	14	0.07 € - 0.26 € (0.04 € - 0.17 €)*			
	2014	15	0.07 € - 0.21 €			
	2015b	13	0.10 €	0.23 €	0.07 €	0.22 €

2.3.3 Further costs

According to (COWI and VHK 2011), the Methodology Report "MEErP 2011" suggests to use EU average values for all preparatory studies, partly adjusted with an overall escalation rate (e.g. for energy prices) which results in the monetary outcomes of all studies being comparable. The EU-27 average data provided in this study are the following for electricity, gas, water, interest, inflation and discount rates.

Table 2.18: Energy, water and financial rates as proposed by (COWI and VHK 2011) for the year 2011

	Domestic (incl. VAT)	Long-term growth per year

	Domestic (incl. VAT)	Long-term growth per year
Electricity	0.18 €/kWh	5%
Gas (net calorific value NCV)	14.54 €/GJ	3-5%
Water	3.70 €/m³	2.5%
Interest	7.7%	-
Inflation rate	2.1%	-
Discount rate (EU default)	4.0%	-
Energy escalation rate, i.e. real (inflation-corrected) increase per year*	4.0%	-
VAT	20.0%	-

* To be applied to the electricity rate in order to adjust the actual rate for 2015 for the case that the real inflation-corrected energy prices growth rates do not deviate more than 1%-point from the given 4%. If that happens, the differentiated LCC calculation with actual prices should be followed.

In (COWI and VHK 2011) the electricity prices for households in EU-27 are indicated as a sum of production and distribution costs, indirect taxes and value added taxes. The total price per kWh lies between 0.09 €/kWh in Bulgaria and 0.28 €/ kWh in Denmark, while the average of all 27 EU countries is 0.18 €/ kWh. Tax rates are fluctuating and contribute a high percentage of the total electricity price in several countries, e.g. Denmark and the Netherlands.

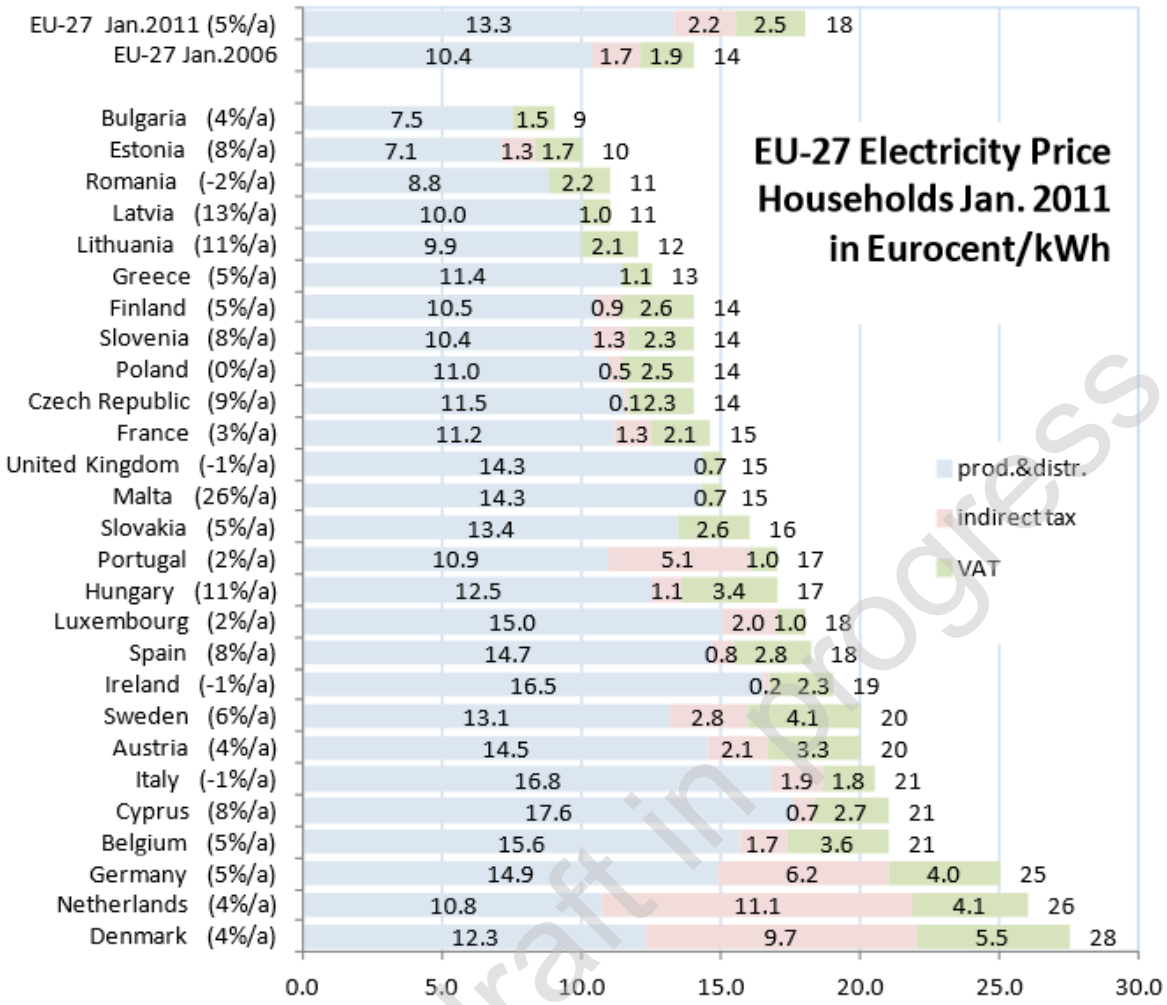

Figure 2.25: EU-27 Electricity prices households Jan. 2011 (recent annual growth rates in brackets, in %/a) (COWI and VHK 2011)

Consumer information material published by (Verbraucherzentrale RLP, 2012) provide a comparison of total costs for energy and water, for dishwashers with different energy efficiency classes (see Table 2.19).

Table 2.19: Comparison of costs for dishwashers of different efficiency classes (12 - 14 ps, 280 cycles/ year, * 12 years old, ** 0.24 €/ kWh, * 3.9 €/ m³) Database: (Verbraucherzentrale RLP, 2012)**

Efficiency class	A+++	A +	old appliance*
Power consumption	237 kWh	292 kWh	384 kWh
Power cost**	57 €	70 €	92 €
Water consumption	2,800 l	3,360 l	4,200 l
Water cost***	11 €	13 €	16 €
Total costs	68 €	83 €	108 €

2.4 Summary and discussion: markets

Based on the market data presented, the following discussion points are proposed for the first stakeholder meeting.

2.4.1 Market data and base cases

Following the MEErP methodology, the definition and assessment of base cases is a necessary step in the proposal of new ecodesign/labelling requirements. Base cases shall be representative in terms of the upcoming technology and sales. The selection of bases cases is discussed in Chapter 0, using the market data presented in the chapter above. The base cases will be discussed with stakeholders, for example in light of the observed evolution of the average size of households in the EU countries; and the market response provided by manufacturers to the methods of EEI calculation for energy labelling, resulting in the supply of appliances of higher average capacities.

Table 2.7 reveals that the majority of household dishwasher models offered on the market are full-size dishwashers, with a capacity of 12 ps (40%). However, in this category appliances with larger capacities are increasing, with 13 ps almost on the same level with 31% and increasingly dishwashers with 15 ps (11%). The downward trend of 12 ps models is along with the upward trend of the larger appliances. Thus, it can be discussed if a 13 ps model should be chosen above a 12 ps model to represent the current base case.

Regarding slim-line (compact) dishwashers, models with 9 ps are the majority (9%); however models with 10 ps are gathering the market (4%). Countertop models with 6 ps are still a niche market with only 1.5% and thus are not taken as Base Case for smaller dishwashers. Instead it could be recommended again taking a model with 9 ps as second Base Case. They seem to have a nearly steady level with 9-10% market share during the past years. Although in this segment 10 ps models are gaining market share, the distance between 9 and 12 or 13 ps as Base Cases might better reflect differences between small and larger appliances.

The average energy and water consumption per cycle in 2013 according to CECED's model database (cf. Figure 2.12 and Figure 2.13) would be:

- 9 ps: 0.827 kWh/cycle and 10.3 litres/cycle
- 12 ps: 1.042 kWh/cycle and 12.4 litres/cycle or
- 13 ps (projected from the consumption per ps of the average 12ps models): 1.131 kWh/cycle and 13.5 litres/cycle;

Discussion point 2.1

Is the market information presented accurate? This information will be used for the selection of base cases.

2.4.2 Niche markets

In the current ecodesign and energy label Regulations 'dishwashers that can also be powered by batteries' are included in the scope. The market data collected, however, reveals that these kinds of dishwashers do not have any market relevance. No battery-operated household dishwashers could be detected. Very small dishwashers with 5 or 4 ps, which might be possibly portable, seem to have disappeared from the market since 2010/2011.

Further, the current test standard does not explicitly describe a test procedure for battery powered appliances. As dishwashers powered by batteries might reach different performance levels, they might require test procedures other than the given ones. Thus, if being included, specifications and test

procedures would have to be developed and included in the performance standard for household dishwashers.

Also for the coming years it is expected that battery powered household dishwashers will not enter the market. Theoretically, battery powered household appliances might work as capacity storage in a smart-grid network; however, it is assumed that such a power storage would rather be implemented as a central storage system for the whole household with the single appliances still being electric-mains operated.

Therefore, subject to further discussion with stakeholders, it is suggested to exclude battery-powered household dishwashers from the revised scope of the ecodesign and energy label Regulations for household dishwashers (cf. section 1.4.1.1).

Discussion point 2.2

Would you agree to exclude battery-powered dishwashers from the scope because of low market presence? A standard to measure the performance of these appliances is at the moment not available.

3 TASK 3: USERS

3.1 Consumer behaviour regarding household dishwashers – what is known so far

For the purpose of this task a study about the consumer behaviour has been initiated. This study will explore how consumer perceive and work with their appliances today, and what they would like to change with a special focus on energy and resource saving. The study is conducted through the internet on samples of about 250 to 500 consumers per country in 11 major countries of EU (plus Turkey) who are selected to be representative for the population in each country regarding age distribution between 20 and 75 years and household size. Results of this study will be added at a later stage to this document. The preliminary results will be discussed at the first stakeholder meeting.
The information provided in the current section is, for the time being, the outcome of a desk review including literature in peer-review publications, consumer's magazines and governmental and non-governmental organizations.

3.1.1 Purchase behaviour

European consumers are aware of the impact of their daily household consumption on environmental pollution. Therefore, reducing home consumption for lightning, heating and household appliances was ranked number 2 of top-three priorities in order to help protect the environment in daily life. Connected to the topic of dishwashing, reducing water consumption at home was ranked number 8 (Figure 3.1).

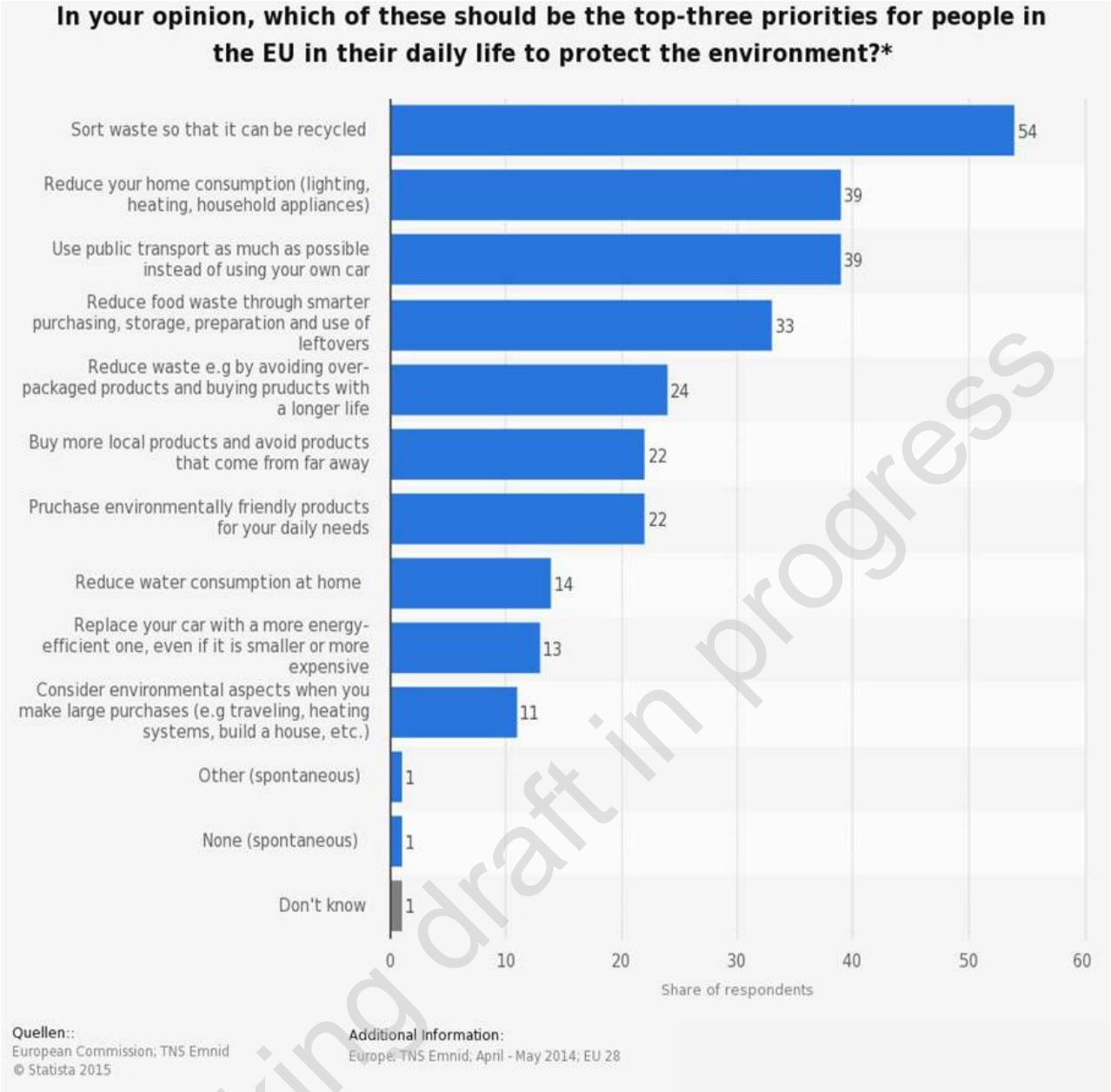

Figure 3.1: Priorities for people in the EU in their daily life to protect the environment (Statista 2015)

This awareness is also expressed in consumers' purchase criteria for white goods. Energy efficiency is the most important criterion in purchase decision making, including the sub-aspect that possible higher investment costs have to pay off after few years of usage. The size of the appliance (i.e. capacity of dishwashers) is the second most important purchase criterion, followed by design, convenience functions, connectivity and the fitting into a build-in kitchen concept. (Stöckle 2013)

Purchase criteria for white goods have also been researched in an online survey of (Richter 2010a), investigating dishwashing habits in Germany, Sweden, Italy and UK with 1,206 respondents (Table 3.1). On average, resource efficiency is the top criterion for decision making (82.9%). Performance quality is ranked number 2 (72.5%), followed by noise emission (48.2%) and a low purchase price (37.1%). Consumers also trust the Energy Label when buying household appliances: for 36.2% of respondents the information given on the Energy Label influences their purchase behaviour (rank 5). Short programme durations are ranked number 7 (20.9 %), whereas the capacity (rank 10, 11.5%) and the appliance design (rank 11, 5.1%) are of less importance. (Richter 2010a)

Table 3.1: Purchase criteria for household appliances (Richter 2010a)

What do you place high importance on when buying a new household appliance? Maximum of four answers allowed, shares in %	Germany (n=331)	UK (n=311)	Sweden (n=256)	Italy (n=308)	Total (n=1206)
Low water and/or energy consumption	95	76	77	81	82.9
Very good cleaning/washing performance	76	84	59	69	72.5
Low operating noise emission	42	34	69	52	48.2
Low purchase price	38	47	31	31	37.1
Good assessment results on the Energy Label	44	37	36	28	36.2
Good dishes/textile protection	39	13	20	24	24.3
Short programme duration	19	22	33	12	20.9
A large number of programmes and options	10	25	14	25	18.3
Low detergent consumption	19	11	19	17	16.3
Higher capacity of the appliance	5	16	10	15	11.5
Innovative aesthetic design	2	6	5	7	5.1

3.1.2 Consumer attitudes and perceptions regarding the lifetimes of electrical products

In a study commissioned by the British organisation WRAP, current British consumers' views, attitudes and perceptions of the lifetimes of electrical products were explored based on a desk review, focus groups and a nationally representative survey in England and Wales. Inter alia, the study analysed washing machines, fridges and vacuum cleaners being heavily and prolonged used ("workhorse products"). (WRAP 2013a)
It is assumed that dishwashers, also "workhorse products", follow the same trends as identified by the study for washing machines:

- Consumers' knowledge about product lifetimes: According to the results of the study, consumers do not feel knowledgeable about how long washing machines last, and are not aware of information on how long these products last being available. They use on a combination of 'general knowledge', sources of knowledge available during the purchase process, and proxies to make assessments about the lifetimes of comparative products. Younger respondents are less likely to have personal experience of how long these products last, and some consumers also have doubts about whether the lifetime of products can be accurately measured. The main sources of information consumers think they can access during the purchase process to compare the likely lifetimes of different products are online reviews by other consumers. However, consumers primarily rely on brand, and to a lesser extent price, as proxies for the lifetime, with the expectation that well-known brands and more expensive products will last longer. Manufacturer guarantees or warranties are also seen by consumers as a show of faith by the manufacturer in the lifetime of their products. The participants of the study were primarily attracted to long guarantees / warranties by the reassurance that products would be quickly repaired or (ideally) replaced if they broke down. (WRAP 2013a)
- Importance of product lifetimes for consumers: The WRAP study revealed that product lifetimes are not a front-of-mind consideration for most consumers when buying products, but are still held to be important. Often product lifetimes are not expressed directly but are inferred through other, more salient terms such as quality, reliability and durability. When prompted, consumers say they do consider product lifetimes of washing machines important, and this is consistent for different socio-demographic groups. The importance of lifetime for workhorse products (inter alia washing machines) is underpinned by a desire to avoid the expense and inconvenience of repair or

replacement if they break down. Older consumers and lower income groups, as well as consumers with a less consumption-driven mind-set, appear to place particular importance on product lifetimes. (WRAP 2013a)

- Consumers' expectations on product lifetimes: On average, consumers expect washing machines six years to last. Older consumers and consumers living alone or without children, expected products to last longer than other consumers, which may reflect the lesser frequency and intensity with which they use these products in comparison to consumers in larger households and with children. Consumers were unlikely to envisage replacing workhorse products, inter alia washing machines, before the end of their functional life and wanted them to last as long as possible. Equally, the majority said they were satisfied with how long these products currently last, with satisfaction being lower for washing machines. Satisfaction with current lifetimes was linked to how long consumers expected these products to last. Those with high expectations were also generally those who were most satisfied, suggesting previous experiences have shaped both expectations and satisfaction. (WRAP 2013a)
- Consumers' pull for longer product lifetimes: According to findings of the WRAP study, the key barriers to the uptake of products with longer lifetimes are that it is not generally a front-of-mind issue for consumers, the current lack of information and advertising on product lifetimes, and consumers' distrust of manufacturers. The key opportunities for increasing the pull for longer lifetimes are the underlying importance of lifetime to consumers, their appetite for more information about product lifetimes, and the malleability of consumers' priorities during the purchase process. Clearly communicated product lifetimes identified by participants were Kia cars 7 year guarantee and Ikea in-store product testing demonstrations. Interest in products with longer lifetimes is not a minority issue, confined to a small subset of consumers. Around half of all consumers would be willing to pay extra for products that are advertised to last longer, and on average they would be willing to pay 10% more. More than eight out of ten consumers would be willing to pay extra for products that are advertised to last longer and have a longer standard guarantee or warranty. The future uptake of longer life products can be maximised if these are accompanied by longer standard guarantees or warranties – both as a means of reassuring consumers about the validity of longer claimed lifetimes and as a potential hook for advertising. Consumers are also likely to respond to advertising which emphasises the existing benefits of longer lasting products, and the provision of trusted information on product lifetimes through mainstream channels. (WRAP 2013a)

3.1.3 Frequency of automatic dishwashing

Due to different data bases, studies reporting on the average dishwashing frequency in a European household show wide ranges. The last EuP survey identified average dishwashing frequencies of 4.1 cycles per week, which adds up to 214 cycles per year (Presutto et al. 2007). According to an in-home consumer study in Italian, Swedish, German and British households by *Richter*, the average number of dishwashing cycles is 3.4 cycles per week = 177 cycles per year (Richter 2010b).
In a representative online survey in 4,000 German households by Bichler et al. "[…] *the average number of dishwashing cycles of the panel in question amounts to 212.7 cycles per year or 4.1 cycles per week. The appliance is used 107.7 times per year in single-person households and this increase with the number of people per household up to 383.7 cycles per year in households comprising five or more peopl*e." (Bichler et al. 2015a)
The calculation of the annual energy and water consumption according to ecodesign Regulation (EC) No 1016/2010 is based on the assumption of 280 dishwashing cycles per year (=5.4 cycles per week), as recommended by ANEC (ANEC 2009). This seems to be overestimated in terms of average European household, but it relates to an important consumer group of frequent users, with a corresponding share on the resource consumption caused by automatic dishwashing. According to (Bichler et al. 2015b) , 22.8% of German households use their dishwasher ≥ 7 times per week, which adds up to at least 364 cycles per

year. According to *Richter* (2010b) a frequency of 280 cycles per year relates to a 4 to 5 person household.
According to stakeholder feedback to the questionnaire (JRC IPTS 2015a), market research across Europe done by a panel of about 500 consumers in 23 countries in October 2014 resulted in an average of 4.3 cleaning cycles per week ranging from 4.1 (Scandinavia) to 4.4 (Eastern Europe) cycles per week.
Table 3.2 summarizes the information collected regarding the average dishwashing frequency across Europe and the corresponding number of annual cycles.

Table 3.2: Overview of the average dishwashing frequency data

Authors	Cycles/week	Cycles/year	Remarks
(Presutto et al. 2007)	4.1	214	
(Richter 2010b).	3.4	177	Study in Italy, Sweden, Germany and UK
(Bichler et al., 2015)	4.1	107.7	in 1-pers households in Germany
		383.7	in households >5 people in Germany
Ecodesign Regulation (EC) No 1016/2010		280	
(Richter 2010b)		280	in 4-5 people households
(JRC IPTS 2015a)	4.3		Variations between 4.1cycles/week in Scandinavia and 4.4 in Eastern Europe.

3.1.4 Capacity use and composition of dishwasher load

According to stakeholder feedback via questionnaire (JRC IPTS 2015a), market research across Europe done by a panel of about 500 consumers in 23 countries in October 2014 resulted in an average of 94% load when asking consumers for the percentage of their washes they considered the dishwasher to be full. The results range from 91% (UK, Eastern Europe) to 95% (Western Europe, Scandinavia)
Using photos of 106 dishwasher loads in German, Swedish, Italian and British households, (Richter 2010b) assessed the degree of space used in the upper (UB) and lower basket (LB). In less than 40% of all dishwasher loads the machines was filled to its full capacity (Figure 3.2).

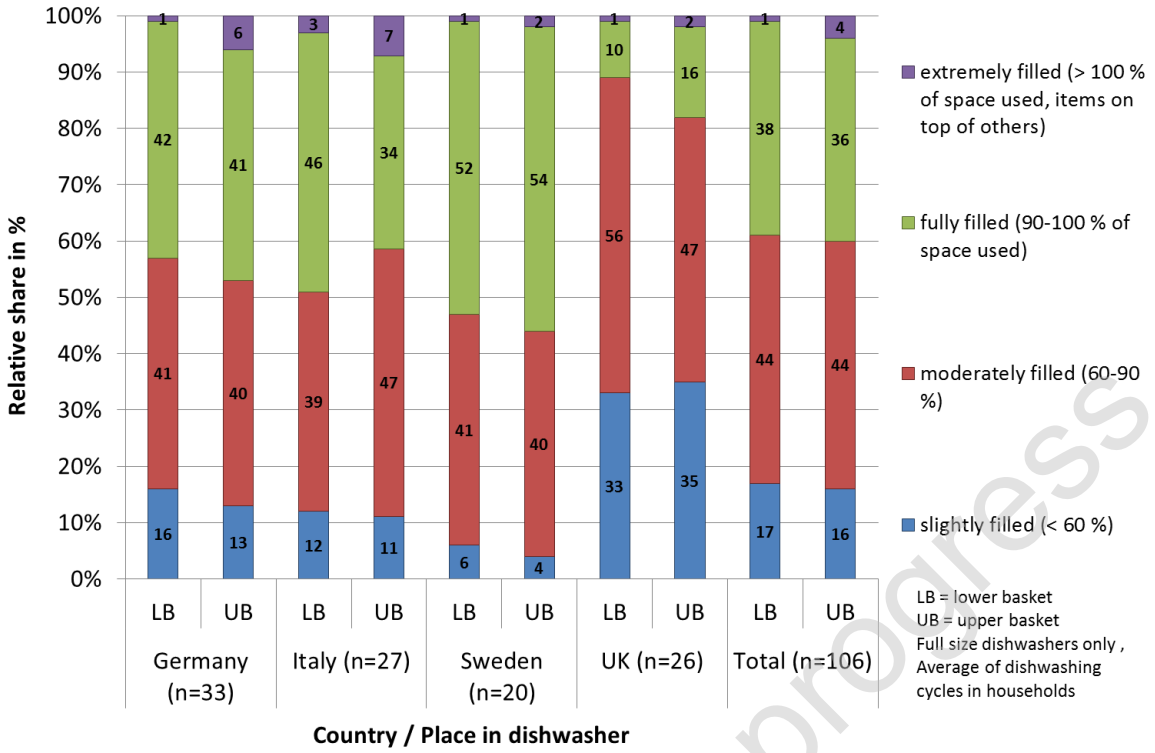

Figure 3.2: Capacity use in dishwashers based on assessment of used space (Richter 2010b)

This finding does not match the self-assessment of these test persons in terms of their loading efficiency. 90% of the respondents claimed to load the dishwasher to its full capacity or even overload the dishwasher. ≤ 10%, especially single- and 2-person households, admitted that they run their dishwasher even with few numbers of dishes inside (Figure 3.3).

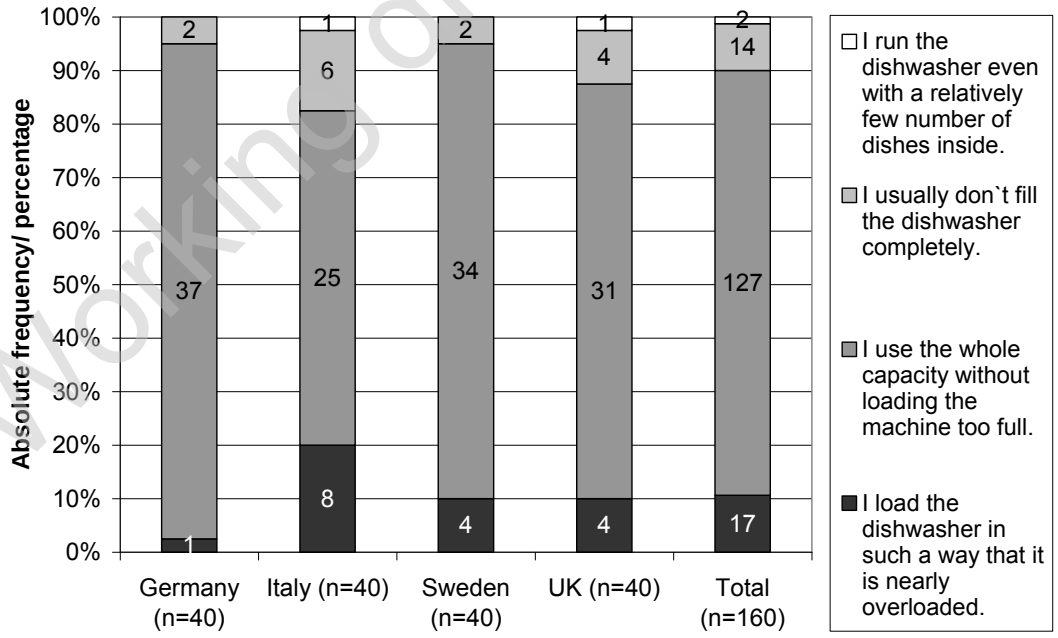

Figure 3.3: Respondents' evaluation on degree of dishwasher capacity use (Richter, 2010b)

By increasing the load efficiency in consumer households, 8% of dishwashing cycles could be saved if they would get loaded to full extent (Richter 2010b).

Asked about the inclusion of partly-load cycles into the calculation of the Energy Efficiency Index, one stakeholder informed that

> *"In contrast to washing machine where a lower amount of load requires less water because less water is bounded by the textiles, a similar reduction is not possible for dishwasher. Each cleaning step requires a certain amount of water which depends on the dishwasher's interior design and the water level required by the pump. Due to the attempt to reduce water and therefore the energy needed to heat up the water, the water level per cycle is already quite low. The amount of water which depends on the load (attached droplets on the load) is relatively low in comparison to the water needed to allow the pump to circulate the water. An adaption on the actual amount of load via a half load button would not further reduce the needed amount of water. The energy consumption is automatically reduced when less load is in the dishwasher because the thermal mass of the load is less and less energy is needed to heat it up. Due to the fact that only app. 1/3 of the energy is required to heat the thermal mass of the load, while the rest is needed to heat the dishwasher and water it is always advisable for the consumer to fully load the dishwasher to be most energy efficient. Instead of including partly loaded cycles in the Regulation the consumer should be informed to fully use the dishwashers' capacity." (JRC IPTS 2015a)*

The photo assessment also revealed that the standard test load used in the EN 50242/EN 60436:2008 does not correspond with the observed average dishwasher load. The standard test load comprises items out of porcelain (cups, saucers, dessert plates, dinner plates, soup plates, serving bowls, an oval platter), glass (drinking glasses) and stainless steel (forks, knifes, dessert spoons, soup spoons, tea spoons, serving spoons, serving fork and gravy ladle) and is designed for testing a dishwasher at is maximum capacity. Also the observed variety of forms and materials in household dishwasher loads is much higher (Table 3.3):

Table 3.3: Average number of dishes per dishwasher load according to type of tableware; SD = standard deviation (Richter 2010b)

Type of tableware	Germany (n=208)		Italy (n= 149)		Sweden (n=127)		UK (n=183)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Cutlery	24.58	10.25	23.48	13.85	23.31	10.24	19.92	9.86
Dinner plates	3.99	3.16	3.66	2.55	4.98	3.12	4.57	2.88
Soup plates	1.66	2.16	3.48	2.57	2.54	3.15	1.31	1.88
Dessert plates	3.82	3.34	1.46	2.16	3.31	4.03	2.48	2.49
Cups	5.18	3.70	4.28	3.62	4.36	3.12	4.62	3.26
Saucers	1.44	2.08	0.52	1.18	0.54	1.32	0.33	1.00
Glasses	6.40	4.50	5.91	4.08	8.24	5.08	4.96	4.28
Pots	1.10	1.08	1.64	1.19	0.63	0.85	0.75	0.97
Pans	0.29	0.58	0.67	0.81	0.07	0.26	0.27	0.52
Casseroles	0.13	0.36	0.23	0.45	0.45	0.66	0.41	0.67
Bowls	3.68	2.54	2.06	2.29	3.62	2.76	2.89	3.17
Plastic items	6.62	5.37	3.74	3.59	3.31	3.38	2.61	2.77
Wooden items	0.47	0.88	1.01	1.32	1.03	1.91	0.36	0.66
Other items	2.01	1.87	2.62	1.89	2.10	2.24	1.79	2.55
Basis: All dishwasher loads with pictures of load available; standard size (60 cm)dishwashers only								

Consumers load large items like pots, pans or bowls into their dishwasher. Especially in Italy the number of cooking utensils per dishwasher load is relatively high. (Richter 2010b)

A German in-home study by Bichler (Bichler 2014) about the consumer acceptance of Eco programmes found that 53.7% of German households load at least one cooking utensil (pot, pan, casserole etc.) into their dishwasher per cycle.
Consumers also load plastic items into their dishwasher. Between a minimum of 7% (UK) and a maximum of 16% (Germany) of all loaded items were made out of plastic (Richter 2010b). The share of plastic items in German dishwashers is very close to the share of 20% that was found in an earlier study (Zott & Hubbuch 2008). Only 1% of German consumers never load plastic items in their electric dishwasher (Bichler 2014)
The variety of different shapes and materials influences the cleaning and drying performance of a dishwashing programme. The shape has an impact on the amount of water residues, e.g. in cup cavities, while different materials with different heat capacities influence heat absorption, which is important to accelerate the drying. (Brückner 2013)
Besides the load, the soiling of EN 50242/EN 60436:2008 does not represent average real-life conditions. Compared to the average soiling load in German households, the test standard overestimates the total amount of soiling and does not reflect their observed composition (Hubbuch & Goodall 1999). Currently, IEC 60436 as a basis of EN 50242/EN 60436:2008 is being revised. The test load and soiling are modified and adjusted to observed conditions in consumer households (Brückner & Schneider, M. et al. 2012), inter alia by an increased diversity of materials and forms (e.g. including pots, coffee mugs and plastic items), cf. section 1.2.5.1.

3.1.5 Pre-treatment of dirty dishes

The energy and water consumption for pre-rinsing dirty dishes that are afterwards cleaned in a dishwasher could be added into the calculation of resource consumptions of a dishwashing cycle (Stamminger & Streichhard 2009). Although dishwasher manufacturers and stakeholders advise that pre-rinsing is not necessary, and recommend scraping or wiping remaining residues off the dishes (Forum Waschen 2015b), many consumers still pre-rinse their dirty dishes before loading them into the dishwasher. According to the last EuP study, on average > 30% of respondents usually pre-rinse each item (Presutto et al. 2007).
The online survey of *Richter* (Richter 2010a) also revealed that on average 30% of respondents in Germany, Sweden, Italy and UK pre-rinse each item. The cross-country comparison shows differences in people's pre-rinsing habits (Figure 3.4): " *[…] in Germany (49%) and the UK (50%), the most common practice is to scrape or wipe food leftovers off the dishes, whereas in Sweden and Italy, respondents stated that they give the dirty dishes a quick rinse before they are loaded into the dishwasher (51% respectively 43%). Only 14% of all households (24% in Germany) do not pre-treat dishes at all. Seven to 10% of the participants only pre-rinse or soak heavily soiled items, such as pots and pans, or casserole dishes.*" (Richter 2010a)

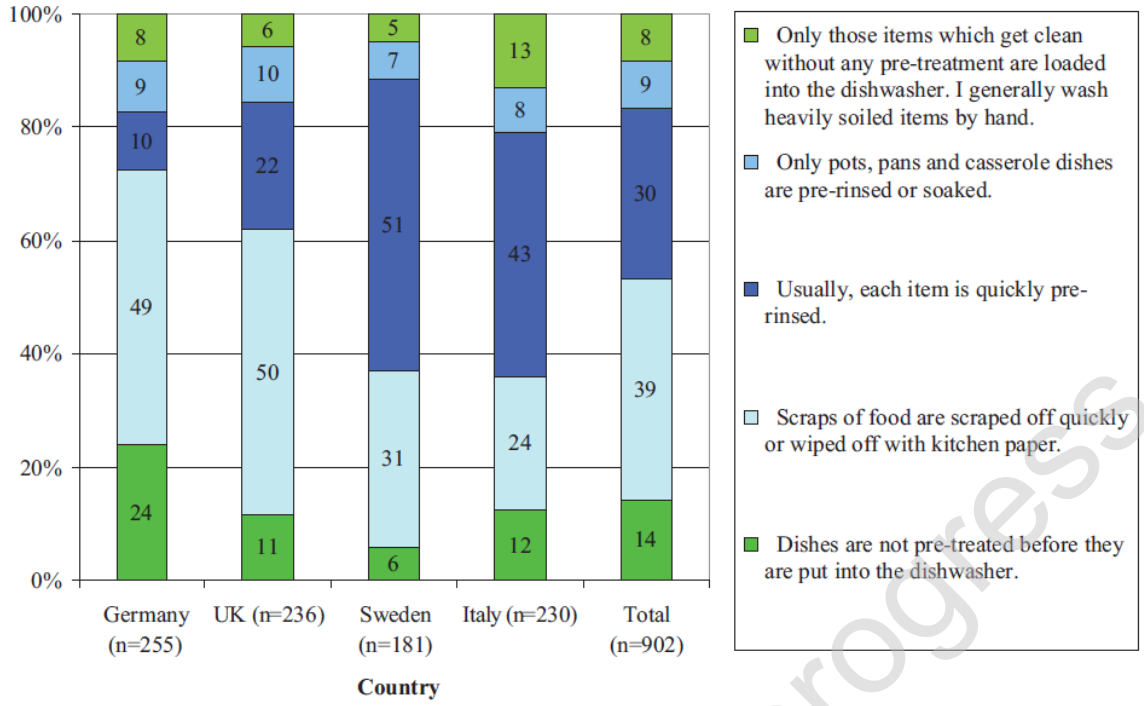

Figure 3.4: Pre-treatment habits of European consumers (Richter 2010a)

Although both online surveys revealed that high shares of consumers still pre-rinse their dirty dishes, the analysis of observation data in the in-home study of *Richter* (Richter 2010b) (Figure 3.5) shows that *"[…] the majority of dishes get loaded without being pre-treated at all. In Germany (90%), the UK (82%) and Sweden (70%) the proportion of non-treated items is way higher than in Italy, where a little less than half of the items did not get pre-treated […]. Almost half of the items cleaned in the Italian dishwashers was pre-rinsed with water, whereas the most common practice is to pre-treat the dishes with water and detergent (42%). Also in Sweden (25%) the proportion of dishes, which got pre-rinsed is still considerably higher than in Germany (4%) or the UK (8%). The proportion of items being soaked in water is relatively small in all the countries, but with a share of 5% the highest in the researched Italian households."* (Richter 2010b)

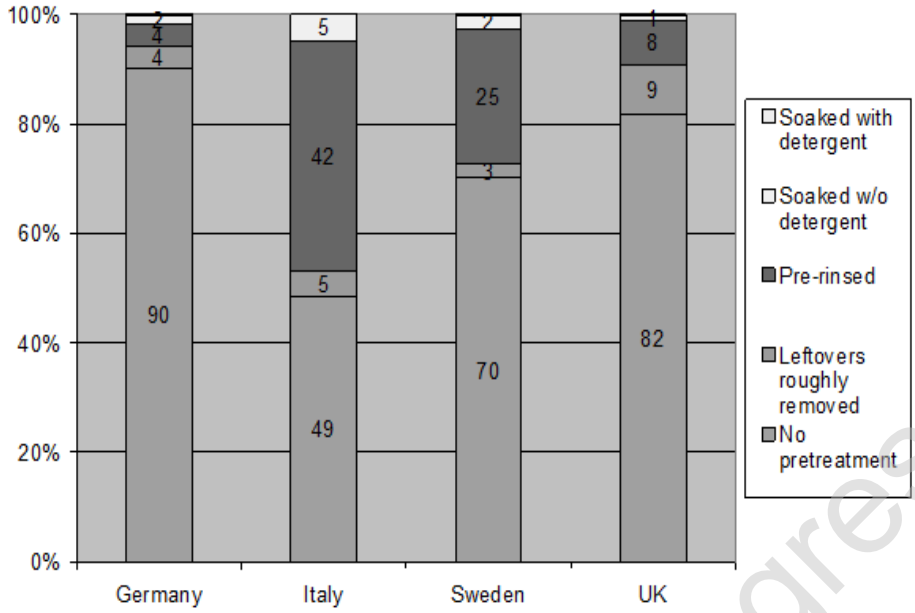

Figure 3.5: Share of pre-treatment types in total number of dishes cleaned (Richter 2010b)

"[…] The most intensive pre-treatment is for heavily soiled items; 15 to 22% of pots, pans or casserole dishes got pre-rinsed or soaked, whereas pans and casserole dishes were more frequently soaked with detergent than pots. In comparison, in Italian and Swedish households 30 to 60% of the cookware got pre-rinsed or soaked." (Richter 2010b)

Even though, the correlation analysis between pre-treatment habits and the satisfaction with the dishwashers cleaning performance did not show significant differences in terms of either dissatisfaction or satisfaction: consumers do not benefit from pre-rinsing by an increased satisfaction in cleaning performance. (Richter 2010b)

3.1.6 Programme choice

The in-home observation of *Richter* (Richter 2010b) revealed that 79% of households have chosen only one programme to clean their dishes throughout the duration of the study. 17% of the observed households used on maximum two different types of programmes. In total, five out of 149 households used more than two different programmes (Table 3.4).

Table 3.4: Use of dishwashers' programme variety within home observation (Richter 2010b)

Number of households	Germany (n=39)	Italy (n=37)	Sweden (n=38)	UK (n=35)
…with no change in programme choice during period of home observation	30	30	29	29
… who used 2 types of programmes	8	6	7	5
… who used 3 types of programmes	1	1	1	1
… who used 4 types of programmes	0	0	1	0

"*Asked for the reasons to do so, the majority of participants (104) mentioned to have made the best experience with that particular programme concerning the cleaning and drying performance. 65 respondents add that it is only a matter of habit and they would not think about it a lot. Only 27 stated that they choose that programme because others would take too much time.*" (Richter 2010b)

Table 3.5 shows the relative share of programme types used by respondents of the online surveys by (Richter 2010a) and (Bichler et al. 2015b) . Most frequently consumers choose a normal programme (33.9 % and 29.1 %). The Eco programme is ranked number 2, followed by the automatic programme (3) and the intensive programme (4).

Table 3.5: Usage behaviour in choosing dishwashing programmes in two studies, relative shares; according to *Bichler* (2015) and *Richter* (2010a)

	Name of dishwashing programme							
	Intensive	**Eco**	**Auto**	**Delicate**	**Quick**	**Normal (50-55°C)**	**Normal (60-65°C)**	**Rinse/Rinse and hold**
German Online Survey (n=3836) (Bichler et al. 2015b)	14.5	18.7	14.3	6.4	12.2	17.0	16.9	
European Online survey (n=1209) (Richter 2010a)	12.4	17.0	14.8	7.8	11.3	29.1		7.7

Regarding water temperatures of dishwashing programmes, the in-home study of Richter (Richter 2010b) revealed an average water temperature of 59.0 °C (Table 3.6). This complies with the average water temperature of 59.3 °C that was identified in the last EuP study, conducted in 2006 (Presutto et al. 2007).

Table 3.6: Distribution of chosen programme temperatures, relative percentage (in %) and absolute number in brackets of households (Richter 2010b)

Programme temperature	**Germany**	**Italy**	**Sweden**	**UK**	**Total**
Other	2.9 (3)	-	7.8 (8)	-	2.6 (3)
35 / 45°C	9.5 (10)	0.9 (1)	2.6 (3)	3.4 (5)	4.0 (5)
50 / 55°C	25.2 (26)	45.5 (54)	41.9 (45)	29.3 (39)	35.0 (40)
65°C	54.5 (56)	32.6 (39)	38.9 (42)	30.8 (41)	38.6 (45)
70 / 75°C	5.4 (6)	5.6 (7)	1.9 (2)	11.0 (15)	6.2 (7)
Average programme temperature	59.6°C	58.5°C	58.0°C	60.1°C	59.0°C

3.1.6.1 Reasons of consumers for not choosing the Eco programme

Even though energy efficiency, low water consumption and information on the Energy Label are important purchase criteria (Figure 3.1 and Table 3.1), the share of consumers using the Eco programme is relatively small.

"[…] for various reasons consumers may not choose these eco programmes […]." (iea-4e 2014)

Within the in-home study of *Bichler et al* (2014) consumers were forced to use the Eco programme for a period of 10 dishwashing cycles. Afterwards, they were asked if they will further use the Eco programme as their main dishwashing programme. Consumers that were not willing to further use the Eco programme were asked about the reasons to do so. Over 60 % of the respondents claimed that the Eco programme takes too much time.

This criterion for not using the Eco programme is supported by findings of the online survey of (Bichler et al., 2013) and are shown in Figure 3.6: 89.1 % of respondents do not accept programme durations ≥ 3

hours, which relates to the programme duration of actual Eco programmes (chapter 2.2.3). 4.8 % do not care about the runtime of their dishwashing programme. For 4.2 % of consumers, the acceptance of the programme running time depends on their actual time schedule. Only 2 % of consumers accept programme running times ≥ 3 hours. (Bichler et al. 2013)

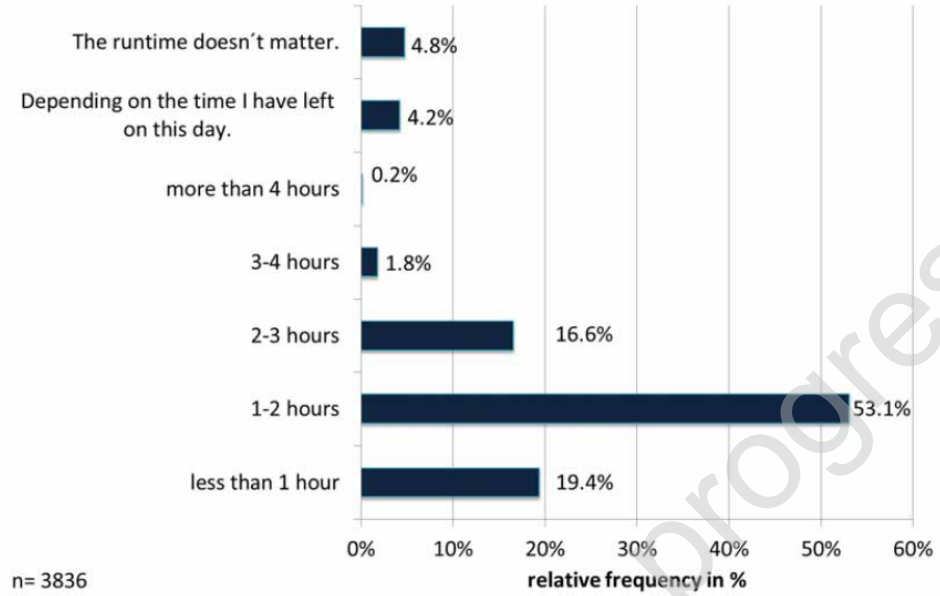

Figure 3.6: Accepted maximum programme durations (Bichler et al. 2013)

Before being forced to use the Eco programme in the in-home study of (Bichler 2014), consumers were informed about the background of Eco programmes by an information flyer. The flyer contained short information about the coherences of Sinner factors and why Eco programmes have long programme durations and still are the most efficient programme to choose. This lead to an increase in acceptance of Eco programmes: three months after the study was finished, the share of households that predominantly use the Eco programme of their dishwasher was almost doubled. (Bichler 2014)

3.1.7 Use of automatic dishwashing detergent products

Data reported in this section have been collected from different studies mainly based in Germany. These data are, therefore, particular and cannot be extrapolated without further indications. Data regarding the use of automatic dishwashing detergent products are expected to be collected through the launched on-line survey.

3.1.7.1 Detergent types

According to (JRC IPTS 2014), functionality is one of the biggest drivers for consumer purchases of dishwasher detergents; consumers increasingly demand a 'perfect result every time' from the use of dishwashers, especially in Western Europe. This means that, although consumers are still price-sensitive and driven by price promotions, they are often willing to spend more money on products with a higher efficacy. This links to the increased use of detergent tablets, which are often 'multi-purpose' and include rinse aid and other additives to ensure better cleaning results, especially for glassware.

Statistical data of consumers' real dosage behaviour of automatic dishwashing detergents is very rare. Two German studies carried out by (Bichler 2014) and (Schneider & Stamminger 2011) have been found, giving an impression of how consumers use automatic dishwashing detergents and other products meant for use in automatic dishwashers (e.g. regenerating salt, rinse aid).

Within the in-home study of (Bichler 2014), 59.0% of 200 participating German households used multifunctional tablet products (2-in-1 to All-in-1), 24.1% used standard tablet (including solely automatic dishwashing detergent) and 16.9% of the household used a detergent powder (Figure 3.7).Data were

gathered through individual in-home visits and by dishwashing diaries. Each of the 200 households participating in the study reported the data from 10 dishwashing cycles.

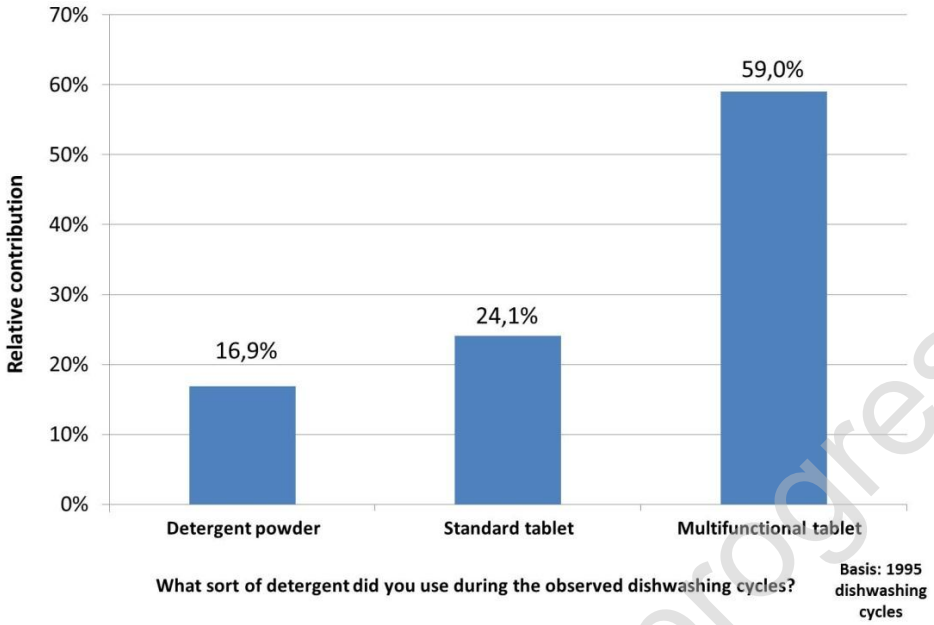

Figure 3.7: Types of dishwasher detergents used in German households, relative shares (Bichler et al, 2014)

An additional use of rinse aid and regenerating salt is necessary for users of detergent powder and standard tablets, and recommended for users of multifunctional tablet living in areas with water hardness ≥ 3.75 mmol/l (=21°dH). However, when asked about the use of rinse aid and regenerating salt, 59.3% of respondents claimed to use rinse aid and 57.6 % claimed to use regenerating salt. Since 41% of observed household used standard tablets and detergent powder, and areas with water hardness ≥ 3.75 mmol/l are very rare in Germany, those shares necessarily include consumers using rinse aid and regenerating salt in addition to a multifunctional tablet product (Figure 3.8).

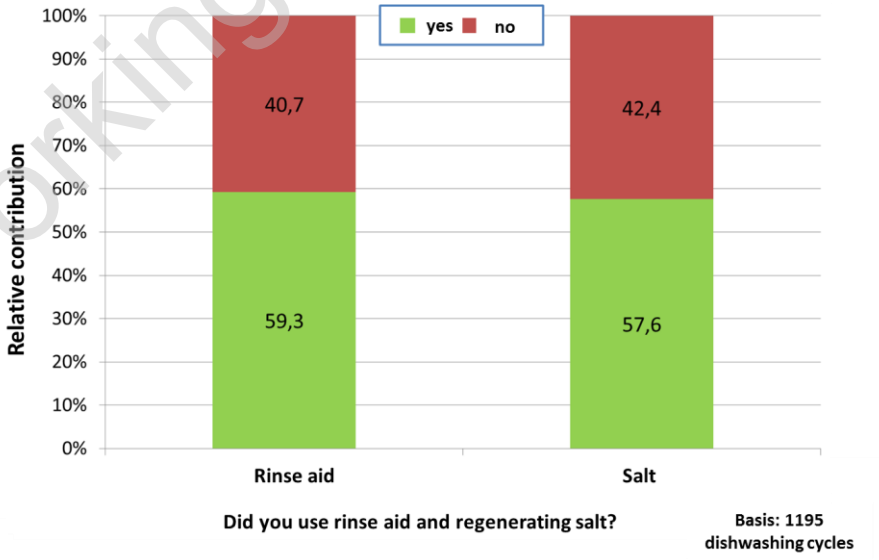

Figure 3.8: Use of rinse aid and regenerating salt (Bichler et al, 2014)

The second German study about consumer behaviour in terms of automatic dishwasher products evaluated 2,567 questionnaires that have been completed within the nation-wide campaign-day "Sustainable washing" in 2010, initiated by the Forum Waschen (http://forum-waschen.de/). (Schneider & Stamminger 2011).

26.4% of respondents use detergent powders, 18.3% use standard tablets ("Mono-tablets"), 57.5% use multifunctional tablets. For multiple answers were allowed, the sum of shares add up to 102.2, which means that some consumers use more than just one type of automatic dishwashing detergent. (Schneider & Stamminger 2011)

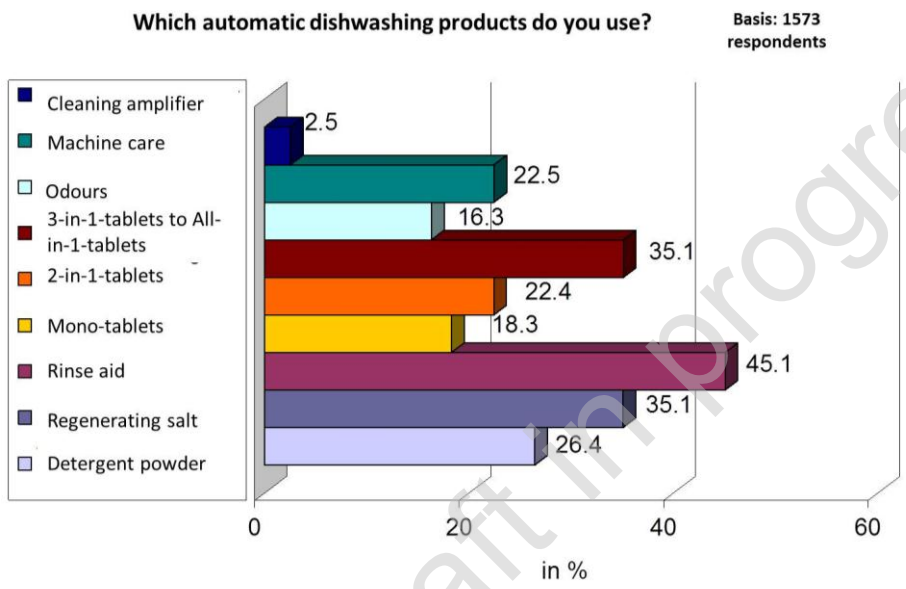

Figure 3.9: Usage of automatic dishwashing products in German households (Schneider & Stamminger 2011)

Users of multifunctional tablet products were asked about their usage of additional dishwashing products (Figure 3.10). Answers were compared to those of a former questionnaire within the campaign-day in 2006.

Figure 3.10 shows that in 2010, 38.6% of multifunctional tablet-users (2-in-1, 3-in-1 up to all-in-1) additionally used a rinse aid product. The share of 2-in-1-tablet users is 22.4% following Figure 3.9. Users of 2-in-1-tablets (combining detergent powder and regenerating salt) are recommended to use a rinse aid product. 16.2% (38.6% (multifunctional) - 22.4% (2-in-1)) of the multifunctional tablet users use an additional rinse aid product, even if their tablet includes rinse aid function. 27.7% of multifunctional tablet-users additionally use regenerating salt, although their tablet already includes regenerating salt. Since 2006, the share of consumers that additionally use rinse aid and regenerating salt has decreased (-11.1% respectively - 13.2%).

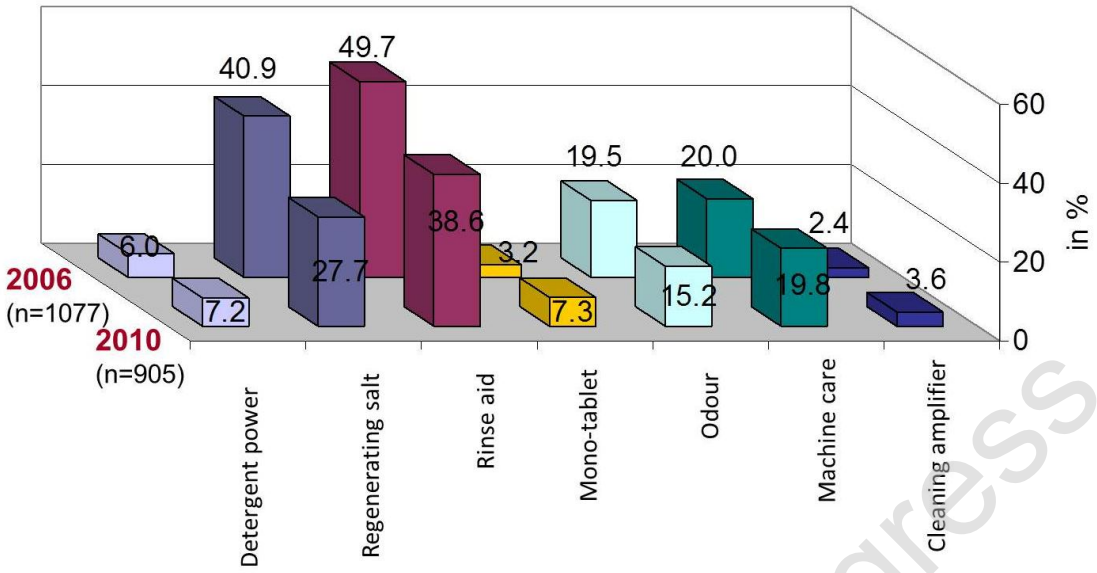

Figure 3.10: Users of multifunctional tablets: usage of additional automatic dishwashing products (Schneider & Stamminger 2011)

With regard to the expected regulatory restriction on phosphorous that would technically mean a ban of phosphates from consumer dishwasher detergents (cf. section 1.3.1.6), a study by (Bio by Deloitte 2014) revealed that consumer attitudes toward phosphate-containing detergents (both consumer automatic dishwasher detergents (CADD) and consumer laundry detergents) in EU have been influenced by advertised environmental friendliness of phosphates-free brands. Environmentally superior detergents remain the top choice of approximately half of customers in Germany (55%), France (64%), UK (50%) and the USA (40%), according to a 2009 consumer survey by Userneeds cited by (Bio by Deloitte 2014). The only hindrance for the interviewed consumers in buying green products would be performance with 47% of French respondents saying they would buy greener products if cleanliness efficiency remained the same.

3.1.7.2 Detergent dosage

Within the technical analysis as basis for the revision of the EU Ecolabel criteria for dishwasher detergents (JRC IPTS 2015c) a sample study of the market leaders for consumer dishwasher detergents was done. The analysis found that multi-function tablets weigh around 19 g and single-function tablets do not weigh over 17g. According to the on-going revision of the EU Ecolabel criteria and its latest proposal for dosage requirements, the reference dosage shall not exceed the amounts proposed in Table 3.7 (rinse aids are proposed to be exempted from this requirement as it is not dosed by the consumer but instead by the dishwasher and as such the dosage is fixed). However, as commented this scheme is under revision and the given values can still be modified.

Table 3.7: Proposal for revised dosage requirements of the EU Ecolabel for dishwasher detergents; source (JRC IPTS 2015c)

Product type	Dosage
Single-function dishwasher detergent	18 g/wash
Multi-function dishwasher detergent	20 g/wash

In the report, also dosage requirements of other ecolabels and voluntary schemes were analysed which are presented in the Table 3.8. The authors of the study noted that the dosage levels for the EU Ecolabel are calculated based on medium water hardness whereas it is calculated based on soft water for other

ecolabels. Washing in soft water requires less detergent and therefore the maximum dosages will be lower.

Table 3.8: Dosage requirements for dishwasher detergents for other ecolabels and voluntary schemes; source (JRC IPTS 2015c)

Scheme	Requirement
AISE Charter for sustainable cleaning	For ADW powders and unit doses (e.g. tabs, gel sachets, liquid sachets) with rinse function: Dosage g/job (1 dish wash cycle, normal soil, excluding free water from liquid / gel unit doses): ≤ 25 g For ADW powders and unit doses (e.g. tabs, gel sachets, liquid sachets) without rinse function: Dosage g/job (1 dish wash cycle, normal soil, excluding free water from liquid / gel unit doses): ≤ 20 g
Nordic Swan	The maximum dosage limits are: Single function products: 18 g/wash Multifunctional products 20 g/wash Rinsing agent is exempted from this requirement.
Env. Choice NZ	No dosage limits specified
Current EU Ecolabel	Total chemicals (TC) are the recommended dosage in g/wash minus the water content: The amount of total chemicals shall not exceed the following amounts: a) For single-functional dishwasher detergents: TC_{max} = 20.0 g/wash b) For multi-functional dishwasher detergents: TC_{max} = 22.0 g/wash
Good Env. Choice	Products must give good results at a dosage not exceeding 18 g for soft water (0-6°dH) in a 12-setting dishwasher.

Using a detergent powder, manufacturers and professional associations recommend a dosage of 20 g for a normally soiled dishwasher load and 30 g for a heavily soiled dishwasher load (Forum Waschen 2015a). Consumers tend to overdose (Figure 3.11): 51.9 % of the observed households used more detergent powder than recommended (30.0 to 40.0 g), 13 % even heavily overdosed the recommendations (≥ 40.0 g). 31.9 % of households dosed according to the recommendations from (Forum Waschen 2015a), 3.2 % used less detergent powder than recommended for a normally soiled dishwasher load. (Bichler et al, 2014)

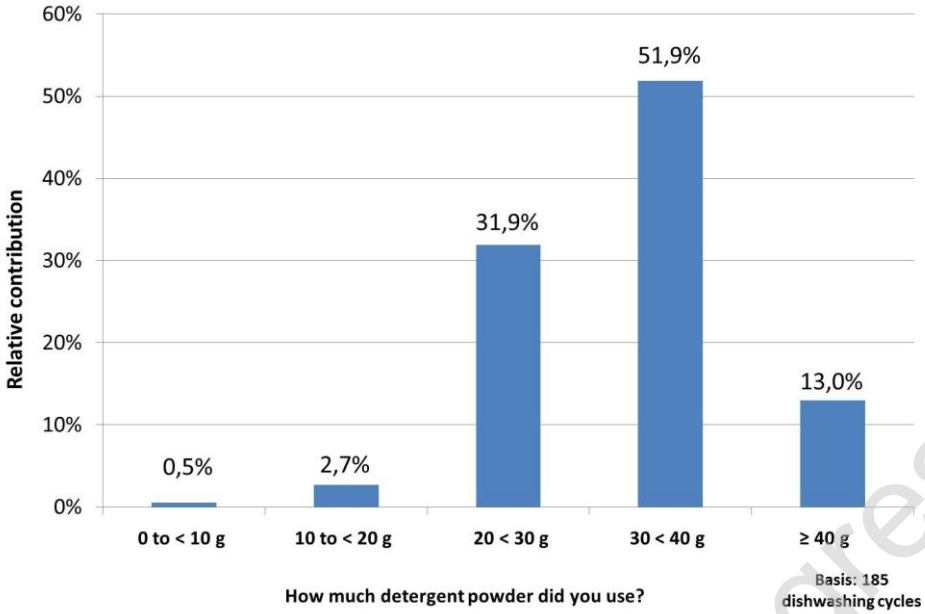

Figure 3.11: Dosing behaviour of detergent powder in German households (Bichler 2014)

3.1.8 Best practices in automatic dishwasher

Forum Waschen provides information on sustainable behaviour in daily housework. Their brochure "Sustainable dishwashing" (Forum Waschen 2014) contains general information on manual and automatic dishwashing, including "Six golden rules in automatic dishwashing". The six golden rules in automatic dishwashing advice consumers to

- Dispose food scraps into the waste bin
- NOT do manual pre-rinsing of the dishes
- Load all items in a way that the surface can be reached by the water jets
- Load the dishwasher to its full capacity
- Use detergents according to manufacturer's advice
- Choose the Eco programme for cleaning normally soiled dishwasher loads

According to stakeholder feedback to the sent out questionnaire (JRC IPTS 2015a), efforts of consumers to avoid under-filling the machine, using the water-saving programme and doing dishes at low temperatures increased over the past years, cf. Figure 3.12

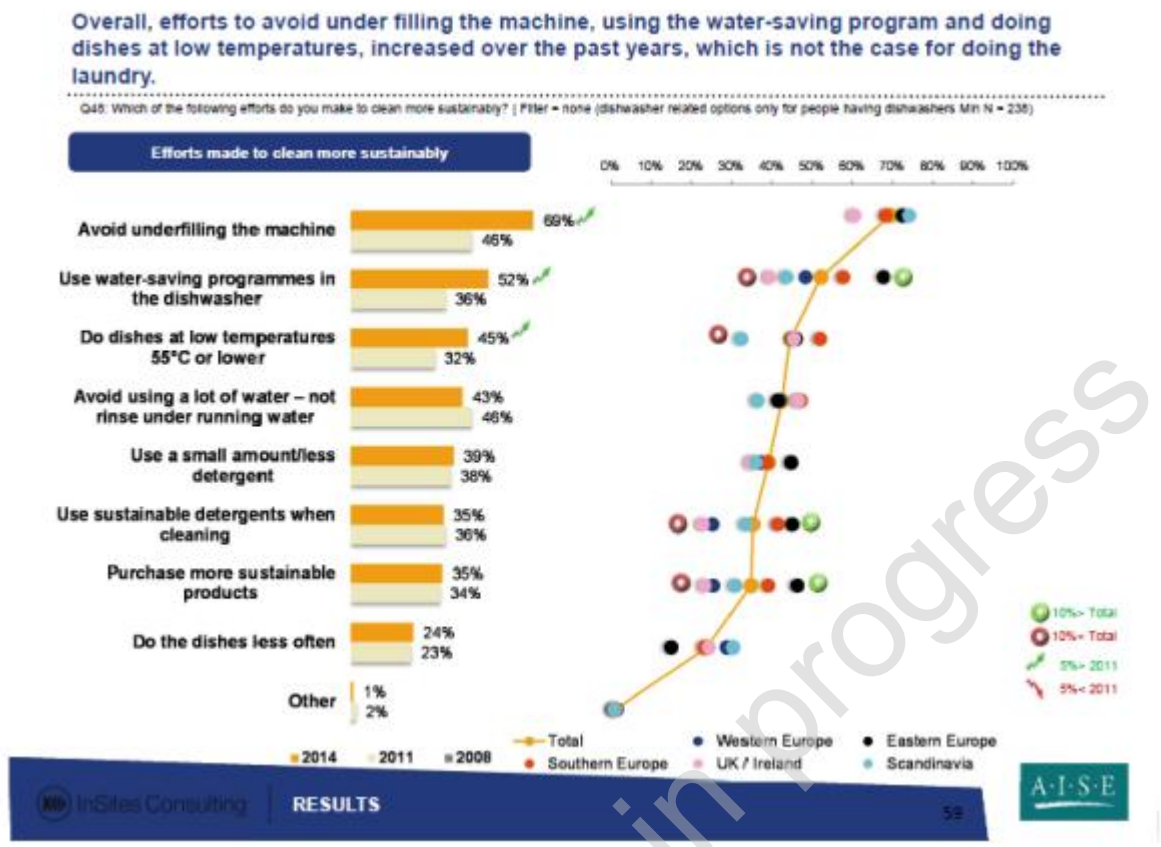

Figure 3.12: Efforts made to clean more sustainable; provided in (JRC IPTS 2015a)

On an international basis, the programme committee Household Technology & Sustainability (PC HT&S) of the International Federation for Home Economics (IFHE) identifies "best practices" for doing household jobs. Among its dissemination activities, in July 2014 a poster dealt with best practices in automatic dishwashing (Figure 3.13). It advices the reader in terms of pre-treating of dishes ("Don't pre-wash dirty dishes!"), gives advice how to load the dishwasher correctly (e.g. to always load to a maximum capacity), how to use it correctly (e.g. choosing the right programme according to the soiling level, dose detergent according to manufacturer's advice), what to do when the dishes are clean (e.g. switch off the dishwasher) or what to consider when buying a new dishwasher (e.g. looking for efficient appliances). (IFHE, 2015.)

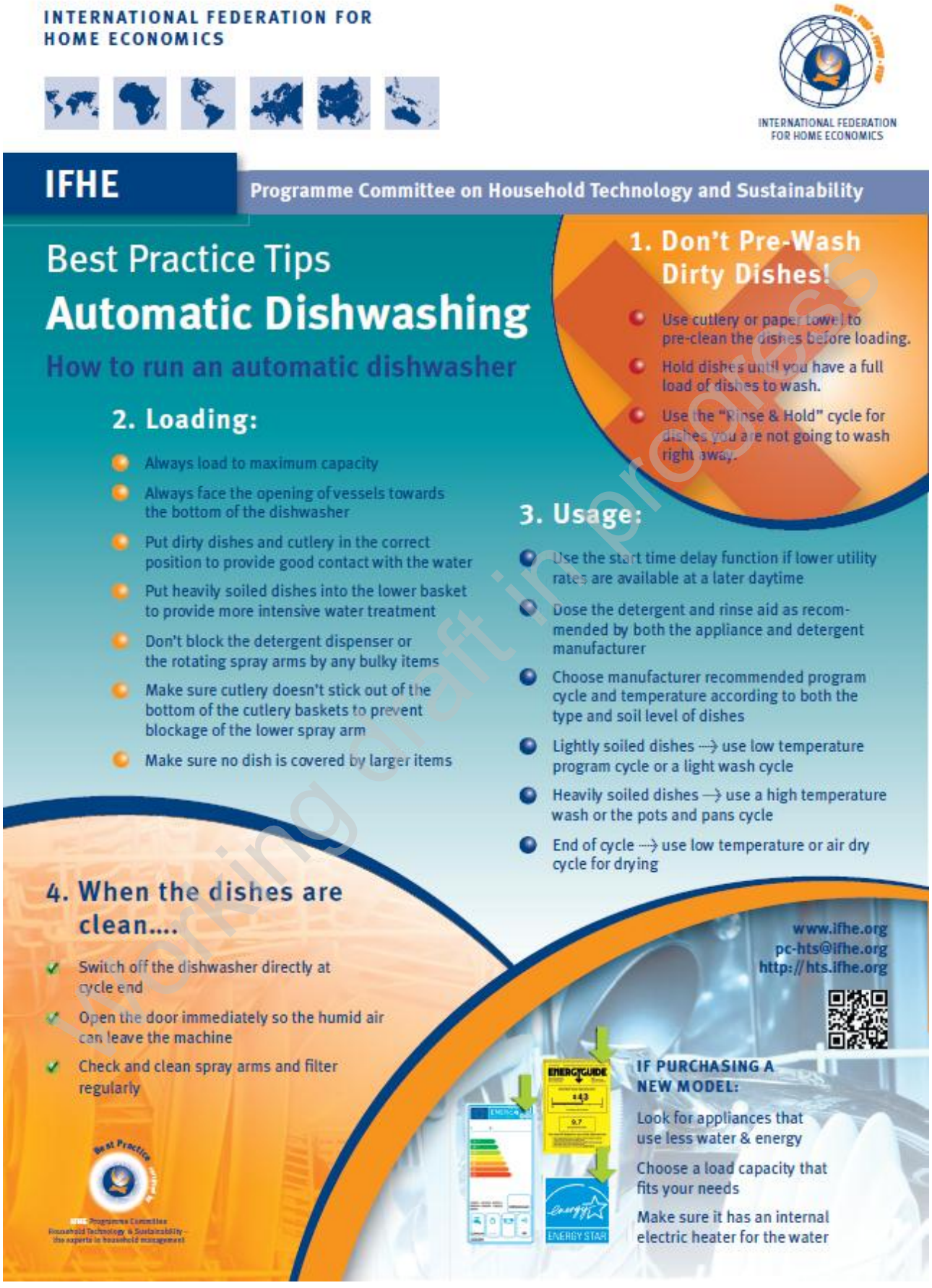

Figure 3.13: IFHE-Poster on best practices in automatic dishwashing (IFHE n.d.)

3.2 End-of-life behaviour

3.2.1 Product use & stock life

Whereas this section describes the *consumer behaviour* with regard to the duration of the product use, in section 4.2.6 the product lifetime from a *technical* point of view (i.e. time to failure of critical parts) is analysed.

In a study commissioned by the German Federal Environmental Agency (Umweltbundesamt), Öko-Institut together with University of Bonn analysed data of the Society for Consumer Research (GfK) for large household appliances in Germany with regard to the developments of the average "first useful service-life" (Prakash et al. 2015). This indicator is the timespan in which the product is *used* only by the *first* consumer; it is – however – not to be confused with the technical product lifetime.

The technical product lifetime might be longer compared to the first useful service-life if the appliance is still functioning and is for example passed on within family members and/or to friends or resold to third persons. The GfK data is based on a consumer survey asking for the reasons in case of purchasing a new product (desire for such a product, no such product possessed so far; wish for an additional product; defect of the old appliance; desire for a better appliance despite functioning of the existing one). In case of replacing existing products, GfK asked for the first useful service-life of the existing product; the GfK data did not provide information about potential second-hand use of products still functioning, i.e. the overall technical lifetime. This can only be derived for those products that were replaced due to a defect (cf. section 4.2.6).

The results of the study show that the average first useful service-life of large household appliances at all (covering washing machines, dryers, dishwashers, ovens, refrigerators and freezers) in Germany has declined slightly from 14.1 to 13.0 years between 2004 and 2012/2013 (Prakash et al. 2015). On average, the product replacement of large household appliances due to a defect slightly decreased from 57.6% in 2004 to 55.6% in 2012. This means that a defect still is the main cause of the replacement; on the other hand, it is important to realise that almost one third of the replaced large household appliance was still functional. In 2012/2013, the proportion of devices that were replaced because of a desire for a better device, although the old device still worked, was 30.5% of the total product replacements.

Extracting the data specific for dishwashers, the results show that the average first useful service-life of dishwashers in Germany nearly stayed the same with 12.1 years in 2004 and 12.4 years in 2012/2013. Considering only those appliances still functioning but being replaced due to a wish for a better appliance, the average first useful service-life was 11.7 years in 2004 and 11.4 years in 2012/2013.

Attention has to be drawn to the aspect that the share of consumers replacing still functioning appliances *rather early* to get a better device, increases. For dishwashers, 18% of all appliances being replaced on the basis of the wish for a better one were *less than 5 years old* in 2012 (while in 2004 this was around 13%).

3.2.2 Maintenance and repair practice

In 2013, RReuse (Reuse and Recycling EU Social Enterprises network) conducted an investigation into some of the main obstacles its members encounter when repairing products, inter alia for dishwashers, to provide part of the basis for setting requirements within implementing measures to improve the reparability of products, and thus their material and resource efficiency. Based on a questionnaire sent out through their network, the findings are answers from 9 individual reuse and repair centres from four national networks of social enterprises namely AERESS (Spain), Repanet (Austria), Réseau Envie (France) and the Furniture Reuse Network (UK). (RReuse 2013)

The study revealed the following common obstacles in repairing household dishwashers which all together result in repair activities being very costly, thus resulting in a high rate of direct replacement of a defect with a new model instead of repairing it (RReuse 2013):

Lack of access and cost of spare parts and repairs:

- The entire replacement price of replacing a new motor, pump and electronic boards is often too high and prohibits repair.
- The retail prices of components such as pumps can be extremely high compared to the cost of their production and yet they play a critical role in the functioning of the machine.
- A lack of interoperability of key components across different brands and even within brands is making repair more difficult. The rapid change of product and component design is making it difficult for reuse centres to stock up with the parts needed for repair especially in the case of motors and electronic boards.
- Accessories are often very difficult to replace because their designs vary significantly from model to model (e.g. dishwasher trays).
- The length of time that spare parts are available to purchase also significantly impacts the potential repair of a given product. For older machines in need of repair, sometimes the spare parts are simply not available from the manufacturer anymore.
- Sometimes only a full set of spare parts can be purchased when only a single part is needed.
- The main problems are the mechanical timers and electronic circuit boards, as a specific replacement part is needed. The costs of the electronic circuit board are too high and the replacements are very specific ones. It is difficult to stock up these items from older machines as one needs the specific design.

Lack of access to service manuals, software and hardware:

- The exact documentation, service manuals and relevant software and hardware to diagnose the faults of the product are difficult to access for reuse and repair operators that are not official after sales service providers of the manufacturers. Further, approved reuse and repair centres/networks often have to pay high prices for this information if they are not the direct after sales service providers of the manufacturers.
- Today's increasing use of electronic instead of mechanical components means that one can often only identify the problem with the appliance by attaching it to a laptop using special hardware and using fault diagnosis software. Use of these tools requires training and are often only available to the after sales service providers of the manufacturers which makes repair of dishwashers for reuse centres often impossible due to a simple lack of information.

Examples of design that hinders disassembly for repair:

- Access to product interior and separation of individual components can be difficult. For example, the casing of the dishwasher is becoming increasingly difficult to open in order to access the internal components. This is especially true in the case of opening the casing at the bottom of the machine to access the internal components as it can be extremely time consuming, and one has to turn the machine on its side which is not easy.
- The internal components cannot be accessed and removed easily; e.g. heating resistors are fastened and must be physically broken due to the use of clips in a restricted space.
- The large number of different models and levels of performance of components make it difficult to interchange components across different machines even from the same manufacturer.
- It is often difficult to diagnose the problem, especially if the problem is a result of washing use and testing for problems is time consuming. This can be for example due to the inaccessibility of certain components within the dishwasher.

The Austrian Ministry for transport, innovation and technology (Pirkner et al, 2008) gathered and compiled the existing knowledge and results from repair industries and distributors of white and brown goods. It was attempted to raise the interest of the producer companies in the Sustainability Label that has been

developed (see section 1.3.3.1) and to motivate at least some producers to apply for the labelling of one of his appliances. This study includes many of the points listed above.
The Ecodesign Preparatory Study Lot 14 (ENEA/ISIS 2007c) used following generic input data for the category "Maintenance, repairs, service" of dishwasher models in 2007:

Table 3.9: Average input data for maintenance, repairs and service of dishwasher models used by Lot 14 in 2007; source: (ENEA/ISIS 2007c)

Maintenance, repairs, service	Dishwasher 9 ps	Dishwasher 12 ps
Number of km over product life	-	160 km/product life
Spare parts (fixed value: 1% of product materials and manufacture)	402 g	482 g

According to stakeholder feedback to the sent-out questionnaire (JRC IPTS 2015a), maintenance and repair are very important, and more important with more efficient machines. Some stakeholders state that products are provided with extensive installation instructions to ensure that maintenance and durability are not impacted. Good maintenance is important and not doing it can result in service requirement. For example, with respect to drain filter cleaning and running an empty cycle every couple of months is recommended. Advice for consumers is given in the instruction manuals. Descalers can also be used on an optional basis.
Some stakeholders assume if products are installed in a kitchen that is used by more than one household (e.g. in student dormitory buildings), it can be expected, that product maintenance is on average not as good as for a product used by only one household. This will then also reduce the durability.
One stakeholder provides results of a study from 2006 analysing what usually breaks in dishwashers (cf. also section 4.2.6). Following information is given regarding the repair practice: 37% of the dishwashers in this survey had been repaired during the first 5 years. 26% was repaired by a professional, 36% repaired the appliances themselves, 33% of the appliances could not be repaired and 5% did not know. The reason of one third repairing their machines themselves is possibly that it is very expensive to get a professional after the warranty expired (as most errors occur after the two year warranty expired).
Another stakeholder points out that for essential household appliances such as dishwashers, consumers can usually not manage without them for a longer time. Offering a similar product as a loan to cover the repair time would make repair more attractive.

3.2.3 Collection rates, by fraction (consumer perspective)

(Huisman et al. 2012) describe the following possibilities for consumers to get rid of no longer used (waste) electric and electronic equipment (W)EEE, inter alia large household appliances like dishwashers.

- Municipal collection point: Also called 'waste transfer station' or 'container park'. Households discard bulky household waste like furniture, hazardous waste and also WEEE at these container parks. By law, municipalities are obligated to have at least one such location. From these collection points, most WEEE is handed over to the system of the compliance schemes (treatment plants being in compliance with at least the minimum standards required for accreditation). Another possibility is that municipalities sell WEEE or dismantled fractions like copper cables to metal scrap processors to receive more money than the reimbursement per ton collected from the compliance schemes.

- Retailers: When households buy new equipment, they can hand in the old item ('old for new'). Retailers having a contract with the compliance schemes will hand over the received equipment to recyclers that are under contract of the compliance schemes. Some of the contracted retailers, however still deliver such equipment outside the compliance scheme. Retailers without a contract can still legally sell WEEE to local or regional metal scrap processors.

- Door-to-door collection: Households can also choose to give or sell WEEE to door-to-door collection which mainly happens in cities or being announced by local collectors collecting metals and used EEE. Driven by high metal prizes informal collection pathways exist and obviously the collected WEEE will never be handed over to the system of the compliance schemes.
- Charity initiatives: Charity initiatives often work in close cooperation with municipalities and businesses. Their main function is to sell 2nd hand appliances, if still functioning, to other consumers.
- 2nd hand/internet market: Usable equipment will be sent from one household to another. Strictly speaking, this is not WEEE but it affects the amounts of WEEE since the equipment can be used for a longer period. In order to prevent double counting of equipment, it is necessary to exclude the 2nd hand market from the WEEE prediction model.

Due to the large size of devices, disposal via the municipal household waste is believed not to be relevant in terms of quantities.
For Italy, (Magalani et al. [n.d.]) state that for large household appliances the two main disposal paths are through municipal collection points and retailers. Regarding retailers, large household appliances are mostly picked up at consumers' homes 75-95% of the time, often in conjunction with the delivery of new equipment.

Table 3.10: Disposal channels for large household appliances used by consumers in Italy in 2012; source: (Magalani et al. [n.d.])

	Average disposal channel of large household appliances*
Municipal collection points	39.1%
Retailers	37.1%
Reuse (sold or given away)	8.0%
Bad habits (e.g. waste bin, plastic waste, other wrong streams)	5.8%
Life extension (old house…)	5.3%
Do not know, do not remember	4.1%
Warranty replacement	0.6%

* Note: In this study large household appliances subsume: dishwashers, washing machines, wash dryers and centrifuges, furnaces and ovens, and microwave ovens. The rates within these waste streams might vary, e.g. the re-use rate is 1.5% for boilers and 20% for microwave ovens. Further, the likelihood of improper disposal practices appears negatively correlated with the size of the equipment, i.e. for dishwashers the values might be smaller.

According to stakeholder feedback to the sent-out questionnaire (JRC IPTS 2015a), about two-thirds of e-waste is managed by commercial actors without the involvement of producer responsibility schemes.

3.2.4 Estimated second hand use, fraction of total and estimated second product life

Although this section shows data for washing machines, it is assumed that the following information and values are also transferrable to household dishwashers as a similar category of large white goods and to the best of the authors' knowledge no specific data for household dishwasher are available.
According to (WRAP 2011), washing machines are thought to pass through a wide range of pathways once they have reached the end of their first life. This may be via direct reuse (e.g. passed on to friends and family, sold in online networks, or given to a charity), retailer „take-back" schemes, bulky waste collections and drop off at Household Waste Recycling Centres. Owing to their bulk, washing machines are not

thought to be disposed off through regular household waste collections. In their case study on benefits of reuse, WRAP indicates that 97% of the washing machines are sent to recycling (43%) or landfill (54%), meaning that 3% might be reused.
Refurbishment for reuse only takes place in cases where it is economically viable. According to (WRAP 2011) , on average, 25% of the machines received by reuse organisations are sent to recycling immediately, with another 10% sent to recycling after initial testing. The result is a low level of reuse of washing machines. In the UK approximately 100,000 washing machines are reused in some form every year. This represents 3% of all washing machines reaching the end of their life each year. Preparation for reuse by charitable and private organisations currently accounts for just 1.5% of discarded washing machines in the UK, while 1.3% are reused directly via online exchanges or otherwise.
(WRAP 2011) identified that typically, a washing machine donated to a preparation for reuse organisation is 4-5 years old. This is likely to be the point at which the item has reached the end of its economic life for the first owner (e.g. it requires a repair the owner has decided not to undertake). With a technical life of 12 years assumed by (WRAP 2011), this suggests that a reused item may last up to 8 years in its second life. The technical lifetime can typically be extended by refurbishment. Data describing refurbishment periods are limited, but the WRAP study assumed that refurbishment occurs once and extends the lifetime of a washing machine by 6 years (1,500 cycles).

3.3 Local infrastructure

3.3.1 Energy

Around 70 to 90 % of the electric energy in dishwashers is used for heating the water, the dishes and the machine. This heat can be supplied by other sources apart from electricity.
Technical options such as heating by hot water circulation loop ("heat-fed machines") or hot fill are among those options. (see section 4.1.4.)
Use of hot water supply
The use of a hot and cold water supply has never been a real option for dishwashers. Since the water needs to be heated up in the main wash phase and in the final rinse of a washing cycle, a cold water intake in between would cool down the loaded tableware and would therefore cause higher energy consumption in the final rinse.
A better option for dishwashers could just to be connected to a hot water supply. Today, many household dishwashers can be connected to a hot water supply. Under certain preconditions (optimal length and insulation of the hot water pipe, efficiency and control characteristics of circulation pump, renewable water heating sources), this can result in reduced energy consumption and greenhouse gas (GHG) emissions.
The reduction of GHG emissions can be greatly achieved if the hot water supply is coming from renewable sources. This option is expected to achieve higher market shares in the near future as the installation of renewable energy technologies in the residential sector are supported by the Art.13 (4) of Directive 2009/28/EC on the promotion of the use of energy from renewable sources (European Parliament 2009). According to this Directive, Member States should have introduced in their building Regulations and codes appropriate measures to increase the share of renewable energy sources.
Demand-response enabled appliances
As the energy system of the future is getting more and more variable due to fluctuating energy production by wind and solar PV stations, it is necessary and helpful to have some flexibility on the demand side as well. This can be realised by appliances which offer a demand-response possibility. However, a sufficiently large number of appliances need to be on the market before such a system can be launched. It is therefore useful for a more renewable energy sourced system (and a better match between generation and consumption of the energy) to support the introduction of demand-enabled appliances.

3.3.2 Water

Water consumption of dishwashers has already been reduced significantly during the past years from 19.14 litres per cycle in 1998 to 10.72 litres per cycle in 2013, cf. Figure 2.11. This reduction is even more significant if the water used per place setting is compared. The water reduction has been achieved by several technical design options which are described in section 4.1.4.5.
With regard to infrastructure and system aspects, following measures of reduced or sustainable use of water are to be mentioned:
Changing use patterns
Avoiding manual pre-rinsing of dishes would be an option to reduce the overall water consumption connected to dishwashing significantly (cf. section 3.1.5).

Use of greywater and rainwater
Reuse of domestic greywater and rainwater has a significant role to play in water efficiency. A rainwater harvesting system can be attached to a tank where the water is stored until needed and using a pump the water can then be recycled through the water supply for dishwashers. This is very useful as rainwater is soft water and therefore causes no limescale which can often cause problems with filters and elements in such appliances (Claridge 2015) Rainwater harvesting systems can provide either a direct or indirect supply from the main storage tank to the appliances. In a direct system the pump sends the rainwater on demand straight to the appliance. In an indirect system, the rainwater is pumped up to a rainwater header tank, where it is gravity fed to where it is needed. The advantage of an indirect system is that pump wear and tear is reduced and 8 to 10 times less electrical power is used because the pump is activated only when the header tank is empty rather than every time an appliance is used (RainWaterHarvesting.co.uk).

3.3.3 Telecommunication

The smart home has reached domestic dishwashers as well and electronics companies are racing to offer Wi-Fi connected multi-featured dishwashers. These connected dishwashers provide the opportunity to consumers to control their appliances remotely. Consumers could have control over almost all operations of their machines including monitoring the cleaning process remotely, trouble shooting, setting the cycles and several other features, to be operated and controlled via smartphones, tablets and PCs. For example, LG, Samsung and Whirlpool have all announced smart dishwasher in CES 2015 (http://www.cnet.com/ces/) with special smart features (Griffin, 2015).
According to (European Commission 2013a), increased frequency of internet usage, coupled with faster speeds and the growth of mobile access are accelerating recent trends in internet use and inducing new and different behaviour patterns by users. In general, the increasing trend to mobile access to internet via smartphone, tablet etc. might also drive the trend towards connected household appliances in future.

3.4 Summary and discussion: users

This section provides a summary of the findings related to user behaviour, as well as a number of discussion points. An important complement to the information provided will be the results of an on-line survey launched in April –May 2015, which will be available mid-June, and will be presented at the first stakeholder meeting.

3.4.1 Programme(s) tested for labelling purposes

(see also the discussion of this point in section 1.4. and Discussion point 1.8)
One of the objectives of the label is to provide a realistic picture of the consumption values of the appliance, under average operation conditions, and not only in one of its programmes.
It seems thus a reasonable assumption that the programme tested to obtain the energy labelling class is a programme suited to clean normally soiled tableware, and therefore may be used on a daily basis by consumers.

Additionally the test programme, which is used to obtain declaration values, should be the one that is most efficient with regard to energy and water consumption for this kind of tableware. Following the requirements of EN 50242/ EN 60436:2008+A11:2012, this programme shall be named 'Eco' on the user interface of the dishwasher.
An article of the German consumer journal Stiftung Warentest (Stiftung Warentest, 2015) points out that 24% of the participants never use the 'Eco' programme. 43% indicate that they use the 'Eco' programme to save energy and water, while 47% use the automatic programme of their dishwasher to optimise the use of energy, water and time (see section 1.2.4.1). Previous studies indicated similar user behaviour (see 3.1.1.6) concerning the programme choice.
Therefore, it is necessary to discuss how to adapt the requirements on the programme used for the label and assign to user programme choice behaviour. The update of the IEC 60436 4th Edition standard are a step in this direction. STIWA is already performing tests with automatic programmes, according to their own procedure, using the basic conditions and procedures of EN 50242/ EN 60436. (Stiftung Warentest 2015)

Discussion point 3.1

How could the test procedure be modified or extended to better reflect real-life user behaviour? Should e.g. half-load cycles be included, automatic programmes, etc.?

How could automatic programmes be included in the test procedure?

3.4.1.1 Programme duration

Programme time is an important parameter for balancing the information on the energy efficiency of a dishwasher. As shown in section 3.1.6, it is possible to achieve low energy consumption by prolonging the programme time. Also, market research reveals that currently there is a trend by manufacturers to supply the market with appliances with longer average duration of the standard Eco programme (cf. section 2.2.3.1).
On the other hand, consumer research reveals that one of the reasons for not using the standard Eco programme is exactly this. The most accepted programme duration by average users was 1 to 2 hours (cf. Figure 3.6) while most of the Eco-programmes of machines on the market last over 2 hours. However, communication plays a role, and consumer research also indicates that better informed consumers with regard to the role of duration in washing (i.e. why Eco programmes have long programme durations and still are the most efficient), had increased acceptance of (long) Eco programmes.
To allow customers at the point of sale to make a well-informed purchase decision and to let them choose the most appropriate dishwashing programme for their daily needs, it is proposed to discuss which, when and how information should be provided on the programme duration.

Discussion point 3.2

Do you think consumers would select longer programme times if they were better informed that longer cycles can have lower energy consumption values (but can have higher water consumption values)? Why (not)? How should the consumer be informed about this?

3.4.2 Facilitate the selection of the tested programme (eco)

EN 50242/ EN 60436 requires manufacturers to equip the appliances with a default programme, which is selected by default when the appliance is switched on. This has been welcomed by consumers.
The standard shall continue to define, in an updated manner, the conditions of testing of the programme that is associated to the attribution of the label class. The name 'Eco' - as defined in the standard – of this programme has proven to help the consumers to identify the most efficient dishwashing programme.

Therefore, it seems sensible to keep both the definition and the name of this programme in the revised ecolabel and energy labelling regulations, and in EN 50242/ EN 60436.

3.4.3 Improving consumer information

3.4.3.1 Consumption values of ALL programmes and information to the consumer

The information that consumers get about energy and water consumption values at the point of sale via the energy label is based on one specific program, the 'eco' programme. To help consumers make better informed purchase choices, and once the appliance is bought, programme selections, It could be recommendable that the appliances provide information on the consumption values of other programmes before and after the buying process.

Therefore, it could be recommended that the user manual contains, besides the information on the Eco programme, also detailed information on energy consumption, water consumption, programme time and the preferred usage of this programme for each individual programme. Similarly, the functioning of options could be described by figures, e.g. how much more or less energy is used.

It is proposed to discuss if information about all programmes could be indicated on the machine itself (e.g. before it starts the programme and/or once the programme has finished). By doing this, the consumer has access to the information easily and at any time the machine is used. This would encourage consumers to choose the most suitable appliances and programme for their needs.

Given the large amount of information already provided to consumers, any proposal of additional information has to be carefully analysed as not to overload with information, especially if of technical character, as this may generate confusion.

Discussion point 3.3

Would it be possible to indicate the consumption values of every programme available in the user manual, in a cost-effective manner? Please explain why / why not

Is it possible to indicate directly on the machine the expected consumption values before the programme starts, and the actual consumption once it finishes? Please explain why / why not

Do you think that the information provided in the user manual should be simplified? Please explain why / why not, and which areas are most critical.

3.4.3.2 Use of hot water

If a user has a hot water supply, especially if based on renewable energy sources, this can be used to feed the dishwasher. To support consumers in using alternative hot water supplies, manufacturers could include clear statements about the fitness of their appliances for a hot water connection, be it in the appliance manual, the energy label, or the product data sheet.

It is proposed to discuss whether additional communication efforts shall be made (e.g. special symbols in the energy label) indicating if the dishwasher can be connected to an external hot water supply, and if additional advice with specific instructions on this (e.g. maximum temperature of the how water inlet) shall be provided in the user manual.

Discussion point 3.4

Do you think that the fitness for a hot water supply should be indicated on the energy label? Why (not)?

Which additional information could be necessary to help the buyer/user save energy, and protect the functioning of the appliance?

Are there any additional constraints to the use of external hot water supplies that one could mention?

3.4.4 Supporting demand-response enabled appliances

This point has also been included in section 1.4.3.4.
As the energy system of the future is getting more and more variable due to fluctuating energy production by wind and solar PV stations, it is necessary and helpful to have some flexibility on the demand side as well. This can be realised by appliances which offer a demand-response possibility. However, a sufficiently large number of appliances need to be in the market before such a system can be launched. It is therefore useful for a more energy efficient power supply to support the introduction of demand-enabled appliances.

Discussion point 3.5

Should demand-response enabled appliances be incentivized, e.g. by a bonus-malus in the EEI? Can showing information about the availability of such feature on the label be of any value? Please explain why / why not

4 TASK 4: TECHNOLOGIES

4.1 Technical product description

4.1.1 General Remarks

4.1.1.1 Sinner Circle

The cleaning process is based on 4 factors: mechanics, temperature, chemistry and time. These factors depend on each other, i.e. one factor cannot be reduced without increasing another one (if the cleaning efficiency shall be maintained). In comparison to hand dishwashing, in a household dishwasher the factors temperature, chemistry, and time are more important (Figure 4.1), while in the hand dishwashing mechanics is by far the most important one. The most energy consuming factor during the dishwashing cycle is the heating of the wash water (i.e. the factor temperature). The fact that the factor temperature in the dishwashing by hand process is less important compared to the dishwasher does not necessarily result in lower energy demand. This is mainly due to the much higher amount of water used to clean the same amount of dishes, which has to be heated. (Richter 2010b).

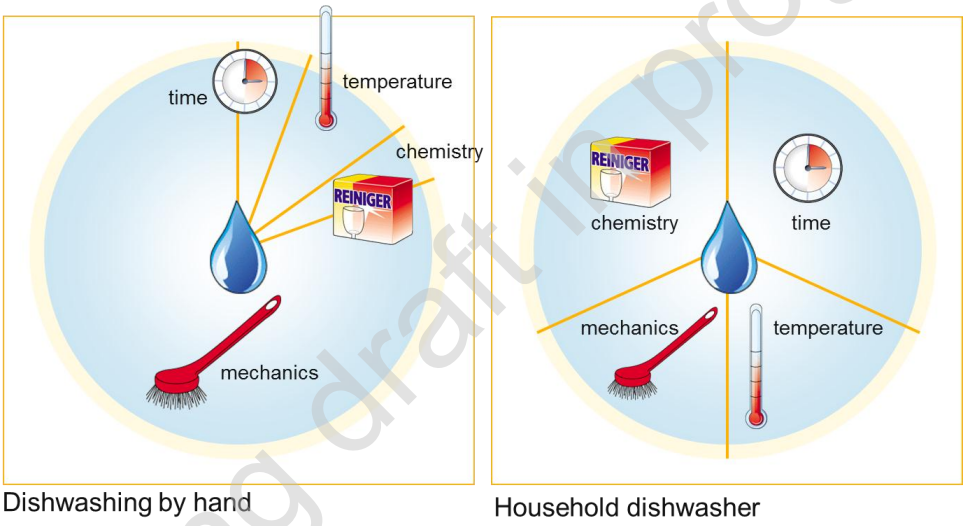

Figure 4.1: Cleaning factors comparing dishwashing by hand and in a household dishwasher source adapted from (Miele 2015)

4.1.1.2 The typical phases of a dishwashing cycle

The typical phases of a dishwashing cycle are

- Pre-rinse with cold or warm water to remove loose dirt from the crockery;
- Main cleaning phase with warm to hot water (usually between 40 and 70°C) and detergent;
- Intermediate rinse with tepid water to avoid carryover of cleaning agent into the hot rinse phase;
- Hot rinse with rinsing agent to remove all remaining suds, to coat the crockery with rinsing agent and to heat it (for hygienic reasons and to facilitate the drying);
- Drying.

Additionally there is a regeneration phase in which the ion exchanger is regenerated. The ion exchanger softens the water by exchanging ions that cause water hardness with chloride ions. It has a certain capacity and has to be regularly regenerated, which is done automatically by the dishwasher. This does not necessarily take place in each dishwashing cycle; it takes about 3 to 4 minutes.

Usually there are two heating phases, the first one in the main cleaning phase, and the second one in the hot rinse phase.

The different programme types mainly differ in the length of different phases, the reached temperatures and the water pressure. In some programme types some phases are missing. The following figure gives an overview of the typical temperature profile of a dishwashing cycle (example programme: "normal 55°C").

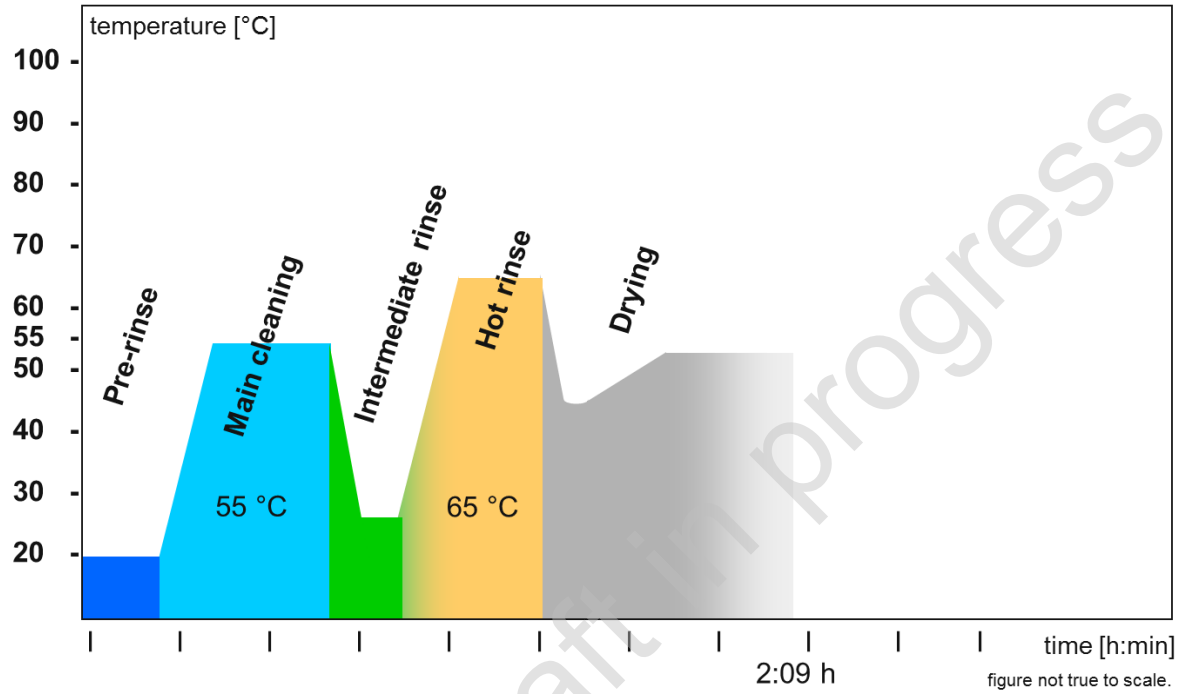

Figure 4.2: Typical temperature profile of a dishwashing programme (example: "normal 55°C"); adapted from (Miele 2015)

4.1.1.3 General approaches to reduce the energy (and water) demand of dishwashing machines

4.1.1.3.1 Reducing the temperature and at the same time extending the cycle duration

Due to the interrelation of the four factors of the Sinner circle one possibility to reduce the energy demand of a dishwasher is to reduce the temperature and compensate it by extending the duration of the dishwashing cycle. Therefore today's most energy efficient programmes have very long cycle duration (Figure 4.3).

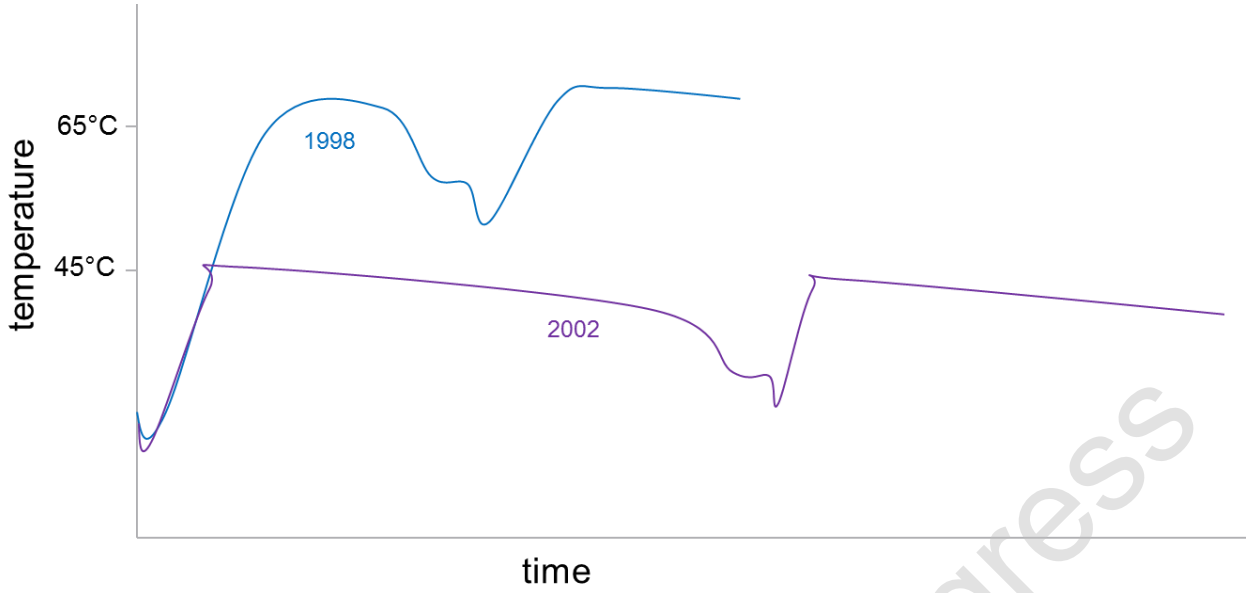

Figure 4.3: Temperature profiles and programme duration* of dishwashing programmes 1998 and 2002; adapted from (Miele 2015)

*Note that time-axis units are lacking as the main purpose of the figure is to show the relation between temperature and time in the Sinner circle

It is important, however, to consider hygiene aspects especially with regard to lowering the temperatures reached during the dishwashing cycle. Consumers apparently not only expect clean dishes but also dishes that are hygienically safe. The trend on the market to offer devices with a special "hygiene" option can be seen as reaction to this development. If the hygiene option is activated the temperatures reached during the dishwashing cycle are much higher (between 60 and 70°C) than in the standard programme thus leading to an increase of the energy demand.
Other than for washing machines, where a trend to washing at lower temperatures than indicated for the (mostly standard) washing programme can be observed, according to stakeholder feedback from the questionnaire for dishwashers (JRC IPTS 2015a), the temperatures indicated to consumers are reached either in the main wash or during the last rinse.

4.1.1.3.2 Reducing the amount of water to be heated

Also reducing the amount of water can help to reduce the energy demand as less water has to be heated. There are various technical possibilities that contribute to lowering the amount of water and at the same time maintaining the water pressure, which were utilised during the last decades, e.g.:

- Alternating spray arms,
- Optimizing the hydraulic system
  - Reduction of the volume of the sump,
  - Reduction of the diameter of the water pipes,
  - Reduction of the diameter and exact adjustment of the jet nozzles,
- Improving the filter system to optimise the removal of the dirt particles leading to the possibility to longer use the wash water or to only partly drain the dirty water together with most of the collected dirt,
- Reduction of certain programme phases (rinse phases) depending on the actual amount and soiling of the crockery,
- Re-use of the water of the final rinse phase for the pre-rinse of the following dishwashing cycle.

According to stakeholder information the current average water consumption of dishwashers is approximately 10 litres, compared to around 15 litres in 2005 (taken as standard base case for a dishwasher with 12 ps in the EuP Preparatory Study Lot 14).

4.1.1.3.3 Partly recovery of heat

Another way to reduce energy demand is to recover part of the heat which otherwise would escape as heat loss (mainly by draining heated water without recovering the contained heat). Possible options are e.g.

- Use of heat exchangers,
- Use of heat-pumps,
- The zeolith® technology that recovers the condensation energy of steam.

4.1.1.3.4 Optimising the drying process

Finally also the drying process can be optimised in a way that the dishes do not have to be heated as much resulting in a lower energy demand. Possible options are e.g.

- Drying through ventilation,
- Use of adsorption material like zeolith® technology,
- Automatic opening of the door at the end of the programme.

4.1.2 Basic product types

According to the definition given by Regulation (EC) No. 1059/2010 (European Commission 2010) and Regulation (EC) No. 1016/2010 (European Commission 2010), a '*household dishwasher' means a machine which cleans, rinses, and dries dishware, glassware, cutlery and cooking utensils by chemical, mechanical, thermal, and electric means and which is designed to be used principally for non-professional purposes*.
Besides this general definition, both Regulations further use various sub-categories of dishwashing appliances (built-in appliances; different requirements related to capacity and size of the machines, cf. section 1.1.1).

4.1.2.1 Basic differentiation of dishwashers by the way of installation

The dishwashers on the market can be divided in various sub-categories according to the way they are installed.

- Freestanding dishwashers have a preinstalled countertop and are not supposed to be integrated into the kitchen cabinets.
- Undercounter dishwashers (non-integrated): usually it is possible to remove the preinstalled countertop of freestanding dishwashers in order to put the appliance under the general countertop of the kitchen.
- Integrated/built-in dishwashers: Besides the freestanding dishwashers there are dishwashers that are capable of being integrated in the kitchen cabinets. In these cases the front door of the dishwasher is hidden behind a kitchen cabinet front. Either they are *semi-integrated* which means that the control panel is located at the front of the door and thus still visible or they are *fully integrated* which means that the control panel is located at the upper side of the door and thus invisible from the front. The front looks identical as any other kitchen cabinet.
- Countertop *dishwashers* are mounted on top of the countertop.

4.1.2.2 Basic differentiation of dishwashers by capacity and size

With regard to size and capacity there is a wide variety of dishwashers on the market, cf. also section 2.2.2.2.

- Full size dishwashers have a rated capacity of 12 to 14 ps. They comply with the standard size of a kitchen cabinet which is a width of 60 cm, a depth of 55 to 60 cm and a usually slightly adjustable height of 81 to 87 cm. Recently, also models with 15 ps appeared on the market.
- Slim line dishwashers have a standard width of 45 cm and a typical rated capacity of 8 ps to 10 ps. Height and depth are similar to those of the full size dishwashers.

Both full size and slim line dishwashers are available as freestanding, undercounter and semi-/fully integrated devices.

- Countertop dishwashers typically have a rated capacity of 6 ps and the following dimensions: width 55 cm, height 44-45 cm, depth 50-52 cm.

4.1.3 Best Available Technologies BAT (best of products on the market)

According to (Topten International Group (TIG) 2015), Topten shows the availability of high efficiency dishwashers, the Best Available Technology (BAT); this information is regularly updated. All dishwashers currently listed are in energy efficiency classes A+++ or A++, in drying efficiency class A, have a maximum water consumption of 2,800 litres per year (based on 280 cycles/year, 10l/cycle,), flood protection and the option to be connected to hot water supply (minimum Topten.eu criteria for household dishwashers).

Table 4.1: Household dishwasher models on www.topten.eu in June 2014 (Topten International Group (TIG) 2015)

Most energy efficient dishwashers on Topten.eu	Built-in (basic / similar models)*	Freestanding (basic / similar models)*
A+++	15 / 29	2
A++	Not on Topten	5 / 1

* Similar models: Products of similar construction and identical technical values

(Topten International Group (TIG) 2015) states that the A+++ class threshold is exceeded clearly by several models which have an EEI of around 41 which is 17% better than the A+++ threshold of EEI < 50. The most energy efficient model on Topten.eu offered by V-ZUG even has an EEI of 29.3 (AEc of 137 kWh/year) which is 40% better than the A+++ threshold and is reached by an integrated heat pump; according to the operating instructions (V-ZUG n.d.), the programme duration for the standard cleaning cycle is 160 minutes.

Figure 4.4 provides an overview of the EEI of the basic dishwasher models presented on www.topten.eu in June 2014.

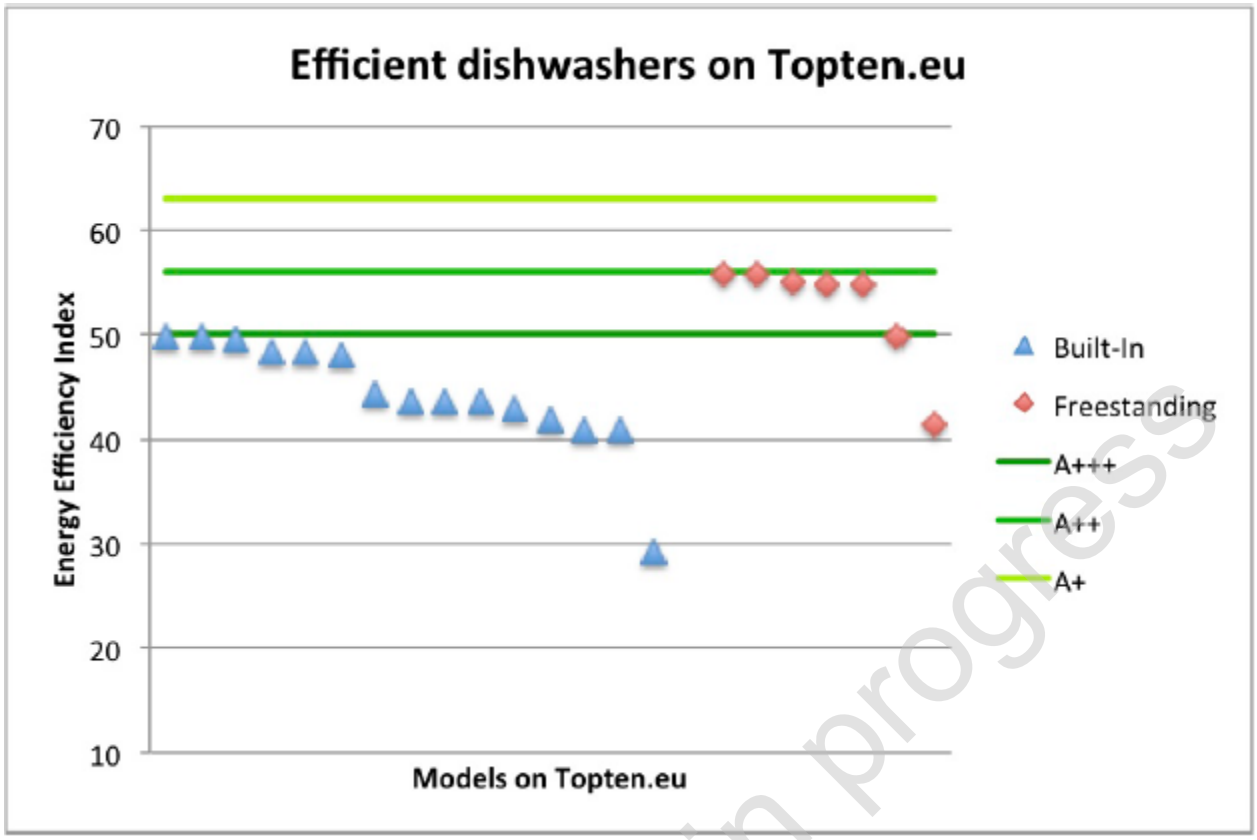

Figure 4.4: Energy efficiency Indices (EEI) of dishwasher models presented on www.topten.eu in June 2014; (Topten International Group (TIG) 2015)

Further benchmarks of freestanding and built-in household dishwasher models listed on Topten.eu with regard to energy and water consumption as well as noise emissions are provided inTable 4.2.

Table 4.2: Benchmarks of household dishwasher models, freestanding and built-in, listed on www.topten.eu with regard to energy and water consumption and noise emissions; (www.topten.eu)

	Benchmarks: Range of BAT-dishwasher models listed on www.topten.eu
Energy Efficiency Index (for comparison: A+++ threshold is EEI < 50)	29.3 - 49.7 (several models with EEI between 41 and 44)
Energy consumption (kWh/cycle)	0.49 – 0.84
Energy consumption (kWh/year), based on 280 cycles per year	137 – 237
Water consumption (litres/cycle)	6.0 – 10.0
Water consumption (litres/year); based on 280 cycles per year	1,680 – 2,800
Noise emissions (dB(A))	40 - 45

4.1.4 Improvement options

The following sections describe different areas of technological progress which have an influence on energy, water and/or other resources consumption (e.g. materials, detergents). Main sources of the description of the development were the GEA study (Group for Efficient Appliances (GEA) 1995),the preparatory study on domestic dishwashers and washing machines (in the following: "Lot 14") of 2007 (ENEA/ISIS 2007b) and new information based on the internet, stakeholder feedback and scientific publications.
Table 4.3 provides an overview of the technologies discussed in this section

Table 4.3: Overview of the area of improvement and technologies that can be implemented in a dishwasher

Technology	**Previous and current state of the art**
Reduction of thermal losses	
Weight reduction of heated parts	Included in all models on the market in 2005. No further optimization possible
Reduced thermal bridging between inside and outside	Included in all models on the market in 2005. No further optimization possible
Heat exchanger (water buffering tank)	HE applied to approx. 15% of the market in 2005 and HE insulation was considered as BNAT due to space limitations. Technology no further developed
Cross flow heat exchanger (with storage tank)	BNAT in 2005
Heat pump system	BNAT in 2005 BNAT in 2015 working with new refrigerants such. R290 or R600a
Motor efficiency	
Dual speed motor (HPS system)	Included in all models in 2005
High efficiency motors	DC brushless motors reached 5% in 2005's market. In 2015, they are often applied in the medium to upper price segments appliances Brushless, permanent magnet synchronous DC motors (PMSM)

Technology	Previous and current state of the art
	applied to 30 to 40% of dishwashers in 2015's market
Time-temperature trade off	
Sensors	
Soil sensors	Applied to 40% of the models on the 2005's market.
Load sensors	Applied to 20% of the models on the market
	At least one sensor is applied in all the dishwashers on 2015's market
Reduction of water consumption	
Optimisation of the hydraulic system	Reduction of the size of the sump, reduction of the diameter of the pipes and the spray nozzles, alternating spraying of water and differentiation of the water levels were fully applied on the 2005's market No further optimization is possible
Partly draining and re-filling (of water):	applied to approx. 20% of the models on the 2005's market not possible to apply under standard conditions
Alternative heating systems	
Hot fill	BNAT in 2005
Heat-fed machines	No market data
Drying phase	
Water tank, condenser for drying	Applied to approx. 25% of the models on the 2005's market
Condenser plus fan for drying	Applied to approx. 25% of the models on the 2005's market In 2015, more elaborated drying systems exist
Zeolith drying technology	Technology patent by BHS
Noise level	
Hygiene options	
UV radiation	Applied by only one producer in 2005 No further developed
Increased temperature of the last rinse	Applied to 20% on the 2005's market. Applied to >20% on the 2015's market
Resources	
Smart appliances	
Internet connectivity	BNAT on the 2005'smarket (0.1%) Still not many appliances are equipped with this feature on 2015's market.
Smart grid ready	No market data
Others	
Direct heating of the load	BNAT on the 2005'smarket No further developed
Optimized regeneration of the softener	Fully applied on 2005's market
Water wall	Introduced by Samsung in 2014
Delay start	Applied to 30% of the models on the 2005's market. Fully applied on 2015's market
Electronic update of the programme	Applied to 20% on the 2005's market Largely applied on 2015's market

Technology	Previous and current state of the art
Voice controlled appliances	*BNAT* on the 2005's market No data on 2015's market
Direct feedback mechanism on presume consumption	Only offered by Miele in 2015's market

4.1.4.1 Reduction of thermal losses

During a dishwashing cycle a part of the energy used for heating up the water and the dishes is also needed to heat up parts of the appliance. This heat is lost by radiation to the environment or is finally lost by draining the heated water without recovering the contained heat. The exact shares for each of these aspects obviously depends on the amount and type of materials used in the machine, the amount and type of load (e.g. plastic items have a lower heat capacity as porcelain or crockery), the reached temperature, etc.. However, there is estimation in the literature indicating the improvement potential of this area. The GEA study of 1995 lists that on average 28% of the input energy is used to heat up water, 25% is used to heat up the load and 37% is absorbed by the machine or dissipated via radiation and convection. According to stakeholder feedback from the questionnaire for dishwashers (JRC IPTS 2015a), the "1/3-rule" can be used as a first estimation, i.e. that one third of the energy consumption is used for heating up the appliance itself, the second third is used to heat up the loaded mass and the last third is used for heating up the water used for the programme.

Possible measures to reduce the thermal losses are:

4.1.4.1.1 Weight reduction of heated parts

The GEA study proposed a 5% reduction of the weight of the heated parts of the appliance as improvement option which would lead to a reduction of the electricity consumption of about 20 Wh (at a final temperature of 65°C). Lot 14 assumed that this improvement option has been implemented to all dishwasher models on the market in 2005. It is assumed that no further optimisation is possible.

4.1.4.1.2 Reduced thermal bridging between inside and outside

A lower thermal loss can also be obtained through an improvement of the thermal bridging effect of inner and outer casing (e.g. through eliminating some of the steel flanges surrounding the inner casing or by using insulating material securing the outside shell from the inside. This option was already proposed in the GEA study and Lot 14 assumed that it has been implemented to all dishwasher models on the market in 2005. It is assumed that no further optimisation is possible.

4.1.4.1.3 Heat exchanger (water buffering tank)

To reduce the amount of heat drained after the main wash phase a water storage tank can be installed in the dishwasher. This tank is filled with fresh tab water after the main wash phase. Due to the temperature difference the cold water is pre-heated until the temperature difference is reduced to a point where no heat transfer is possible anymore. Thus the fresh water for the intermediate cold rinse is pre-heated through some of the heat of the main wash phase and less heat is drained with the waste water of the main wash phase. The crockery is then not as much cooled down during the intermediate cold rinse and subsequently less energy is needed to heat the crockery during the final rinse phase. In Lot 14 the saving potential of this improvement option was quantified to be 30 Wh per cycle. It was then considered as applied to approximately 15% of the models on the market.

The insulation of the water tank was in Lot 14 considered as an improvement of this option, i.e. this would make it possible to preserve the heat of the water of the hot rinse phase for the subsequent dishwashing cycle. This option was considered as not being feasible due to the long intervals between two dishwashing cycles in households (hygienic problems, decrease of water temperature to ambient temperature). However it was considered as *BNAT*. Today it can be assumed that other developments (e.g. heat pump, zeolith drying system, see below) are more promising approaches to reduce the heat loss in the end of the dishwashing cycle.

4.1.4.1.4 Cross flow heat exchanger (with storage tank)

This option is another way to recover heat from the waste water stream and can be seen as improvement to the previous option (water tank heat exchanger). The waste water and the fresh water are passed through a cross flow heat exchanger. The fresh water flows to a buffer tank to prevent mixing of fresh and waste water in the machine. It is essential that the waste and fresh water flow in opposite directions thus theoretically all energy from the waste water can be recovered. This option is not applicable to machines of 9 ps due to the lack of space. See also (Paepe et al. 2003). This option was already mentioned in the GEA study and Lot 14, however still not applied to any machine on the market. One reason for this could be that with lowering the temperature of the main wash phase the saving potential was decreasing over time.

4.1.4.1.5 Heat pump system

Through heat-pumps it is possible to (partly) replace the electric energy usually used to heat the dishwasher cabinet, dishes and water. Measurements and simulations by (Bengtsson et al. 2015) showed that the electricity consumption can be reduced by 24% through the use of a heat pump.

V-ZUG already introduced a dishwasher to the market with a heat pump. (V-ZUG Heat Pump 2014) This dishwasher uses 8.7 litres of water and 0.49 kWh of electricity in the standard programme (13 ps). (V-ZUG 2014; V-ZUG Website n.d.) The following table compares the data of the dishwasher with heat pump (Adora SL WP) with the equivalent dishwasher without heat pump (Adora SL).

Table 4.4: Comparison of A+++ dishwashers with and without heat pump; (V-ZUG 2015; V-ZUG Website n.d.)

	Adora SL WP	Adora SL
Energy Efficiency Class	A+++ (-40% of the current threshold)	A+++
Capacity (in ps)	13	13
Annual energy consumption (in kWh/annum)	137	196
Annual water consumption (in L/annum)	2,445	1,820
Noise level (in dB)	44	40
Price (in CHF)	5,140	3,700
Relative price increase to next “lower” model	39%	25%

A possible environmental drawback of this technology is the refrigerant used in the heat pump. Currently the most used refrigerant in heat pumps is R134a (tetrafluoroethane), which is also mentioned by (Bengtsson et al. 2015) and used in the heat pump dishwasher by V-ZUG. The necessary amount of this refrigerant is approximately 150 to 200 g. R134a however has a very high specific global warming potential of 1,430 kg CO_2e / kg which could be released in the end-of-life phase if the dishwasher if it is

not properly collected and/or de-polluted (cf. sections 1.3.3.2). Table 4.5 shows the global warming potential of the refrigerant per appliance.

Table 4.5: Global warming potential (GWP) of refrigerant used in heat pump dishwasher

	Used amount per dishwasher	Specific Global Warming Potential R134a	Total GWP in case of 100% loss per dishwasher
R134a (Tetrafluoroethane)	0,150 kg 0,200 kg	1,430 kg CO_2e / kg	215 kg CO_2e 286 kg CO_2e

In principle also other refrigerants are possible (e.g. R290 (propane) or R600a (isobutane)) with much lower specific global warming potential. However this technology is currently not implemented.

4.1.4.2 Motor efficiency

The motor is the second most important component with regard to the energy consumption of a dishwasher (after the heating element). A dishwasher is equipped with two pumps with motors, the recirculation pump and the drain pump. The energy consumption of the drain pump is negligible due to the very short running time. Therefore only the efficiency of the recirculation pump is considered.

The recirculation pump is responsible for spreading the water via spray arms over the soiled dishes during the cleaning process. Depending on the chosen programme (e.g. intensive programmes for pots or special glass wash programmes on the other hand), the motor has to realise different spray powers. According to stakeholder information (personal communication), the peak power input of dishwashers is lower compared to the motor power of washing machines and washer-dryers; however, the continuous base load is comparable (around 50 W to 150 W).
In the GEA study of 1995 a motor efficiency of 20% was assumed as base case (i.e. only 20% of the motor energy consumption is used to transport water, the rest dissipates) with a possible improvement of 10% (resulting in a motor efficiency of 30%). According to Lot 14 this improvement was already applied to all models on the market in 2005.

4.1.4.2.1 Dual speed motor (HPS system)

Dual speed motors were considered as not leading to the claimed savings in the normal cycle but as possibly usable for more intensive cycles. According to (Walkden 2012) the desire for a variable speed comes from the desire for a variable pressure water supply provided by the pump motor. Varying the speed of the pump is an easy way to achieve this. With a single pump pressure, the cleaning effect is a compromise between delicate objects which can be damaged by high pressure and cooking utensils which require a high pressure to be cleaned properly. The result is often broken delicate crockery and unclean pots and pans. With a variable speed pump, different dishwashing programs can be chosen allowing fine delicate china or even crystal to be cleaned by the same dishwasher that can effectively clean the toughest cooking pans. It also allows shorter cycles by using higher pump speeds and quieter modes by operating at slower pump speeds for longer cycles. By controlling the acceleration as well as the speed, the rate of increase in water pressure can be controlled. With the direct current (DC) motor having a built in motor controller to allow the motor to have a soft start, multiple speeds, smooth ramping between speeds and load control, this allows for an energy efficient system and noise prevention

4.1.4.2.2 High efficiency motors

In household appliances such as dishwashers, different types of motors are applied.

- Initially, universal motors (commutator motors) with brushes were common. They can be operated at direct current (DC) as well as alternating current (AC); driven through pulse width modulation, they are also called PWM motors. According to stakeholder information (personal communication), their efficiency is low (up to 50%), they are prone to wear and noisier compared to other motors. They are still used in the low-price segment.
- DC brushless motors were in Lot 14 considered as applied to approximately 5% of the models on the market (after entry into the market in 2003). Today, in the medium to upper price segments of household appliances, brushless, inverter driven asynchronous DC motors are often applied. With about 50-60% their efficiency is higher compared to universal motors. They are also more reliable and more silent due to absence of brushes and commutator.
- Brushless, permanent magnet synchronous DC motors (PMSM) have found application where compactness (lower volume and weight compared to the above motors), high torque per unit volume, better dynamic response (due to the low inertia of the rotor), reliability (no brushes), low-noise machinery and high efficiency are primary requirements. The lifetime of both brushless asynchronous inverter driven motors and permanent magnet synchronous motors is similar and being higher compared to universal motors with brushes as only the bearings are prone to wear. According to stakeholder information (personal communication), the motor efficiency of PMSM motors is high, between 65% and 80% depending on the operational mode. They are also smaller and lighter (around 3.5 kg compared to 6.5 kg for asynchronous inverter driven motors). According to estimation of one stakeholder (personal communication), around 30 to 40% of dishwashers might be equipped with PMSM motors.

Permanent magnets contain rare earth elements (REE) which are identified as critical raw materials. According to (Dalhammar et al. 2014), the employment of REEs substantially contributes to achieving better energy efficiency in PM motors. The production of these magnets commonly entails the use of power metals of REE, which are classified as chemicals under REACH, such as Dysprosium (Dy), which is a less abundant heavy REE, and Neodymium (Nd), and Praseodymium (Pr), light rare earths, whereby Pr can substitute Nd by up to 6% in these magnets. Dy is used to keep the magnetic properties of Nd at high temperatures.
(Dalhammar et al. 2014) assume that the potential in terms of the improved energy efficiency level which can be attained by PM motors means that their market share is expected to increase with further commercialization, resulting in increased supply, and a price decrease for such motors.

4.1.4.3 Time-temperature trade off

Lower wash temperatures lead to lower energy consumption for heating. However, in accordance to the Sinner Circle, this has to be compensated by another factor. The limit to increase the mechanical action is the power achieved by the water jets and the delicateness of the crockery and the chemistry cannot be influenced easily by the appliance manufacturers. Thus the main factor that compensates lower wash temperatures is the time, i.e. the dishwashing cycles became ever longer during the past decades.

Lot 14 describes a development of the temperature of the main wash phase of dishwashers that initially (i.e. until the mid 1990ies) started at 65°C.
According to Lot 14 the wash temperature of 55°C, introduced in the GEA study as improvement option as opposed to the base case of 65°C, was already outdated in 2005 as manufacturers already moved to even lower wash temperatures.
By then a wash temperature of 50°C with further prolonged cycle time was considered as (still) applied to approximately 30% of the models on the market. For the remaining 70% an even lower wash temperature of 45°C was assumed. Problems with cleaning efficiency were reported due to the detergents that did not work well at temperatures below 50°C, especially on specific "difficult" stains like tea and coffee.
In Lot 14 even a wash temperature as low as 40°C seemed possible due to a newly introduced detergent (introduced in 2006 by Henkel) that was supposed to effectively clean dishes even at 40°C.

The temperature of the final hot rinse phase was in 2007 still at 65°C, independently from the temperature of the previous main wash phase. Besides hygienic reasons, the high hot rinse temperature had the main purpose to heat up the crockery to enable their subsequent drying (the remaining water is evaporated by the energy contained in the dishes). A hot rinse at (only) 55°C was seen as improvement option (by then as BNAT), however it was supposed that it might cause problems with drying and manufacturers considered it critical, both because of drying issues and hygiene aspects.

Even though in Lot 14 a temperature in the cleaning phase of 50°C (the base case assumption) was considered as "still" applied to 30% of the models and a temperature of 45°C (improvement option) to 70% of the models in 2007, today the majority of the models still has a wash temperature in the standard programme ("eco") of or around 50°C. According to stakeholder information (personal communication), there are several factors explaining this at first sight contradictory finding. First, the cleaning performance is always better (in a given time) at higher temperatures. Secondly there was a reasonable technological development in the area of drying of the dishes (see section 4.1.4.7). Through these developments the dishes dry (in a reasonable time) also without such high temperatures during the hot rinse phase which results in a lower energy demand for this phase. This reduction in energy demand reduced the pressure on temperature reductions during the main cleaning phase with regard to the thresholds of the energy label. Another advantage of reducing the temperature of the hot rinse instead of that of the main cleaning phase is that some of the heat can be transferred from the main cleaning to the hot rinse phase and thus is re-used during the cycle. The latter possibility is of course reached much easier with today's low water consumption (in average some 10 litres for the whole cycle, i.e. only around 3 to 4 litres for each water intake) – the smaller the amount of fresh cold water the less are the dishes cooled down.

The exact time-temperature management of today's dishwashers depends on the applied drying technology. E.g. zeolith® dishwashers are usually not heated during the hot rinse phase at all and dishwashers with automatic opening do not need as high temperatures during hot rinse as dishwashers without this option. This results in certain differences in the reached temperatures in the cleaning and hot rinse phase between the models on the market depending on the applied drying technology. This makes it difficult to determine a certain temperature profile as "base case" and lower temperature as "improvement option".

4.1.4.4 Sensors

By the use of sensors several aspects of a dishwashing cycle can be optimised.
Both an improved accuracy of the water level and of the temperature in the main wash and hot rinse phase due to more accurate electronic sensors was already in Lot 14 considered as applied to all models on the market.
Further sensors are electronic sensors for the detection of the actual soiling and for the detection of the load weight.

- Soil sensors detect the actual load soiling and consequently adjust the programme characteristics. It is supposed that this option leads to savings proportional to the soil reduction (i.e. therefore only relevant under real-life conditions). In Lot 14 it was considered as applied to 40% of the models on the market.
- Load sensors detect the actual weight of the load and consequently adjust the programme characteristics. This option is only of advantage if the dishwasher is not fully loaded (i.e. therefore only relevant under real life conditions). In Lot 14 it was considered as applied to 20% of the models on the market.

Both possibilities only adapt the programme characteristics under real-life conditions. They do not have an influence on the parameters under standard conditions as this is measured and tested with standard

soiling and full load only. It can be assumed that at least one of these sensor types is applied in all dishwasher models on the market today as they are necessary to adapt the programme characteristics in the automatic programme.

4.1.4.5 Reduction of water consumption

A reduction of the water consumption partly leads to lower energy consumption as less water has to be heated. There are three main possibilities to save water:

4.1.4.5.1 Optimisation of the hydraulic system

This possibility means to reduce the amount of water necessary during the different phases of the dishwashing cycle. It has to be considered, that a certain water pressure during water circulation is necessary for a proper functioning of the spray arms and cleaning of the dishes. Thus with a given system, the reduction of the water consumption is limited. Developments to reduce the amount of water while maintaining the pressure were e.g. the reduction of the size of the sump, reduction of the diameter of the pipes and the spray nozzles, alternating spraying of water (if the spray arms are used alternatingly the amount of water needed to maintain the necessary water pressure can be reduced), differentiation of the water levels (i.e. reduction of the water flow in certain phases of the cycle).
Some of these developments were already fully applied to the models on the market before 2005 (see Lot 14). It can be assumed that today the hydraulic system is fully optimised in all models on the market.

4.1.4.5.2 Partly draining and re-filling (of water)

There is the possibility to only partly drain the (dirty) water of the main wash or intermediate rinse phase thus also only draining part of the contained heat and to re-fill the machine with the same amount of fresh water. This is facilitated with better filter systems where the soil particles are collected directly at the drain. Thus only part of the water with the most soil can be drained and the missing water refilled. It was in Lot 14 considered as applied to approximately 20% of the models on the market. According to stakeholder information (personal communication) this option is not possible under standard conditions as the water level not to be drained is very low with regard to the standard soiling. It might be applied in programmes for light soiled crockery.

4.1.4.5.3 Avoidance of certain phases of the programme

- Avoidance/reduction of the cold pre-rinse: even though this option might cause drawbacks of cleaning performance, in Lot 14 it was considered as applied to 40% of the models on the market. This option does not lead to energy savings as the water is not heated.
- Avoidance/reduction of the intermediate cold rinse was expected in Lot 14 to disappear soon from the market due to problems of re-deposition of soil. It is supposed that today all dishwashers have an intermediate cold rinse phase.
- (Partly) reuse of last rinsing water: this option was critically discussed in Lot 14 due to the very low water consumption of dishwashers, even though the last rinsing water was supposed to be too dirty to be stored for many hours without hygiene problems. Also it usually has no effect on the energy demand as the heat contained in the waste water would dissipate until the next dishwashing cycle. No machines were equipped with this option in 2007 but it was considered as a BNAT for the future. Today, BSH offers dishwashers with a so called resource-saving water management, where the water of the last rinse is stored and used for the pre-rinse of the following dishwashing cycle. The water consumption is lowered to 6 litres per dishwashing cycle. However, hygiene aspects have to be considered as the stored water does not have drinking water quality. The hygiene aspect becomes more important nowadays because of very low water

consumption during the wash and rinse phases (possibly leading to dirtier water) and the very low temperatures of the programmes (leading to rather low micro-organism reduction levels).

4.1.4.6 Alternative heating systems

Most dishwashers have integrated electric resistance heating elements to heat up the water, the crockery and the machine. There are two possibilities to replace (part of) the electric energy needed by the dishwasher by energy generated outside of the appliance.

4.1.4.6.1 Hot fill

In principle it is possible to connect all dishwashers to a hot water line, as studies by (Bush & Nipkow 2005), (Gensch et al. 2009) and (Saker et al. 2015) show. In cases where / under the assumption that the hot water delivery of the dwelling is more energy efficient than the heating of water within the machines using electricity. This measure could result in certain energy savings. However, there are few scientific studies assessing these savings on a quantitative basis. While (Saker et al. 2015) consider both dishwashers and washing machines equipped with an additional hot-fill connection, (Gensch et al. 2009) focus on several types of dishwashers only, one of them specifically designed for hot-water filling. However, it must be taken into account that both studies only focus on energy efficiency and GHG emissions, whereas for example (life cycle) costs have not been taken into consideration.

The authors of both studies conclude that the potential benefits of hot filling appliances depend on the specific site conditions and parameters, like the length and the insulation of the hot water pipe, efficiency and control characteristics of the circulation pump, water heating sources (e.g. gas boiler, off-peak electric, solar combined with gas or electric). (Gensch et al. 2009) additionally point out that the savings depend on the dishwasher technology: for example, when using dishwashers with Zeolith® drying technology or with (water tank) condenser for drying, the savings through using hot filling are less compared to the savings of other types of dishwashers. Also the quite low water consumption of current dishwashers reduce the saving potential: today in general only 6 to 7 litres of water are heated at all (split in two take-ins), the amount of water taken in at the same time is between 3 and 4 litres. This means the length between the hot water generation/circulation pipe and the dishwasher needs to be very short. Otherwise the losses due to the hot water remaining in the tubes and cooling down outweigh the benefits from the alternative heating system.

Aside from such details, both studies conclude that the additional connection of a hot water feed to dishwashers or washing machines can help to reduce household GHG emissions, and provide the possibility to reduce and shift electricity demand. (Saker et al. 2015) concluded that the magnitude of electricity savings was higher for dishwashers compared to washing machines due to the following reason: for washing machines, (Saker et al. 2015) recorded an overall high share (80% of washes) of washing programmes at 30°or 40°C, resulting that not so much electric heating could be replaced. On the other hand, in the case of dishwashers, the users regarded in that study preferred to operate the appliances at 60°C or above, i.e. much more heating could be replaced.

(Gensch et al. 2009) and (Saker et al. 2015) coincide in the result that solar hot water combined with gas heating for hot water supply is the option resulting in the lowest GHG emissions for hot water generation and consequently for dishwashers using the hot fill options (if site conditions and parameters are beneficial).

4.1.4.6.2 Heating by hot water circulation loop (“heat-fed machines”)

This option describes the possibility to replace the electric heating elements with a hot water circulation loop using a heat exchanger to transfer the heat from the hot water to the machines. This means in contrast to the “hot fill” option, the dishwashers itself is connected to cold water which is then heated NOT by an electric resistance heater but by a hot water heat exchanger. The hot water heat exchanger is fed by the hot water generated by the hot water delivery of the dwelling (central or district heating).

The advantage of this option compared to the hot fill option is that not only the heating of the water can be replaced (which according to stakeholder information accounts for approximately 1/3 of the heating energy consumed by a dishwasher) but also the heating of the machine itself and the crockery.
The saving potential depends on the temperature of the hot water. With a hot water temperature of 70°C the whole electricity demand for heating can be replaced by the heat from the hot water circulation loop, i.e. the electricity demand can be reduced to about 0.13 kWh. (Persson 2007)

4.1.4.7 Drying phase

The basic principle of the drying of the dishes is that the dishes are heated in the final hot rinse phase up to a certain temperature (which today might vary depending on the drying technology). After the draining of the water of the final rinse the water of the dishes evaporates and condensates on the cold inner walls of the cabinet. While in the beginning most dishwashers had a heated drying phase, i.e. also during the drying phase the dishes were heated to improve evaporation, already during the 1990s a lot of dishwashers did not feature such a heated drying phase anymore (Group for Efficient Appliances (GEA) 1995). This led to a reduction in energy saving of 40 Wh/cycle. Obviously, for a sufficient drying performance additional heating was not necessary with a hot rinse phase of 65°C. Drying time was however increased. To shorten the drying time both GEA and Lot 14 describe two possibilities:

4.1.4.7.1 (Water tank) condenser for drying

After the hot rinse phase a water storage tank bordering the tub is filled with cold water. This fosters the condensation of the hot vapour and thus the drying of the dishes. The condensed water flows off the cold tub wall in the drain. In Lot 14 it was considered as applied to approximately 25% of the models on the market.

4.1.4.7.2 Condenser plus fan for drying

The condenser is equipped with an additional fan to generate an air flow that can be either conducted along a condenser or out of the appliance. An additional energy consumption of 4 Wh for the fan is assumed. It was in Lot 14 considered as applied to approximately 25% of the models on the market.

Today, more elaborated drying systems exist that reduce the energy needed for the hot rinse while keeping a sufficient drying performance:

4.1.4.7.3 Automatic door opening system

This technology serves to improve the drying efficiency by opening the door of the dishwasher at the end of the programme. The humid air escapes from the dishwasher and the crockery dries more quickly. In relation to the standard drying process the technology is also slightly more energy efficient as the temperature during the final rinsing can be lower, thus heating energy is saved. In case of built-in or under-counter appliances special care has to be taken to avoid damaging of the furniture through the escaping steam. Miele for example avoids damaging of the surrounding furniture (especially the countertop) through the humidity by generating a separate air stream to preheat the surface of the furniture (thus less humidity condenses on the surface) and to faster dry the remaining humidity.

Several manufacturers already use this option (e.g. Auto-open® patented by Miele, "Automatic door-opener" by VZUG).

One stakeholder mentioned in the feedback from the questionnaire for dishwashers (JRC IPTS 2015a) that a possible drawback of the technology could be that small children might get easy access to knives or other possibly dangerous items inside the dishwasher. However this could probably easily be overcome by providing a sort of 2nd lock. The cost increase is comparably low.

4.1.4.7.4 Zeolith® drying technology

About 1 to 1.5 kg of zeolite, a natural moisture-absorbing mineral, is used in the bottom of the dishwasher to adsorb water molecules during the drying process. When water is adsorbed the zeolite heats up as the adsorption process is an exothermic process which helps evaporating the water from the dishes. The zeolite is regenerated (i.e. desorption of the moisture) at the beginning of the next dishwashing cycle by heating it up. In that phase additional energy is needed. The adsorption energy released during the drying phase and the energy needed for desorption is the same. The energy saving is mainly due to the recuperation of the condensing heat of the steam (i.e. the heat released by condensation of vapour) during the drying process which is lost as waste heat in conventional dishwashers. The technology is patented by BSH and is supposed to lead to energy savings of about 20% compared to similar devices without this technology.

4.1.4.8 Noise level

Noise reduction is increasingly important due to open kitchens, i.e. kitchens that are directly integrated in the dining and/or living room. Lower noise emissions can be achieved through various means, e.g. better insulation, optimisation of the hydraulic system (direction and pressure of the water jet), dampers for the tub and the pumps, motor placing on insulated supports, high efficient brushless motors etc. However, an increased insulation might increase the machine weight and thus the energy consumption (more energy is needed to heat up the respective machine parts).
Lot 14 distinguishes 3 noise levels:

- Noise reduction, level 1: 50 dB(A) was in Lot 14 applied to the base cases.
- Noise reduction, level 2: 44 dB(A)): It was in Lot 14 considered as applied to 20% of the models on the market.
- Noise reduction, level 3: 41 dB(A): It was in Lot 14 considered as the lowest noise level available on the market in some models, applied to 5% of the models on the market.

It is supposed that today the basic noise level is lower (around 48 dB(A)) and the number of models on the market with better noise reduction levels (i.e. lower noise emissions) is higher.

4.1.4.9 Hygiene options

The hygiene aspect gets increasingly important especially due to lower cleaning and rinsing temperatures. The demand of more hygiene however may also be created by advertising of corresponding products (e.g. “hygiene plus option” in dishwashers, disinfecting cleaning agents and detergents, cold appliances with silver coating, etc.). Thus this development is not purely “consumer driven” but also a result of technological developments and marketing focus.

The following developments are seen in this area:

- UV radiation after the increase of the temperature of the last rinse to high temperature: this option was described in Lot 14. The UV radiation was supposed to be applied by only one manufacturer but its effectiveness was doubted by other manufacturers. Therefore it was not further considered in Lot 14.
- Manufacturers increasingly offer special “hygiene” options. If this option is activated the temperatures reached during the dishwashing cycle are much higher (between 60 and 70°C) than in the standard programme and held over a certain time period thus leading to an increase of the energy demand. In Lot 14 an increased temperature of the last rinse was supposed to be applied to 20% of the models on the market. It is supposed that today the availability of such a “programme option” is higher than 20%.

4.1.4.10 Resources related aspects (other than water and energy)

4.1.4.10.1 Use of recycled plastic

In its Sustainability Report 2013, Indesit Company informs that it has developed technological solutions and recycled materials or biopolymers or materials from renewable sources that can potentially reduce amounts of bitumen dampening material, soundproofing felts and, in certain models, also eliminate metal side panels and reinforced concrete counterweights. Over and above the obvious benefits in terms of energy savings for the industrial process (elimination of gluing in "hot melt" ovens) and the thermodynamic and acoustic performance of the product, the achievement of such objectives makes it possible to significantly increase the use of recycled materials (currently only 3% of the total) and facilitates dismantling at the end of the product's life (as well as improving the quality of the recovered materials). The project aims to limit, eliminate or replace certain materials habitually used in home appliances and in particular direct oil derivatives in dishwashers. (Indensit Company 2014)

Sharp and Kansai Recycling Systems Co. Ltd. jointly developed a closed-loop plastic material recycling technology that repeatedly recovers plastic from used consumer electronics and reuses it in parts of new consumer electronics for the Japanese market. This technology has been in practical use since 2001. By combining a high-efficiency metal removal line, high-purity polypropylene (PP) separation and recovery technology, and other property improvement/quality control technologies, Sharp has been able to recover recyclable plastic, as well as to find applications for its use, such as in the exterior panels of home appliances and as flame-retardant materials. Because recycled plastic can be reused numerous times, the practice has been adopted for use inter alia in washing machines (base frame and washing tub), and other similar home appliances sold within Japan which are subject to the Home Appliance Recycling Law. (Sharp 2012)

According to the study "Material recycling without hazardous substances – experiences and future outlook of ten manufacturers of consumer products" of the Swedish Chemicals Agency cited in (Dalhammar et al. 2014), the main barriers for increased use of recycled materials include risk of contamination, costs associated with avoidance of such risks, and limited availability. Verification by market surveillance authorities could be an issue as well. For some recycled materials, most notably plastics, it is difficult to find material that complies with quality requirements. The companies interviewed in the study see future opportunities in overcoming the barriers: increased use of recycled materials depends on the development of cleaner material streams, which require cleaner input materials, development of better separation/cleaning technologies, and standards for recycled materials.

4.1.4.10.2 Automatic Detergent Dosage for dishwashers

While common for professional dishwashers, an automatic detergent dosage system for household dishwashers is not applied in the market yet. In this design option, the detergent is dosed automatically by the appliance from a pre-filled multi-dose reservoir. The amount of detergent can thus be adjusted to the load and the level of dirtiness leading to correct dosage (to avoid over or under dosage). This option would lead to savings only under real-life conditions, as the standard programme is tested and measured under fixed load and dosage of the detergent. Under real life conditions however both the load and the soiling is often lower than under standard conditions and users mainly use tablets. With tablets it is not possible to adapt the amount of detergent according load and soiling.

Moreover, according to one stakeholder feedback from the questionnaire for dishwashers (JRC IPTS 2015a) this option would highly increase the cost of the appliance and should be developed in dialogue with the detergent sector in order to optimise the adjustment between appliance and the detergent.

4.1.4.11 Smart appliances

4.1.4.11.1 Internet connectivity

This option is offered for some high end models. It offers various functions to the user, e.g. to connect different household appliances with each other (like hobs and kitchen hood). It also allows displaying the status information of connected appliances on a central display located on one of the appliances, e.g. the

oven in the kitchen. Furthermore with a central gateway the user can remote control and manage the appliances with a PC via the internet or with a mobile phone, e.g. start or stop certain programmes or functions. The appliances are also able to communicate with a customer service unit of the manufacturer. There is no direct energy or water saving. With regard to low power modes Ecodesign Regulation 801/2013 on networked standby applies to this type of appliances (see section 1.2.1.1)

It was in Lot 14 considered as applied to none or only few (0.1%) models on the market and as a BNAT. Still not many appliances are equipped with this feature.

4.1.4.11.2 Smart grid ready (SG ready)

Some "smart" appliances, i.e. appliances with internet connectivity, also offer the possibility to communicate with the electricity grid enabling the integration of renewable energy via load shifting. (Vanthournout et al. 2015)

The vision of such smart appliance operation is that they autonomously start operation according to signals from the grid regarding the availability of electric energy within a consumer-defined time range. Thus electricity use can be shifted according to availability. Also signals from a local PV system can be received to adjust the starting time according to the availability of local electricity. There are no direct water or energy savings but rather changes in the time when electricity is used optimizing the use of the renewable energy sources. Besides a smart-grid ready appliance the consumers need a communication module (to be installed at the appliance) and a central gateway. The communication module communicates via powerline communication with the central gateway.

Although currently certain models of household appliances, also dishwashers, are equipped with this feature, so far this option cannot be used in practice as other prerequisites have to be ready as well, like smart meters and a flexible electricity tariff that communicates directly with the gateway. According to stakeholders a possible drawback could be negative effects on the performance parameters of the appliance (e.g. cleaning efficiency, energy demand, drying efficiency) if the dishwashing cycle is interrupted intermediately by signals from the smart grid (e.g. additional heating energy might be necessary if the cycle was interrupted and the water temperature dropped).

See also sections 1.2.1.1 and 1.2.2.6.

4.1.4.12 Others

4.1.4.12.1 Direct heating of the load (avoid last hot rinse)

This option means that the last rinse is performed without additional heating, i.e. with cold water. Instead the load is heated up directly to 65°C after the last rinse water has been drained. Thus only the dishes and not the rinse water would need to be heated.

This option was mentioned in the GEA study as long term option and described in Lot 14. In 2007 still no suitable technology was available to heat the dishes without water. It was however addressed as *BNAT*.

From a today's perspective it seems that manufacturers chose different ways of reducing the energy demand of the final hot rinse, e.g. reduced water demand of only 3 to 4 litres for the hot rinse and lower temperatures of the hot rinse phase due to improved drying technologies.

4.1.4.12.2 Optimized regeneration of softener

Through electronic sensors measuring the conductivity of the water the regeneration is only run when really necessary, leading to savings of water and regeneration salt. In Lot 14 it is supposed to be already applied to all models on the market.

4.1.4.12.3 "Water Wall"

Samsung introduced a new technology in 2014. Instead of rotating spray arms, Samsung introduced a line of spray jets that move back and forth along the bottom of the tub (the so called water wall). It is not clear if the technology leads to savings in water or energy demand as the dishwasher equipped with this technology needs 10.7 litres of water and 0.937 kWh per dishwashing cycle (of 14 ps), resulting in energy efficiency class A++, which is not an outstanding low consumption.

4.1.4.12.4 Delay start

This option allows starting the dishwashing cycle after a certain number of hours (delay), leaving the machine loaded and ready for start. It does not have an influence on the water or energy consumption of the dishwashing cycle but allows running the machine during off-peak times with lower electricity costs. The 'delay start mode' however consumes a certain amount of power for the timer and respective electronic functions, which is not regulated by Regulation 1275/2008 for standby and off-mode, as 'delay start' is not defined as standby mode as not lasting for an indefinite time.

This option was in Lot 14 considered as applied to 30% of the models on the market. It is supposed that today more models are equipped with this feature as it improves the convenience for the user.

4.1.4.12.5 Electronic update of the programmes/diagnostics

An update of the dishwashing programmes can be done by connecting the appliance to an assistance PC. This option can also be used for machine diagnostics in case of failure. It allows for more efficient washing cycle management if external conditions change, however it has no immediate effect on water and energy consumption. In Lot 14 it was assumed that 20% of the models on the market have this option. It can be assumed that today the share is much higher.

4.1.4.12.6 Voice controlled appliances

In Lot 14 voice controlled appliances were considered as *BNAT*. However there is no effect on the water and energy consumption but rather an improved convenience for elderly or disabled users.

4.1.4.12.7 Direct feedback mechanism on presumed consumption

Miele offers machines that give a prognosis on the estimated energy and water demand of the chosen programme in advance via a TFT display. The user can directly see differences in the consumption values and might choose a more economic programme. After the cycle the exact consumption values are shown that might differ from the estimation due to the actual load and soiling. This option does not lead to direct savings in water and energy in the standard programmes but enables consumers to do informed choices and might enhance a more sustainable washing behaviour.

4.2 Production, distribution and end-of-life

4.2.1 Product weight and Bills-of-Materials (BOMs)

In general, large white goods, such as dishwashers, are composed of the following materials/metals (UNEP 2013):

- Metals (steel, copper, aluminium, stainless steel and their alloys).
- Diverse plastics and organic materials, including their additives, fillers, stabilizers, as well as rubber, wood, textile, fibres, etc.
- Inert materials, such as glass and concrete (incl. ferrite-containing concrete in washing machines).
- Low value printed wire boards (PWB) and electronics containing precious and platinum-group metals. PWBs are boards that have only copper connections and no embedded components. Printed circuit boards (PCB) is a term used for both bare and assembled boards.

Table 4.6 provides a first general average material composition of dishwashers based on 2011 data (UNEP 2013).

Table 4.6: Average composition of dishwashers; source: (UNEP 2013)

Dishwasher	Material (%)
Iron/Steel	45.2
Copper	1.5
Aluminium	0.8
Stainless steel	23.2
Brass	0.2
Plastics	12.6
Rubber	1.6
Wood	2.1
Other organic	5.3
Concrete	1.9
Other inert material	0.9
PWB	0.1
Cables (internal / external)	1.5
Other materials	3.2
Total	100

The Ecodesign Preparatory Study Lot 14 (ENEA/ISIS 2007c) used following average production input data for dishwasher models in 2007 (Table 4.7).

Table 4.7: Average production input data for 9 ps and 12 ps dishwasher models used by Lot 14 in 2007; source: (ENEA/ISIS 2007c)

PRODUCTION			
Materials type	**Material**	**DW 9 ps (g)**	**DW 12 ps (g)**
Ferrous metals	Galvanized steel	504	403
	Iron	2,136	2,303
	Prepainted Steel	1,941	1,269
	stainless steel	6,866	8,691
	Steel	1,828	6,536
	Steel strip	6,298	7,097
	Steel+PA	1,208	967
	Sum Ferrous metals	***20,781***	***27,266***
Non ferrous metals	Al	172	269
	Brass (Cu+Zn alloy)	--	23
	Cr	--	71
	Cu	398	656
	Zn	7	4
	Sum Non ferrous metals	***577***	***1,023***
Plastics	ABS	708	751
	EPDM - rubber	433	524
	EPS	88	40
	PA	172	399
	PBT polybutylene terephthalate	58	35
	PE	178	187
	Plastics, others	121	268
	PMMA	10	6
	POM	191	230
	PP	5,026	4,948
	PP volute	--	32
	PS	367	512
	PU Foam - Insulation	3	2
	PVC	--	184
	PVC (excl. wire insul.)	210	219
	Sum Plastics	***7,564***	***8,337***
Various	Adhesive	15	10
	Bitumen	5,043	6,089
	Concrete (9 ps) / Cement - Gravel (12 ps)	2,153	1,263
	Cotton	--	452
	Cotton+Resins noise absorbers	565	489
	Electronic, boards, switches, lamp, etc	694	448
	others	36	59
	paper	130	206
	Resins	200	120
	Thermostat	17	10
	Wiring	503	350
	Wood	1,928	2,034
	Sum Various	***11,284***	***11,530***
	Sum TOTAL	**41,160**	**50,699**

The following general variations might be observed at individual dishwasher models (for details on materials and weight, stakeholder information about current Bill of materials (BOM) of current dishwashers are needed; this will be discussed at the stakeholder meeting):

- If the machine is equipped with a permanent-magnet synchronous motor (PMSM, cf. section 4.1.4.2), the motor weight is reduced from around 6.5 kg to 3.5 kg; further there is presence of rare-earths in the permanent magnets, most likely the NdFeB-type. Rare earths like Neodymium

(used as NdFeB) or Samarium (used as SmCo) enhance the magnet field. Neodymium further stabilises magnets against demagnetisation due to mechanical shocks or other magnet fields. Dysprosium, for example, is added to get permanent magnets more heat resistant.

- The use of the zeolith® or similar heat storage technology requires additional materials, for the heat exchanger unit itself (zeolith or other appropriate material and metals for encapsulation) as well as for the air venting system (electric motor and fan impeller). Electric motor and fan impeller are also needed for dishwashers with drying through ventilation.
- Where heat pumps are being used additional components are required: copper pipes for the refrigerant circuit, a compressor system consisting of an electric motor and the compressor itself (mainly made of steel), heat-exchanger (commonly made of aluminium and copper) and electronics for the control unit. If the system works with latent heat storage, additional material is required.
- The use of automatic opening of the door at the end of the programme requires an electromagnet (consisting of copper wires and iron material), some mechanical elements (mainly steel) and electronics for the control unit.

According to (UNEP 2013), the composition of white goods strongly varies from product to product, and as they become 'greener' their resource efficiency increases. “Critical” materials are mainly found on Printed Wiring Boards PWBs. According to a study by UNU 2007 cited in (UNEP 2013), large white goods contain on average

- 20 ppm palladium (Pd),
- 160 ppm silver (Ag) and
- 38 ppm gold (Au).

Industry argues with the expectation that the base cases of Lot 14 will no longer be the same today, but ask to reuse the bill of materials of from the last study. If the base case changes, industry might be able to review the BOMs accordingly and might be able to share a new version at a later stage.

4.2.2 Assessment of the primary scrap production during sheet metal manufacturing

According to the EcoReport tool, the primary scrap production during sheet metal manufacturing is calculated as a percentage of the total sheet metal manufacturing value.
Deviating from the default value of 25% given in the EcoReport tool, the Ecodesign Preparatory Study Lot 14 (ENEA/ISIS 2007c) has chosen 5% as input for the sheet metal scrap during the manufacturing of dishwasher models in 2007 which leads to the following values in Table 4.8.

Table 4.8: Average input data for sheet metal scrap of dishwasher manufacturing used by Lot 14 in 2007; source: (ENEA/ISIS 2007c)

	Dishwasher 9 ps	Dishwasher 12 ps
Sheet metal manufacturing	22,013 g	29,867 g
Sheet metal scrap (5% of the sheet metal manufacturing)	1,101 g	1,493 g

4.2.3 Packaging materials

According to (WRAP [n.d.]a), different product packaging is possible: typically used across the industry is a mixture of cardboard and expanded polystyrene (EPS). The use of polyethylene (PE) foams instead of EPS could be considered as it will help with recyclability. If practical, the use of all corrugated carton board for packaging needs could also be considered. The corrugated carton board used for the caps could be

changed to use newer flute designs which provide the same strength but use less material and are therefore lighter.
The Ecodesign Preparatory Study Lot 14 (ENEA/ISIS 2007c) used following production input data for the packaging of dishwasher models in 2007:

Table 4.9: Average production input data for packaging of dishwasher models used by Lot 14 in 2007; source: (ENEA/ISIS 2007c)

PRODUCTION			
Materials type	Material	DW 9 ps (g)	DW 12 ps (g)
Packaging	Cardboard	123	632
	EPS	648	724
	Paper	5	3
	PE – foil	132	173
	Wood	47	1,011
Sum Packaging		*955*	*2,543*

4.2.4 Volume and weight of the packaged product

The Ecodesign Preparatory Study Lot 14 (ENEA/ISIS 2007c) used following input data for the volume and weight of the packaged dishwashers:

Table 4.10: Input data for volume and weight of packaged dishwashers used by Lot 14 in 2007; source: (ENEA/ISIS 2007c)

Model	Volume of final packaged product (m^3)	Weight of final packaged product (kg)
Dishwasher, 9 ps	0.303	41.16
Dishwasher, 12 ps	0.400	50.70

4.2.5 Actual means of transport employed in shipment of components, sub-assemblies and finished products

The EcoReport 2011 software tool uses an average mix of transport modes by type of product. If for the appliances in scope the real transport mix deviates substantially from the average transport mix, this can be corrected ex-post giving the industry sectors with an environmentally-friendly transport policy (local suppliers, ship instead of airplane) an option to take their effort into account.
Exemplary, BSH GmbH informs in their Group Sustainability Report 2013 about the share of transport means of exported appliances from Germany. In 2013, 33% of the total export transport volume was per rail, 40% per truck, 14% per short sea shipping (Europe) and 13% per general sea shipping. (BSH Bosch und Siemens Hausgeräte GmbH 2013)
The Ecodesign Preparatory Study Lot 14 (ENEA/ISIS 2007c) used following input data for the transport distance of dishwashers:

- Dishwasher, 9 ps model: average transport = 706 km
- Dishwasher, 12 ps model: average transport = 652 km

4.2.6 Technical product life (time-to-failure of critical parts)

4.2.6.1 Data on technical product lifetime of dishwashers

The Ecodesign Preparatory Study Lot 14 (ENEA/ISIS 2007c) used following input data for the product life of dishwashers:

- Dishwasher model with 9 ps: 12.5 years
- Dishwasher model with 12 ps: 12.5 years

(VHK 2014) studied the application of a newly developed accounting method to the existing Ecodesign preparatory studies and impact assessment (cf. section 2.2). These data were based on a product lifetime of 15 years for dishwashers, thus deviating from Lot 14 data in case of household dishwashers.
(Prakash et al. 2015) analysed various international literature with regard to the lifetime of dishwashers. The retrieved product life data vary between 9 and 15 years for dishwashers. The large variations are explained with different countries (Netherlands, Greece, UK, Canada) and years (2005-2014) of the analysed studies, as well as very different survey and calculation methods used (e.g. official statistics, consumer surveys, calculations based on sales data, surveys in households and electrical stores).
Further, (Prakash et al. 2015) analysed data of GfK for large household appliances in Germany with regard to the developments of the average "first useful service-life" (in section 3.2.1). The results show that the average life-span of large household appliances at all (covering washing machines, dryers, dishwashers, ovens, refrigerators and freezers) which had to be replaced due to a defect decreased from 2004 to 2012/2013 by one year and lies at 12.5 years in 2012/2013. On average, the product replacement of large household appliances due to a defect slightly decreased from 57.6% in 2004 to 55.6% in 2012. This means that a defect still is the main cause of the replacement. On the other hand, it is important to realise that almost one third of the replaced large household appliance was still functional.
Extracting the data specific for dishwashers, the results show that for appliances which were replaced due to a defect of the existing one, the first useful service-life was 12.3 years in 2004 and 12.5 years in 2012/2013.
According to (Prakash et al. 2015), the need for replacing devices being less than 5 years old due to a defect has increased. The proportion of dishwashers which had to be replaced within less than 5 years due to a defect rose from around 7% to 14% of all defective dishwasher replacements between 2004 and 2012.
According to stakeholder feedback via the questionnaire (JRC IPTS 2015a), one stakeholder provides results of a study from 2006 analysing what usually breaks in dishwashers (cf. also section 4.2.6). Following information is given regarding the age of the dishwasher when it broke the first time:

- 0-2 years: 16%
- 2-5 years: 21%
- 5-10 years: 29%
- > 10 years: 17%
- Don't know: 17%

Most errors occur after the two year warranty expired.
Another stakeholder informs that internal testing shall ensure a minimum lifetime of 10 years but there are also some appliances in households which are much older, i.e. exceed the lifetimes for which the appliances have been tested. During the development process all stages of the product life cycle are taken into consideration in order to maximise quality and durability. The after sales service is also involved to ensure good reparability of the appliance. The instruction for installation should be followed carefully, otherwise there might be problems (e.g. do not bend the inlet/outlet hose).The lifetime itself, independent from the product, is dependent of the use and maintenance of the appliance.

Extended warranty options vary across EU countries. For dishwashers, stakeholders provided following information via the questionnaire (JRC IPTS 2015a):

- Warranty by manufacturers is provided according to the national requirements; sometimes consumers can buy an extended warranty up to 5 years. Some features have a longer warranty, e.g. tub against corrosion: 10 years.
- Some retailers may offer extended warranties at the point of purchase, either free of charge – mostly proposed by a commercial action – or against a fee.

4.2.6.2 Common causes of breakdowns and product design with regard to durability and reparability

In the following, relevant studies and test reports with regard to typical defects and failures of household dishwashers have been analysed, also with regard to recommendations for proposed design improvements.

4.2.6.2.1 RReuse study

In 2013, RReuse conducted an investigation into some of the main obstacles its members encounter when repairing products (cf. section 3.2.2), The study revealed the following examples of common causes of break downs for household dishwashers (RReuse 2013):

- Motor break down: This is often caused by the use of low quality rolling element bearings instead of plain bearings. In addition, if there is water leakage from the seals of the water pump, the leakage causes oxidation, flooding and / or the activation of the security sensor, but also the eventual oxidation of the plain bearings.
- The pump can break down as water can leak from the pump seals due to low quality joints and / or their bedding.
- Timer break down: If the timer is mechanical, a breakdown is caused due to the wearing out of the cams and contacts. In case of an electronic timer, it is due to the breakdown of an individual component (not further specified in the study).
- Problems with the electronic board: These are often caused by the lack of current and voltage protectors that protect sensitive electronic components. Furthermore the electronic steering components linked to the timer can fail, which is an issue as it is increasingly difficult to identify the fault. These problems were not encountered in the past when the steering mechanisms were primarily mechanical.
- The hoses can become damaged because of excessive heat due to the proximity of the hoses to the resistor or because of the poor quality of the tubes used.

With regard to product design, (RReuse 2013) suggests following measures to help improve the reparability of dishwashers:

Design for disassembly for repair:

The product should be able to be disassembled non-destructively into individual components and parts without the need for special proprietary tools to do this. If special tools are required however, these must be readily and freely available to every repair shop (not just to the after sales service providers of the manufacturers). Design for better disassembly could include:

- Making the casing of the appliance in such a way that it can be easily and quickly opened, especially the bottom- would help facilitate easy access to the internal components.
- Designing the internal component structure in a way that would facilitate easy removal and separation of components would be very helpful e.g. the heating resistor should be easily accessible in order to be able to remove limescale.

- Regarding the motor, it should be able to be easily separated from the pump in order to change the damaged part whilst at the same time maintaining the operational part of the pump.

Potential standardisation of components:

- Electronic boards are very fragile and only a specific and identical component can be used as a replacement for a given make or model of a dishwasher. Standardisation of critical component design such as timers and electronic boards would help to enhance ease of replacement and thus repair.
- Better quality seals on the motor would make them last longer.

4.2.6.2.2 Stakeholder information

In March 2015, the Spanish consumer organisation OCU (www.ocu.org) published the results of a survey of more than 23.638 users (4.821 of which amongst its Spanish subscribers) aiming to discover what was their level of satisfaction with regards to domestic appliances such as washing machines, dishwashers and fridges. Aside from Spain, the survey also covered geographically Italy, Portugal and Belgium.
With regards to dishwashers, the most frequent breakdowns noticed concerned

- the drain pump (12%)
- the buttons and controls (11%),
- the drying function (9%), and
- the door (9%).

Another stakeholder informed via the questionnaire (JRC IPTS 2015a) about results of a study from 2006 that provide some information on what usually break in dishwashers. The parts that broke (number of answers in brackets):

- Circulation pump (37)
- Door spring (30)
- Programmer (28)
- Leakage (25)
- Inlet valve (21)
- Level switch (18)
- Circuit board (13)
- Edge at the door (12)
- Interior (12)
- Programme knob, on and off button (11)
- Rinse agent (11)
- Flood protection (11)
- Motor (10)
- Stop in the tube / hose problems (10)
- Detergent dispenser (7)
- Door switch / door lock (6)

The following parts had only 1-5 answers: sealing; pump; thermostat; sieve; heater; hinges to the door; lamp; spray arm; touch buttons.

A stakeholder commented via the sent-out questionnaire (JRC IPTS 2015a) that any list of components that would be developed needs to be justified and supported by robust quantitative and qualitative data, in a clear and transparent way. Assessments should be empirically and scientifically based. A focus on components that are crucial for the correct functioning of appliances is fundamental, i.e. if that component breaks down, the appliance cannot be longer used for the main functions of use for which it was intended. There should therefore be a clear differentiation of a component that is critical to the main functions versus the auxiliary functions of the product.

4.2.7 Materials flow and collection effort at end-of-life (secondary waste), to landfill/ incineration/ recycling/ re-use

The following sections provide an overview of European end-of-life management paths of household dishwashers.

4.2.7.1 Collection rates

Dishwashers are classified under category 1 "Large household appliances" of the WEEE-Directive 2012/19/EU (cf. section 1.3.1.2). From 15th August 2018 on, new WEEE categories will be imposed in the EU. Within this categorisation, most dishwashers will fall under the new category 4 (large equipment – any external dimension more than 50 cm). However, devices using refrigerants, such as the dishwashers equipped with a heat pump, or any other fluids other than water for heat exchange will fall under category 1 (temperature exchange equipment).

In any case, this means that special collection and management systems for end-of-life dishwashers are in place within the EU.

Generally, the current category 1 equipment (large household appliances) is, on a weight base, the most significant WEEE-category and makes up 49 % of the EEE put onto the EU-market and 43 % of the WEEE collected in the EU in 2010 (Eurostat 2013). Cited feedback of one stakeholder via the questionnaire (JRC IPTS 2015a) confirms

> "*that the collection rate (waste units collected from the market) is at an average of 40% of dishwashers compared to dishwashers sold to the market. These quantities are collected and recycled through official producer managed channels. The percentage of reuse and remanufacture is low due to the fact that these devices have a high metal content and are actively sought and recycled also by commercial channels, effectively bringing the collection rate probably up to 100%.*"

Therefore, high collection rates of category 1 equipment are crucial in order to achieve the collection targets laid out in Article 7 of the WEEE-Directive. From 2016 on, the minimum collection target over all categories will be 45 % on a Member State level and will further increase to a minimum of 65 % from 2019 on (calculated on the basis of the total weight of WEEE collected as a percentage of the average weight of EEE placed on the market in the three preceding years on a Member State level).

A 2008 review of the WEEE-Directive 2002/96/EC revealed that only 16.3% of the arising waste of this product-category was collected within the formal system in the EU in 2005 (Huisman et al. 2007). Data from Eurostat suggests that this situation has somehow improved until 2010, when 4,693,199 t of category 1 equipment was put onto the EU-market (EU27 + Iceland + Norway) and 1,512,920 t (i.e. 32%) of the same category were collected (Eurostat 2013).

The fate of devices not collected cannot be exactly quantified. Nevertheless, the following pathways are believed to be responsible for the majority of the items not collected:

- Prolonged storage in households and offices (including for reuse);
- Recycling within the EU but without collection being covered by official member state statistics;
- Export as used EEE or end-of-life equipment to non-European destinations.

Regarding exports to non-European destinations, no product group specific figures are available. Regarding second-hand markets outside the EU, visual impressions from EEE-trading hubs in Nigeria and

Ghana suggest that second-hand washing machines and dishwashers meet a comparably low demand in the West-African region (Manhart, personal communication 2009-2014). Information from other potential second-hand markets such as Eastern Europe is not available.
Generally, dishwashers have a stable positive net-value in the European recycling markets (Henkes 2012). This net-value applies to equipment that has already been collected. In case collection costs are also taken into account, the net-value is mostly negative (Huisman et al. 2007). This is largely based on the high metal content and the comparably low content of materials requiring separate and costly treatment and disposal. Therefore, there is no obvious economic motivation for illegal exports into non-EU countries as this is observed for other types of WEEE (Manhart, personal communication 2009-2014). There might be cases when dishwashers are not fully functional when exported or where used devices are not properly packed and certified. Although in such cases, the devices are classified as WEEE according to Annex VI of the WEEE-Directive, it can still be assumed that the primary motivation for export is reuse and not sub-standard recycling and disposal.
According to (Digital Europe et al. 2013), recycling within the EU – but without collection being registered officially – is quite significant in some member states and might – if these volumes would be accounted for in official figures – lead to a collection rate of around two thirds of the volumes placed onto the market.
Due to the large size of devices, disposal via the municipal household waste is believed not to be relevant in terms of quantities.

4.2.7.2 Recycling process

Different materials are recycled into raw materials and used to make new products. Some of the equipment is not collected separately, but as part of waste fractions where WEEE waste is mixed with other waste. Some of this is sorted and then becomes available for further processing and recycling. The rest ends up in the waste incinerators or at a landfill.
The devices collected within the formal WEEE-System in the EU undergo recycling treatments, which can be classified into the following steps:

- Preparation for reuse;
- Pre-processing / dismantling (including depollution);
- End-processing and final disposal.

4.2.7.2.1 Preparation for reuse

Preparation for reuse, i.e. checking, cleaning or repairing, by which products or components of products that have become waste are prepared so that they can be re-used without any other pre-processing. This is mostly conducted with devices deemed suitable in terms of age, product model, appearance and spare part availability.

4.2.7.2.2 Pre-processing / depollution

The majority of end-of-life dishwashers are passed-on to the pre-processing stage, which starts with a depollution step which requires a selective treatment during which certain substances, mixtures and components are removed from the WEEE stream. In this step, the following components are removed from the devices for separate treatment:

- Power-cables,
- Large accessible printed circuit boards > 10 cm^2. According to (Ardente & Talens Peirò 2015), printed circuit boards can be removed preventively, by specific dismantling, hand-picking or mechanical sorting after preliminary and fine shredding.
- Capacitors with a height >25mm and a diameter >25mm might contain substances of concern. In particular old capacitors might contain polychlorinated biphenyls (PCB). Capacitors, generally

included in printed circuit boards, are generally manually separated after the removal of the printed circuit boards.

- Some modern devices might contain LCD displays > 100cm^2, which have to be removed for separate treatment to comply with the WEEE Directive. However, (Ardente & Talens Peirò 2015) state that according to recyclers, also smaller LCD displays in dishwashers easy to dismantle are generally extracted to avoid potential contamination of other recyclable fractions (mainly electronic parts) which can result in downcycling.
- Devices containing volatile hydrofluorocarbons (HFC) or hydrocarbons (HC) – which might be the case for modern dishwashers with an integrated heat pump – have to undergo degassing to prevent emissions to the atmosphere. Devices containing volatile hydrocarbons need to be handled with care (also during collection, transport and storage) as uncontrolled leakages might cause fires and explosions (CENELEC 2012).
- For very old devices, depollution might also have to consider mercury-containing parts and components containing asbestos.

In the subsequent pre-processing step, the remaining devices are treated in order to liberate the various materials such as steel, aluminium and plastics. This is either done by manual disassembly, or by mechanical means (shredding and automated sorting). Pre-processing (manual and mechanical) typically yields the following output fractions:

- Steel
- Stainless-steel
- Aluminium
- Copper (insulated or liberated)
- Plastics (including thermoplastics, thermosets and rubber)
- Glass
- Concrete

Some of the above listed fractions undergo further pre-treatment and/or sorting (examples: liberation of insulated copper-cables, sorting of aluminium in different grades, further sorting of plastics according to colour and polymer-types).

4.2.7.2.3 End-processing

The outputs are generally fed into end-processing units, which can be described as follows:

- Steel and stainless-steel is fed into secondary steel plants;
- Aluminium is fed into secondary aluminium smelters;
- Copper is fed into copper-refineries;
- Printed circuit boards are fed into integrated smelters to recover copper, precious metals and other metals as by-products (e.g. lead, tin, indium);
- Plastics are either recycled (material recovery of thermoplastics) or incinerated (energy recovery);
- Glass is fed into glass recycling;
- Concrete is disposed together with inert construction/demolition waste.

4.2.7.3 Recycling and recovery rates

The Ecodesign Preparatory Study Lot 14 (ENEA/ISIS 2007c) used following input data for end-of-life parameter:

Table 4.11: Input data for end-of-life handling of household dishwashers used by Lot 14 in 2007; source: (ENEA/ISIS 2007c)

End-of-life handling	Household dishwashers, 9 ps model (%)	Household dishwashers, 12 ps model (%)
Recycling	80.42	82,66
Energy recovery	16.80	15,86
Land-filling	2.78	1,47
Total	100%	100%

For re-use and closed-loop recycling of the plastics in dishwashers, (ENEA/ISIS 2007c) assumed 0% in their study 2007.

In general, recyclers of large household appliances are obliged to achieve a minimum re-use and recycling rate of 75% and a recovery target of 80%. In contrast to recycling, the term recovery additionally includes the use of waste for other useful purposes, including energy recovery. These targets will be raised to 80% and 85% after 14 August 2015 (see Table 4.12).

Table 4.12: Re-use and recycling targets specified in Directive 2012/19/EU (European Parliament 2012a)

Quantitative targets for WEEE category 1	Until 14 August 2015	After 14 August 2015
Re-use and recycling target	75%	80%
Recovery target	80%	85%

Feedback of one stakeholder provided via the questionnaire (JRC IPTS 2015a) states that recycling rates of household dishwashers can be up to 95% depending on the technologies used during the treatment. Another stakeholder provides the following information for the category of Large Household Appliances (Category 1 + 4), including cooling appliances, washing machines, washer-dryers, dryers, dishwashers, freestanding cookers etc.:

- Recovery: 85,9 %
- Recycling and re-use: 80,8 %

However, according to (UNEP 2013), legal recycling-rate targets have two implicit weaknesses: They do not differ between individual substances, but are calculated solely by weight based on an entire fraction. Hence, to achieve the targets, recovery of mass substances such as plastics, glass or steel becomes much more important than recovery of precious and special metals, which are usually only present in small amounts. And, as the targets do not consider metallurgical steps, the high legal recycling targets pretend a recycling quality that in reality is not obtained. If smelting and refining are included, real recycling rates will be much lower, especially for precious and special metals.

For large white goods, usually the recycling focuses on the recovery of bulk commodity materials according to WEEE recycling guidelines. For PWBs, containing palladium, silver and gold, the following holds true according to (UNEP 2013): PWBs form a very small part of this recycling stream and are mostly lost. If recovered, physics limit the production of clean recyclates from PWBs, which makes subsequent processing in metallurgical plants difficult. PWBs will, because of the nature of mechanical separation plants, be spread throughout the recyclates of commodity materials (steel, aluminium, etc.). After that,

they get lost during the metallurgical processes for these commodity metals, which do not cater for the thermodynamics that maximize recovery of "critical" elements.

4.2.7.3.1 End-of-life treatment of permanent magnet (PM) motors

(Dalhammar et al. 2014) conducted a case study in 2012 on the potential inclusion of PM motors in the revision of Ecodesign Regulation (EC) 640/2009 for electric motors. The objective was to see how the Ecodesign Regulation could promote eco-innovation for resource use in PM motors. Within their study they researched that to-date methods for post-consumer rare earth element (REE) recycling are inexistent. However, one technological niche is constituted by a Siemens led motor recycling project which investigates options for the extraction of REE from electric motors. Also the Danish REEgain project (cf. http://www.reegain.dk) represents a technological niche, as various representatives from industry and academia collaborate to investigate both different processing options for rare earth ores and the recycling of REE.

According to (Dalhammar et al. 2014), to date only about 10 to 15% of machines with REE (typical hard disc magnets) can be recycled, the remainder ends up as dust in scrap yards or as pollutant in steel melts. There are currently many uncertainties. These include for example, if – and how – the magnetic properties of REEs and combinations of materials will last if the material is crushed into a material mix, or if the material must be separated into pure streams. The latter option would require much more energy at the recycling stage.

(Buchert et al. 2014) describe in their study on permanent magnets motors that the production of these motor types has only reached in the past 10 to 15 years a significant increase; due to their long life, however, so far only few magnets containing valuable rare earths arrive at the potential recycling streams. A general recycling process of permanent magnet motors is not yet established, although some manufacturers of industrial permanent magnet motors already disassemble magnets at their end-of-life and store them for potential future recycling purposes. To establish a future recycling process on an industrial-scale basis in the near future, some hundreds of tons magnet materials would have to be available, which requires a collection and disassembly system to separate the permanent magnets from the motors ideally at European level.

(Buchert et al. 2014) point out that rare earths containing magnets are mostly installed in their appliances in such a way that specific expert knowledge is necessary to detect them. Further, todays established pre-processing technologies cannot separate magnets to pure fractions but rather sort them together with the steel fraction where the rare earths get dissipative lost. Also according to assessment of one stakeholder, although in a manual recycling process brushless motors can be simply identified at first sight, a further differentiation for example between asynchronous inverter driven motors and permanent magnet motors (cf. section 4.1.4.2) is difficult.

This is why (Buchert et al. 2014) request for a marking obligation for industrial appliances containing a minimum weight of permanent magnets (for example > 10 grams) which shall inform about the following aspects:

- Are permanent magnets included in the appliance?
- If yes, which type of permanent magnet is included?

Such a marking obligation, which is proposed to take place for example in the current revision of the Ecodesign Regulation on motors (cf. section 1.2.1.1), would facilitate recycling companies localising valuable magnets.

4.3 Summary and discussion: technologies

The selection of revised base cases for household dishwashers still requires further feedback from stakeholders refining and/or complementing the initial assumptions made with regard to the current application of technical design options to the market summarised in section 4.1.4.

Depending on the final choice of base cases and improvement options, also further feedback from stakeholders with regard to current Bill of Materials (BOM), transport data, primary scrap production

during sheet metal manufacturing, packaging composition, volume and weight of packaging and actual means of transport is needed to update the input data for the MEErP tool.

Discussion point 4.1

Would you be able to provide additional input regarding BOM, transport, etc. once the base cases have been defined? Why (not)?

Regarding the technical product lifetime, research indicates that the initial product lifetime of 12.5 years of household dishwashers is still valid and is recommended to be kept.

Discussion point 4.2

Do you agree with a product lifetime of 12.5 years for household dishwashers? Why (not)?

On the other hand, research also indicates that the proportion of dishwashers which have to be replaced quite early due to a defect has increased (cf. section 4.2.6). Common causes of breakdowns are for example the pump, the electronic board, buttons and controls, the hoses, the motor or the door. It is proposed for discussion if these common defects with regard to possible design options might be implemented as ecodesign requirements enhancing durability of household dishwashers. Examples of these requirements can be operational motor lifetime, durability of hoses, design for disassembly or others which already have been partly implemented in a similar way for other product groups (e.g. vacuum cleaners).

Discussion point 4.3

Which possible design options might be implemented as ecodesign requirements enhancing durability of household dishwashers?

Are there any ecodesign requirements related to resource efficiency from other product groups which could be implemented for dishwashers? Why (not)?

Regarding end-of-life management of household dishwasher, research indicates that in general, the collection rates as well as recycling and recovery rates are rather high for this product group, but to a very large extent, this does not take place through official channels. More than 1/3 of the large appliances collected (including washing machines, dishwashers and washer dryers) are scrapped not following the prescriptions of WEEE in Member States, and this percentage is closer to 2/3 of the total flow of EoL appliances in some of the EU Member States. The EoL management of these appliances is largely driven by the value of the metal content, which pulls considerable amounts of them for shredding together with other metal scrap.
For dishwashers, special treatment according to WEEE is essentially needed for the treatment of the large printed circuit boards (PCB), and – when applicable – for the refrigerants of heat pumps.
Specific EoL treatment not involving direct shredding can be interesting for other reasons too. The increasing use of permanent magnet motors in household dishwashers deserves attention, as these motors contain valuable rare earth elements which are more difficult to collect if the motors are not separated before shredding. This aspect will be analysed during the further course of the study.

Discussion point 4.4

In your view, are there any other components of concern from an End-of-Life perspective than the ones outlined above? (permanent magnet motors, PCBs, displays, refrigerants of heat pumps)?

The data collected indicate that the current recycling of plastics in these appliances is not extended. The use of recycled plastics in new machines is not common either. Could you characterise the main types of

plastics used in dishwashers? Have you explored the possibility of using recycled plastics for those applications? Which are the main hurdles for using recycled plastics?

Do you have any concise information about the 2nd hand market of this product group, e.g. the share and characteristics of the products reused, and the estimated "first" and "second" product life times, and the percentage of collected items that is reused?

Could you identify any simple and inexpensive design option that could enhance the easier identification and removal of

- printed circuit boards and displays

- permanent magnets.

5 ANNEX A – OTHER EXAMPLES OF RESOURCE EFFICIENCY CRITERIA IMPLEMENTED IN REGULATIONS AND ECOLABELS

Note: The following European legislations, namely the Ecodesign Regulations, and ecolabels are not directly related to the product group household dishwashers. However, they are listed as examples of current implementing measures with regard to resource efficiency (e.g. durability, and end-of-life requirements).

5.1 EU Ecodesign Regulation 1194/2012/EU on directional lamps, light emitting diode lamps and related equipment

The Ecodesign Regulation 1194/2012 sets specific functionality requirements which include different functionality parameters on the lifetime of lamps (European Commission 2012):

- Lamp survival factor at 6,000 h (for LED lamps only). Lamp survival factor (LSF) means the defined fraction of the total number of lamps that continue to operate at a given time under defined conditions and switching frequency. Test procedure: The test shall end when the required number of hours is met, or when more than two lamps fail, whichever occurs first. Compliance: a maximum of two out of every 20 lamps in the test batch may fail before the required number of hours. Non-compliance: otherwise.
- Number of switching cycles before failure. Test procedure: The test shall end when the required number of switching cycles is reached, or when more than one out of every 20 lamps in the test batch have reached the end of their life, whichever occurs first. Compliance: at least 19 of every 20 lamps in the batch have no failure after the required number of switching cycles is reached. Non-compliance: otherwise.
- Premature failure rate which means when a lamp reaches the end of its life after a period in operation which is less than the rated life time stated in the technical documentation. Test procedure: The test shall end when the required number of hours is met, or when more than one lamp fails, whichever occurs first. Compliance: a maximum of one out of every 20 lamps in the test batch fails before the required number of hours. Non-compliance: otherwise.
- Rated lamp lifetime in hours at 50% lamp survival. 'Lamp lifetime' means the period of operating time after which the fraction of the total number of lamps which continue to operate corresponds to the lamp survival factor of the lamp under defined conditions and switching frequency. For LED lamps, lamp lifetime means the operating time between the start of their use and the moment when only 50% of the total number of lamps survive or when the average lumen maintenance of the batch falls below 70%, whichever occurs first
- Product information requirements to be visibly displayed to end-users prior to their purchase on the packaging and on free access websites: Nominal lifetime of the lamp in hours (no longer than the rated lifetime); number of switching cycles before premature failure.

5.2 EU Ecodesign Regulation 666/2013/EU on vacuum cleaners

The Ecodesign Regulation on vacuum cleaners sets specific requirements on durability from 1 September 2017 (European Commission 2013):

- Durability of the hose: The hose, if any, shall be durable so that it is still useable after 40,000 oscillations under strain. Measurement and test method: The hose shall be considered useable after 40,000 oscillations under strain if it is not visibly damaged after those oscillations. Strain shall be applied by means of a weight of 2.5 kg.

- Operational motor life-time: The operational motor lifetime shall be greater than or equal to 500 hours. Measurement and test method: The vacuum cleaner shall run with a half-loaded dust receptacle intermittently with periods of 14 minutes and 30 seconds on and 30 seconds off. Dust receptacle and filters shall be replaced at appropriate time intervals. The test may be discontinued after 500 hours and shall be discontinued after 600 hours. The total run-time shall be recorded and included in the technical documentation. Air flow, vacuum and input power shall be determined at appropriate intervals and values shall, along with the operational motor lifetime, be included in the technical documentation.

According to (Bundgaard et al. 2015), implementing these specific requirements on resource efficiency was enabled by the existence of measurement and test standards so that the requirements can be monitored when the product are put on the market.
Further, the Ecodesign Regulation on vacuum cleaners sets information requirements on resource efficiency from 1 September 2017 (European Commission 2013):
The technical documentation and a part for professionals of the free access websites of manufacturers, their authorised representatives, or importers shall contain the following elements:

- Information relevant for non-destructive disassembly for maintenance purpose, in particular in relation to the hose, suction, inlet, motor, casing and cable.
- Information relevant for dismantling, in particular in relation to the motor and any batteries, recycling, recovery and disposal at end-of-life.

5.3 Draft EU Ecodesign Regulation on electronic displays

End of 2014, a Consultation Forum meeting with regard to possible Ecodesign and Energy Labelling requirements for electronic displays has taken place. In this context, the European Commission provided draft proposals for the Ecodesign and Energy label Regulations on electronic displays as well as related explanatory notes. Please note that the following paragraphs are extracts from the preliminary proposal which will be changed according to discussions at and after the Consultation Forum meeting.
The draft Ecodesign Regulation includes a comprehensive set of end-of-life requirements. According to the explanatory notes of the possible Ecodesign and Energy Labelling requirements for electronic displays (European Commission 2014b),

> *"The proposed measure sets specific requirements for manufacturers to (1) disclose information relevant for disassembly, recycling and/or recovery at end-of-life, (2) mark plastic parts, (3) declare the recyclability rate of plastic parts, and (4) label for mercury and presence of brominated flame retardants (BFR). These requirements are devised to help recyclers to better comply with the WEEE Directive (2012/19/EU) by providing information relevant for the depollution, disassembling and/or shredding operations. These requirements are in line with the approach taken in the Ecodesign Regulations that were adopted so far and with the Commission Communication "Towards a circular economy: a zero waste programme for Europe" aimed at establishing a common and coherent EU framework to promote the circular economy. The proposed requirements should result in marginal costs to manufacturers with possibly relevant cost reduction and improved efficiency for the recycling industry."*

The following end-of-life requirements were proposed for electronic displays (European Commission 2014a):

- Design for recovery of electronic displays
- Marking of plastic parts of electronic displays
- Declaration of the recyclability index for plastic parts
- Mercury free logo
- Brominated Fire retardants logo

- Documentation for recycling at end of life of displays

Design for recovery of electronic displays

Manufacturers shall ensure that electronic displays are designed so that the following four types of components (when present) can be dismantled:

- Printed circuit boards assembly (larger than 10 cm^2);
- Thin-film-transistor liquid-crystal display (larger than 100 cm^2);
- PMMA board;
- Mercury containing backlighting lamps;

This shall be ensured by:

- Documenting the sequence of dismantling operations needed to access the targeted components, including for each of these operations: type of operation, type and number of fastening technique(s) to be unlocked, and tool(s) required;
- Describing the design strategies / innovations implemented to facilitate the disassembly, recycling and/or recovery of the electronic display;
- Providing a video showing the dismantling operations and the indicative time needed to extract the targeted components.

Marking of plastic parts of electronic displays

1. Plastic parts larger than 25g, other than the Polymethyl Methacrylate Board (PMMA) and display optical plastics, shall be marked by specifying the type of plastic using the symbols as specified in EN 11469 and EN 1043, set between the marks ">" and "<". The marking shall be legible and located in a visible position. Exemptions are made in the following cases:

(i) Where the marking would impact on performance or functionality of the plastic part

(ii) Where marking is technically not possible due to the production methods; or

(iii) Where the marking could cause defect rates under quality inspection, leading to unnecessary wastage of materials

Each exemption shall be justified in the 'end-of-life report'.

2. Plastic parts larger than 25g, other than the PMMA board and display optical plastics, containing Brominated Fire Retardants (BFR) shall be marked in the following way:

(i) >x-FR-y<

where:

x= plastic polymer

FR = Fire Retardant

y= brominated fire retardant coding, according to EN 1043.

3. Plastic parts larger than 25g, other than the Polymethyl Methacrylate board (PMMA) and display optical plastics may include information related to the presence of fillers and fire retardants other than BFR in plastic parts. When the information is added voluntarily, this shall be presented in the following way:

(i) the presence of fillers as: 'x-y'

where:

x = plastic polymer

y = abbreviated term for the fillers.

(ii) the presence of fire retardant in plastic parts as: 'x-FR-y'

where:

x= plastic polymer

FR = Fire retardant

y= type of the fire retardant coding.

Declaration of the recyclability index for plastic parts

The recyclability index of plastic parts (heavier than 25g) in electronic displays shall be determined in accordance with the following equation:

$$R_{plastic} = \frac{\sum (m_i \times RCR_i)}{m_{tot}} \times 100 \qquad [\%]$$

Where:
$R_{plastic}$ = recyclability index of plastic parts [%]
m_i = mass of the ith plastic part heavier than 25g
m_{tot} = total mass of plastic parts heavier than 25g
RCR_i = recyclability rate of the ith plastic part heavier than 25g [%] as specified in the table.

Plastic parts lighter than 25g, Printed Circuit Boards (PCB), wiring and speakers are excluded from the calculation.

The manufacturer shall declare in the instruction booklet for users the value of the recyclability index of plastic parts (heavier than 25g) in the electronic display. The manufacturer shall illustrate in the 'end-of-life report' the calculation of the recyclability index for plastic parts ($R_{plastic}$) and the values used for the recyclability rate of plastics (RCR_i).

Table 5.1: Recyclability rate of plastics (RCR_i); source (European Commission 2014a)

Material	Recyclability rate
Acrylonitrile Butadiene Styrene (ABS)	94%
Acrylonitrile Butadiene Styrene (ABS) with any additives	94%
High impact polystyrene (HIPS)	94%
High impact polystyrene (HIPS) with any additive	94%
Polyamide (PA)	94%
Polycarbonate (PC)	94%
Polycarbonate/ Acrylonitrile Butadiene Styrene (PC-ABS)	94%
Polycarbonate/Acrylonitrile Butadiene Styrene (PC-ABS) with any additives	94%
Polymethyl methacrylate (PMMA)	94%
Polypropylene (PP)	94%
Polypropylene (PP) with natural fibres	0%
Polypropylene (PP) with other additive	94%
Co-injected plastics	0%
Other plastics	0%

If the manufacturer has evidence that the recyclability rate is actually higher (e.g. based on tests) then the manufacturer can use the determined recyclability rate.

Mercury free logo

Electronic displays shall be labelled with the "Mercury inside" or the "Mercury free" logo. The logo shall be immediately and clearly visible on the back of the electronic display without the removal of a cover. The logo shall be visible, durable, legible and indelible and be in the form of the following graphic.

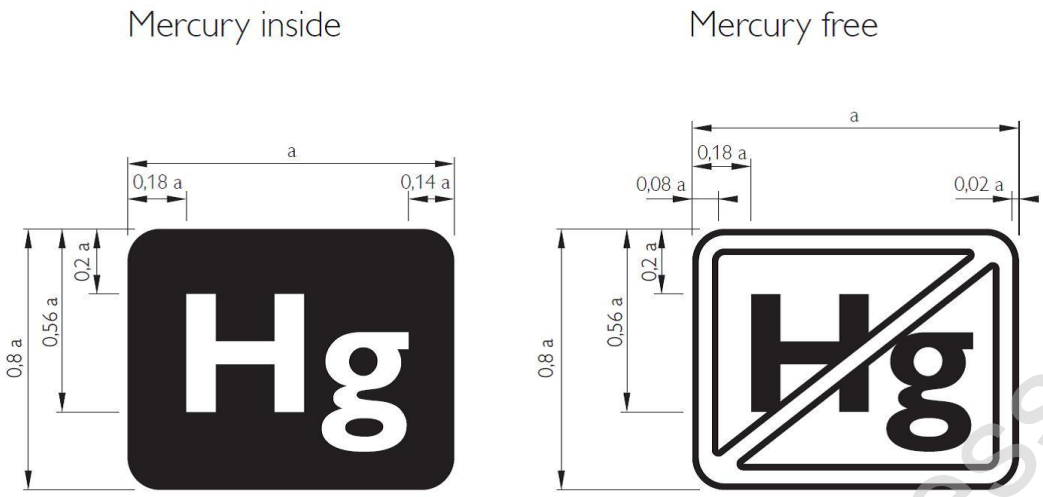

Figure 5.1: Mercury free logo as proposed in the draft Ecodesign Regulation for displays; source (European Commission 2014a)

Brominated Fire retardants logo

Electronic displays having plastic parts larger than 25g (other than PMMA board and display optical plastics) containing Brominated Fire Retardants (BFR) shall be labelled with the "BFR plastics inside" logo. Electronic displays with plastic parts larger than 25g (other than PMMA board and display optical plastics) not containing BFR shall be labelled with the "BFR-free plastics" logo.

The logo shall be immediately and clearly visible on the back of the electronic display without the removal of a cover. The logo shall be visible, durable, legible and indelible and be in the form of the following graphic.

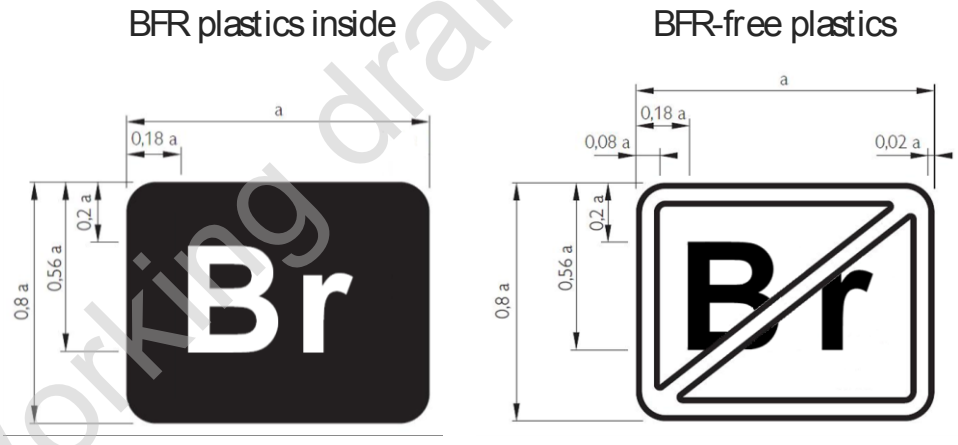

Figure 5.2: Brominated fire retardants logo as proposed in the draft Ecodesign Regulation for displays; source (European Commission 2014a)

Documentation for recycling at end of life of displays

From 24 months after the publication of the Regulation in the Official Journal of the European Union, manufacturers, and/or importers in the European Union shall provide the following product information on every equivalent electronic display model in a freely accessible websites and kept available for 10 years from the day of the last model placed on the market:

- An 'end-of-life report' containing information relevant for disassembly, recycling and/or recovery at end-of-life. The report shall include at least the following:

  - the exploded diagram of the product labelling the targeted components defined, when present, together with a documentation of the sequence of the dismantling operations needed to access to these components. Each of these operations shall be described in terms of type of operation (e.g. unscrewing, removing, levering, positioning), type and number of fastening techniques to be unlocked (e.g. M3 screw, snap-fit) and tool(s) required;
  - the description of the design strategies / innovations implemented to facilitate disassembly, recycling and/or recovery of the displays;
  - the rationale for each exemption, if some plastic parts are not marked as set out;
  - the declared value of the recyclability index for plastic parts larger than 25 g, accompanied by a description of the calculations (including at least: the list of the plastic parts; their material composition; the considered recyclability rates for each plastic type, plus a justification in case the values differ from the ones presented.
- A video showing the dismantling operations and the indicative time needed to extract the four types of targeted components, when present.

The value of the 'recyclability index of plastic parts' in the electronic display shall be declared in the instruction booklet for users.
The following **measurement methods** were proposed, accompanied with a standardization request of the European Commission to the European standardization organisations (ESOs) to develop generic methodologies related to material efficiency, such as durability, reusability, recyclability and recoverability (cf. section1.3.3.2):

- Extraction of key components: Measurements of the extraction time of key components shall be made using a reliable, accurate and reproducible measurement procedure, which takes into account the generally recognised state of the art measurement methods, including the provision by manufacturers (through e.g. DVD, website) of the information necessary for the measurement, such as: technical documentation illustrating the dismantling sequence and a supporting video-recording that shows the compliance to the requirement.
- Measurements of marking of plastic parts of electronic displays: Measurements of marking of plastic shall be made using a reliable, accurate and reproducible measurement procedure, which takes into account the generally recognised state of the art measurement methods.
- Minimum recyclability rate index for certain plastic parts: Measurements of minimum recyclability rate index shall be made using harmonised standards, the reference numbers of which have been published in the Official Journal of the European Union, or using other reliable, accurate and reproducible methods which take into account the generally recognised state of the art, and produce results deemed to be of low uncertainty.
- Mercury free logo: Measurements and checks of backlighting systems of electronic displays for mercury content shall be made using harmonised standards, the reference numbers of which have been published in the Official Journal of the European Union, or using other reliable, accurate and reproducible methods which take into account the generally recognised state of the art, and produce results deemed to be of low uncertainty.

5.4 Review of Regulation 327/2011 with regard to ecodesign requirements for fans

Currently, the Ecodesign Regulation 327/2011 with regard to ecodesign requirements for fans is under revision. The working document presented to stakeholders relating to a meeting of the Ecodesign Consultation Forum on the review of the Regulation 327/2011 on fans on 30 April 2015 includes information requirements for the use of permanent magnet motors for fans:

- Manufacturers shall indicate the total weight per fan of the permanent magnets, if any, used in the motor, in kg with 2 digit precision.

The related explanatory notes further explain that the use of Rare Earth Elements (REE) in Electronically Commutating (EC) motors which are used e.g. in fans are expected to be become a noticeable part of the waste stream. Most types contain permanent magnets with on average 18% Neodymium and smaller fractions of other REE. As these REE are regarded as 'critical raw materials' due to their ever increasing prices and dependence on supply from a single country it may be useful to indicate the weight of the magnets on the nameplate of the fan.
Discussions at the Consultation Forum meeting, however, proposed to change the requirement into information about the type of rare earths the motor is composed of rather than the weight of the permanent magnets.

5.5 National legislation: France

5.5.1 Decree n° 2014-1482 of 9 December 2014 regarding information and supply requirements for spare parts which are essential for the use of a good

On 9 December 2014 the French government published a decree in France's Official Journal that puts into effect Article L111-3 of the Consumption Law (Code de la consommation, Version consolidée au 22 mars 2015, Art. L111-3). According to this article, French retailers will have to inform consumers about the availability of spare parts for products. The article requires manufacturers and importers to inform vendors how long spare parts that are essential for the use of a product will continue to be produced. This can be done either by specifying the period of availability or the final date. The vendor is then required to inform the buyer. The information is required to be displayed "in a visible manner" before a purchase is made and to be confirmed in writing after the purchase. Manufacturers will have to deliver the parts needed to make repairs to vendors or repair enterprises within two months. The rules apply to products placed on the market since March 2015. (French Government 2014)

5.5.2 Draft legislation against planned obsolescence

Further, in France the legislative project concerning the energy transition for green growth has been adopted in first reading by the national assembly on October 14th, 2014. It is currently in the Senate for first reading. Various amendments within this legislative project deal with planned obsolescence, among them article 22b (new) which introduces in the Code de la Consommation (Consumption Law), Art. L. 213-4-1, the following definition of planned obsolescence (French Administration 2014):
I – "Planned obsolescence means all techniques by which a placer on the market aims, especially by product design, at purposefully shortening the lifetime or the potential time of use of this product in order to increase the rate of replacement."
II – "Specifically, these techniques can include the purposeful introduction of a defect, fragility, a programmed or premature stop, a technical limitation, an impossibility to repair or an incompatibility."

Further, under the existing Article L213-1 of the Codes de la Consommation which lists diverse facts of consumer deception being penalised with 2 years' imprisonment or 300,000 Euro fine, another criminal offence shall be included: - „be it an intentionally reduced lifetime of a product at the design stage". (French Senat 2014)
On 11 March 2015, the act has gone into a committee for a second reading in the parliament, with a first report of the committee provided on 16 April 2015. After that, further sessions in the parliament and the senate will follow, before the law will be finally put into effect by the president. The version which has gone into the parliament redefined Art. L 213-4-1 as follows: „Programmed obsolescence is defined by each manoeuvre through which the lifetime of a good is knowingly reduced since its design stage, thereby limiting its usage time for business model reasons. It is punished by two years prison and 300.000 EUR fine." (French Parliament 2015)
Further, a new Article L-110-1-2 paragraph II 1a shall be included into the environmental law (code de l'environnement), which defines as one target of the national waste management policy „to fight planned obsolescence of products by means of consumer information. Voluntary experiments may be conducted with a display of product lifetime in order to promote extended usage time of manufactured products by means of consumer information. They will allow putting in place standards shared by economic actors of industrial sectors who are concerned with the notion of lifetime"

5.6 Draft Commission Decision establishing the criteria for the award of the EU Ecolabel for personal, notebook and tablet computers

Currently, the EU Ecolabel criteria for "Personal, notebook and tablet computers" are under revision with the final draft of the EU Ecolabel criteria published to be voted in the Regulatory Committee on 17 April 2015.
The criteria include rather detailed requirements on the product lifetime extension (such as durability testing for portable computers, rechargeable battery quality and lifetime, data storage drive reliability and protection, as well as upgradeability and repairability). Further, the requirements on design, material selection and end-of-life management (material selection and compatibility with recycling as well as design for dismantling and recycling) have been updated and detailed. Finally, a new criterion on sourcing of 'conflict-free' minerals has been introduced.
Although the product categories of personal, notebook and tablet computers are not directly comparable to large household appliances, this approach shall be listed as most current example for defining durability and end-of-life criteria which might be partly applicable also to other electrical and electronic equipment.
In the following, the proposed criteria are listed detailed (European Commission 2015b):

<u>Criteria on product lifetime extension of personal, notebook and tablet computers</u>

- Durability testing of portable computers (mainly based on test procedures of IEC 60068)
  - Mandatory durability test specification for notebook computers:
    - Resistance to shock
    - Resistance to vibration
    - Accidental drop
  - Additional durability test specifications for notebook computers
    - Temperature stress
    - Screen resilience
    - Water spill ingress

        - Keyboard lifespan
        - Screen hinge lifespan (Specification: The screen shall be fully opened and then closed 20,000 times. Functional requirement: The screen shall then be inspected for any loss of stability and hinge integrity.)

    - Mandatory durability test specification for tablet and two-in-one notebook computers
        - Accidential drop
        - Screen resilience

- Rechargeable battery quality and lifetime (not relevant for large household appliances)
- Data storage drive reliability and protection (not relevant for large household appliances)
- Upgradeability and Repairability: For the purpose of upgrading older components or undertaking repairs and replacements of worn out components or parts, the following criteria shall be fulfilled:

    - Design for upgrade and repair: The following components of computers shall be easily accessible and exchangeable by the use of universal tools (i.e. widely used commercially available tools such as a screwdriver, spatula, plier, or tweezers):
        - Data storage (HDD, SSD or eMMC),
        - Memory (RAM),
        - Screen assembly and LCD backlight units (where integrated),
        - Keyboard and track pad (where used)

    - Rechargeable battery replacement: The rechargeable battery pack shall be easy to extract by one person (either a non-professional user or a professional repair service provider) according to the steps defined below. Rechargeable batteries shall not be glued or soldered into a product and there shall be no metal tapes, adhesive strips or cables that prevent access in order to extract the battery. In addition, the following requirements and definitions of the ease of extraction shall apply:

        - For notebooks and portable all-in-one computers it shall be possible to extract the rechargeable battery manually without tools;
        - For sub-notebooks it shall be possible to extract the rechargeable battery in a maximum of three steps using a screwdriver;
        - For tablets and two-in-one notebooks it shall be possible to extract the rechargeable battery in a maximum of four steps using a screwdriver and spudger.

      Simple instructions on how the rechargeable battery packs are to be removed shall be marked on the base cover of the product or provided in the user instructions.

    - Repair manual: The applicant shall provide clear disassembly and repair instructions (e.g. hard or electronic copy, video) to enable a non-destructive disassembly of products for the purpose of replacing key components or parts for upgrades or repairs. This shall be made publicly available or by entering the products unique serial number on a webpage.

Additionally, a diagram shall be provided on the inside of the casing of stationary computers showing the location of the components listed above can be accessed and exchanged. For portable computers a diagram showing the location of the battery, data storage drives and memory shall be made available in pre-installed user instructions and via the manufacturer's website for a period of at least five years.

- Repair Service / Information: Information should be included in the user instructions or on the manufacturer's website to let the user know where to go to obtain professional repairs and servicing of the computer, including contact details. During the guarantee period referred to above this may be limited to the applicant's Authorised Service Providers.
- Availability of spare parts: The applicant shall ensure that original or backwardly compatible spare parts, including rechargeable batteries (if applicable), are publicly available for at least five years following the end of production for the model.
- Commercial Guarantee: The applicant shall provide at no additional cost a minimum of a three year guarantee effective from purchase of the product during which time they shall ensure the goods are in conformity with the contract of sale. This guarantee shall include a service agreement with a pick-up and return option for the consumer. This guarantee shall be provided without prejudice to the legal obligations of the manufacturer and seller under national law.

Criteria on design, material selection and end-of-life management of personal, notebook and tablet computers

- Material selection and recyclability
  - Improving the recyclability of plastic casings, enclosures and bezels: Parts shall not contain molded-in or glued-on metal inserts unless they can be removed with commonly available tools. Disassembly instructions shall show how to remove them; for parts with a weight greater than 25 grams for tablet computers and 100 grams for all other computers, the following treatments and additives shall not result in recycled resin with a >25% reduction in the notched izod impact when tested according to ISO 180:
    - Paints and coatings
    - Flame retardants and their synergists

    Existing test results for recycled resin shall be accepted provided that the recycled resin is derived from the same input material as described above.

  - Material information to facilitate recycling: Plastic parts with a mass greater than 25 grams for tablet computers and 100 grams for all other computers shall be marked in accordance with ISO 11469 and ISO 1043, sections 1-4. The markings shall be large enough and located in a visible position in order to be easily identified. Exemptions are made in the following cases:
    - Printed circuit boards, Polymethyl Methacrylate Board (PMMA) and display optical plastics forming part of display units;
    - Where the marking would impact on the performance or functionality of the plastic part;
    - Where the marking is technically not possible due to the production method; or

        - Where the marking causes defect rates under quality inspection, leading to an avoidable wastage of materials.
        - Where parts cannot be marked because there is not enough appropriate surface area available for the marking to be of a legible size to be identified by a recycling operator.
    - Minimum recycled plastic content: The product shall contain on average a minimum 10% content post-consumer recycled plastic measured as a percentage of the total plastic (by weight) in the product excluding Printed Wiring Boards and display optical plastics. Where the recycled content is greater than 25% a declaration may be made in the text box accompanying the Ecolabel. Tablets, subnotebooks, two-in-one notebooks and products with a metal casing are exempt from this sub-criterion.

- Design for dismantling and recycling:
  For recycling purposes computers shall be designed so that target components and parts can be easily extracted from the product. A disassembly test shall be carried out according to the test procedure in Appendix 1 to the Decision. The test shall record the number of steps required and the associated tools and actions required to extract the target components and parts identified under the following points.
    - The following target components and parts, as applicable to the product, shall be extracted during the disassembly test:
        - All products: Printed Wiring Boards relating to computing functions >10 cm^2
        - Stationary computer products: Internal Power Supply Unit; HDD drives
        - Portable computer products: Rechargeable battery
        - Displays (where integrated into the product enclosure): Printed Circuit Boards >10 cm^2; Thin Film Transistor unit and film conductors in display units >100 cm^2; LED backlight units
    - At least two of the following target components and parts, selected as applicable to the product, shall also be extracted during the test, following-on in the test from those above:
        - HDD drive (portable products)
        - Optical drives (where included)
        - Printed circuit boards ≤ 10 cm^2 and > 5 cm^2
        - Speaker units (notebooks, integrated desktops and portable all-in-one computers)
        - Polymethyl Methacrylate (PMMA) film light guide (where the screen size is >100 cm^2)

The test procedure, i.e. protocol for a product disassembly test, inter alia specifies following aspects:

- Operating conditions for the extraction:
    - Personnel: The test shall be carried out by one person.
    - Tools for extraction: The extraction operations shall be performed using manual or power-driven standard commercially available tools (i.e. pliers, screw-drivers, cutters and hammers as defined by ISO 5742, ISO 1174, ISO 15601).

  - Extraction sequence: The extraction sequence shall be documented and, where the test is to be carried out by a third party, information provided to those carrying out the extraction.

- Recording of the test conditions and steps
  - Documentation of steps: The individual steps in the extraction sequence shall be documented and the tools associated with each step shall be specified.
  - Recording media: Photos shall be taken and a video recorded of the extraction of the components. The video and photos shall enable clear identification of the steps in the extraction sequence.

Criteria on sourcing of 'conflict-free' minerals

The applicant shall support the responsible sourcing of tin, tantalum, tungsten and their ores and gold from conflict-affected and high-risk areas by:

- Conducting due diligence in line with the OECD Due Diligence Guidance for Responsible Supply Chains of Minerals from Conflict-Affected and High-Risk Areas, and
- Promoting responsible mineral production and trade for the identified minerals used in components of the product in accordance with OECD guidance within conflict-affected and high-risk area

6 REFERENCES

A.I.S.E. (2012). CHARTER UPDATE 2010: Advanced Sustainability Profiles for Automatic Dishwashing (ADW) Detergents: Final Version. Available at http://www.sustainable-cleaning.com/content_attachments/documents/ASPs_ADW_23Feb2012_FINAL.pdf, last accessed on 26 Apr 2015.
Almeida, A. de; Falkner, H.; Fong, J. & Jugdoyal, K. (2014). EuP Lot 30: Electric Motors and Drives: Task 1: Product Definition, Standards and Legislation. Available at http://www.eup-network.de/fileadmin/user_upload/EuP-LOT-30-Task-1-April-2014.pdf, last accessed on 15 May 2015.
ANEC (2009). Consumer Relevant Eco-Design and Labelling requirements for domestic dishwashers.
Ardente, F.; Mathieux, F. & Forner, J. (2012). Integration of resource efficiency and waste management criteria in European product policies – Second phase: Report n° 1. Analysis of Durability (final). Available at http://publications.jrc.ec.europa.eu/repository/bitstream/JRC77316/lb-na-25656-en-n.pdf, last accessed on 18 Mar 2015.
Ardente, F. & Talens Peirò, L. (2015). Environmental Footprint and Material Efficiency Support for Product Policy: Report on benefits and impacts/costs of options for different potential material efficiency requirements for Dishwashers. Available at http://publications.jrc.ec.europa.eu/repository/bitstream/JRC95187/lb-na-27200-en-n.pdf, last accessed on 15 May 2015.
AREA (ed.) (2014). AREA F-Gas GUIDE: A practical guide on the application of the new F-Gas Regulation to refrigeration, air conditioning & heat pump contractors. Available at https://www.fluorocarbons.org/uploads/Modules/Library/area-guidelines-fgas-master-2-final.pdf, last accessed on 09 Apr 2015.
Australian Government (2012). Australia's Greenhouse and Energy Minimum Standards (Dishwashers) Determination 2012 under section 23 of the Australian Greenhouse and Energy Minimum Standards Act 2012 (25.10.2012). Available at http://www.comlaw.gov.au/Details/F2012L02119, last accessed on 25 Mar 2015.
Australian, State and Territory and New Zealand Governments (2014a). High Energy Performance Standards – Energy Star. Available at http://www.energyrating.gov.au/about/other-programs/energy-star/, last accessed on 25 Mar 2015.
Australian, State and Territory and New Zealand Governments (2014b). Star Rating Calculations - Dishwashers. Available at http://www.energyrating.gov.au/products-themes/washing-drying/dishwashers/star-rating/, last accessed on 25 Mar 2015.
Australian, State and Territory and New Zealand Governments (2014c). The Energy Rating Label. Available at www.energyrating.gov.au, last accessed on 25 Mar 2015.
Australian, State and Territory Governments (2014a). Water Rating: Water Efficiency Labelling and Standards (WELS) scheme. How are products tested? Available at http://www.waterrating.gov.au/consumers/product-testing, last accessed on 25 Mar 2015.
Australian, State and Territory Governments (2014b). Water Rating: Water Efficiency Labelling and Standards (WELS) scheme. About WELS. Available at http://www.waterrating.gov.au/about-wels, last accessed on 25 Mar 2015.
Bachl T. & Koll O. (2013). E-commerce, The potential for retailing? In ECR - Efficient Consumer Response . Brussels.
Bengtsson P.; Berghel J. & Renström R. (2015). A household dishwasher heated by a heat pump system using an energy storage unit with water as the heat source. International Journal of Refrigeration, 49, pp. 19–27. doi:10.1016/j.ijrefrig.2014.10.012.
Bichler S. (2014). Verbraucherakzeptanz von Energieeinsparpotentialen an automatischen Geschirrspülmaschinen. University of Bonn.
Bichler S.; Gorny S.; Seifert M.; Kessler A. & Stamminger R. (2015a). How to improve sustainability and environmentally friendly behaviour in automatic dishwashing? Example: Germany. Tenside Surfactants Detergents (submitted and accepted).,

Bichler S.; Gorny S.; Seifert M.; Kessler A. & Stamminger R. (2015b). How to improve sustainability and environmentally friendly behaviour in automatic dishwashing? Example: Germany. Tenside Surfactants Detergents (submitted and accepted),
Bichler et al. (2013). Are German consumers using their dishwashers in an energy efficient way? An online study of German households. In EEDAL, 7th International Conference. .
Bio by Deloitte (ed.) (2014). Evaluation of the use of phosphates in consumer automatic dishwasher detergents (CADD): Final Report. Report prepared for European Commission – DG Enterprise and Industry. Available at http://ec.europa.eu/DocsRoom/documents/7245/attachments/1/translations/en/renditions/native, last accessed on 28 Apr 2015.
Bio by Deloitte (ed.) (2015). Study on Socioeconomic impacts of increased reparability – DG ENV: Questionnaire 1. Available at http://www.google.de/url?sa=t&rct=j&q=&esrc=s&frm=1&source=web&cd=1&cad=rja&uact=8&ved=0CCgQFjAA&url=http%3A%2F%2Fwww.energimyndigheten.se%2FGlobal%2FF%25C3%25B6retag%2FEkodesign%2FEkodesign%2FBIO_ENV_Impacts_of_reparability_questionnaire_1.docx&ei=yydFVcl8iOJom42A-AM&usg=AFQjCNFe73PSl_Stf8yWADqGFHRAA5VKiA, last accessed on 02 May 2015.
BIO Intelligence Service (ed.) (2013). Material-efficiency Ecodesign Report and Module to the Methodology for the Ecodesign of Energy-related Products (MEErP): Part 1: Material Efficiency for Ecodesign – Draft Final Report. Prepared for: European Commission - DG Enterprise and Industry. Available at http://www.google.de/url?sa=t&rct=j&q=&esrc=s&frm=1&source=web&cd=2&cad=rja&uact=8&ved=0CCwQFjAB&url=http%3A%2F%2Fec.europa.eu%2FDocsRoom%2Fdocuments%2F105%2Fattachments%2F1%2Ftranslations%2Fen%2Frenditions%2Fpdf&ei=iSRFVc-SFYi67gbnmoDQCw&usg=AFQjCNHSiyvwigeFrVdPMSo5FjtgldpvZQ, last accessed on 02 May 2015.
Brückner A. (2013). Consumer-relevant Assessment of automatic dishwashing machines by a new testing procedure for 'automatic' programmes. (Doctor thesis). Rheinische Friedrich-Wilhelms-Universität, Bonn, Germany.
Brückner A. & Schneider, M. et al. (2012). A new place setting - Consumer-relevant measuring unit for domestic dishwashers. Tenside Surfactants Detergents, 49(1), pp. 48–56.
Brückner A. & Stamminger R. (2011). In Accuracy in measuring performance criteria of household dishwashers . WFK.
BSH Bosch und Siemens Hausgeräte GmbH (ed.) (2013). Creating Transparency: Group Sustainability Report 2013.
BSI Group (n.d.). Design MADE simple: Shedding light on the BS 8887 series of standards and their influence on sustainable design in the UK and beyond. Available at https://www.bsigroup.com/documents/standards/case-studies/BSI-maximizing-performance-BS-8887-design-for-manufacture-assembly-disassembly-and-end-of-life-processing-case-study-UK-EN.pdf, last accessed on 27 Feb 2014.
Buchert, M.; Manhart, A. & Sutter, J. (2014). Untersuchung zu seltenen Erden: Permanentmagnete im industriellen Einsatz in Baden-Württemberg. Available at http://www.oeko.de/oekodoc/2053/2014-630-de.pdf, last accessed on 12 Apr 2015.
Bundgaard, A.; Remmen, A. & Overgaard Zacho, K. (2015). Ecodesign Directive version 2.0: From Energy Efficiency to Resource Efficiency. Available at http://www2.mst.dk/Udgiv/publications/2015/01/978-87-93283-56-5.pdf, last accessed on 08 Apr 2015.
Bush, E. & Nipkow, J. (2005). Energie- und Kostenoptimierungen bei Waschmaschinen und Geschirrspülern: Kriterien für Warmwasseranschluss: Pilotprojekt im Auftrag des Amts für Hochbauten der Stadt Zürich.
Capgemini Consulting (ed.) (2012). White goods distribution in the spotlight - Sustainable distribution networks: what can be learned? (https://www.capgemini.com). https://www.capgemini.com/resource-file-access/resource/pdf/White_goods_distribution_in_the_spotlight.pdf.
CECED (ed.) (2014). Appliance testing - Call for interest (No. 20/04/2015). http://www.ceced.eu/site-ceced/news/2014/01/Appliance-testing---call-for-interest.html.
CENELEC (n.d.). European Mandates. Available at http://www.cenelec.eu/aboutcenelec/whatwestandfor/supportlegislation/europeanmandates.html, last accessed on 21 Apr 2015.

CENELEC (ed.) (2012). European Committee for Electrotechnical Standardization: Eu-ropean Standard EN 50574 – Collection, transport & treatment requirements for end-of-life household appliances containing volatile fluorocarbons of volatile hydrocarbons.
CENELEC (2015). CLC/TC 59X Performance of household and similar electrical appliances - Project prEN50242. Available at http://www.cenelec.eu/dyn/www/f?p=104:110:17952650572601::::FSP_PROJECT,FSP_LANG_ID:44549,25, last accessed on 13 May 2015.
Claridge, J. (2015). Using Rainwater in Your Home. Available at http://www.goselfsufficient.co.uk/using-rainwater-in-your-home.html.
CLASP (ed.) (2013). Estimating potential additional energy savings from upcoming revisions to existing regulations under the ecodesign and energy labelling directives: a contribution to the evidence base (http://www.clasponline.org). http://www.clasponline.org/en/Resources/Resources/PublicationLibrary/2013/CLASP-and-eceee-Point-To-Additional-Savings-from-Ecodesign-and-Energy-Labelling.aspx.
COWI and VHK (ed.) (2011). Methodology for Ecodesign of Energy-related Products MEErP 2011: Methodology Report. Part 1: Methods. Available at http://ec.europa.eu/enterprise/policies/sustainable-business/ecodesign/methodology/files/meerp_methodology_part1_en.pdf, last accessed on 07 Apr 2015.
Dalhammar, C.; Machacek, E.; Bundgaard, A.; Overgaard Zacho, K. & Remmen, A. (2014). Addressing resource efficiency through the Ecodesign Directive: A review of opportunities and barriers. Available at http://norden.diva-portal.org/smash/get/diva2:710881/FULLTEXT01.pdf, last accessed on 08 Apr 2015.
Digital Europe et al. (ed.) (2013). Guidance document on measuring all WEEE flows and establishing WEEE treatment standards under the WEEE recast implementation. Available at http://www.digitaleurope.org/DocumentDownload.aspx?Command=Core_Download&EntryId=514.
Ecofys (ed.) (2014). Impacts of the EU's Ecodesign and Energy/Tyre Labelling Legislation on Third Jurisdictions: Appendices. Available at https://ec.europa.eu/energy/sites/ener/files/documents/201404_ieel_third_jurisdictions_appendices.pdf, last accessed on 25 Mar 2015.
ECOS, EE and UK SNS (ed.) (2015). ECOS, EEB and UK SNS discussion paper on the draft standardisation request on material efficiency aspects for Ecodesign products. Available at http://ecostandard.org/wp-content/uploads/ECOS-EEB-UKSNS-Discussion-Paper-on-Material-Efficiency-Mandate.pdf, last accessed on 27 Feb 2015.
EN 50424/ EN 60436 Edition (2012). Electric dishwashers for household use - Methods for measuring the performance. Brussels, Belgium.
EN M/481 (2011). Mandate to CEN, CENELEC and ETSI for standardization in the field of household dishwashers. Brussels, Belgium.
ENEA/ISIS (ed.) (2007a). Preparatory Studies for Eco-design Requirements of EuPs Lot 14: Domestic Dishwashers & Washing Machines: Task 1: Definitions. Draft final report. Available at https://circabc.europa.eu/sd/a/48b885cf-3bf6-47cc-aea6-e7d071291734/Task%201%20Definitions.pdf, last accessed on 12 Mar 2015.
ENEA/ISIS (ed.) (2007b). Preparatory Studies for Eco-design Requirements of EuPs Lot 14: Domestic Dishwashers & Washing Machines: Task 6: Technical Analysis. Rev. 3.0. Available at http://www.eup-network.de/fileadmin/user_upload/Task_6_Technical_Analysis.pdf, last accessed on 19 Mar 2015.
ENEA/ISIS (ed.) (2007c). Preparatory Studies for Eco-design Requirements of EuPs Lot 14: Domestic Dishwashers & Washing Machines: Task 5: Definition of Base Case. Task Final Report. Available at http://www.eup-network.de/fileadmin/user_upload/Task_5_Definition_of_Base_Case.pdf, last accessed on 19 Mar 2015.
Energy Efficient Strategies (EES) (2010). Appliance Energy Consumption in Australia: Equations for Appliance Star Ratings. Available at http://www.energyrating.gov.au/wp-content/uploads/Energy_Rating_Documents/Library/General/Labelling_and_MEPS/appliance-star-ratings.pdf.
Energy Saving Trust (n.d.). Certification. Available at http://www.energysavingtrust.org.uk/businesses/certification, last accessed on 28 Apr 2015.

European Commission (ed.) (2007 / modif. 2012). Guidelines on the application of Directive 2006/95/EC (Electrical equipment designed for use within certain voltage limits). August 2007; last modified January 2012. Available at http://ec.europa.eu/enterprise/sectors/electrical/files/lvdgen_en.pdf, last accessed on 28 Apr 2015.
European Commission (2008). Commission Regulation (EC) No 1275/2008 of 17 December 2008 implementing Directive 2005/32/EC of the European Parliament and of the Council with regard to ecodesign requirements for standby and off mode electric power consumption of electrical and electronic household and office equipment (OJ L 339, pp. 45 to 52). Available at http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:339:0045:0052:en:PDF, last accessed on 07 Mar 2015.
European Commission (2009). Commission Regulation (EC) No 640/2009 of 22 July 2009 implementing Directive 2005/32/EC of the European Parliament and of the Council with regard to ecodesign requirements for electric motors (OJ L 191, pp. 26 to 24). Available at http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32009R0640&from=EN, last accessed on 11 Mar 2015.
European Commission (2010a). Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of Regions: Energy 2020 - A strategy for competitive, sustainable and secure energy. Available at http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2010:0639:FIN:EN:PDF, last accessed on 19 May 2015.
European Commission (2010b). Commission Delegated Regulation (EU) No 1059/2010 of 28 September 2010 supplementing Directive 2010/30/EU of the European Parliament and of the Council with regard to energy labelling of household dishwashers (Text with EEA relevance) (OJ L 314, 11.11.2010, pp. 1 to 16). Available at http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32010R1059&from=en, last accessed on 19 Feb 2015.
European Commission (2010c). Commission Regulation (EU) No 1016/2010 of 10 November 2010 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for household dishwashersText with EEA relevance (OJ L 293, 11.11.2010, pp. 31 to 40). Available at http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32010R1016&from=en, last accessed on 19 Feb 2015.
European Commission (2011a). Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of Regions: Energy Efficiency Plan 2011. Available at http://eur-lex.europa.eu/resource.html?uri=cellar:441bc7d6-d4c6-49f9-a108-f8707552c4c0.0002.03/DOC_1&format=PDF, last accessed on 19 May 2015.
European Commission (2011b). EP supports ban of phosphates in consumer detergents. Available at http://europa.eu/rapid/press-release_IP-11-1542_en.htm, last accessed on 17 Apr 2015.
European Commission (2012). Commission Regulation (EU) No 1194/2012 of 12 December 2012 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for directional lamps, light emitting diode lamps and related equipment (Text with EEA relevance) (OJ L 342, pp. 1 to 22), last accessed on 28 Feb 2015.
European Commission (2013a). Commission Regulation (EU) No 666/2013 of 8 July 2013 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for vacuum cleaners (OJ L 192, pp. 24 to 34). Available at http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32013R0666&from=EN, last accessed on 27 Feb 2015.
European Commission (2013b). Commission Regulation (EU) No 801/2013 of 22 August 2013 amending Regulation (EC) No 1275/2008 with regard to ecodesign requirements for standby, off mode electric power consumption of electrical and electronic household and office equipment, and amending Regulation (EC) No 642/2009 with regard to ecodesign requirements for televisions (OJ L 225, pp. 1 to 12). Available at http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32013R0801&from=EN, last accessed on 04 May 2015.
European Commission (ed.) (2013a). Digital Agenda Scoreboard 2013: Commission staff working document. Available at https://ec.europa.eu/digital-agenda/sites/digital-agenda/files/DAE%20SCOREBOARD%202013%20-%20SWD%202013%20217%20FINAL.pdf, last accessed on 03 May 2015.

European Commission (ed.) (2013b). Mandate M/518 EN to the European Standardisation Organisations for standardisation in the field of waste electrical and electronic equipment (Directive 2012/19/EU (WEEE)). Available at ftp://ftp.cencenelec.eu/CENELEC/EuropeanMandates/M_518.pdf, last accessed on 21 Apr 2015.
European Commission (ed.) (2014a). Commission Regulation (EU) No .../2015 of XXX implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for electronic displays and repealing Regulation 642/2009 with regard to ecodesign requirements for televisions: Possible requirements for electronic displays.
European Commission (ed.) (2014b). Possible Ecodesign and Energy Labelling requirements for electronic displays: Explanatory Notes.
European Commission (ed.) (2015a). Commission Implementing Decision of 7.1.2015 on a standardisation request to the European standardisation organisations pursuant to Article 10(1) of Regulation (EU) No 1025/2012 of the European Parliament and of the Council in support of the implementation of Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements on material efficiency aspects (recyclability, recoverability and reusability indexes, durability, reversible disassembly and end of life extraction time).
European Commission (ed.) (2015b). Draft Commission Decision of XXX establishing the criteria for the award of the EU Ecolabel for personal, notebook and tablet computers: Annex: EU Ecolabel criteria and assessment and verification requirements. Final criteria proposal for voting on 17th April 2015.
European Parliament (2004). Regulation (EC) No 648/2004 of the European Parliament and of the Council of 31 March 2004 on detergents (OJ L 104, pp. 1 to 35). Available at http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32004R0648&from=EN, last accessed on 17 Apr 2015.
European Parliament (2006a). Directive 2006/42/EC of the European Parliament and of the Council of 17 May 2006 on machinery, and amending Directive 95/16/EC (recast) (OJ L 157, pp. 24 to 86). Available at http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2006:157:0024:0086:EN:PDF, last accessed on 24 Feb 2015.
European Parliament (2006b). Regulation (EC) No 1907/2006 of the European Parliament and of the Council concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), establishing a European Chemicals Agency, amending Directive 1999/45/EC and repealing Council Regulation (EEC) No 793/93 and Commission Regulation (EC) No 1488/94 as well as Council Directive 76/769/EEC and Commission Directives 91/155/EEC, 93/67/EEC, 93/105/EC and 2000/21/EC (OJ L 396, pp. 1 to 849). Available at http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32006R1907&from=en, last accessed on 15 May 2015.
European Parliament (2008). Regulation (EC) 1272/2008 of the European Parliament and of the Council on classification, labelling and packaging of substances and mixtures, amending and repealing Directives 67/548/EEC and 1999/45/EC, and amending Regulation (EC) No 1907/2006 (OJ L 353, pp. 1 to 1355). Available at http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:353:0001:1355:en:PDF, last accessed on 15 May 2015.
European Parliament (2009a). 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) (OJ L 285, pp. 10 to 35). Available at http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32009L0125&from=EN, last accessed on 19 Mar 2015.
European Parliament (2009b). Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources (OJ L 140, pp. 16 to 62). Available at http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32009L0028&from=en, last accessed on 3.5.2105.
European Parliament (2011). Directive 2011/65/EU of the European Parliament and of the Council of 8 June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment (OJ L 174, pp. 88 to 110). Available at http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32011L0065&from=EN, last accessed on 15 Apr 2015.
European Parliament (2012a). Directive 2012/19/EU of the European Parliament and of the Council of 4 July 2012 on waste electrical and electronic equipment (WEEE) (OJ L 197, pp. 38 to 71). Available at

http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32012L0019&from=EN, last accessed on 13 Mar 2015.
European Parliament (2012b). Regulation (EU) No 259/2012 of the European Parliament and of the Council of 14 March 2012 amending Regulation (EC) No 648/2004 as regards the use of phosphates and other phosphorus compounds in consumer laundry detergents and consumer automatic dishwasher detergents (OJ L 94, pp. 16 to 21). Available at http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2012:094:0016:0021:en:PDF, last accessed on 17 Apr 2015.
European Parliament (2014a). Directive 2014/30/EU of the European Parliament and of the Council of 26 February 2014 on the harmonisation of the laws of the Member States relating to electromagnetic compatibility (OJ L 96, pp. 79 to 106). Available at http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32014L0030&from=DE, last accessed on 12 Mar 2015.
European Parliament (2014b). Directive 2014/35/EU of the European Parliamant and of the Council of 26 February 2014 on the harmonisation of the laws of the Member States relating to the making available on the market of electrical equipment designed for use within certain voltage limits (OJ L 96, pp. 357 to 374). Available at http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32014L0035&from=EN, last accessed on 12 Mar 2014.
European Parliament (2014c). Regulation (EU) No 517/2014 of the European Parliament and of the Council of 16 April 2014 on fluorinated greenhouse gases and repealing Regulation (EC) No 842/2006 (OJ L 150, pp. 195 to 230). Available at http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32014R0517&from=EN, last accessed on 09 Apr 2014.
Eurostat (n.d.). Prodcom. Available at http://ec.europa.eu/eurostat/web/prodcom/data/database.
Eurostat (ed.) (2013). Waste statistics – electrical and electronic equipment. Available at http://ec.europa.eu/eurostat/statistics-explained/index.php/Waste_statistics_-_electrical_and_electronic_equipment, last accessed on 18 Mar 2015.
Eurostat (ed.) (2015a). Statistics on the production of manufactured goods: Sold production, exports and imports by PRODCOM list (NACE Rev. 2) - annual data. Extraction for household dishwashers (Prodcom Code 27511200). Available at http://ec.europa.eu/eurostat/web/prodcom/data/database, last accessed on 30 Mar 2015.
Eurostat (ed.) (2015b). Traditional international trade database (ComExt): EU Trade Since 1988 by CN8. Extraction for dishwashing machines of the household type (CN Code 84221100). Available at http://epp.eurostat.ec.europa.eu/newxtweb/, last accessed on 30 Mar 2015.
Fletcher, Y. (2015). How we test dishwashers. Available at http://www.which.co.uk/home-and-garden/home-appliances/guides/how-we-test-dishwashers/.
Forum Waschen (ed.) (2014). Aktionstag Nachhaltiges (Ab-)Waschen: Thema: Spülen / Abwaschen. Available at http://forum-waschen.de/tl_files/content/pdf-waschen-abwaschen-reinigen/Faltblatt-Nachhaltiges-abwaschen-14.pdf, last accessed on 15 May 2015.
Forum Waschen (2015a). Reiniger: Welche Arten von Reinigern gibt es und wie werden sie dosiert?
Forum Waschen (2015b). Wie kann ich als Verbraucher nachhaltig spülen?
French Administration (2014). Qu'est-ce que l'obsolescence programmée ?: Direction de l'information légale et administrative (Premier ministre). Available at http://www.service-public.fr/actualites/007182.html, last accessed on 23 Apr 2015.
Décret n° 2014-1482 du 9 décembre 2014 relatif aux obligations d'information et de fourniture concernant les pièces détachées indispensables à l'utilisation d'un bien. JORF n°0286 du 11 décembre 2014 page 20707 (French Government 2014).
French Parliament (2015). Projet de loi modidié par le sénat, relatif à la transition énergétique pour la croissance verte (Procédure accélérée). Available at http://www.assemblee-nationale.fr/14/projets/pl2611.asp, last accessed on 23 Apr 2015.
French Senat (2014). Projet de loi adopté par l'assemblée nationale après engagement de la procédure accélérée, relatif à la transition énergétique pour la croissance verte. Available at http://www.senat.fr/leg/pjl14-016.html, last accessed on 23 Apr 2015.

FTC (2012). EnergyGuide label templates for manufacturers. Available at https://www.ftc.gov/tips-advice/business-center/guidance/energyguide-labels-templates-manufacturers, last accessed on 25.3.2914.
GEA (ed.) (1995). Study of Efficient Washing Machines, Dishwashers and Driers.
Gensch, C.-O.; Baron, Y.; Blepp, M.; Bunke, D. & Moch, K. (2014). Study for the review of the list of restricted substances under RoHS 2 - Analysis of impacts from a possible ban of several new substances under RoHS 2: Analysis of Impacts from a Possible Restriction of Several New Substances under RoHS 2. Available at http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Substance_Review/20140806_Substance_Review_revised_version_final_plus_Dossier.pdf, last accessed on 15 Apr 2015.
Gensch, C.-O.; Brommer, E. & Weber, A. (2009). Einsparpotenziale durch Warmwassernutzung und andere technologische Entwicklungen bei Geschirrspülmaschinen: Ermittlung typischer Randbedingungen in Haushalten: Endbericht im Auftrag der BSH Bosch und Siemens Hausgeräte GmbH.
Groß, R.; Bunke, D.; Gensch, C.-O.; Zangl, S. & Manhart, A. (2008). Study on Hazardous Substances in Electrical and Electronic Equipment, Not Regulated by the RoHS Directive. Available at http://ec.europa.eu/environment/waste/weee/pdf/hazardous_substances_report.pdf, last accessed on 15 Apr 2015.
Groß, R.; Bunke, D. & Moch, K. (2010). Study of critical substances in hand dishwashing and machine dishwasher detergents, identification of substitution options, and assessment of the environmental risk posed by dishwasher detergents.
Henkes W. (2012). Schärfere Optionsregeln. Recycling Magazin, (16/2012).
Hong Kong Green Council (ed.) (2010). Hong Kong Green Label Scheme Product Environmental Criteria for Dishwashers (GL-007-004). Available at http://www.greencouncil.org/hkgls/GL007004_rev3.pdf, last accessed on 25 Mar 2015.
Hubbuch M. & Goodall K. (1999). Amount and Composition of Soils in German Dishwashers. Composition to Standard Test Method. SÖFW Journal - Seifen Öle Fette Wachse, 125(10), pp. 14–20.
Huisman, J.; Magalini, F.; Kuehr, R.; Maurer, C.; Ogilvie, S.; Poll, J.; Delgado, C.; Artim, E.; Szlezak, J. & Stevels, A. (2007). 2008 Review of Directive 2002/96 on Waste Electrical and Electronic Equipment (WEEE): Final Report. Available at http://ec.europa.eu/environment/waste/weee/pdf/final_rep_unu.pdf, last accessed on 20 Mar 2015.
Huisman, J.; van der Maesen, M. & Eijsbouts, R. (2012). The Dutch WEEE Flows. Bonn, Germany. Available at http://www.weee-forum.org/system/files/2012_the_dutch_weee_flows_unu.pdf, last accessed on 09 Apr 2015.
iea-4e (2014). Benchmarking report for Dishwashers (http://mappingandbenchmarking.iea-4e.org). http://mappingandbenchmarking.iea-4e.org/shared_files/552/download.
IEC (ed.) (2012). IEC/TR 62635 Technical Report: Guidelines for end-of-life information provided by manufacturers and recyclers and for recyclability rate calculation of electrical and electronic equipment. Available at www.webstore.iec.ch/preview/info_iec62635(ed1.0)en.pdf, last accessed on 27 Feb 2015.
IEC 60436 4th Edition, FDIS (ed.) (2015). Electric dishwashers for household use – Methods for measuring the performance.
IFHE (ed.) (n.d.). Best Practice Tips Automatic Dishwashing: How to run an automatic dishwasher. Poster. Available at http://he.ifhe.org/index.php?eID=tx_nawsecuredl&u=0&file=fileadmin/user_upload/redaktion-he/Home_Economics/HT_S/4_Poster_Best_Practice_Automatic_Dishwashing_Version_3_20.09.2012.pdf&t=1431827216&hash=db143bacf813f6c810e95169491837ff, last accessed on 15 May 2015.
IKW (2006). Methods for Ascertaining the Cleaning Performance of Dishwasher Detergents: Part B, updated 2005. SÖFW-Journal, 132(08), pp. 35–49.
Indesit Company (ed.) (2014). Sustainability Report 2013. Available at http://www.indesitcompany.com/pages/_saved_files/content/link/en_GB/1622_IndesitCo_CSR_2013_ENG.PDF, last accessed on 19 Mar 2015.
International Energy Agency IEA (2014). Energy Efficiency Policies and Measures Databases: Equipment Energy Efficiency Program (E3), Australia. Available at http://www.iea.org/policiesandmeasures/energyefficiency/index.php, last accessed on 27 Mar 2015.

JRC IPTS (ed.) (2014). Revision of European EU Ecolabel Criteria for Detergents for Dishwashers: Preliminary report for the revision of European ecological criteria for detergents for dishwashers: domestic and industrial and institutional. Available at http://susproc.jrc.ec.europa.eu/detergents/docs/DD%20Preliminary%20Report.pdf, last accessed on 25 Apr 2015.
JRC IPTS (ed.) (2015a). Revision of EU Ecodesign and Energy/Resource Label for household dishwashers: Stakeholder consultation - 1st questionnaire. Available at http://susproc.jrc.ec.europa.eu/Dishwashers/docs/1st_Questionnaire_DISH.doc.
JRC IPTS (ed.) (2015b). Revision of EU Ecodesign and Energy/Resource Label for household washing machines and washer-dryers: Stakeholder consultation - 1st questionnaire. Available at http://susproc.jrc.ec.europa.eu/Washing_machines_and_washer_dryers/docs/1st_Questionnaire_WASH.doc, last accessed on 19 May 2015.
JRC IPTS (ed.) (2015c). Revision of European Ecolabel Criteria for laundry detergents, dishwasher detergents, industrial and institutional automatic dishwasher detergents, industrial and institutional laundry detergents, hand dishwashing detergents and all-purpose cleaners and sanitary cleaners. Available at http://susproc.jrc.ec.europa.eu/detergents/docs/ELS-DP_2_15-01-2015.pdf, last accessed on 25 Apr 2015.
Korea Environmental Industry & Technology Institute KEITI (ed.) (2005). Ecolabel certification criteria for dishwashers. Available at http://el.keiti.re.kr/enservice/enpage.do?mMenu=2&sMenu=1, last accessed on 27 Mar 2015.
Livesey, B. (2014). Whirlpool to Buy Control of Italy's Indesit for $1B. Available at http://www.bloomberg.com/news/articles/2014-07-11/whirlpool-to-buy-stakes-totalling-67-in-italy-s-indesit, last accessed on 15 May 2015.
Magalani, F.; Huisman, J. & Wang, F. ([n.d.]). Household WEEE generated in Italy: Analysis on volumes & consumer disposal behaviour for waste electrical and electronic equipment. Available at http://www.weee-forum.org/system/files/2012_ecodom_weee_arising_in_italy_en.pdf, last accessed on 09 Apr 2015.
Manhart A. (2009-2014). Visual observations in EEE trading hubs in Ghana and Nigeria between 2006 and 2014.
Miele (2015). Präsentation zur Multi-Tagung 2015, last accessed on 29 Apr 2015.
Nordic Ecolabelling (ed.) (2014). Nordic Ecolabelling of White Goods: Version 5.0. 20 June 2013 - 30 June 2017. Available at http://www.svanen.se/Templates/Criteria/CriteriaGetFile.aspx?productGroupNumber=3&language=e, last accessed on 25 Mar 2015.
Paepe M. de; Theuns E.; Lenaers S. & van Loon J. (2003). Heat recovery system for dishwashers. Applied Thermal Engineering, 23(6), pp. 743–756. doi:10.1016/S1359-4311(03)00016-4.
Persson T. (2007). Dishwasher and washing machine heated by a hot water circulation loop. Applied Thermal Engineering, 27(1), pp. 120–128. doi:10.1016/j.applthermaleng.2006.05.005.
Prakash, S.; Dehoust, G.; Gsell, M.; Schleicher T. & Stamminger, R. (2015). Einfluss der Nutzungsdauer von Produkten auf ihre Umweltwirkung: Schaffung einer Informationsgrundlage und Entwicklung von Strategien gegen „Obsoleszenz": ZWISCHENBERICHT: Analyse der Entwicklung der Lebens-, Nutzungs- und Verweildauer von ausgewählten Produktgruppen. Available at http://www.umweltbundesamt.de/sites/default/files/medien/378/publikationen/texte_10_2015_einfluss_der_nutzungsdauer_von_produkten_auf_ihre_umwelt_obsoleszenz_17.3.2015.pdf, last accessed on 06 Apr 2015.
Presutto, M.; Stamminger, Rainer, Scaldoni, Raffaele; Mebane, W. & Esposito, R. (2007). Preparatory Study of Eco-Design Requiremetns of Eups: Lot 14: Domestic Washing Machines and Dishwashers, Task 1-2.
Ral gGmbH (ed.) (2013). Household Dishwashers RAL-UZ 152: Basic Criteria for the Award of the Environmental Label. Available at https://www.blauer-engel.de/sites/default/files/raluz-downloads/vergabegrundlagen_en/e-UZ-152-2013.zip, last accessed on 19 Feb 2015.
Ricardo-AEA (ed.) (2014a). The Durability of Products: Task 1 Report: Standard assessment for the circular economy under the Eco-Innovation Action Plan. Task 1 – Selection of Products. Available at www.productdurability.eu/assets/Product-Durability-Task-1-Report.pdf, last accessed on 18 Mar 2015.

Ricardo-AEA (ed.) (2014b). The Durability of Products: Task 2 Briefing: Standard assessment for the circular economy under the Eco-Innovation Action Plan. Task 2 – Review of Existing Methodologies. Available at http://www.productdurability.eu/assets/Product-Durability-Task-2-Briefing-tc.pdf, last accessed on 18 Mar 2015.
Richter C. (2010a). Automatic dishwashers: efficient machines or less efficient consumer habits? International Journal of Consumer Studies, 34(2), pp. 228–234.
Richter C. (2010b). In-house Consumer Study on Dishwashing Habits in Four European Countries: Saving Potentials in Households with Dishwashing machine, last accessed on 30 Apr 2015.
RReuse (ed.) (2013). Investigation into the repairability of Domestic Washing Machines, Dishwashers and Fridges. Available at http://www.rreuse.org/wp-content/uploads/RREUSE_Case_Studies_on_reparability_-_Final.pdf, last accessed on 08 Apr 2015.
Rüdenauer, I.; Blepp, M.; Brommer, E.; Gensch, C.-O.; Graulich, K.; Mudgal, S.; Cervantes, R.; Faninger, T.; Lyons, L. & Seifried, D. (2011a). Preparatory Studies for Eco-design Requirements of Energy-using Products: Lot 24: Professional Washing Machines, Dryers and Dishwashers; Final Report, Part Dishwashers. Task 1: Definition. Available at http://www.eup-network.de/fileadmin/user_upload/Produktgruppen/Lots/Working_Documents/Lot24_Dish_T1_ENER_clean_final.pdf, last accessed on 28 Apr 2015.
Rüdenauer, I.; Blepp, M.; Brommer, E.; Gensch, C.-O.; Graulich, K.; Mudgal, S.; Cervantes, R.; Faninger, T.; Lyons, L. & Seifried, D. (2011b). Preparatory Studies for Eco-design Requirements of Energy-using Products: Lot 24: Professional Washing Machines, Dryers and Dishwashers; Final Report, Part Dishwashers. Task 4: Technical Analysis Existing Products. Available at http://www.eup-network.de/fileadmin/user_upload/Produktgruppen/Lots/Working_Documents/Lot24_Dish_T4_ENER_clean_final.pdf, last accessed on 28 Apr 2015.
Saker D.; Vahdati M.; Coker P. & Millward S. (2015). Assessing the benefits of domestic hot fill washing appliances, 93 (2015), pp. 282–294.
Scharf B. (2015). The dishwasher market. (04/2015).
Schneider M. & Stamminger R. (2011). Consumer behavior in dishwashing and cleanser consumption in German households. In SEPAWA - Congress & EDC Conference 2011 . Fulda.
SENS/Swico/SLRS (ed.) (2014). Technical Report 2014. Available at http://www.swicorecycling.ch/downloads/dokumente/technical-report-swico-sens-slrs-2014.pdf/1841, last accessed on 21 Apr 2015.
Sharp (ed.) (2012). Sustainability Report 2012. Available at http://www.sharp.co.jp/corporate/eco/report/backnumber/pdf/esr2012e.pdf, last accessed on 19 Mar 2015.
Stamminger R. & Streichhard C. (2009). Selected Aspects of Consumer Behaviour in the Manual and Mechanical Dishwashing in Germany. SÖFW Journal - Seifen Öle Fette Wachse, 135, pp. 50–56.
Stiftung Warentest (2014). Von sauber bis ruiniert. test, (8/2014), pp. 70–74.
Stiftung Warentest (2015). Blitzblank im Sparprogramm. test, (05/2015), pp. 67–71.
Stöckle F. (2013). Household Appliances. In IFA - Consumer Electronics Unlimited . Berlin.
Stöckle, F. (2014). Household Appliances. In: IFA - Consumer Electronics Unlimited, Berlin.
TIG (ed.) (2015). Policy recommendations for Dishwashers. Available at http://www.topten.eu/uploads/File/Recommendations_Dishwashers_March_15.pdf, last accessed on 07 Apr 2015.
U.S. Government (ed.) (2014). Code of Federal Regulations (CFR): Title 10 (Energy), Part 430 (Energy Conservation Program for Consumer Products). Available at http://www.gpo.gov/fdsys/pkg/CFR-2014-title10-vol3/pdf/CFR-2014-title10-vol3-part430.pdf, last accessed on 24 Feb 2015.
UNEP (ed.) (2013). Metal Recycling: Opportunities, Limits, Infrastructure. A Report of the Working Group on the Global Metal Flows to the International Resource Panel. Available at http://www.unep.org/resourcepanel/Portals/24102/PDFs/Metal_Recycling_Full_Report.pdf, last accessed on 12 Apr 2015.
US EERE (2014). Energy Conservation Programs: Standards for Residential Dishwashers; Notice of proposed rulemaking (NOPR) and public meeting (2014). Available at http://www.regulations.gov/, last accessed on 19 Mar 2015.

US EPA (ed.) ([n.d.]a). ENERGY STAR® Program Requirements - Product Specification for Residential Dishwashers: Eligibility Criteria Version 5.2. Available at http://www.energystar.gov/ia/partners/product_specs/program_reqs/ENERGY_STAR_Dishwasher_Program_Requirements_V5-2.pdf.
US EPA ([n.d.]b). Learn More About EnergyGuide. Available at http://www.energystar.gov/index.cfm?c=appliances.pr_energy_guide, last accessed on 25 Mar 2015.
US EPA (ed.) (2014). ENERGY STAR® Program Requirements: Product Specification for Residential Dishwashers. Eligibility Criteria Version 6.0. Available at http://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Residential%20Dishwasher%20Version%206.0%20Final%20Program%20Requirements_0.pdf, last accessed on 15 May 2015.
Userneeds (2009). Consumers want green and clean detergents. Focus on Surfactants, (09/2009).
Vanthournout, K.; Ectors, D.; Bogaert, S.; Viegand, J.; Stamminger, R.; Geppert, J.; Rivière, P. & Götz, T. (2015). Ecodesign Preparatory study on Smart Appliances: Discussion note on Interoperability and Standardisation, last accessed on 17 Apr 2015.
VHK (ed.) (2014). Ecodesign Impact Accounting: Part 1 – Status Nov. 2013. Available at https://ec.europa.eu/energy/sites/ener/files/documents/2014_06_ecodesign_impact_accounting_part1.pdf, last accessed on 07 Apr 2015.
VHK et al. (ed.) (2014). "Omnibus" Review Study on Cold Appliances, Washing Machines, Dishwashers, Washer-Driers, Lighting, Set-top Boxes and Pumps. Available at http://susproc.jrc.ec.europa.eu/Washing_machines_and_washer_dryers/docs/omnibus_studyf_2014-03.pdf.
VITO et al. (ed.) (2015). Ecodesign Preparatory study on Smart Appliances: Discussion note on Interoperability and Standardisation. In preparation of the Stakeholder meeting of 10 March 2015. Available at http://www.eco-smartappliances.eu/Documents/Ecodesign%20Smart%20appliances_Discussion%20note_workshop_150310.pdf, last accessed on 11 Apr 2015.
Vito NV (2015). Preparatory study on Smart Appliances. Available at http://www.eco-smartappliances.eu/Pages/welcome.aspx.
V-ZUG (ed.) (n.d.). Dishwasher Adora SL fully and design integrated: Operating instructions. Available at http://www.vzug.com/medias/J41001.013-3.PDF?context=bWFzdGVyfGltcG9ydGVkLWRvY3VtZW50c3wzNjI0MDU4fGFwcGxpY2F0aW9uL3BkZnxpbXBvcnRlZC1kb2N1bWVudHMvaGI4L2g2My84ODkyNDE1NzcwNjU0LnBkZnxjODQ5NWQzMjRlNGNlNWZkNGVmZTNkYjg5MGVjNmQ0YWQ0ZmRlNDFlMTdkNmQ4N2NhMmU3NmY5YzBlZGFiNTY4&attachment=true, last accessed on 15 May 2015.
V-ZUG (2014). Adora SL product manual, last accessed on 30 Apr 2015.
V-ZUG (2015). Produktvergleich Adora SL WP, Adora SL, Adora S. Available at http://www.vzug.com/ch/de/controller/ProductPdfController/V-ZUG-.pdf?code=4103800055&cat=dishwasher&code=4100600055&cat=dishwasher&code=4103400063&cat=dishwasher&generatePDF=, last accessed on 23 Apr 2015.
V-ZUG Heat Pump (2014). Wärmepumpentechnologie Spülmaschine. Available at http://www.vzug.com/ch/de/int_novelties_heatpump_dishwasher_2014_vzug, last accessed on 23 Apr 2015.
V-ZUG Website (n.d.). Geschirrspüler. Available at http://www.vzug.com/ch/de/category/ch-Catalog/productType/kitchen/dishwasher, last accessed on 23 Apr 2015.
Walkden, T. G. (2012). Dishwasher with high voltage DC motor: Google Patents. Available at http://www.google.tl/patents/US8241434, last accessed on 02 May 2015.
WRAP ([n.d.]a). Product design review - Washer Dryer. Available at http://www.wrap.org.uk/sites/files/wrap/WRAP%20Design%20Review%20Case%20Study%20Washer%20Dryer.pdf, last accessed on 17 Mar 2015.
WRAP ([n.d.]b). Re-use protocols for electrical products. Available at www.wrap.org.uk/content/re-use-protocols-electrical-products, last accessed on 27 Feb 2015.
WRAP (ed.) (2011). Benefits of Reuse: Case Study: Electrical Items. Available at http://www.wrap.org.uk/sites/files/wrap/Electricals%20reuse_final.pdf, last accessed on 18 Mar 2015.

WRAP (ed.) (2013a). Electrical and electronic product design: product lifetime. Available at http://www.wrap.org.uk/sites/files/wrap/WRAP%20longer%20product%20lifetimes.pdf, last accessed on 18 Mar 2015.
WRAP (ed.) (2013b). PAS 141 Protocol: Product Guide: Dishwashers. Available at http://www.wrap.org.uk/sites/files/wrap/PAS%20141%20Product%20Guide%20-%20Dishwashers.pdf, last accessed on 27 Feb 2015.
Zott A. & Hubbuch M. (2008). Durchschnittliche Verbraucherbeladung beim maschinellen Spülen. SÖFW Journal – Seifen Öle Fette Wachse, 132(1), pp. 48–55.

7 LIST OF ACRONYMS

ABS	Acrylonitrile butadiene styrene
AC	Alternating current
AE_C	Annual Energy Consumption
Al	Aluminium
BAU	Business-as-usual (scenario)
BAT	Best available technology
BEC	Base Energy Consumption
BNAT	Best not yet available technology
BOM	Bill of material
CEC	Comparative Energy Consumption
CI	Cleaning Index
Cr	Chromium
Cu	Copper
DC	Direct current
DoC	Declaration of Conformity
DOE	US Department of Energy
EC	European Commission
EEI	Energy Efficiency Index
EPDM	Ethylene Propylene Diene Monomer
EPS	Expanded Polystyrene
FDIS	Final Draft International Standard
FTC	US Federal Trade Commission
HiNa	High Network Availability
IA	Impact Assessment
I_D	Drying efficiency index
LCC	Life cycle costs
OJEU	Official Journal of the European Union
PA	Polyamide
PBT	Polybutylene terephthalate
PCB	Printed Circuit Board
PE	Polyethylene
PMMA	Polymethylmethacrylate
PMSM	Permanent magnet synchronous motors
POM	Polyoxymethylene
PP	Polypropylene
ppm	parts per million
PS	Polystyrene
ps	place settings
PU	Polyurethane
PVC	Polyvinylchloride
PWB	Printed Wiring Board
REE	Rare Earth Element
RRT	Round Robin Test
SAE_C	Standard Annual Energy Consumption
US	United States
VA	Voluntary Agreement
Zn	Zinc