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Ecodesign and Energy Label for Household Dishwashers

Preparatory study
Final report

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List of acronyms

ABS	Acrylonitrile Butadiene Styrene
AC	Alternating current
ADW	Automatic Dishwashing
AE_C	Annual Energy Consumption
Al	Aluminium
BAT	Best Available Technology
BAU	Business As Usual (scenario)
BC	Base Case
BEC	Base Energy Consumption
BNAT	Best Not Yet Available Technology
BoM	Bill of Material
CADD	Consumer Automatic Dishwasher Detergents
CCD	Combined Cleaning and Drying
CEC	Comparative Energy Consumption
CEN	European Committee for Standardization (Comité Européen de Normalisation)
CENELEC	European Committee for Electrotechnical Standardization (Comité Européen de Normalisation Électrotechnique)
CI	Cleaning Index
Cr	Chromium
Cu	Copper
DC	Direct current
DoC	Declaration of Conformity
DOE	US Department of Energy
DW	Dishwasher
EC	European Commission
EEI	Energy Efficiency Index
EoL	End-of-life
EPDM	Ethylene Propylene Diene Monomer
EPS	Expanded Polystyrene
ETSI	European Telecommunications Standards Institute
FDIS	Final Draft International Standard
FTC	US Federal Trade Commission
GWP	Global Warming Potential

HICP	Harmonised Index of Consumer Prices
HiNa	High Network Availability
IA	Impact Assessment
I_D	Drying efficiency index
LCC	Life Cycle Costs
LLCC	Least Life Cycle Costs
MEPS	Minimum Energy Performance Standard
OEM	Original Equipment Manufacturer
OJEU	Official Journal of the European Union
p.a.	per annum (per year)
PA	Polyamide
PAH	Polycyclic Aromatic Hydrocarbons
PBT	Polybutylene terephthalate
PC	Polycarbonate
PCB	Printed Circuit Board
PE	Polyethylene
PM	Particulate Matter
PMMA	Polymethylmethacrylate
PMSM	Permanent magnet synchronous motors
POM	Polyoxymethylene
POP	Persistent Organic Pollutants
pp	percentage points
PP	Polypropylene
ppm	parts per million
ps	place settings
PS	Polystyrene
PU	Polyurethane
PVC	Polyvinylchloride
PWB	Printed Wiring Board
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
REE	Rare Earth Element
RoHS	Restriction of Hazardous Substances
RRT	Round Robin Test
SAE_C	Standard Annual Energy Consumption
TWG	Technical Working Group
US	United States

VA	Voluntary Agreement
VOC	Volatile Organic Compounds
Zn	Zinc

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 2010c) 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. On the 15 June 2015 the European Commission agreed its revision to propose a new regulation that seeks to restore the A-G scale for labelling by creating a mechanism for rescaling products that can accommodate further improvements in energy efficiency, establishing a product database on energy efficiency and introducing a safeguard procedure to improve national market surveillance.

The European Commission launched in 2014 the revision of the ecodesign and energy-/resource label implementing measures for the product group 'household dishwashers (DW)'. The revision study has been 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 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 2011b), 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 economics
- Task 6 – Design options
- Task 7 – Policy analysis and 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 2010a) and the Ecodesign Regulation (EC) 1016/2010 on household dishwashers (European Commission 2010b).

The research is based on available scientific information and data, uses a life-cycle thinking approach, and has engaged stakeholder experts in order to discuss key issues, and to the extent possible reach consensus on the proposals.

A set of information of interest has been collected. Starting from the initial preparatory study (so-called 'ENER Lot 14') prepared in 2007 (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 was advisable.

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

As final result, this updated preparatory study includes a comprehensive techno-economic and environmental assessment for this product group. This document provides policy makers with the evidence basis for assessing whether and how to revise the existing Regulations.

A Technical Working Group (TWG) of stakeholders 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 has contributed to the study with data, information and written feedback to questionnaires and working documents. Interaction with stakeholders has also taken 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.

Additionally, a webinar was organised on 7 October 2016 to discuss potential material efficiency requirements.

Structure of this report

This document is structured in the following chapters, following Tasks 1 to 7 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.
- Chapter 5 – Environment and economics: an environmental and economic assessment of base-cases
- Chapter 6 – Design options: an analysis of the improvement potential achievable for this product group through the implementation of best available technologies and best not available technologies
- Chapter 7 – Policy scenarios assessment: a streamlined impact assessment of different policy options

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 dishwashers 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 (ISIS 2007b), 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. Regulations (EC) No 1016/2010 and (EC) No 1059/2010

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

> *‘<u>Household dishwasher</u>’ 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, p. **Error! Bookmark not defined.**) 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, p.28) 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:

- '<u>Dishwasher</u>'*: 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.*
- '<u>Compact Dishwasher</u>': *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.*
- '<u>Standard Dishwasher</u>': *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.*
- '<u>Portable Dishwasher</u>': *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. <u>Included Products:</u> 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. <u>Excluded Products:</u> 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":

> *<u>Consumer product</u> 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 (section 2.4.3, Definition of professional dishwashers within Lot 24), defines professional dishwashers as follows (Rüdenauer et al. 2011):

> *'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 2006a) 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.

1.1.1.7. Summary

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	"Residential dishwasher"; "Consumer product: means any product which ... to any significant extent, is distributed in commerce for personal use or consumption by individuals."

EU Ecodesign / Energy Label Regulations	IEC / EN standards	EU Prodcom statistics	German Blue Angel ecolabel	US Energy Star label
			offices, kindergar-tens etc.”	
		Design format		
Including “Built-in, i.e. intended to be installed in a cabinet, a prepared recess in a wall or a similar location, requir-ing furniture finishing”	---	---		“Cabinet-like”; “Stand-ard”; “Compact”; “Portable: not perma-nently 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 in-cludes 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 and definition

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 2015b). 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.

Based on this input, a revised scope and definition were presented at the 1st TWG meeting (23 June 2015, Seville). Further stakeholder feedback during and after the meeting led to a slight adaption of the scope presented again to stakeholders at the 2nd TWG meeting (17 November 2015, Brussels).

All recommendations provided by stakeholders are summarised in the following points, leading to a final draft revised scope and definitions to be used for this study (cf. section 1.1.3)

1.1.2.1. Clarity of the existing definitions

Only few stakeholders commented on this point. Those who answered consider the existing definitions as comprehensive and clear.

For feedback regarding the term “built-in” see section 1.1.2.3 .

1.1.2.2. Functional parameters

The given main functions (cleaning, rinsing, and drying) were explicitly put forward by one stakeholder to be the most important parameters. 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.

Regarding the functional parameters the following definition was presented at the 1st TWG meeting:

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.

General agreement was expressed regarding the definition including the main functions of DWs, since it is pretty close to the definition already in place. The second part was discussed more extensively. Some stakeholders found that drying is one of the main functions of the DWs and that this process should be always included. If not, it would be possible to sell DWs without the drying function. Other stakeholders consider that the proposed definition is in line with the definition in the Standard EN50242/IEC60436 and that it reflects the real-life and market where there are programs that do not carry out a drying process at the end of the cycle (e.g. short or fast programs focus on cleaning and not on drying processes). The purchase of a DW without the drying function is not possible on the current market since all DWs should demonstrate their performance by compliance with the energy label and ecodesign regulations that require testing against the standard program including both cleaning and drying processes.

1.1.2.3. Built-in appliances

Those stakeholders answering to this question state that generally there is no need for a separate category because there is no difference, in terms of covered efficiency and performance, between built-in and free-standing machines. “Built-in” was in the past used as one of the differentiation criteria for professional appliances. One stakeholder comments that a separate category would only be needed if requirements were different from those for free-standing machines. 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.

Also in the 1st TWG it was discussed if the separate reference to "built-in appliances" in the current scope and definitions might be removed. Stakeholders welcomed the proposal to remove it but pointed out that the Energy Label Directive should be checked before the final drafting to determine if it requires explicit mentioning of built-in.

At the 2nd TWG meeting on 18 November in Brussels, stakeholders were informed that there is explicit reference made to built-in appliances in the Energy Label Directive 2010/30/EU (European Parliament 2010) (currently under revision), where §4 “Information requirements” states

> *Member States shall ensure that:*
>
> *(a) information relating to the consumption of electric energy, other forms of energy and where relevant other essential resources during use, and supplementary information is, in accordance with delegated acts under this Directive, brought to the attention of end-users by means of a fiche and a label related to products offered for sale, hire, hire-purchase or displayed to end-users directly or indirectly by any means of distance selling, including the Internet;*
>
> *(b) the information referred to in point (a) is provided in respect of **built-in** or installed products only where required by the applicable delegated act.*

Based on this explicit reference it was proposed and agreed by stakeholders to keep ‘built-in’ appliances mentioned in the current scope of the revised regulations on household dishwashers just for the purpose of aligning to the framework Energy Label Directive 2010/30/EU.

In case of the future revised Energy Label Directive 2010/30/EU not including this reference anymore, the explicit reference to built-in appliances might also be removed from the revised scope of the dishwasher regulations.

1.1.2.4. Battery-powered dishwashers

The picture of the stakeholders responding to this topic is rather indifferent.

On the one hand, the market data collected reveals that battery-powered dishwashers could not be detected on the EU market. Battery-powered dishwashers do not have any market relevance. No battery-operated household dishwashers could be detected since very small dishwashers with 4 or 5 ps, which might be possibly portable, seem to have 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.

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.

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, argues that all dishwashers should be covered by identical requirements, i.e. that the best / most energy saving models should be promoted in a technology-neutral way.

Also, some of the responding 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. Theoretically, battery-powered household appliances might work as capacity storage in a smart-grid network; however, it is assumed that such power storage would rather be implemented as a central storage system for the whole household with the single appliances still being electric-mains operated.

In the 1st TWG meeting stakeholders welcomed the proposal to exclude battery-powered dishwashers from the scope due to the lack of the relevance of this type of machines on the market. However, it was recommended by stakeholders that the exclusion of battery-operated appliances should apply only to those that are solely operated by batteries and not to those appliances that either have a battery as one of their components to operate auxiliaries or those that can be both mains-operated and operated by batteries (e.g. battery back-up).

1.1.2.5. 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. They inform 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 networked 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.

1.1.2.6. Semi-professional appliances

The current regulations apply to “household” dishwashers. The following aspect has been discussed:

- Should semi-professional appliances (which at first glance seem to be comparable to household dishwashers) be additionally included in the revised regulations?

Although some stakeholders argued that semi-professional dishwashers should have energy label requirements since their use of resources is more intensive, most stakeholders agreed not to handle semi-professional appliances under the scope of this revision on household appliances, but rather under the professional ones which are currently covered under Lot 24 and for which work is already ongoing. Arguments of stakeholders against their inclusion in the current regulation on household dishwashers:

- The different way the product is used (e.g. the frequency of use);
- They cannot be compared with household dishwashers: semi-professional dishwashers need higher voltage (400 V) and 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.

Table 1.2 shows the main differences between household and semi-professional dishwashers.

Table 1.2: Main differences between household and semi-professional dishwashers

	Household dishwashers	Semi-professional dishwashers (category: undercounted water-change); source: Rüdenauer et al. (2011)
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

Based on this feedback, it was recommended to keep only household appliances in the scope of this revision.

Additionally, the question was asked if the current definition of "household" is sufficient to delimit these products from (semi-) professional appliances. The current definition states that a household dishwasher means a machine which is designed to be used principally for non-professional purposes.

It seems that the current definition might not be clear enough as it is in general possible for a private consumer to acquire and use an appliance designed and intended for professional use or for a professional user to acquire and use a household appliance. Besides the design, also the way household and professional products are marketed to and accessible for consumers is relevant.

In general, for household appliances the requirements of the "Low Voltage" Directive (LVD) 2014/35/EU (European Parliament 2014b) apply, whereas professional appliances fall under the scope of the "Machinery" Directive (MD) 2006/42/EC (European Parliament 2006a).

In order to provide greater legal certainty for manufacturers and to avoid potential misinterpretations, the "Guidelines on the application of the Low Voltage Directive 2006/95/EC" (European Commission 2007 / modif. 2012) clarify the borderline between the scope of these two Directives. 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 so called "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 which Directive (LVD or MD) 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".

In this sense, the reference to the LVD was confirmed by stakeholders to appear the most objective means to differentiate between household and non-household use of the appliance.

1.1.3. Final proposals for product scope and definitions

Based on the previous analysis of existing scopes and definitions, stakeholder feedback related to the scope during the course of the preparatory study (cf. section 1.1.2) as well as the analysis of market data and trends (cf. Task 2), the following draft final product scope and definitions are proposed for the revision of the ecodesign and energy label regulations for household dishwashers.

1.1.3.1. Final proposal for a product scope

Current scope of 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'.

Regulation (EC) No 1059/2010 with regard to energy label of household dishwashers has the same scope.

Proposal for a revised scope of the ecodesign regulation 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 built-in household dishwashers.

The energy label regulation would have the same scope, as follows:

This regulation establishes requirements for the labelling of and the provision of supplementary product information on electric mains-operated household dishwashers and electric mains-operated household dishwashers that can also be powered by batteries, including built-in household dishwashers.

1.1.3.2. Final proposal for definitions

Current definitions for household dishwashers in the Ecodesign Regulation (EC) No 1016/2010 and the Energy Label Regulation (EC) No 1059/2010:

> *'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.*

Proposal for revised definitions of the ecodesign and energy label regulations for household dishwashers:

> ***'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 and which is designed in a way principally intended for domestic use complying with the Low Voltage Directive 2014/35/EU as stated by the manufacturer in the Declaration of Conformity (DoC).***

The definition of a built-in household dishwasher is kept unchanged:

'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.

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

Table 1.3: Overview of the European legislation on ecodesign, energy efficiency and performance

European legislation	
Ecodesign Regulations	Ecodesign Regulation (EC) No 1016/2010 for household dishwashers
	Ecodesign Regulation (EC) No 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 Label 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

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) No 1016/2010 with regard to ecodesign requirements for household dishwashers establishes 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 1.4) according to the Energy Efficiency Index (EEI), cleaning and drying performance (Table 1.5) for appliances of different sizes and load capacities with the associated dates of entry into force.

Table 1.4: Specific ecodesign requirements in Regulation (EC) No 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 1.5: Specific ecodesign requirements in Regulation (EC) No 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 prescribes formulas for the calculation of EEI and the annual energy consumption (AE_C) (see section 1.2.1.2). 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.

It has to be mentioned that there is a mistake in the AEC calculation in the Ecodesign Regulation (EC) No 1016/2010. Instead of „T_l“ (time in left-on mode) which would be correct, „T_t“ (program time) is written. The calculation given in Energy Label Regulation (EC) No 1016/2010 (see section 1.2.1.2) is correct.

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 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 1.6) 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 1.6.

Ecodesign Regulation (EC) No 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 un-

der 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), the left-on mode might 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 might 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.
  - 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 “*the shortest possible period of time appropriate for the intended use of the equipment*”. The timeframe has not been further specified; according to stakeholder feedback, this is for example realised after at most 30 minutes. The power management for networked appliances switches the equipment automatically into a condition providing networked standby within 20 minutes (see following paragraphs on networked standby).

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

Regulation (EC) No 801/2013 (European Commission 2013b) is an amendment to Regulation (EC) No 1275/2008 for standby and off mode, expanding this by ecodesign requirements related to 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 that can be connected to a network (“smart dishwashers”).

While Ecodesign Regulation (EC) No 1275/2008 for standby and off mode requires power management for all equipment other than networked equipment put on the market 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) No 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 (high network availability 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).

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, 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, 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 (EC) No 640/2009 to motors below 750 W, asynchronous inverter motors and permanent magnet motors, household dishwashers would indirectly also be affected (cf. also section 4.3.5).

On 29 April 2015, an ecodesign horizontal matters consultation forum meeting took place in Brussels. Before the meeting, 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.*

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 autumn 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 1.2.2.5), 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 NV (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 NV (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 NV (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

Energy Label 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 label 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 Directive 92/75/EEC with regard to energy label of household dishwashers, which was the basis for the design and content of the former energy label, was 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 1.6).

Table 1.6: Energy efficiency classes for household dishwashers (European Commission 2010a)

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:

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 consumption in left-on mode and off-mode

T_l = 30 minutes before automatically reverting into off-mode by the power management system, assumed as maximum scenario
T_t = 196 minutes programme time for the standard cleaning cycle (cf. section 5)
P_l = 0.5 to 3 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 0.84 kWh/year to maximum 4.27 kWh/year.

The exemplary calculation of the annual energy consumption in left-on and off-mode only shows that the low power energy consumption is a rather minor contribution to the annual energy consumption, especially since the mandatory implementation of a power management system in 2013 according to Regulation (EC) No 1275/2008 (see section 1.2.1.1).

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:

$$SAE_C = 7{,}0 \times ps + 378$$ **Equation 1.4**

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

$$SAE_C = 25{,}2 \times ps + 126$$ **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:

$$AW_C = W_t \times 280$$ **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 1.7). (Please note: further standardisation activities on tolerances and resulting recommendations are provided in sections 1.2.2.5 and 1.2.5.1)

Table 1.7: Verification tolerances for household dishwashers (European Commission 2010a)

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. Comparing Ecodesign Regulation (EC) No 1016/2010 (see section 1.2.1.1) and Energy Label Regulation (EC) No 1059/2010 there is an inconsistency regarding the threshold width of the machines, i.e. less than 45 cm (ecodesign) or 50 cm (labelling), and 12 or more ps. This delimitation between the different types of dishwashers should be aligned in the future regulations. It is proposed by a stakeholder to use 50 cm width as threshold. Alternatively it is proposed to use the number of place settings to differentiate between the main appliance widths (e.g. >10 ps and ≤10 ps).

Low Voltage Directive (LVD) 2014/35/EU

The purpose of the LVD Directive (European Parliament 2014b) is to ensure that electrical equipment on the market fulfils the requirements providing 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. For example, 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 the 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.

Electromagnetic Compatibility Directive (ECD) 2014/30/EU

ECD 2014/30/EU (European Parliament 2014a) 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 this 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 1.8: 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

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

Regulations (EC) No 1016/2010 and (EC) No 1059/2010 refer to standard EN 50242 which is linked to IEC 60436.

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 using 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 (EC) No 1059/2010 (European Commission 2010a). 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 as “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, emphasizing 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 RRT. 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.

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

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 the current EN 50242. 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 combined cleaning and drying performance (CCD), 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.

At the time of writing this report, EN 50242/EN 60436:2016 was published (July 2016). It includes the CCD methodology but not a higher variety of shapes and materials. However, ecodesign and energy label requirements continue to be based on the old version EN 50242/EN 60436:2008 +A11:2012 until the new edition is referenced in the Official Journal of the EU (expected mid-2017).

Note that some topics (e.g. automatic programmes) are included as 'informative' element in the standard. A more detailed discussion on the new 4th edition of IEC 60436 can be found in section 1.2.5.1.

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 when 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.

Standby for Dishwasher

The sequence and approach of the measurements for off mode and left-on mode power (and proposed to be extended to cover the delay mode power in the revised standard) 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 (proposed to be changed to 1 min in the revised standard) 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 (although this time period can be increased in the revised standard). The result is indicated as mean value of the measured data. (EN 50424/ EN 60436 Edition 3.1 2012)

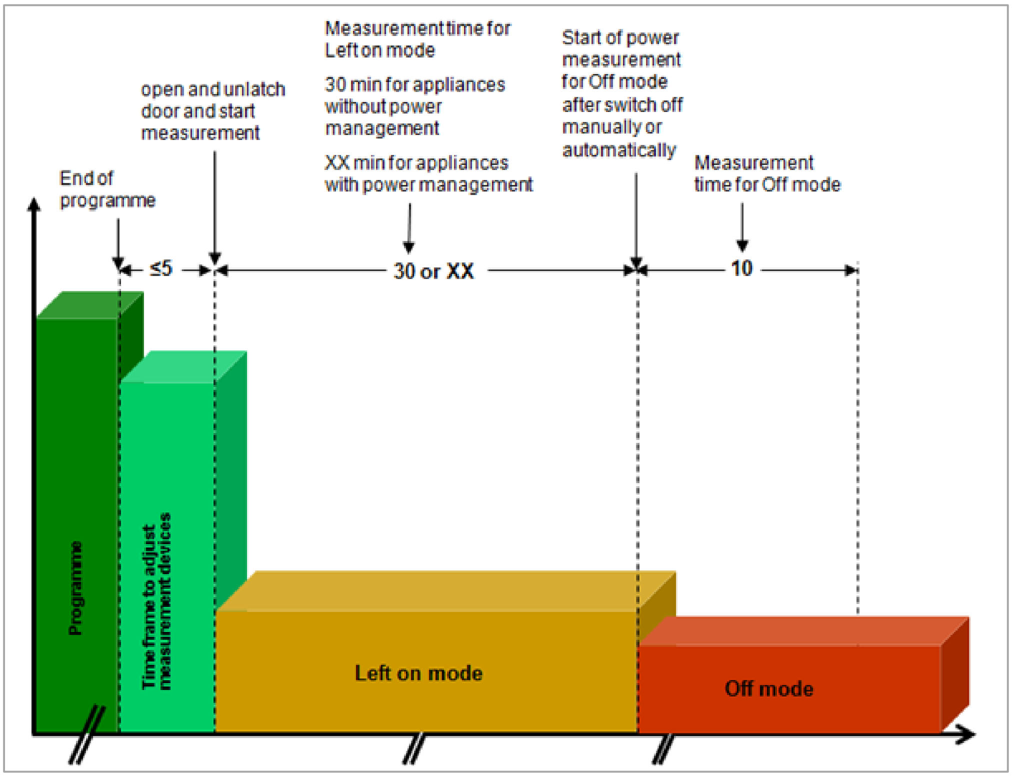


Figure 1.1: **Measurement procedure for the low power modes (left-on mode and off mode)**

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

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 determination 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. It addresses a 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.

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.

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. Additional standardisation activities

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 in the EN50242/EN60436:2016 was published in July 2016.

Uncertainty, tolerance, repeatability and reproducibility

In order to encourage the efficient use of energy as well as other resources, the European Parliament and the European Commission have issued regulations which mandate the provision of information to consumers or set up essential requirements for specific products. This information is conveyed by label obligations according EU Label Directive 2010/30/EU and the Directive (2009/125/EC) for ecodesign for energy-related products. According to this directive the information has to be provided by manufacturers at the point of sale or in the manuals.

Methods for measuring the resource consumption and performance characteristics of the products must be sufficiently accurate to give 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). Both are measured by standard procedures. The repeatability must be sufficiently accurate for comparative testing. The reproducibility must be sufficiently accurate for the determination of values which are declared and for checking of the declared values.

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

Market Surveillance Authorities have the responsibility for verifying the information given at the point of sale or requested by ecodesign regulations 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 that in addition to the product variation will contribute to the differences between the measured values and the values 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 for the manufacturer (e.g. withdraw from market, fines, etc.).

The assessment of verification tolerances is identified as a revision point for both Regulations (EC) No 1059/2010 and (EC) No 1016/2010.

CENELEC TC59X WG16 “Uncertainty and tolerances” has taken up the initiative of IEC 59D and produced 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” that requires the reporting of expanded uncertainty values for all measurements defined in their standards.

However, the assessment of the expanded uncertainty and the definition of verification tolerances will, in many cases, only be possible after a round-robin test (also called ring test). The analysis of the RRT results will deliver a good knowledge 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”). In May 2014 CLC 59X released the documentTC59X/ (Sec)0597/INF “Application of measurement uncertainty in setting verification tolerances”, where the relation between the expanded uncertainties as a characteristic value of the measurement to the political issue of how tolerances are set is explained.

Recently a round robin test on dishwashers (RRT DW 2014) was carried out at European level (Belke & Stamminger 2015). The aim of the RRT DW 2014 was first to test the existing standard EN 50242:2008 +A11:2012 with separate cleaning and drying evaluation (SCE and SDE) and secondly to gain practical experience with the newly introduced combined cleaning and drying (CCD) procedure. The results of both test series were compared to get fundamental information whether the CCD method can be applied to the new edition of IEC- and EN- standards and replace the SCE and SCD methods. A further RRT is currently ongoing (results available end of 2016) using the 4th edition of the IEC 60436 which was approved in 2015. (cf. also section 1.2.5.1)

Stakeholders were asked to 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. Stakeholders generally reported that products are designed in such a manner that seeks to meet safely the verification tolerances provided in the relevant standards and regulations.

CECED has also provided the industry positions with respect to

- the verification tolerances in ecodesign and energy label (see: http://www.ceced.eu/site-ceced/media-resources/Position-Papers/Archive/2014/10/Verification-tolerances-in-Ecodesign-and-Energy-Labelling-future-legislation.html)
- the noise verification procedure (see: http://www.ceced.eu/site-ceced/media-resources/Position-Papers/Archive/2015/03/CECED-comments-on-the-noise-verification-procedure.html)

CECED recommends referring to the existing standard EN 50242/EN 60436, where Annex ZC summarizes all relevant details and where the numbers related to RRTs are frequently reported. The Annex ZC of this standard should be updated with the results of the currently conducted RRT.

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 NV 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 are summarised.

SG-CG developed a generic functional architecture for the flexibility use cases, which is represented in Figure 1.2.

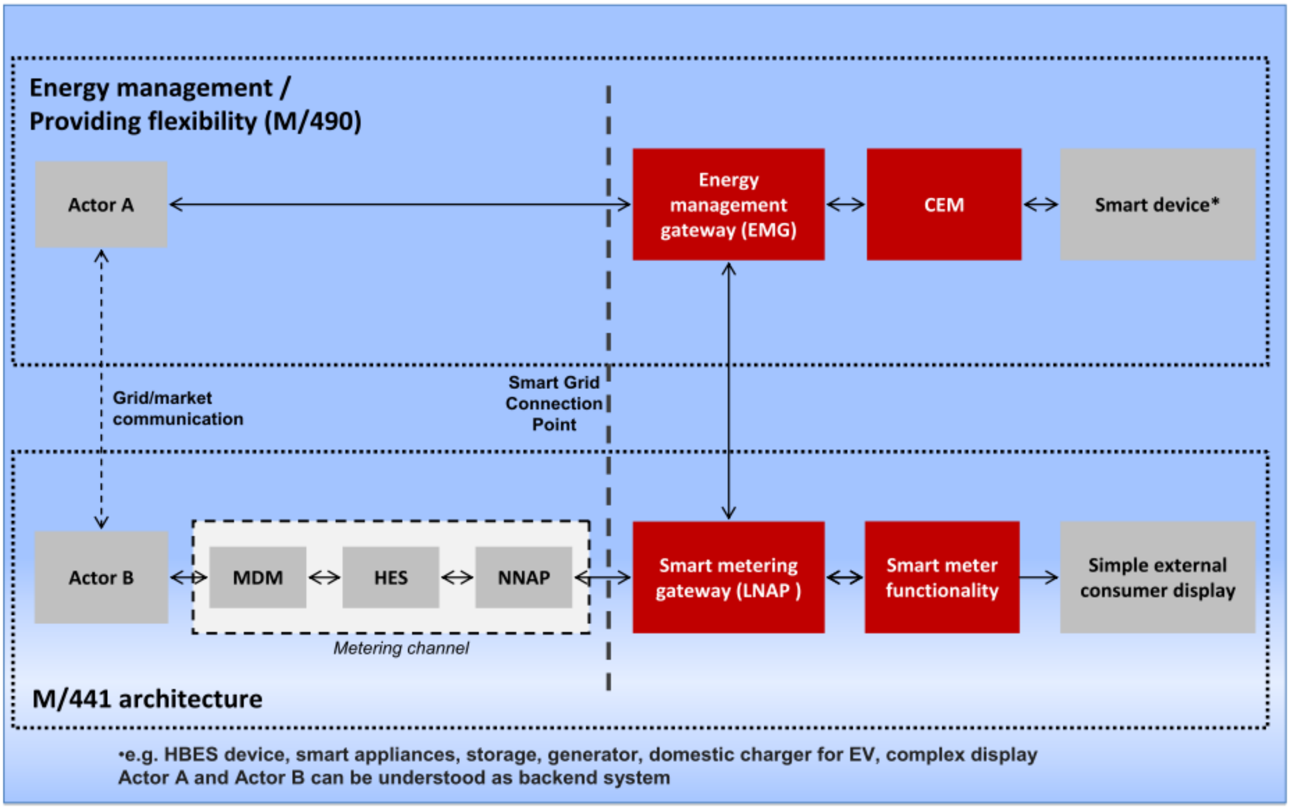


Figure 1.2: Flexibility functional architecture (CENELEC 2014)

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 (ISIS 2007b), the following European policy instruments and measures were described:

Table 1.9: 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 Prod-	no	

Scheme	Still valid?	Comments
ucts label for dishwashers		
Swedish "Environmental Product Declaration (EPD) scheme for washing machines and dishwashers for household use"	No, valid until September 2004	cf. http://epdsystem.it/en/PCR/Detail/?Pcr=5656).
UK Energy Saving Trust Recommended described in Lot 14 (ISIS 2007b)		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 1.10: 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 label 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

Criteria category	Requirements
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):

<u>Energy Efficiency</u>

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)

<u>Power Consumption in "Left-On", "Delay Start" and "Off" Mode</u>

- 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.

<u>Water Consumption</u>

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.

<u>AquaStop</u>

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 1 January 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.

In dishwasher testing, both Stiftung Warentest and Which? focus on performance and consumptions of the tested dishwasher model, but their results are not directly comparable. 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.

1.2.4.1. 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 processing 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.

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 €/m^3.

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 soiling 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.

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 1.11.

Table 1.11: Country-specific criteria for dishwashers to be placed on the national Topten websites (compiled on July 2015)

Countries	Listed product sub-categories	Topten Dishwasher criteria in different EU countries	National Topten websites
Austria	• Freestanding 60 cm • Semi-integrated 60 cm	• Freestanding: – Gold: A+++ / ≤ 44 dB – Silver: A++ / ≤ 44 dB	www.topprodukte.at

Countries	Listed product sub-categories	Topten Dishwasher criteria in different EU countries	National Topten web-sites
	• Fully integrated 60 cm	• Semi/fully integrated: – Gold: A+++ / ≤ 42 dB – Silver: A+++ / ≤ 44 dB	
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
Luxem-bourg	• 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

Countries	Listed product sub-categories	Topten Dishwasher criteria in different EU countries	National Topten web-sites
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

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.

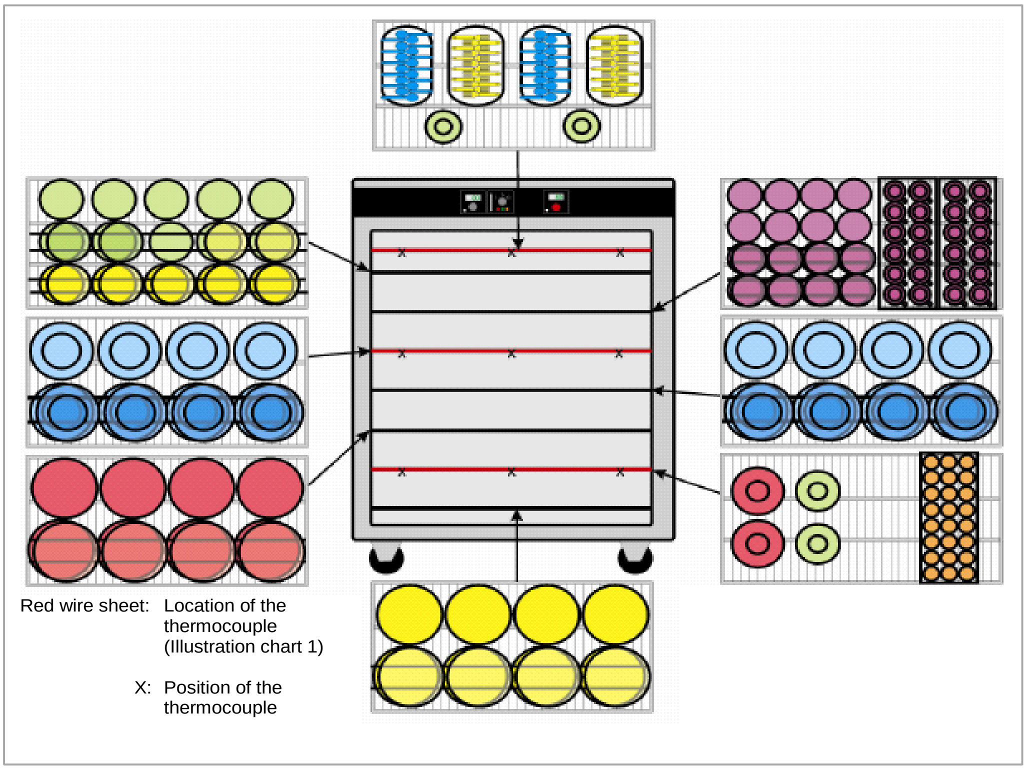


Figure 1.3: Loading scheme of the thermal cabinet for 24 ps

- 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 label 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 B is used, the quantity should be as recommended by the manufacturer but no more than 2.5 g/ps for dishwashers with a capacity higher or equal than 10 ps or 3.0 g/ps for dishwashers with a capacity of lower than 10 ps. If no recommendation is given by the manufacturer, use 2.0 g/ps for dishwashers with a capacity higher or equal than 10 ps or 2.5 g/ps for dishwashers with a capacity of lower than 10 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 1.12:

Table 1.12: 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.

New 4th Edition of IEC 60436

The 3rd Edition of the IEC 60436 is currently under revision. The revision 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 (CCD method).* Combining the cleaning and drying performance evaluations into one test, along with the energy and water consumption evaluation, prevents an opportunity for circumvention compared to 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. With this new detergent, the dosage will be lower.
- *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 changes 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.

Manufacturers stress that with the introduction of the new standard the measured consumption and hence the calculation of the EEI as well as the cleaning and the drying performance values might change. The new standard includes a new definition of the load – as mass and the heat capacity also determine the energy consumption of a dishwasher – this most presumably will change. By today, it is not clear how big these differences are, but it is expected that they are small (<10%).

The results of (round robin) tests on the new standard currently conducted (see below) will give further insight in this topic. Anyhow, it can be expected that dishwashers are going to be optimised after the introduction to work under these new conditions.

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.

Round Robin Tests and other testing activities

In 2014, a RRT on dishwashers was carried out at European level (Belke & Stamminger 2015). 20 laboratories took part and 17 of them tested the Combined Cleaning and Drying (CCD) method. The aim of the RRT DW 2014 was first to test the existing standard EN 50242:2008 +A11:2012 with separate cleaning and drying evaluation (SCE and SDE) and secondly to gain practical experience with the CCD procedure. The results of both test series were compared to get fundamental information whether the CCD method can be applied to the new edition of IEC- and EN- standards and replace the SCE and SCD method. The results were very satisfactory; the comparative differences between SCE / SCD and CCD were small and not significant. The new CCD method is more relevant to households than the existing method because drying and cleaning are both carried out with soil, detergent and rinse aid in one go. The introduction of the CCD is in preparation by CENELEC TC59X WG2.

The conclusions from this RRT are as follows. Through the round robin test it was possible to gain a deeper insight into the laboratory praxis of manufactures and test laboratories. The examination of the collected data on the one hand and the laboratory visits on the other hand revealed good knowledge in applying the current standard but also showed that practicing of the newly introduced CCD method is necessary.

While the precision of the water consumption measurements is comparable to the previous RRT, the precision of the performance values advanced since then. The decreasing precision with decreasing cleaning or drying performance indicates that there is still room for improvement by practising the assessment to reach consistent results.

Summary of important findings of the round robin test

- Uncertainties of measurements are in line with values in the current standard. Adaption of relative expanded uncertainty only recommended for the drying performance.
- Improvement and alignment to EN 50242 of the laboratory practice is necessary, especially for the assessment behaviour of tableware with higher soil or water residues.

- Regular ring-testing is necessary to exchange experience and align and verify laboratory practice.
- As for neither the cleaning nor the drying performance test results showed significant differences between SCE/SDE and CCD for the two test appliances the CCD method has qualified to be introduced as the new method for performance testing in an updated EN 50242.

Proposals for further improvements

- Cleaning performance results differ most for glasses. An improvement of the glass soiling is needed to reach more consistent results.
- As the cleaning results for spinach differ in the labs quite often, the preparation of the spinach should be better standardized (use of a mincer, measuring method for moisture). Use of other spinach than in EN can cause differences.
- As porridge does not always stick on the dipped spoons in the same way, the amount of oat flakes differs. Proposals are made for an adapted preparation (e.g. spoons could be wiped with a clean towel to remove rests of rinse aid after cleaning cycles and then dipped into porridge or porridge could be prepared in a "Thermomix"), but more investigations are required for an official recommendation.
- Procedure of cooling down after oven drying should be more consistent: in the room, in the machine when to start, use of fan allowed? If prewash in DW is only done with cold water, remaining heat in load is less important.
- Important to define that water rims around all types of soil, not just milk, do not count in the drying evaluation with the CCD method.

In 2016, University of Bonn has tested five dishwashers both under old and new conditions (EN50242 4th ed. (with combined cleaning and drying) and a future EN60436 5th ed. respectively) to compare the performance and consumption values (Hook & Stamminger 2016). These limited tests have provided following conclusions:

- The consumption values are slightly affected by the new test standard. The energy consumption is reduced by 0 – 6 % by the modified load of the IEC standard. The influence on the water consumption is larger as regeneration cycles are taken into account in IEC, leading to a higher mean consumption and much higher statistical standard deviations. The effect can be even larger if more than one regeneration cycle occurs during the five to eight runs of the test series, leading to difficulties for market surveillance authorities and test laboratories when declared values have to be verified.
- The average cleaning performance of the test machines is slightly higher when tested according to IEC, but no systematic influence of the new standard can be observed for the reference machine.
- No systematic influence of the new standard on the cleaning performance index can be observed. However, no conclusions can be drawn from these results, with three test series beyond the target range of cleaning result as prescribed in the standard for the reference machine. A repetition of the tests or additional investigations is necessary to show the impact of the new standard on cleaning performance results.
- The drying performance of the reference machine for the EN test is close to the upper limit of the given tolerances when tested in accordance to EN and by this it is hard for the test machines to reach a drying performance index of 1.08 or higher. The drying performance of the reference machine is clearly lower for the IEC tests, due to water residue on plastic items, pots and cavities of cups and mugs.
- The average drying performance of the five test machines is decreased to a lesser extent than the reference machine, leading to a higher drying index for four out of five machines for the test series according to IEC.

The energy consumption of low power modes and noise emissions have not been measured. Conclusions concerning these aspects can therefore not be drawn from the tests. An influence of the pots on the noise emissions can be anticipated, depending on their position in the machine.

In conclusion, these tests show that there are no major effects to be expected from the change of the standard as anticipated now. Final conclusions can only be taken when the final version of the common modifications of the IEC 60436 4th ed. to an EN 60436 are decided and when more tests are done in manufacturer laboratories (which may result also in optimization of the loading plans or basket designs) and independent laboratories.

Additionally a Round Robin Test is currently carried out on the fourth edition of the international standard for testing the performance of dishwashers IEC 60436, which was approved in 2015 (results will be available end of 2016). Modifications to this IEC standard as needed for European adaptation will be incorporated via the usual harmonization process of CENELEC.

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 has been working as working group 2 for the last decades. A new structure of SC 59A (Table 1.13) 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 1.13: 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

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

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 1.15: Proposed New US Federal Energy Conservation Standards for Residential Dishwashers (US EERE 2014b)

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.

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 Labelling 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.

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 [n.d.]a):

- 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 [n.d.]a):

> *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 [n.d.]a):

> *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 ([n.d.]a) 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 [n.d.]a):

- 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

China – Hong Kong

<u>The Hong Kong Green Label Scheme (HKGLS)</u>

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.

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

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)

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.

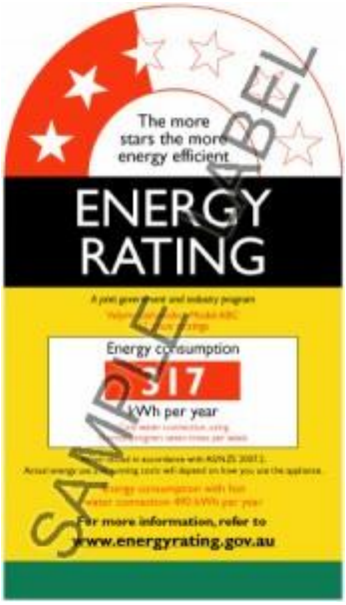


Figure 1.4: Australia's Energy Rating Label for dishwashers; source: Australian, State and Territory and New Zealand Governments (2014)

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). (Australian, State and Territory and New Zealand Governments 2014; EES 2010)

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 label 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.

<u>Energy Star Australia</u>

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 2014)

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 1.16: 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 2009a), 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 1.17 shows an overview of the European Directives and Regulation discussed in this section.

Table 1.17: 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 1.18), 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 1.18: 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 Oeko-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 Oeko-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 Oeko-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 2012a) 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 2006b) 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. section 1.3.1.3) 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 2014c) 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 (tetrafluoroethane). 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 2012c), 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 1.19: 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

Criteria category	Requirements
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.
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 1.20: 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

Criteria category	Requirements
	• 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
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 (Na_2O + K_2O+ 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

Criteria category	Requirements
	• 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 dish-washer; 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

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).

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 1.21: 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 packaging – recycled content	Minimum requirement: ≥ 60% 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 1.22 shows an overview of the standards discussed in this section.

Table 1.22: Overview of the standards for resource efficiency, durability and recyclability

	Standards for resource efficiency, durability and recyclability
All	European Commission Mandate M/543 (2015) on horizontal requirements on material efficiency aspects for ecodesign and energy labelling
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	European Commission's Mandate M/518 for standardisation in the field of Waste Electrical and Electronic Equipment (WEEE)
	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
	EN 50574: Collection, logistics and treatment requirements for end-of-life household appliances containing volatile fluorocarbons of volatile hydrocarbons
	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
	IEC/TR 62635: Guidelines for end-of-life information provided by manufacturers and recyclers and for 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

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 sending a mandate for acceptance to CEN or CENELEC. The Technical Board Members are invited to accept (or reject) the given mandate, with or without restrictions, based on the Technical Body and CEN/CENELEC feedback. In case of acceptance of the mandate, the Technical Body is entrusted with the task of starting expected standardization work within CEN/CENELEC.

On a horizontal level, Mandate M/543 (European Commission 2015a) has the objective to develop generic standards, for any product group covered by Ecodesign, in support of ecodesign requirements related to material efficiency aspects.

Standardization bodies CEN and CENELEC shall by the end of 2018 / beginning 2019 develop generic methodologies and terminology 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 also included if appropriate.

CEN and CENELEC have established a joint technical committee (TC10), which has deployed 6 working groups to deal with the specific aspects of the mandate:

- WG1: Terminology

- WG2: Durability
- WG3: Reparability, upgradability and reusability
- WG4: Ability to Remanufacture
- WG5: Recyclability, recoverability and recycled content, including critical raw materials
- WG6: Provision of information, including critical raw materials

As of June 2017, the work is up and running in all working groups.

1.3.3.1. Durability

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

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.

This standard describes a label for repair-friendly designed appliances. Manufacturers of electrical and electronic equipment who intend to label their products have to test their products according to the requirements of ONR 192102 verifying compliance with a test report. According to Ricardo-AEA (2015), this standard suggests a labelling system with three levels of achievement (good, very good, excellent) based mostly upon reparability criteria. The standard includes ca. 40 criteria for white goods (such as dishwashers or washing machines), and 53 criteria for small electronics (brown goods). 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 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.

In 2015, a test was undertaken by RUSZ (Vienna, AT) to 28 washing machines. The result was that none of them passed the minimum criteria of the test and would be awarded with the label. The main reason of failing was the restriction of access to information which is essential for repair, for instance manuals for (reversible) disassembly, or access to diagnostics software.

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.]).

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 1.23: PAS 141 Protocol Product Guide for Dishwashers; source: adapted from 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
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

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 8.1.1.1 to 8.1.1.3.

<u>International IEC 60068-1 ed7.0 Environmental testing</u>

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)

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 EN 60335-2-5 and washing machines EN 60335-2-7.

Table 1.24: 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:

Standard	Component	Requirement
		• 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 appliances - Safety - Part 1: General requirements; EN 60335-1:2012/FprAD:2014, section 24; standard for switches: IEC 61058-1	Components: Switches	Number of operating cycles have to add up to at 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 The section (number 18) on endurance is void.
Household and similar electrical appliances - Safety - Part 2-7: Particular requirements for washing machines (IEC 60335-2-7)	Many	This standard contains an array of test protocols to ensure safe operation of washing machines, for application by manufacturers. They deal mainly with electrical risks (e.g. appliances shall be constructed so that foaming does not affect electrical insulation) and management of heating elements. Section 18 on endurance specifies several tests on: door opening cycles (10000, of which first 4000 also with electrical lock; for WD: 13000 cycles, of which 9000 first with electrical lock), and braking mechanism (1000 cycles).
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 2015b), 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 (2015) 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

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

In January 2013, the European Commission 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 2013d)

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 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 appliances with heat pumps (dishwashers, washing machines, washer dryers). 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 depollution (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 and washing machines, 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 and washing machines.

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.

Further national and international standards with regard to end-of-life treatment and facilitating recyclability are listed in the following:

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 and washing machines, 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 and washing machines with a heat pump.

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.

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.

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.

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.

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

Appliance manufacturers doubt the relevance of the IKW standard for appliance testing as it has been developed to test detergents, not dishwashers, and therefore it is supposed to be quite different to existing standards developed for appliances.

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" the 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.

<u>Bill of materials (BOMs)</u>

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.

<u>Identification of plastic components</u>

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, 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 (currently the large majority of treatment) 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 (e.g. Radio Frequency ID), 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. Several manufacturers have already such systems in place, based on the use of liquid detergents. Some manufacturers require the use of a specific detergent, while others can adapt to different detergents. None of them offers currently the option of using powder detergent, as it is more prone to clogging and requires more maintenance. Therefore, two liquid containers are necessary for cycles where bleaching is required, making the system more complex. This limits also the usability of the system for the cycles where powder detergent is necessary, or recommended, including during testing.

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. by removal for separate treatment of 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 the 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.

- 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. As in case of the information on hazardous substances, precious metals and rare earths it is suggested that such information could be made more easily available, by embedding it in the product in e.g. a RFID. This results in a higher benefit for the recyclers 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:

- <u>Recyclability benefit ratio</u>, 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.
- <u>Recycled content</u>, 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 2015)

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 (2009a), 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 (2015) 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 <u>its reparability should not be hindered by its design</u>."*

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 (2015), the following definitions for a number of relevant terms:

- <u>Design for durability</u>: considering the product's longevity, reparability and maintainability; considering environmental improvements emerging from new technologies (ISO/TR 14062 2002).
- <u>Operating time</u>: average time frame during which the product is supposed to be used. Operating time can be derived from product statistics or from estimating models.
- <u>Extension of operating time</u>: 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 (2015), 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 or washing machines, 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 reparability 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 and washing machines, 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 identifies obstacles for repair and maintenance of dishwashers and washing machines. Examples of common causes of break downs as well as suggestions for product design to help improve reparability of domestic dishwashers are provided. 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 (without specifying what reasonable is).
- 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

DG Environment has commissioned a study to BIO by Deloitte to analyse the socioeconomic impacts of increased reparability (Deloitte 2016). A second part of the study deepening the analysis on some aspects is underway in 2017.

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" (Ardente & Talens Peirò 2015) and study "Durability, Reusability, Reparability - Assessment for dishwashers and washing machines" (Tecchio et al. 2016)

The objective of the study "*Report on benefits and impacts/costs of options for different potential material efficiency requirements for dishwashers*" (Ardente & Talens Peirò 2015) 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, assuming an overall labour cost for a dismantler of about 150 €/day;
- 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).
  - The study "*Durability, Reusability, Reparability - Assessment for dishwashers and washing machines*" Tecchio et al. (2016) is an updated and enlarged version of the previous study. The study consists of four section that focus on the environmental assessment of the durability of dishwashers and washing machines, the analysis of reusability of dishwashers and washing machines with data derived from data collected from reuse and refurbishing companies, statistics data on repair services over the last 7 years and finally recommendations and potential policy requirements to promote durability, reusability and reparability of dishwashers and washing machines.
  - This study provides results regarding reparability and reuse and confirms that an extension of the lifetime of the product is positive from an environmental point of view provided that the energy efficiency improvement of the new product remains with a given range (e.g. >15% for DWs). The study also points out that a significant percentage of the defects are caused by inappropriate use of the appliance.

On reuse/repair, the study provides information on what are considered the "common failures/defects". For example for dishwashers, the study considers that "electronics" and "pumps" are the most common failures and also the failures where a large percentage is not repaired. Several reasons are given for not repairing the appliances, mainly linked to the cost of the repair (breaking down the costs into labour cost and spare part cost) and the possibility of reusing spare parts from older appliances.

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 requirements for electric motors (permanent magnet motors are also used in household dishwashers, cf. section 4.3.5). 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. Study " Resource efficiency requirements in ecodesign: Review of practical and legal implications" (2014)

This study for the Dutch Ministry of Infraestructure and Environment explores the potential role of material resource efficiency, except energy efficiency during use, in the ecodesign of ErP Directive. This study strengths the role of material efficiency in Ecodesign, beyond energy efficiency and concludes that Ecodesign measures regarding savings on non-energy resources consumption in the use-phase have proven to be enforceable, at least for directly consumed resources, legally and in practice. Methodology and measures regarding weight-saving measures in Ecodesing would need to be developed. Measures on product durability (lifetime extension) have proven to be enforceable when formulated in terms of minimum technical life of the product or components according to harmonised test and calculation procedures. Also minimum warranty times and the time period during which spare parts are available can be enforced.

Should ecodesign preparatory studies be able to provide robust evidence that justifies introduction of specific RRR measures in legislation (a set of) specific or tailor-made requirements should be introduced in Ecodesing legislation that could meet legal and practical criteria enforceability. Amongst others this means that the requirements should be technically and economically feasible and preferably relate to parameters that can be assessed with an accurate, reliable and reproducible test and calculation methods at product-level. If they would depend on input from upstream actors (suppliers) or downstream (end-of-life) processes, the administrative burden would be considerable and still the accuracy and reproducibility of measurements would require robust test standards to be in place to guarantee a level playing field.

International trade agreements emphasize the relation between the proposed measure and its means of verification. Measures that can be verified on the product itself are considered to constitute less of a (potential) barrier to trade than measures that can only be verified indirectly as they relate to non-product related production and process methods. Several RE parameters incorporate such non-product related measures. There are however measures that may relate solely to the product, such as parameters dealing with durability, light-weighting, presence of substances (hazardous or critical raw materials, etc.)

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 (2015b).

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 (Eurostat 2015b)

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

Declarant	2007	2008	2009	2010	2011	2012	2013
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	:	:	:
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
Lithuania	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; (Eurostat 2015b)

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

Declarant	2007	2008	2009	2010	2011	2012	2013
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
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
Lithuania	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 (Eurostat 2015b)

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

Declarant	Exports			Imports		
	Quantity (units)	Value (Euro)	Unit value (Euro)	Quantity (units)	Value (Euro)	Unit value (Euro)
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
Lithuania	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:

Apparent consumption= Production + Imports - Exports **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 EU-28 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; own calculations based on (Eurostat 2015b)

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
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
Lithuania	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 (2015c).

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; (Eurostat 2015c)

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

2.2.1. Ecodesign Impact Accounting

The European Commission has identified a need to systematically monitor and report on the impact of ecodesign, energy label, 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 / status 2013)

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 label, Energy Star, Tyre Label and/or 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 electricity in 2050 causing 8 $MtCO_2$ 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 ISIS (2007e), automatic dishwashing is using considerably less amount of energy/electricity and water and thus the total amount of greenhouse gases emitted is at least partly balanced by the reduced amount needed for manual dishwashing.

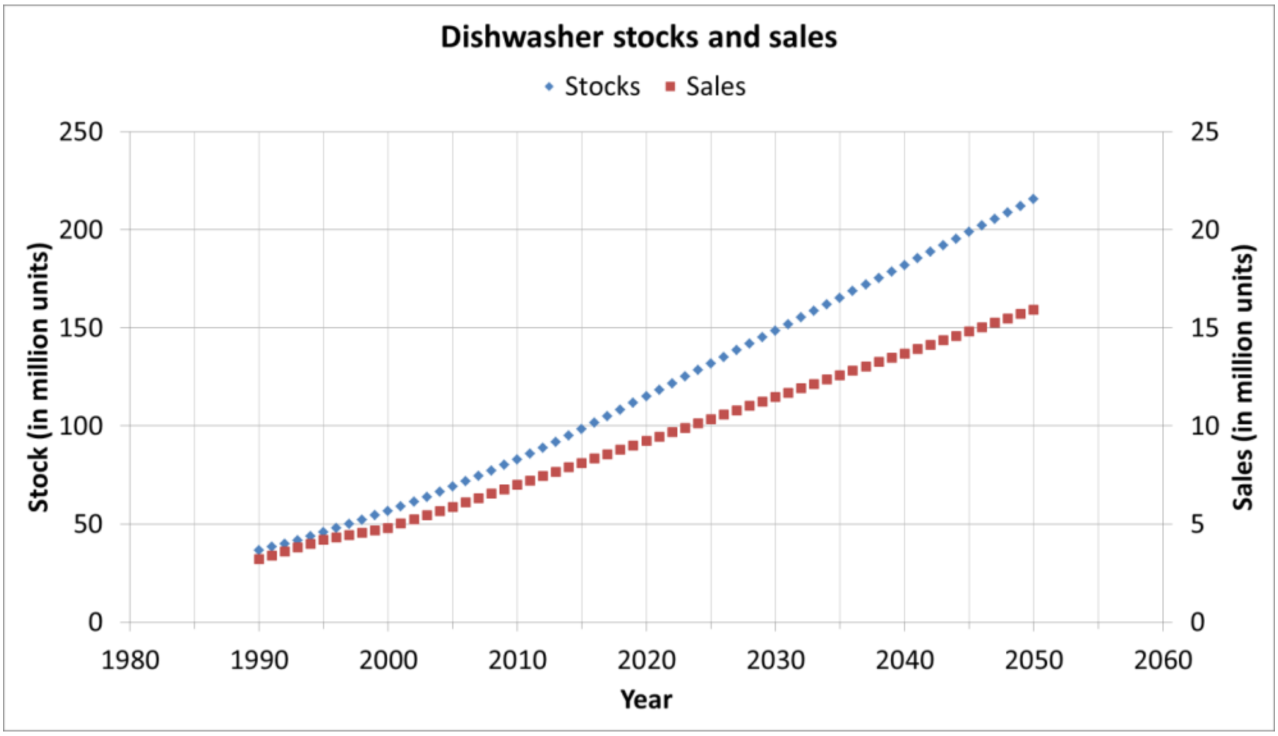


Figure 2.1: **Sales and stock of dishwashers in the European market from 1990 to 2050 (data from VHK (2014 / status 2013)**

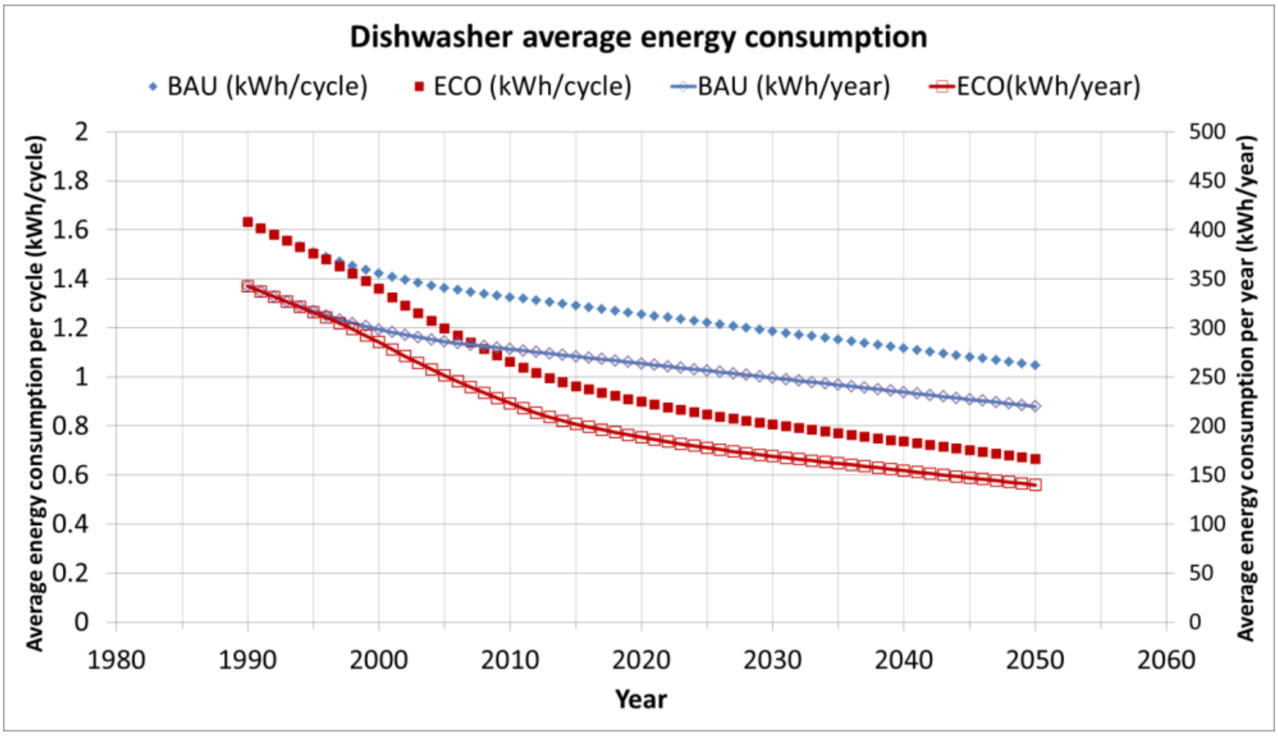


Figure 2.2: **Average energy consumption of a dishwashers installed in the European market from 1990 to 2050 (data from VHK (2014 / status 2013))**

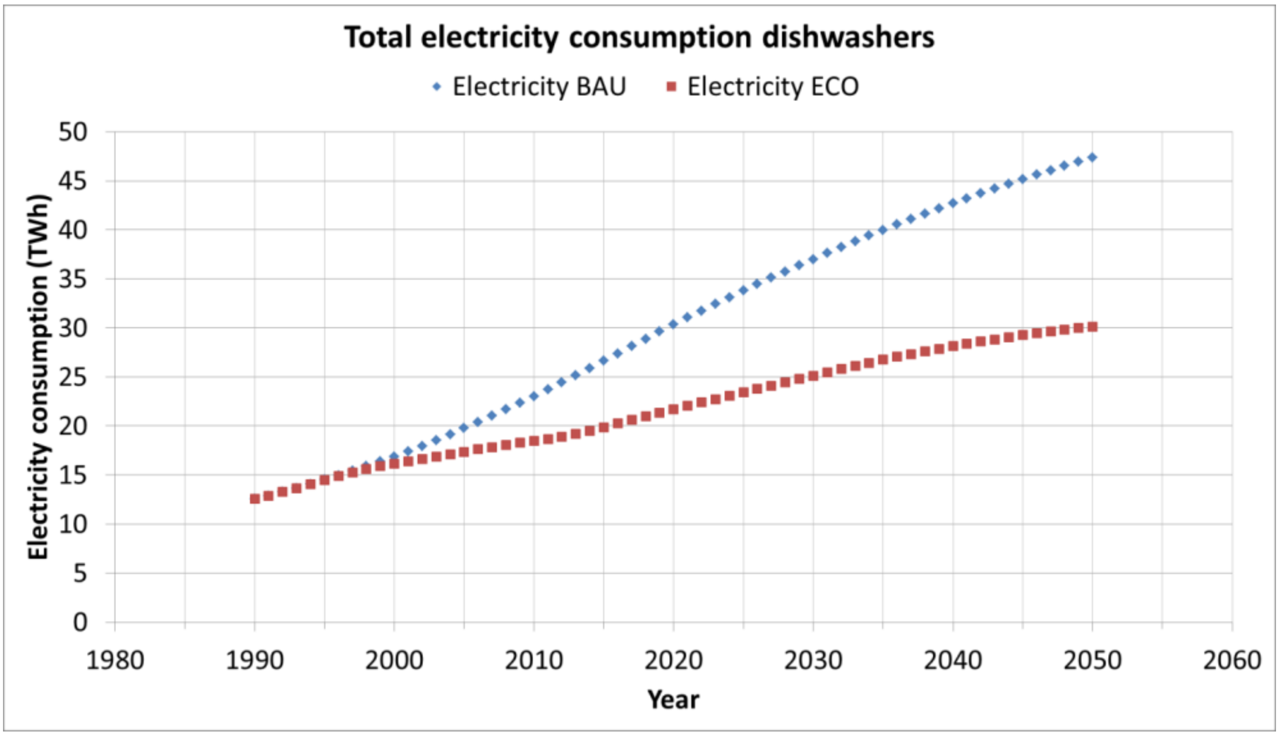


Figure 2.3: **Total electricity consumption of installed dishwashers in the European market from 1990 to 2050 (data from VHK (2014 / status 2013))**

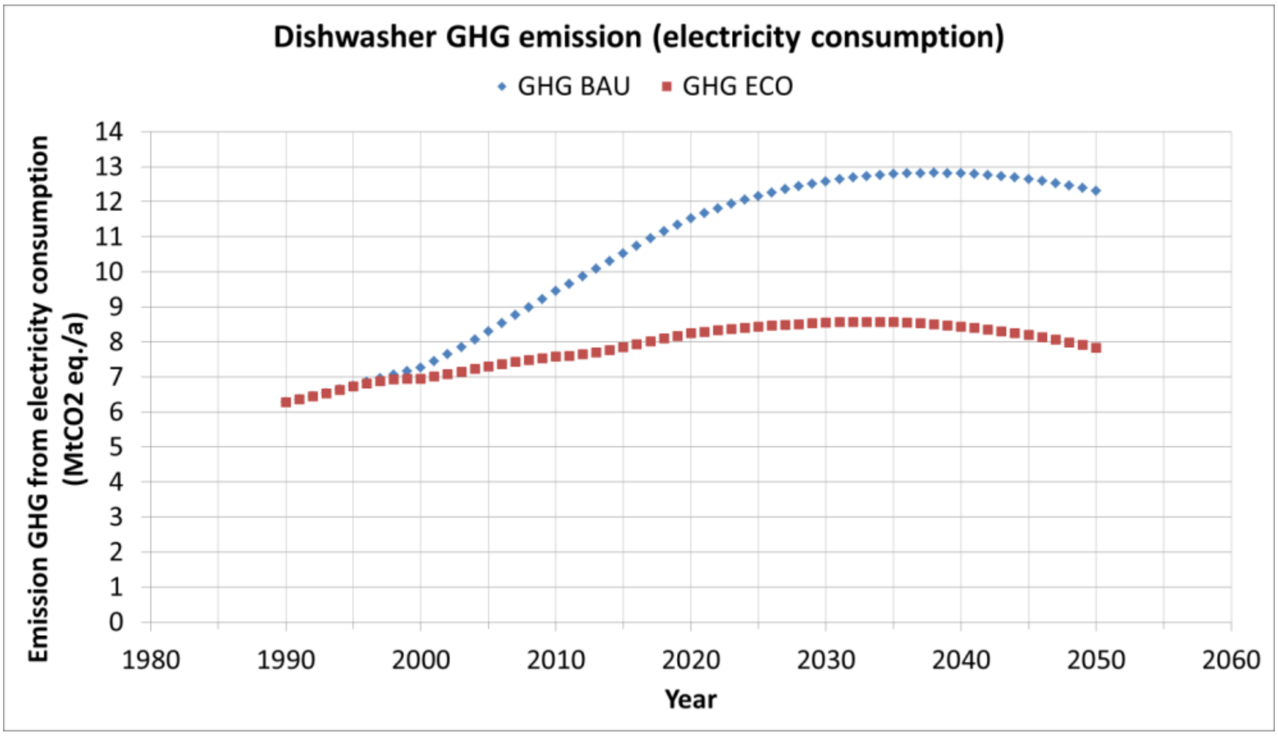


Figure 2.4: **Total greenhouse gas emissions originating from the electricity use of dishwashers installed in the European market from 1990 to 2050 (data from VHK (2014 / status 2013))**

Table 2.6 **Summary of data regarding dishwashers from ECODESIGN IMPACT ACCOUNTING (VHK 2014 / status 2013)**

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

2.2.2. Market and sales data

2.2.2.1. 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 (JRC IPTS 2014). 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.

2.2.2.2. Sales and stock data of dishwashers

According to CLASP (2013) and VHK (2014 / status 2013), 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 / status 2013)

	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 penetration/diffusion of dishwashers, population and, as a standardized comparative figure, the inhabitants per sold appliance of various European countries in 2014 (Scharf 2015).

Penetration 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. “*Even without the recent statistical data, we can affirm with certainty that the situation is not different in Norway, Sweden and Finland*.” (Scharf 2015):

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
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 ("NMS-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 by (CLASP 2013) and VHK (2014 / status 2013).

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

	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.

2.2.2.3. 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 2.2.3.4), 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 by about 25% (2011: 28%, 2012: 52.9%).

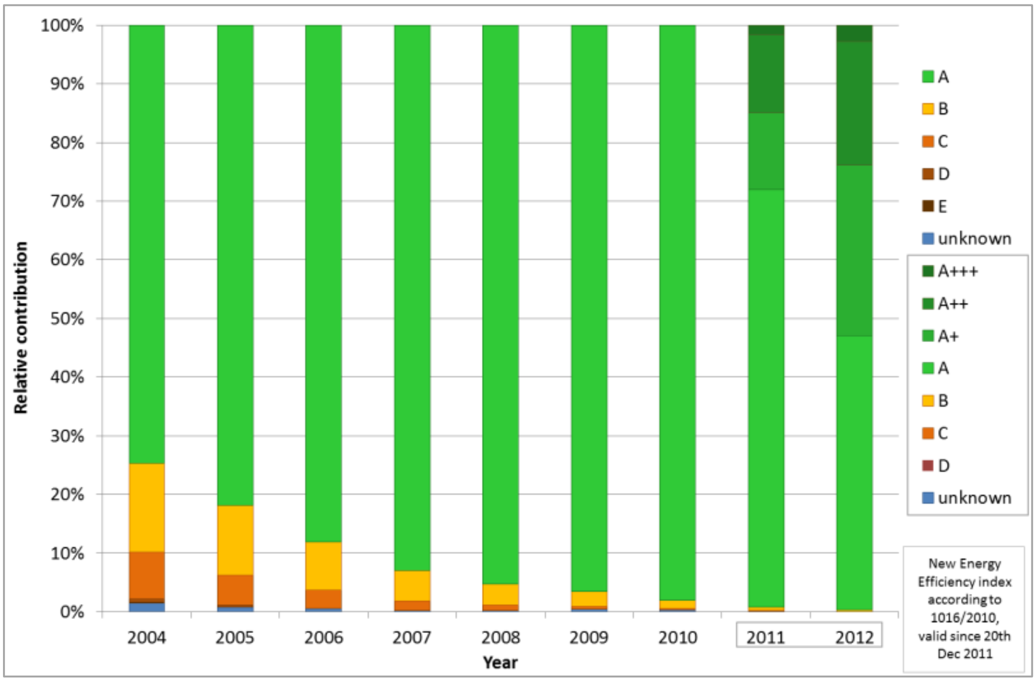


Figure 2.5: **Relative distribution of energy efficiency classes on total dishwasher sales from 2004 - 2012 in 14 European countries (AT, BE, DE, DK, ES, FI, FR, GB, GR, IE, IT, NL, PT, SE), (data from GfK, personal communication)**

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 (between 50% and 40%). Low shares (> 30%) can be seen in France, UK, Ireland and Eastern European countries like Hungary, Romania, Croatia, Serbia and Ukraine.

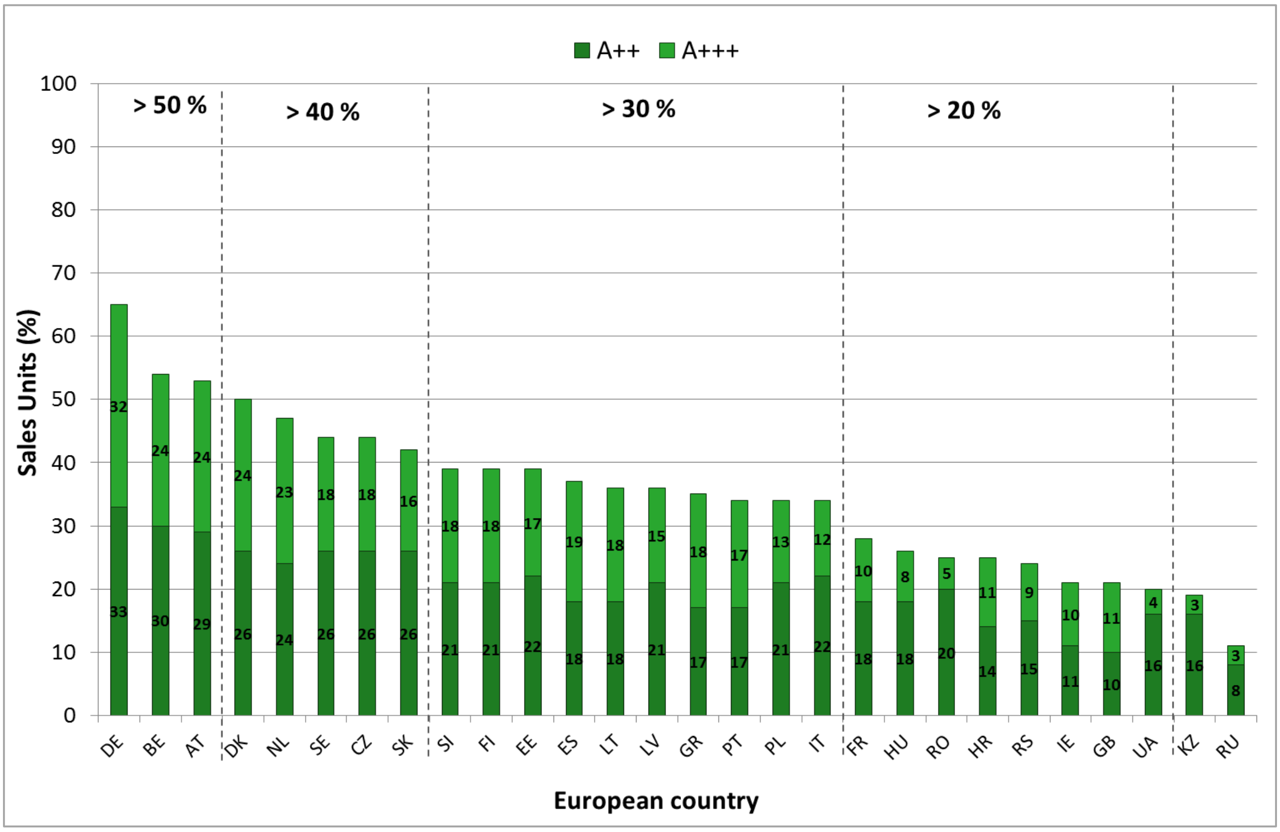


Figure 2.6: **Share of A++ and A+++-appliances (accumulated for washing machines, dishwashers, fridges, freezers) on the total amount of sold units in January-February 2014 in 28 European countries (Stöckle 2014)**

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 12.5 years. As the average energy efficiency has been much lower 12.5 years ago (cf. Figure 2.16) it is highly likely that many older and inefficient dishwashers will be replaced by new high efficient appliances in the next years.

2.2.2.4. 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 at European and global market level. 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
Samsung**	Samsung	1.7***		7.5	

Company	Main brands (non exhaustive)	Total turnover* in EU (2010, bln €)	European ranking	Total turnover* (2010, bln €)	Global ranking
LG**	LG	1.2***		6.1	
Miele	Miele	--		2.8	
* Not all turnover is white goods related. Most figures concern the overall home appliance turnover, incl. 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.

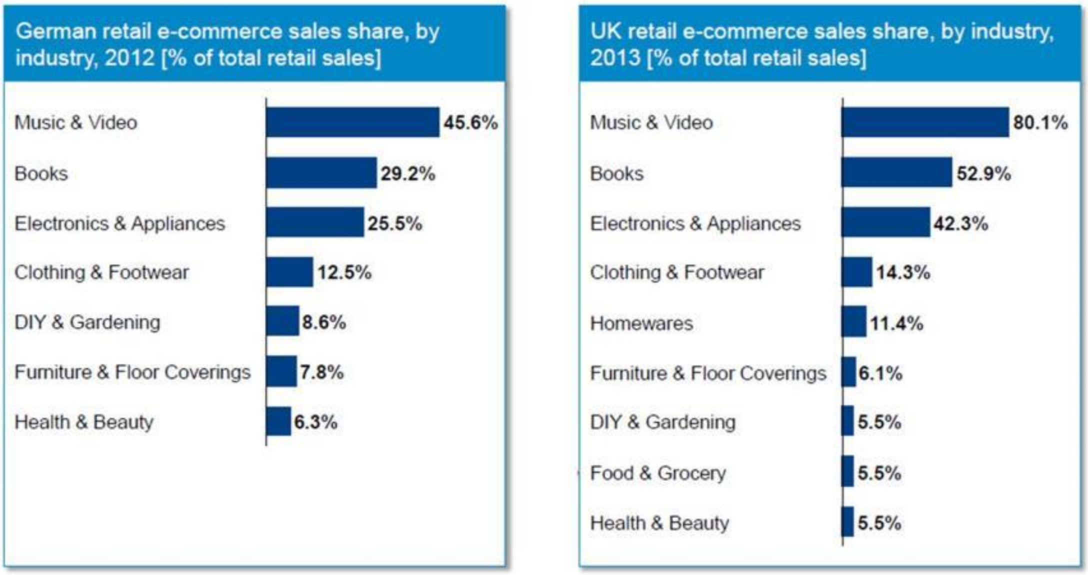


Figure 2.7: E-commerce with household Electronics and Appliances in 2012 (Bachl & Koll 2013)

2.2.3. 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 2014.

2.2.3.1. 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 2.2.2) 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.

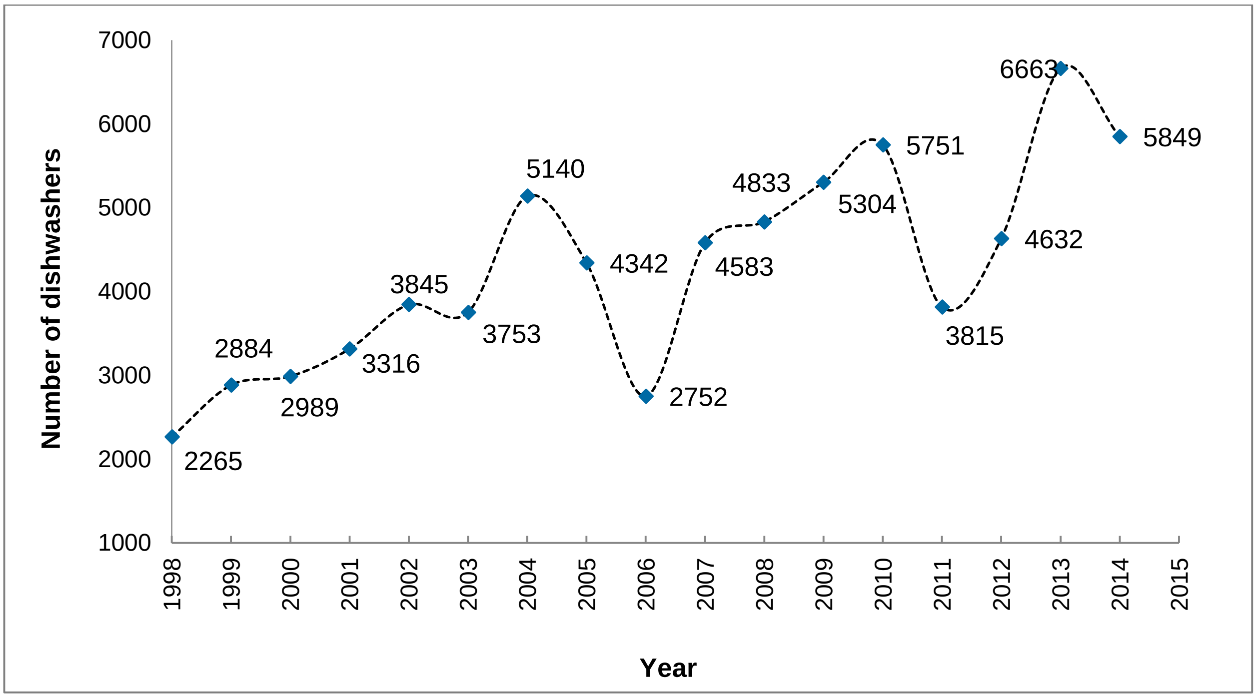


Figure 2.8: Development of number of dishwasher models available on the European market from 1998 to 2014 (data from CECED, personal communication)

2.2.3.2. Capacities of dishwasher models available on the market

The capacity of a dishwasher is declared by the manufacturer by the amount of ps that can be loaded into the baskets, also called rated capacity. 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 until 2013, 12 ps models have been dominating the dishwasher market. However, since 2005, their market share has continuously been decreasing (2005: 81.7%; 2013: 40.1% and 2014: 25.4%) in favour of dishwashers with a capacity of 13 ps (2005: 0%; 2013: 31.1% and 2014: 31.2%) and 14 ps (2005: 0.6%; 2013: 10.9% and 2014: 23.3%). 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 and 5.62% in 2014. The rated capacity of dishwashers increased by 3.2% from 2013 to 2014 resulting in an average capacity of 12.6 ps.

Since 2001, the share of slim line models is on a constant level of (15 ± 3)%. but the rated 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% and 7.1% in 2014 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±2)% 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 0.5% 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 2014, 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	2014
	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	n=5841
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	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	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	0.6
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	0.0
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	7.7
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	6.2
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	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	25.4
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	31.2
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	23.3
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	5.6

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

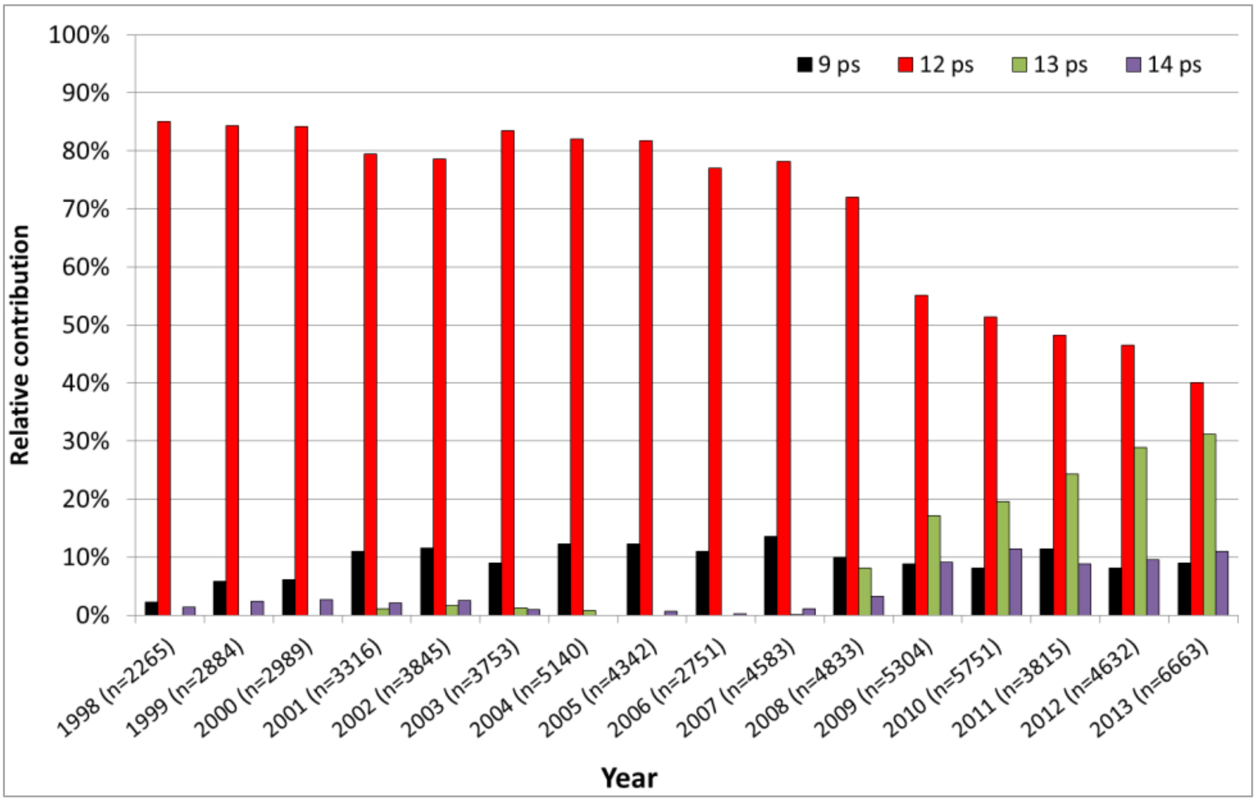


Figure 2.9: Shift of market shares of dishwasher capacities (in ps=place settings, n = number of dishwashing models available on the European market in a certain year) (data from CECED, personal communication)

2.2.3.3. 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 (or programme declared for energy label purposes before Regulation (EC) No 1016/2010), 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 4.2.4.

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 label. 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
- 2013 to 2014: - 0.017 kWh per cycle and - 0.005 kWh per ps

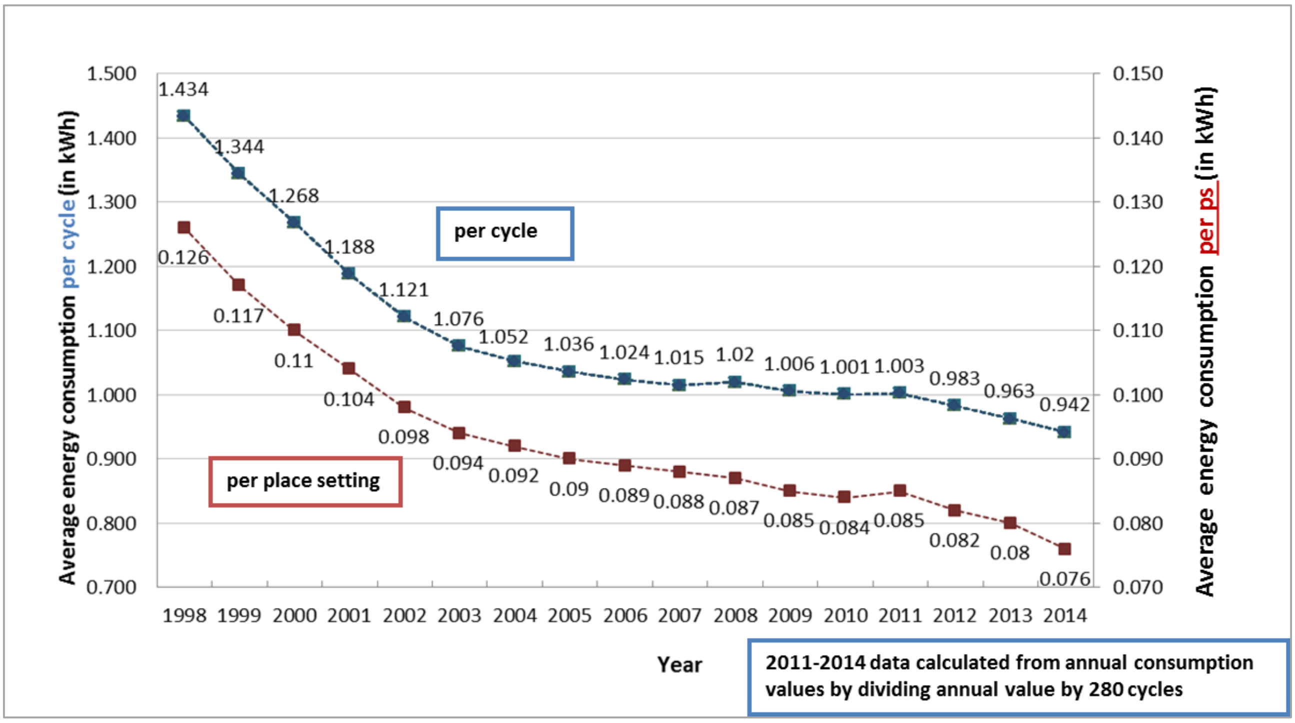


Figure 2.10: **Development of average energy consumption per cycle or per ps. Note that before 2011 the data were declared as per cycle (data from CECED, personal communication)**

Water consumptions per cycle and place setting have been reduced (Figure 2.11) by 46% from 1998 to 2014, while energy consumption per cycle and place setting has been reduced by 34% over the same time period (Figure 2.10). Besides technical advances (section 4.2.4), 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."*

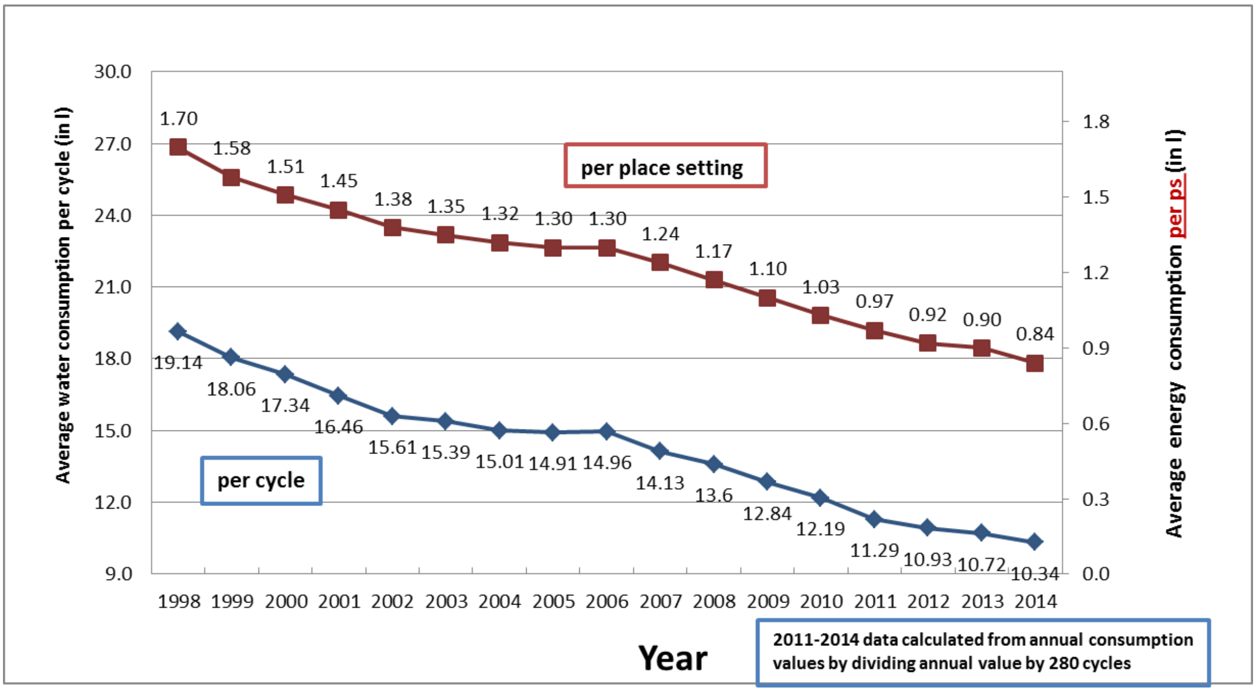


Figure 2.11: Development of average water consumption per cycle or per ps (data from CECED, personal communication)

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 2014. 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.

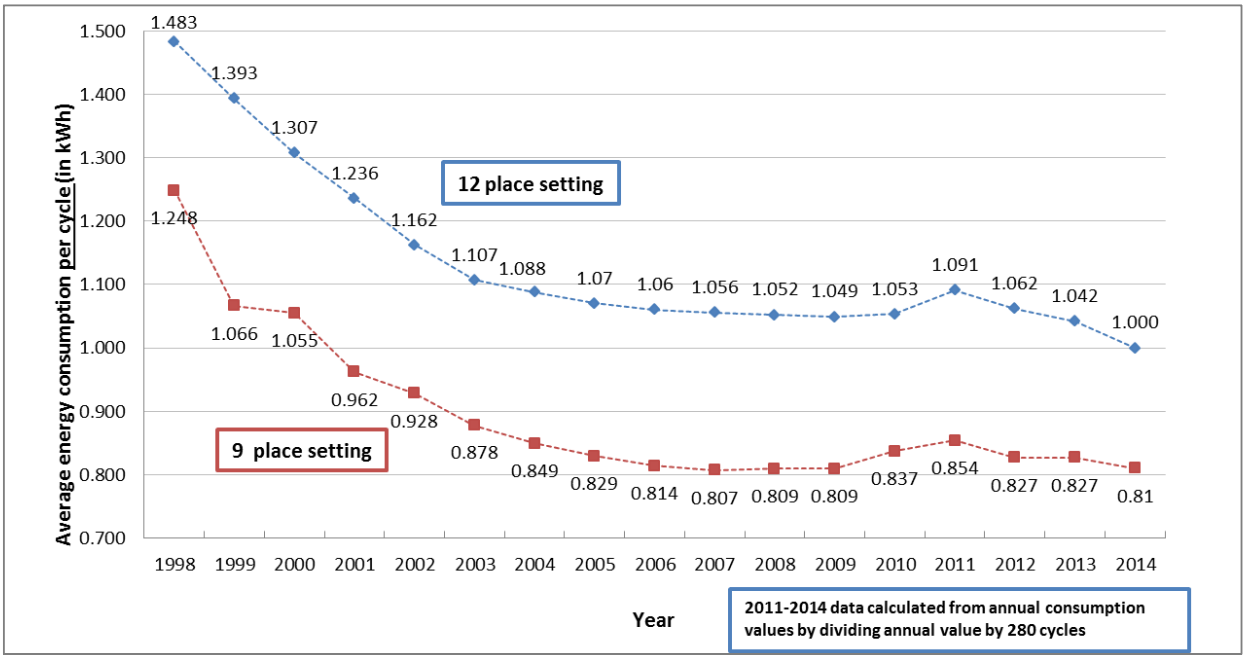


Figure 2.12: **Development of average energy consumptions per cycle for 9 and 12 ps-models on the European market (data from CECED, personal communication)**

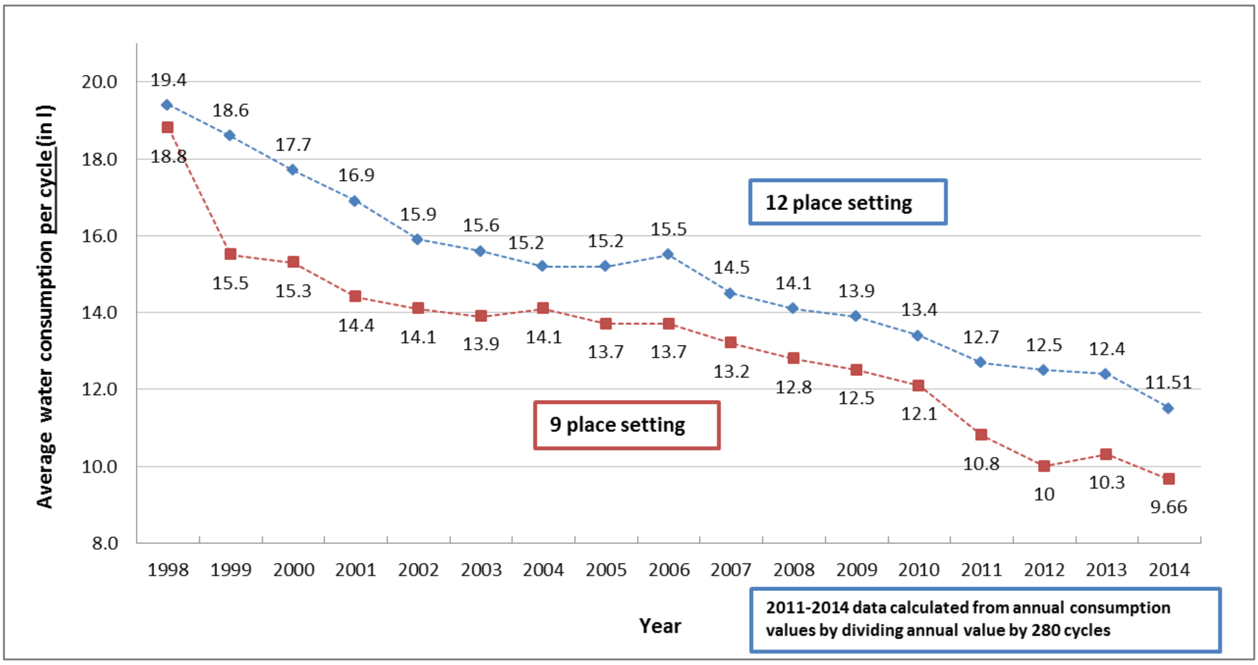


Figure 2.13: **Development of average water consumptions per cycle for 9 and 12 ps-models on the European market (data from CECED, personal communication)**

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 dish-washer 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.

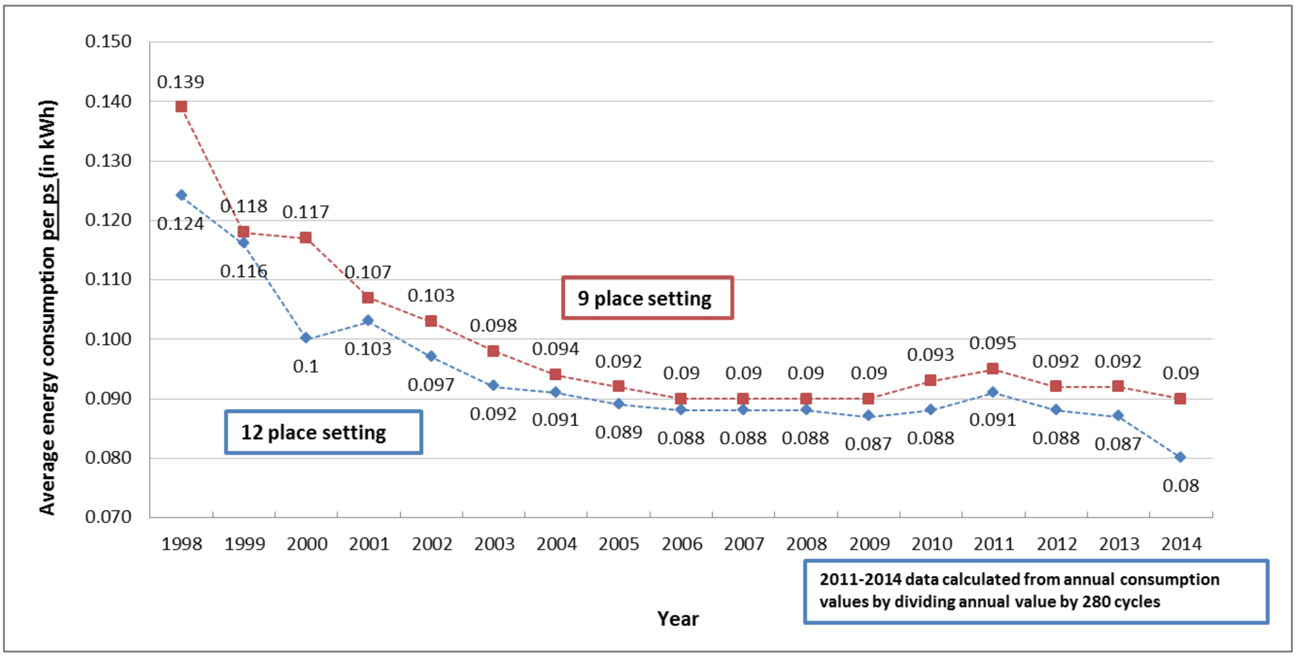


Figure 2.14: **Development of average energy consumptions per ps for 9 and 12 ps-models on the European market (data from CECED, personal communication)**

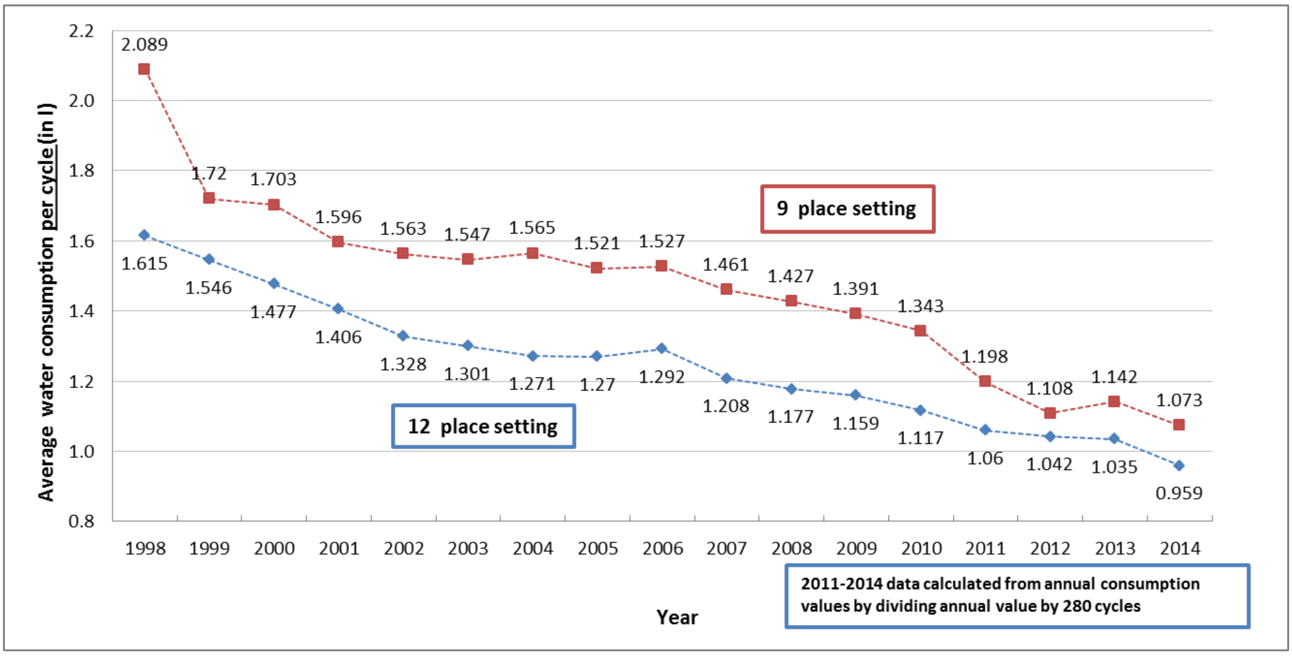


Figure 2.15: **Development of average water consumptions per ps for 9 and 12 ps-models on the European market (data from CECED, personal communication)**

Table 2.11 provides a breakdown of the energy and water consumption of 2014 models available on the market with regard to different capacities. A similar table with the data from 2013 is included in the annex. 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 2014 (data from CECED (2014)

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	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
6	191.78	0.68	0.11	2 213	7.90	1.32
7	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
8	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
9	225.87	0.81	0.09	2 704	9.66	1.07
10	245.35	0.88	0.09	2 885	10.30	1.03
11	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
12	280.28	1.00	0.08	3 221	11.51	0.96
13	267.90	0.96	0.07	2 733	9.76	0.75
14	259.08	0.93	0.07	2 825	10.09	0.72
15	272.76	0.97	0.06	3 038	10.85	0.72

For the year 2014, the average values of the most popular full-size dishwasher with 13 ps are shown in Table 2.13.

Table 2.13: Average values of CECED (2014) for dishwashers with 13 ps

	2014	
	average	valid data
Annual energy consumption in (kWh/year)	267.90	1 821
Annual water consumption (in L)	2 733	1 821
Noise (in dB(A))	45.19	1 821
Width (in cm)	61.9	1 821
Weight (in kg)	44.0	1 703
Energy consumption per cycle (in kWh)*	0.96	1 821
Energy consumption per standard place setting (in kWh)	0.074	1 821
Water consumption per cycle (in L)*	9.76	1 821
Water consumption per place setting (in L)	0.750	1 821

*calculated from annual consumption values by dividing annual value by 280 cycles.

For dishwashers with 10 place settings the performance and consumption values are shown Table 2.14. The average energy consumption per cycle is reported to be 0.874 kWh and water consumption at 10.28 L. The partly higher values than those as for 13 ps machines may be attributed to the lower market segment of these machines which can be seen from the lower number of models available in the market (362 versus 1821). It is expected that manufacturers do not put equal amounts of effort in these machines to make them more efficient.

Table 2.14: Average values of CECED databases 2014 for dishwashers with 10 ps

	2014	
	average	valid data
Annual energy consumption in (kWh/year)	245.35	362
Annual water consumption (in)	2 885	362
Noise (in dB(A))	47.80	362
Width (in cm)	45.7	362
Weight (in kg)	36.8	358
Energy consumption per cycle (in kWh)*	0.88	362
Energy consumption per standard place setting (in kWh)	0.0874	362
Water consumption per cycle (in)*	10.28	362
Water consumption per place setting (in)	1.028	362

*calculated from annual consumption values by dividing annual value by 280 cycles.

2.2.3.4. 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 and 94% in 2014.

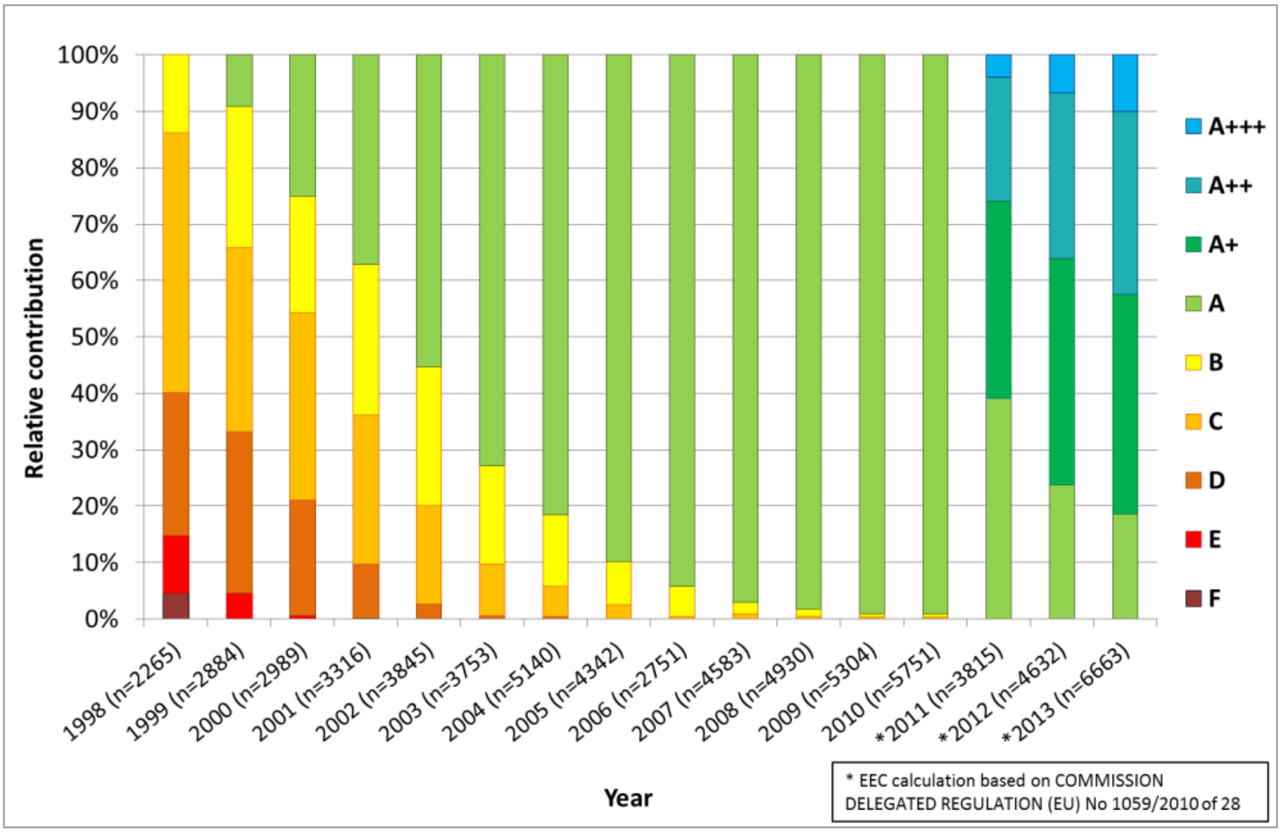


Figure 2.16: **Development of the distribution of dishwasher models of a certain energy efficiency class on the European market (personal communication)**

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 9 to 10 ps already were 16% class A++ and 1% A+++; for full-size models with 12 ps or more, 41% achieved A++ and 18% A+++. Data for the year 2014 showed that the percentage of dishwasher that achieved A+++ was 16%, A++ was 37%, A+ was 41% and finally A was only 5.75.

After 2013 a market shift has been observed 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. Data for the market breakdown regarding the energy efficiency classes is included in Figure 2.17. From December 2016, class A will be banned for all models (Tier 3).

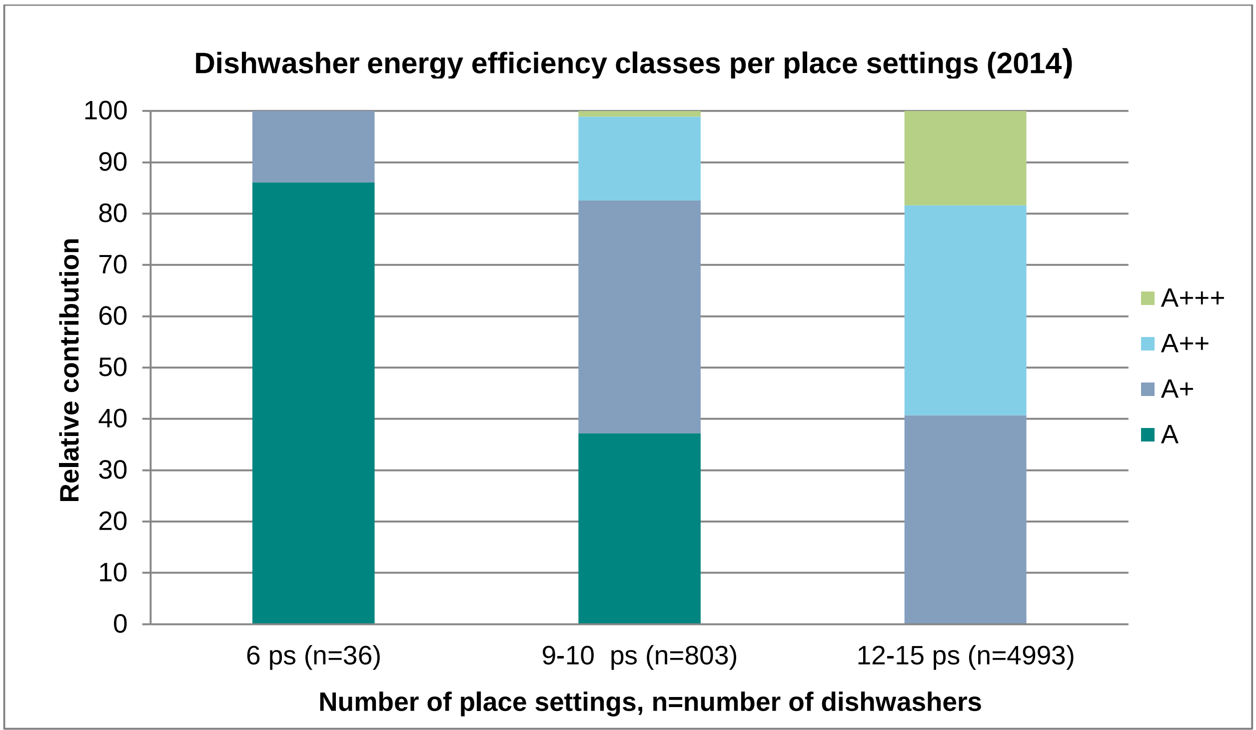


Figure 2.17: Distribution of different dishwasher capacities to certain energy efficiency classes on the European market (2014) (data from CECED, personal communication)

In 2014, 5 832 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., 2 033 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.

Data from 2013 are included in the Annex 8.1.4, although the observed tendency is exactly the same.

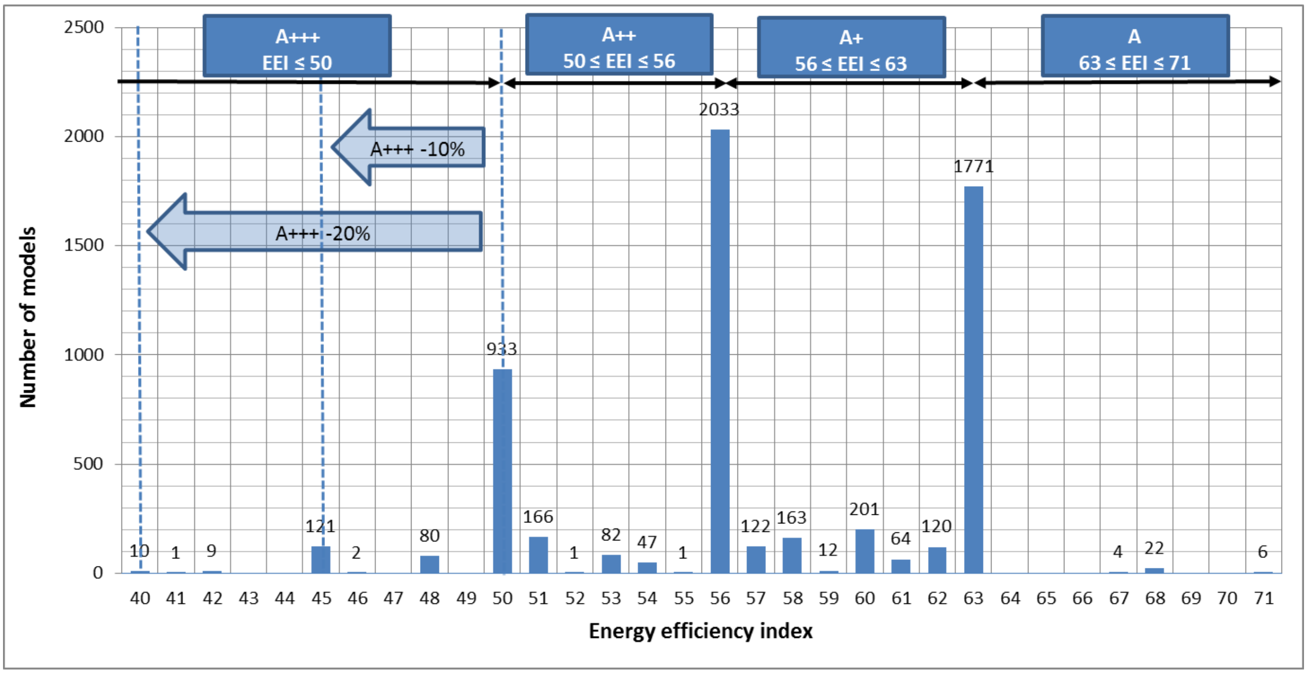


Figure 2.18: **Distribution of dishwasher models of a certain energy efficiency index on the European market in 2014 (data from CECED, personal communication)**

2.2.3.5. 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 and this number increased to 99.6% in 2014. 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 (the 0.4% dishwasher that did not reach the drying performance class A in 2014 were dishwashers with 6ps).

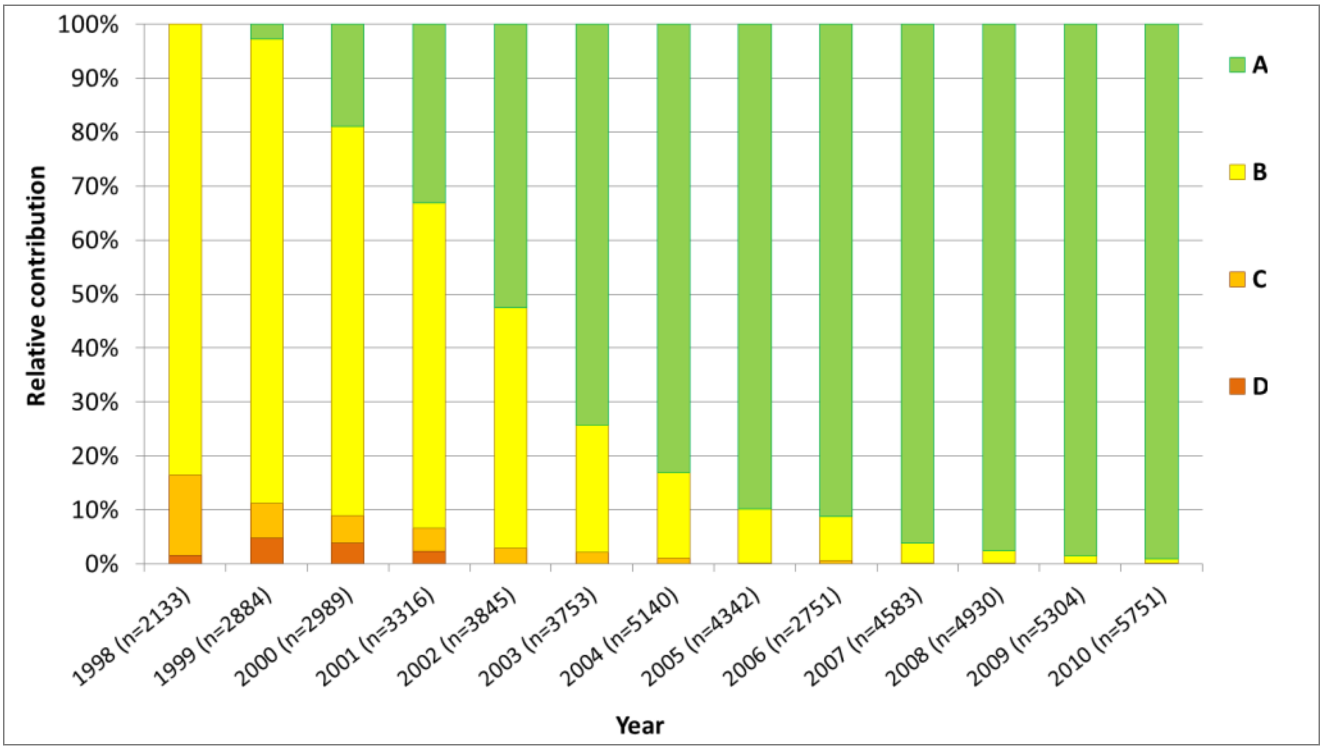


Figure 2.19: **Development of the distribution of dishwasher models of a certain cleaning performance class (data from CECED, personal communication). Note that cleaning performance is obligatory class A since December 2011.**

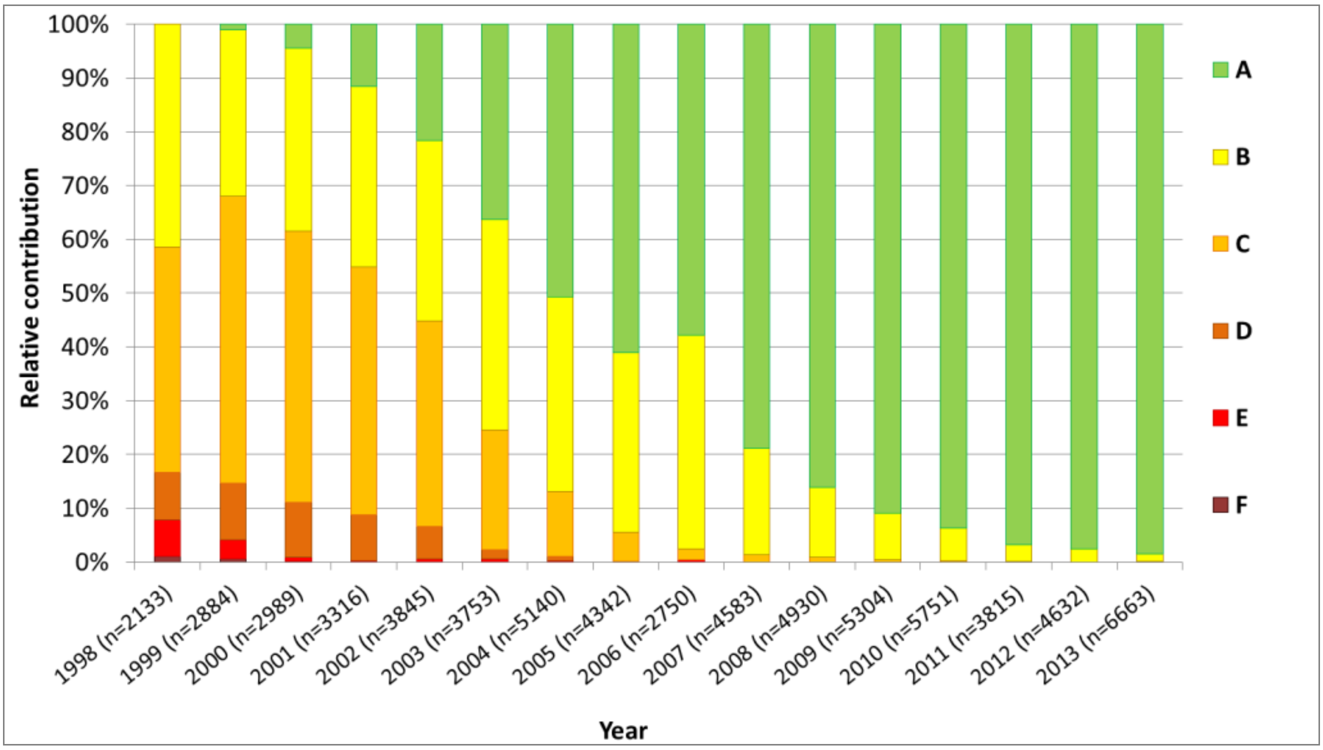


Figure 2.20: **Development of the distribution of dishwasher models of a certain drying performance class. (data from CECED, personal communication) Note that drying performance is obligatory class A for ps > 8 and class B for ps < 8 since December 2013.**

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 4.2.2), 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 2.2.4).

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 4.2.4.

2.2.4. Market trends with regard to product design and features of dishwashers

2.2.4.1. Trends to increasing programme duration of household dishwashers

Besides technical improvement options (cf. section 4.2.4), 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 2015a)

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.

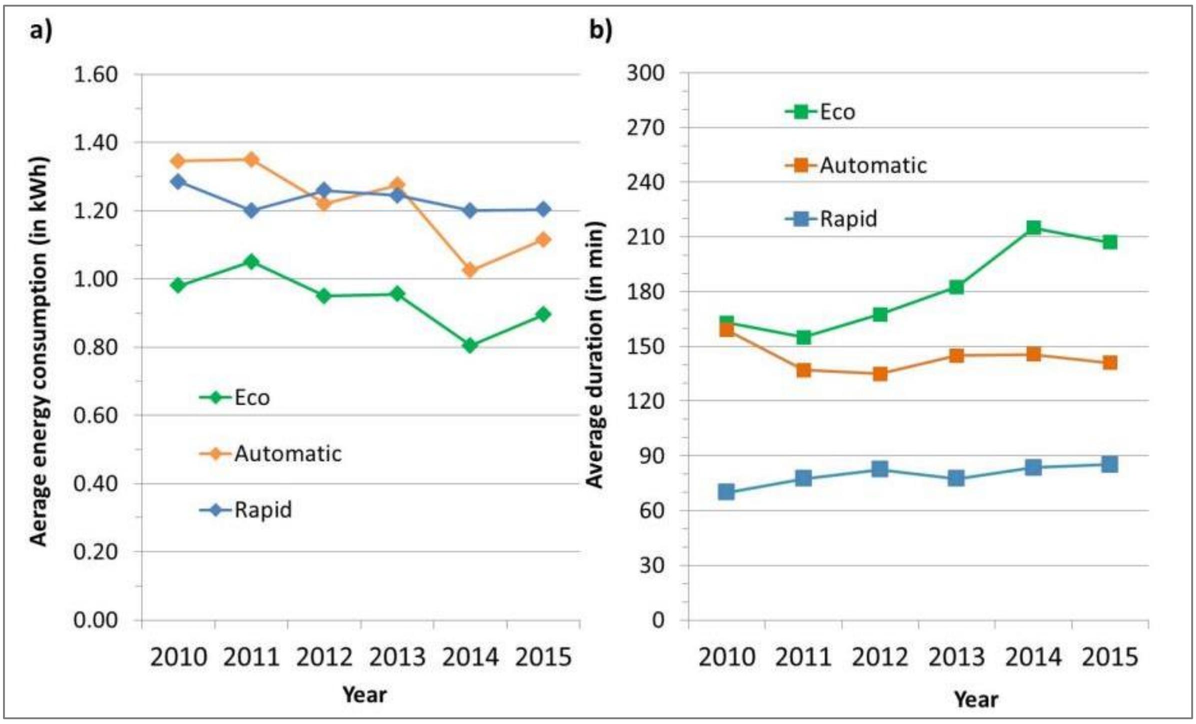


Figure 2.21: **Development of the average a) energy consumption and b) programme durations of the Eco, Rapid and Automatic programme, full size models (12-15 ps); calculation by Uni Bonn from data published by Stiftung Warentest from 2010 to 2015**

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 choosing other programmes than the Eco programme. The compilation, conducted by Uni Bonn, 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%). The data is not representative. It is taken from instruction manuals of twelve dishwasher models of various producers that were offered on the European market since 2010 (see Table 2.15). The models were selected according to tests published by consumer organisations.

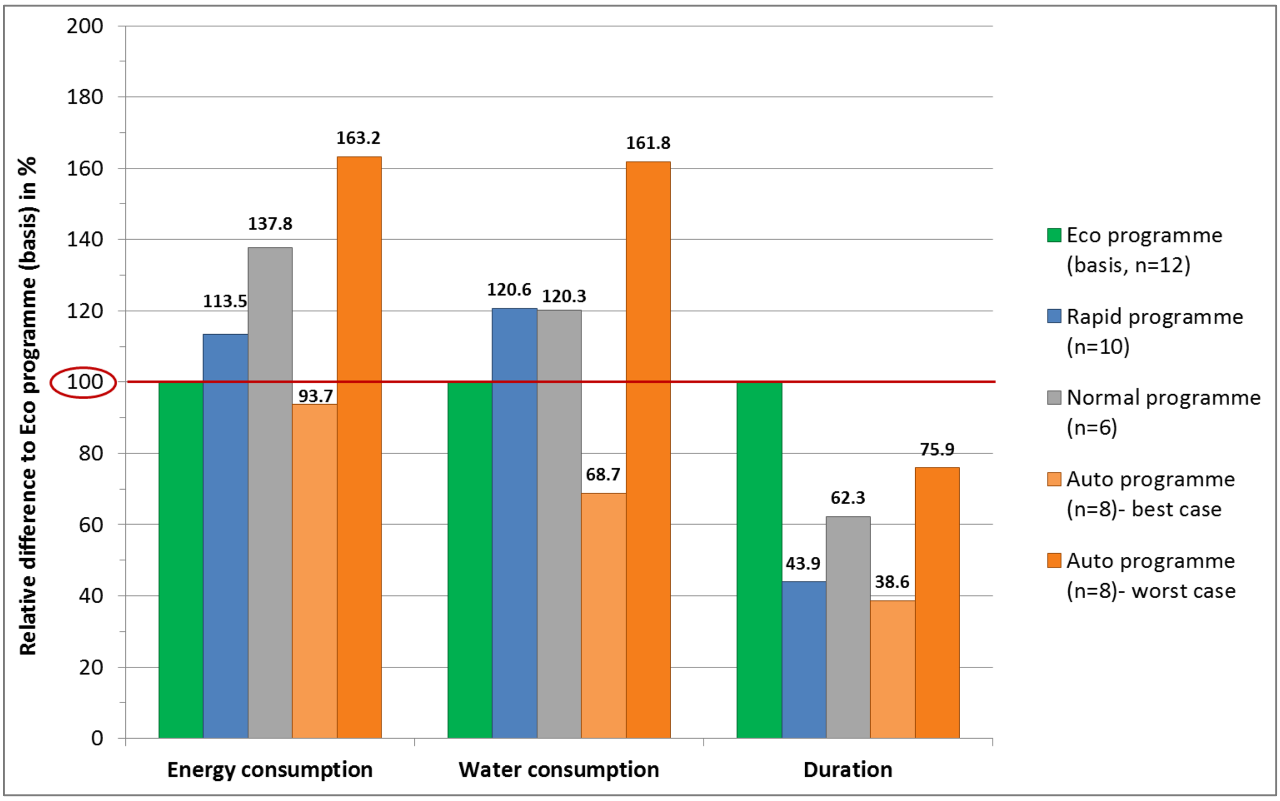


Figure 2.22: **Relative heights of consumption values and programme durations of popular dish-washing programmes in relation to the Eco programme as a basis (note: "best case" means the lowest (consumption) value, "worst case" the highest (consumption) value, corresponding to light or heavy soiling). Source: compilation by University of Bonn.**

Table 2.15: **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	DIF04Integrated	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
EEI	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)

2.2.4.2. 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).

2.2.4.3. 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.

2.2.5. 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 2.2.2), an increase of detergent consumption per capita is also to be expected.

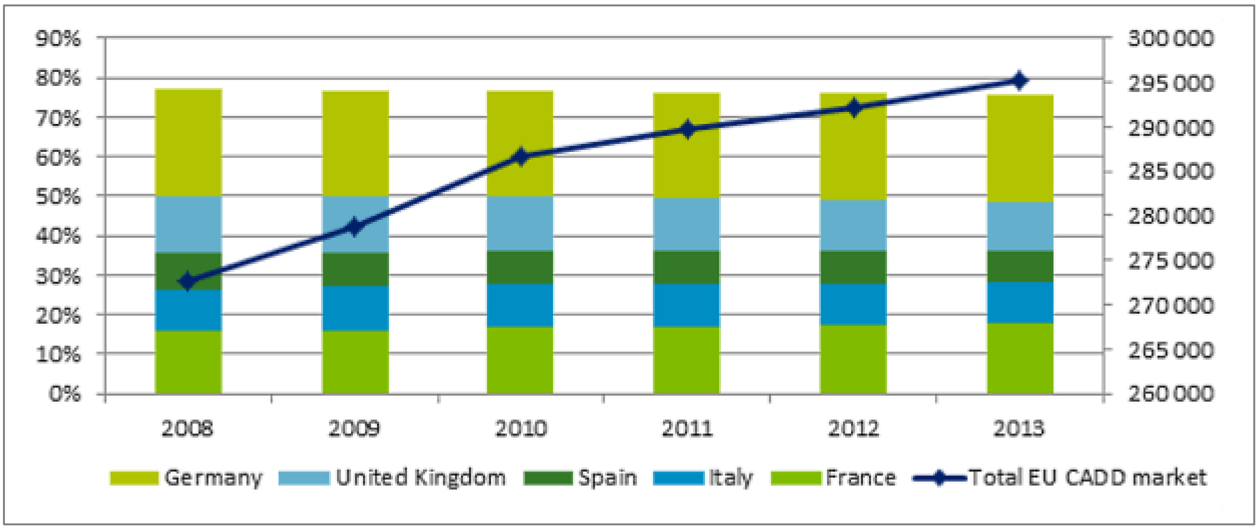


Figure 2.23: Development of automatic dishwashing detergent market (retail volume of powders, liquids and tablets, in tonnes) in EU including percentage shares of the five countries with biggest market share, database: Eurostat (Bio by Deloitte 2014)

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) summarises 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 2.16: 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 lime scale.)	not available	not available	not available

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 (Rüdenauer 2006), absolute and relative annual costs of household dishwashers are shown (see Table 2.17), 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 €/m³ 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 2.17: Total annual costs of household dishwashers (efficiency class A) (Rüdenauer 2006)

Dishwasher type	Annual costs for				Total annual costs
	Acquisition	Power	Water	Detergent	
Absolute					
Average appliance	50 €	41 €	11 €	22 €	125 €
Free-standing	36 €	41 €	11 €	22 €	110 €
Built-in	54 €	41 €	11 €	22 €	129 €
Relative					
Average appliance	40%	33%	9%	18%	100%
Free-standing	32%	37%	10%	20%	100%
Built-in	42%	32%	9%	17%	100%

In the following sections, more recent figures are compiled and discussed. On that basis the assumptions for further calculations are described in Task 5.

2.3.1. Average unit value of household dishwashers produced in EU28

According to the Ecodesign Impact Accounting study by VHK (2014 / status 2013), 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 label requirements according to EU Regulation 1059/2010 and ecodesign requirement according to EU Regulation 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.

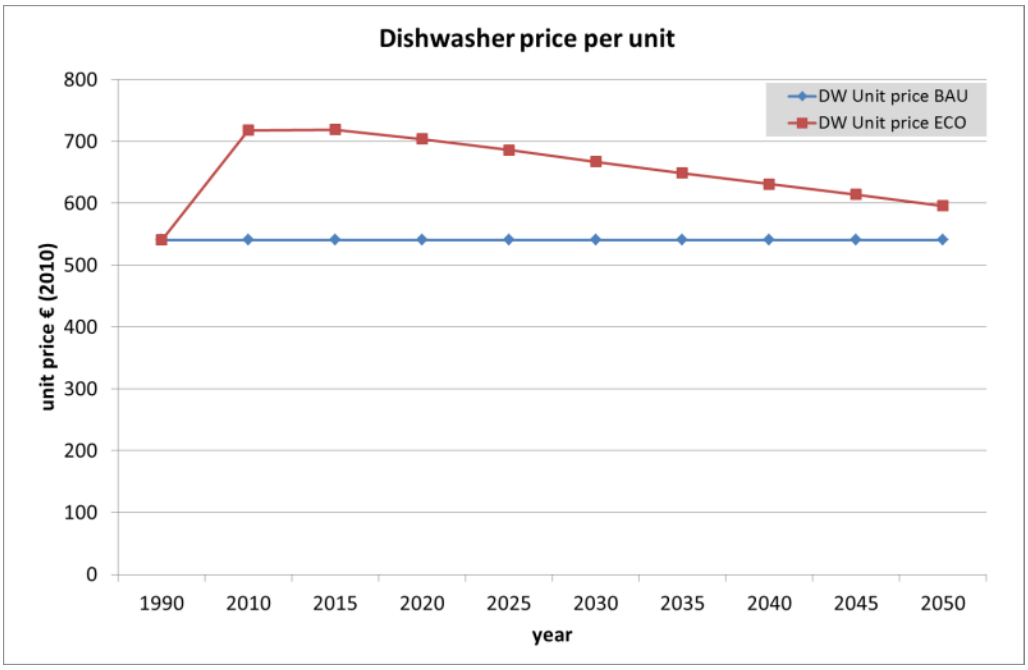


Figure 2.24: Average price in € (basis 2010) for a dishwasher in the European market from 1990 to 2050 (VHK 2014 / status 2013)

Additional to these data, Table 2.18 shows the calculated average unit values of household dishwashers produced in EU28 and certain Member States as reported by Eurostat (2015b) 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 / status 2013) 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 2.18: Calculated average unit value (in Euro) of household dishwashers produced in the EU28 between 2007 and 2013; source: own calculation based on Eurostat (2015b)

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 2.19). 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, 2010b, 2013, 2014, 2015b)

Table 2.19: Prices per tablets (incl. VAT) in Germany 2010-2015

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

2.3.3. Further costs

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 out-comes of all studies being comparable (COWI and VHK 2011b). The EU-27 average data provided in this study are the following for electricity, gas, water, interest, inflation and discount rates.

Table 2.20: Energy, water and financial rates as proposed by COWI and VHK (2011b) for the year 2011

	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 (2011b), 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.

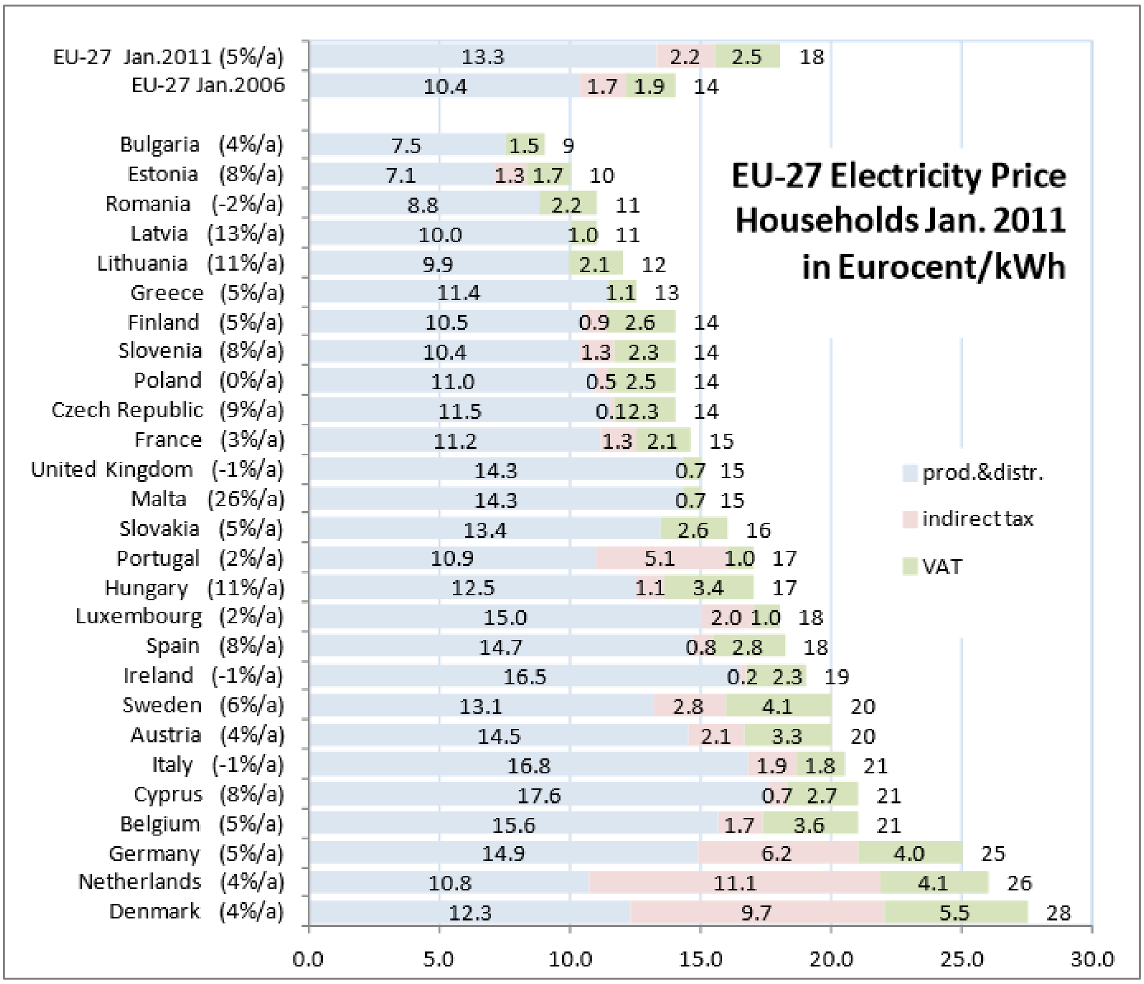


Figure 2.25: EU-27 Electricity prices households Jan. 2011 (recent annual growth rates in brackets, in %/a) (COWI and VHK 2011b)

Consumer information material published by VZ RLP & Öko-Institut (2012) provide a comparison of total costs for energy and water, for dishwashers with different energy efficiency classes (see Table 2.21).

Table 2.21: Comparison of costs for dishwashers of different efficiency classes (Database: VZ RLP & Öko-Institut (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 €
Assumptions: 12 - 14 ps, 280 cycles/year; * 12 years old, ** 0.24 €/ kWh, *** 3.9 €/ m³			

3. Task 3: Users

For the purpose of this task a study about the consumer behaviour was carried out. This study explores how consumers 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 was conducted through an on-line survey in April 2015 on samples of about 250 to 500 consumers per country in 11 major countries of the EU (plus Turkey). Participants were selected to be representative for the population in each country regarding gender, age distribution between 20 and 75 years and household or family size. Results of this study were discussed in the 1st TWG meeting and are reported in section 3.2

The information reported in section 3.1 is the outcome of a desk review including literature in peer-review publications, consumer's magazines and governmental and non-governmental organizations.

In section 3.4, the end-of-life behaviour is discussed.

3.1. Consumer behaviour regarding household dishwashers – status before 2015

3.1.1. Purchase behaviour

TNS Opinion & Social (2014) shows that European consumers are aware of the impact of their daily household consumption on the environment. Therefore, reducing home consumption for lighting, 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).

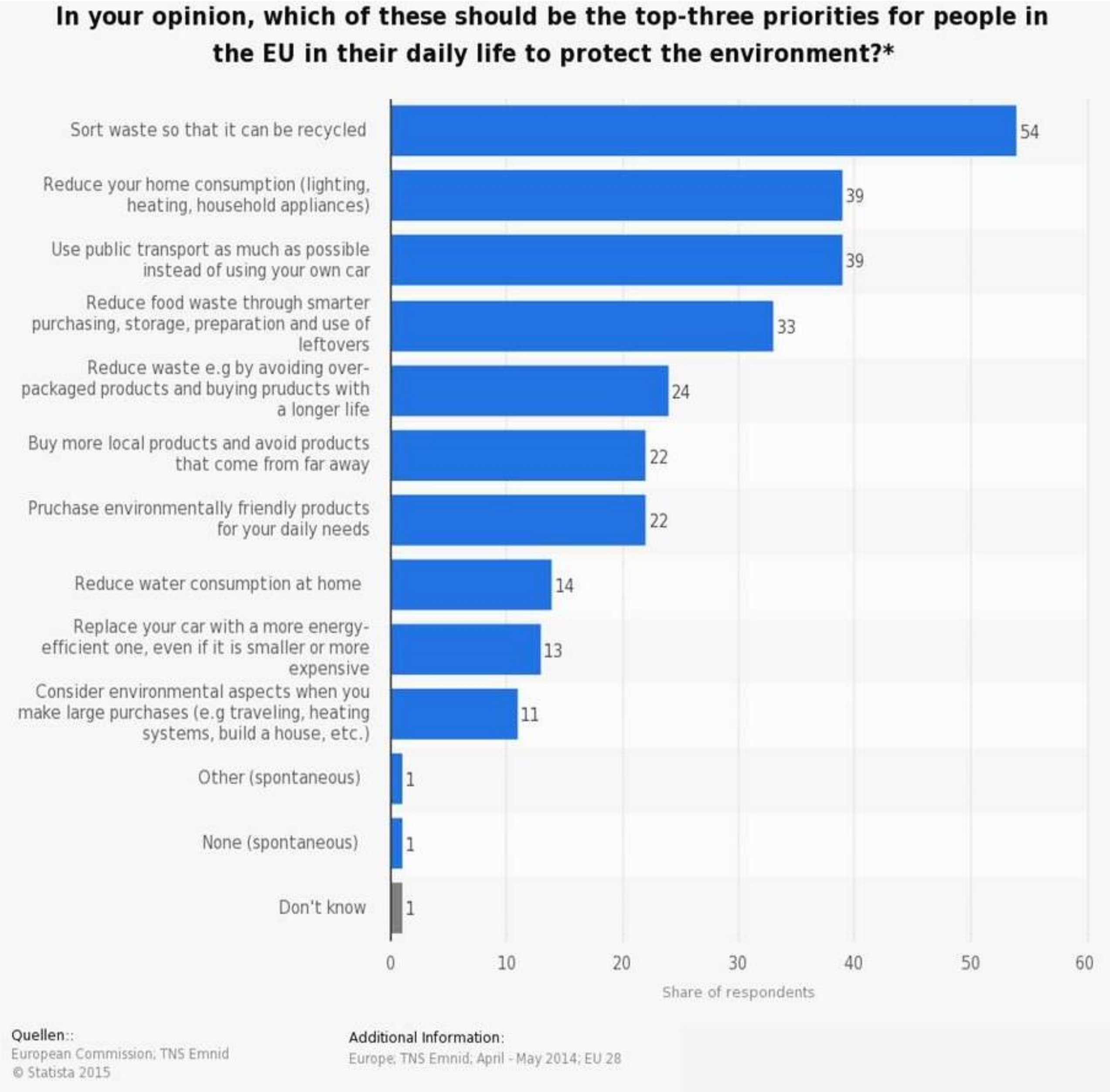


Figure 3.1: Priorities for people in the EU in their daily life to protect the environment (TNS Opinion & Social 2014)

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 (Richter 2010a), investigating dishwashing habits in Germany, Sweden, Italy and UK with 1 206 respondents (Table 3.1). On average, resource efficiency related to energy and water 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.

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=1 206)
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

Dünnhoff & Palm (2014) confirm that the most important criterion for the consumers when choosing electrical or electronic appliances is the electricity consumption and energy efficiency (49%). Additionally, they show that, the durability of the products (43%) and the price-performance ratio (36%) are important criteria for consumers as well. (Figure 3.2).

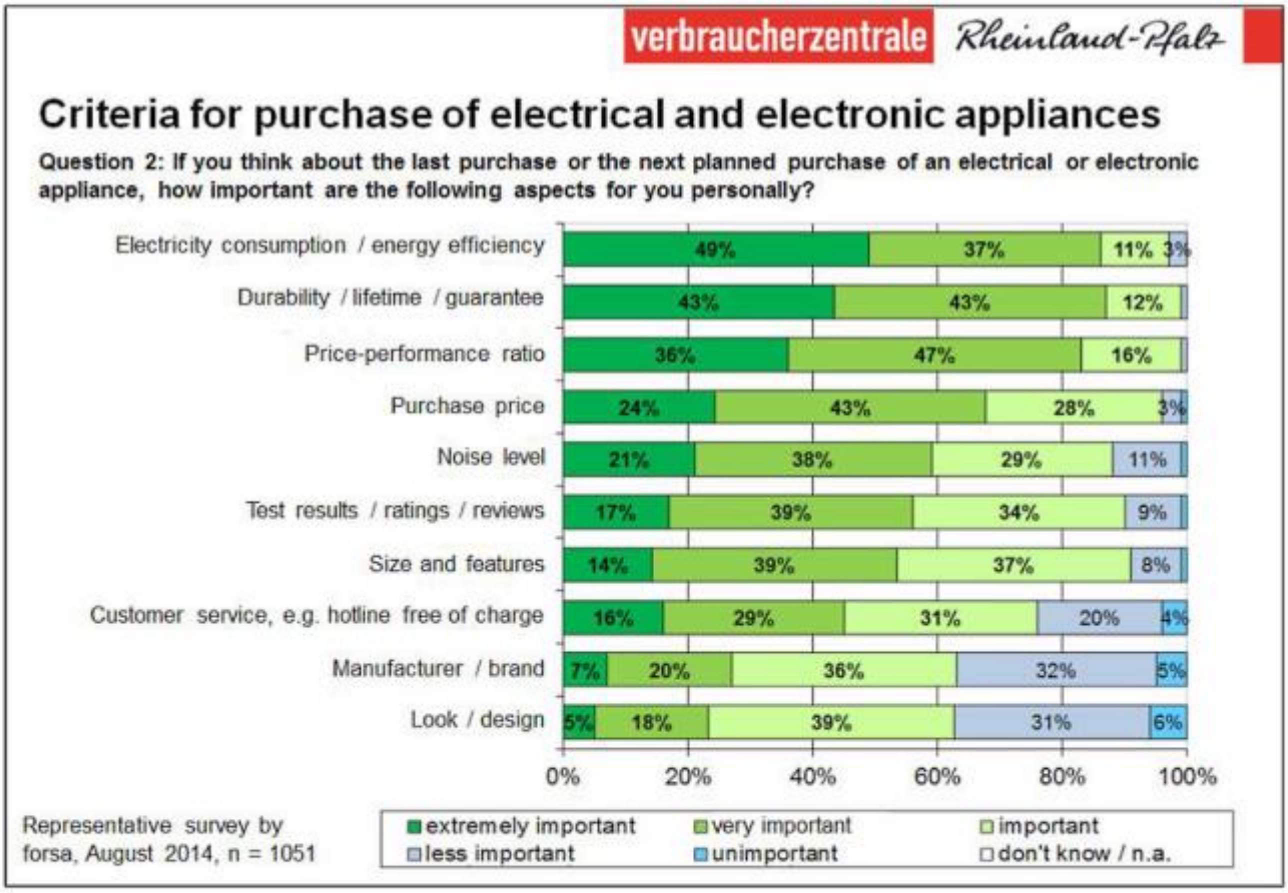


Figure 3.2: Selection criteria for the purchase of electrical and electronic appliances (Dünnhoff & Palm 2014)

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 available on how long these products last. They use 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 (ISIS 2007a). 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 people.*" (Bichler et al. 2015)

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 (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. (2015), 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 2015b), 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

Reference	Cycles/week	Cycles/year	Remarks
ISIS (2007a)	4.1	214	Previous preparatory study for ecodesign requirements
Richter (2010b)	3.4	177	Study in Italy, Sweden, Germany and UK
Bichler et al. (2015)	4.1	107.7	In 1-person households in Germany
		383.7	In households >5 persons in Germany
Ecodesign Regulation (EC) No 1016/2010		280	
Richter (2010b)		280	In 4-5-persons households
JRC IPTS (2015b)	4.3		Variations between 4.1 cycles/week in

Reference	Cycles/week	Cycles/year	Remarks
			Scandinavia and 4.4 in Eastern Europe

3.1.4. Capacity use and composition of dishwasher load

A stakeholder indicated via the questionnaire (JRC IPTS 2015b) that 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 around 1200 dishwasher loads from 106 households in Germany, Sweden, Italy and UK, (Richter 2010b) assessed the degree of space used in the upper and lower basket. In less than 40% of all dishwasher loads the machines was filled to its full capacity (Figure 3.3).

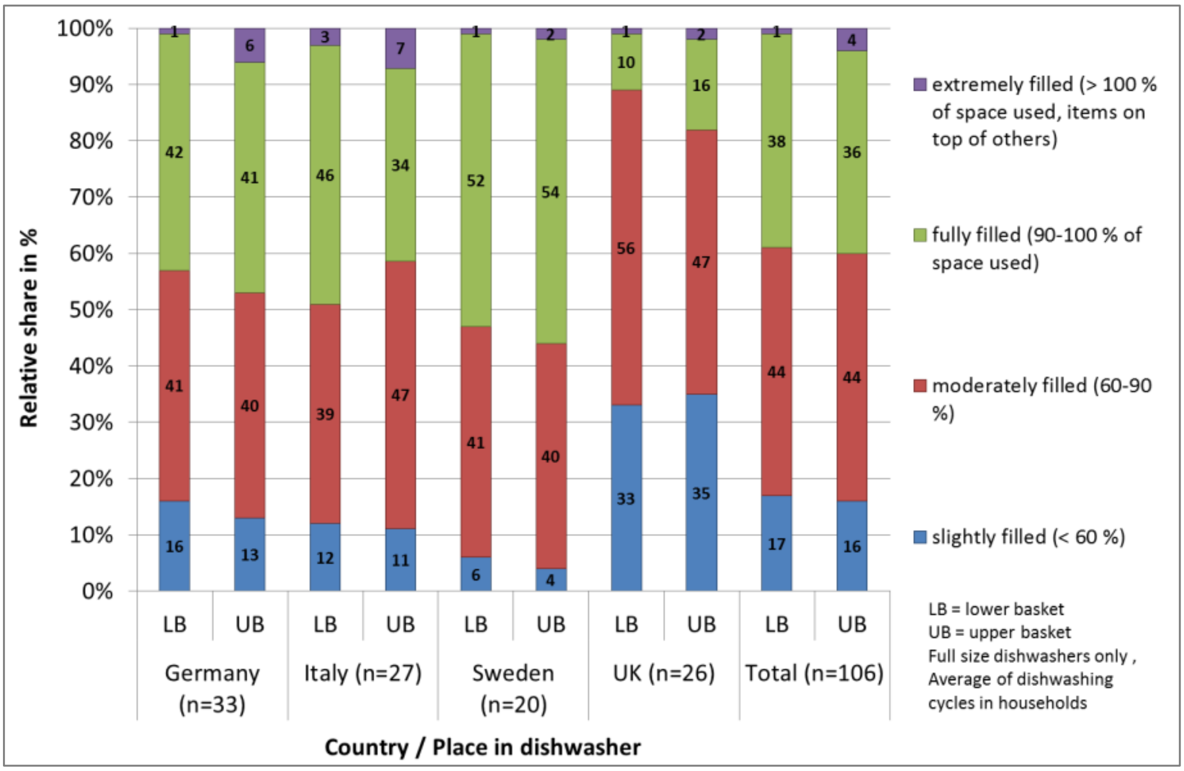


Figure 3.3: Capacity use in dishwashers based on assessment of used space (Richter 2010b)

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. Less than 10%, especially single- and 2-person households, admitted that they run their dishwasher even with few numbers of dishes inside (Figure 3.4).

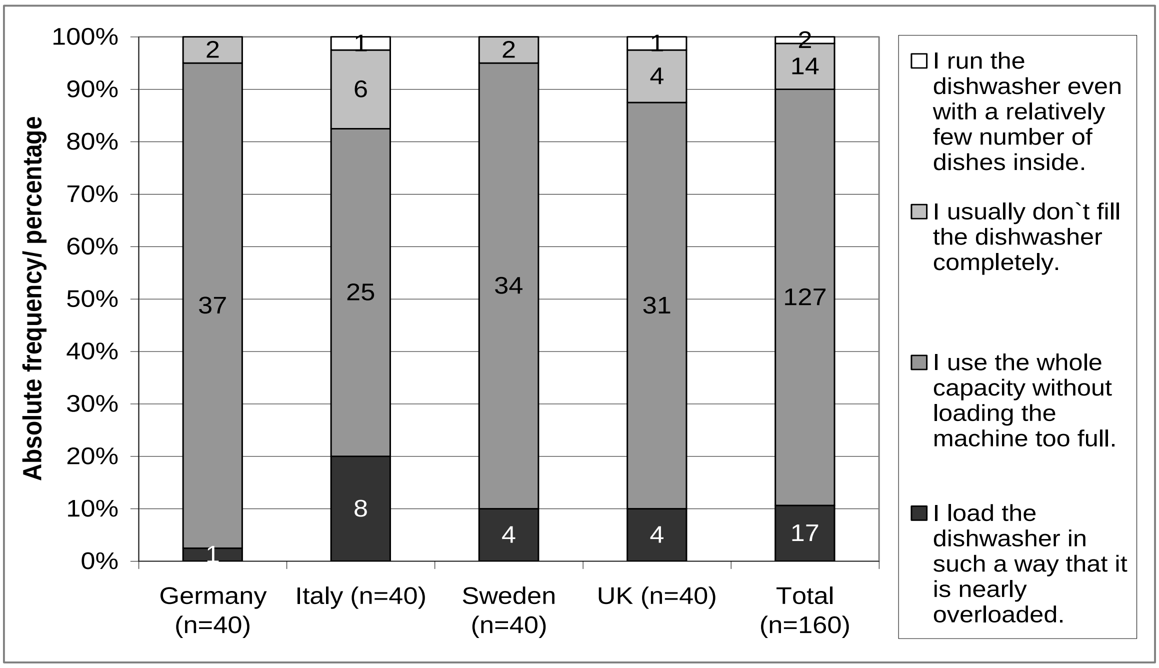


Figure 3.4: Respondents' evaluation on degree of dishwasher capacity use (Richter 2010b)

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 2015b)

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 (2014) 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 dish-washing 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 acceler-ate the drying .

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 modi-fied and adjusted to observed conditions in consumer households (Brückner 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 dishwash-er 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 (ISIS 2007a).

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 3.5):

> *"[…] 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)*

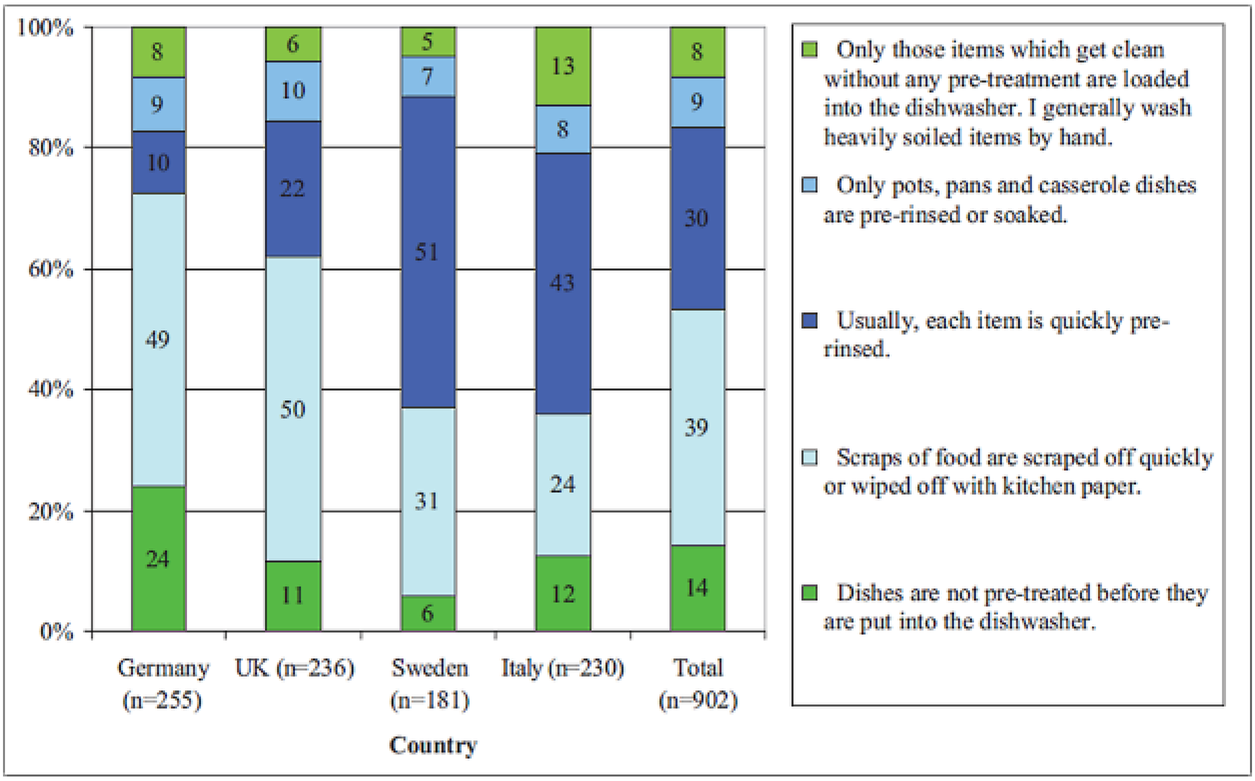


Figure 3.5: Pre-treatment habits of European consumers (Richter 2010a)

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 (2010b) (Figure 3.6) 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)*

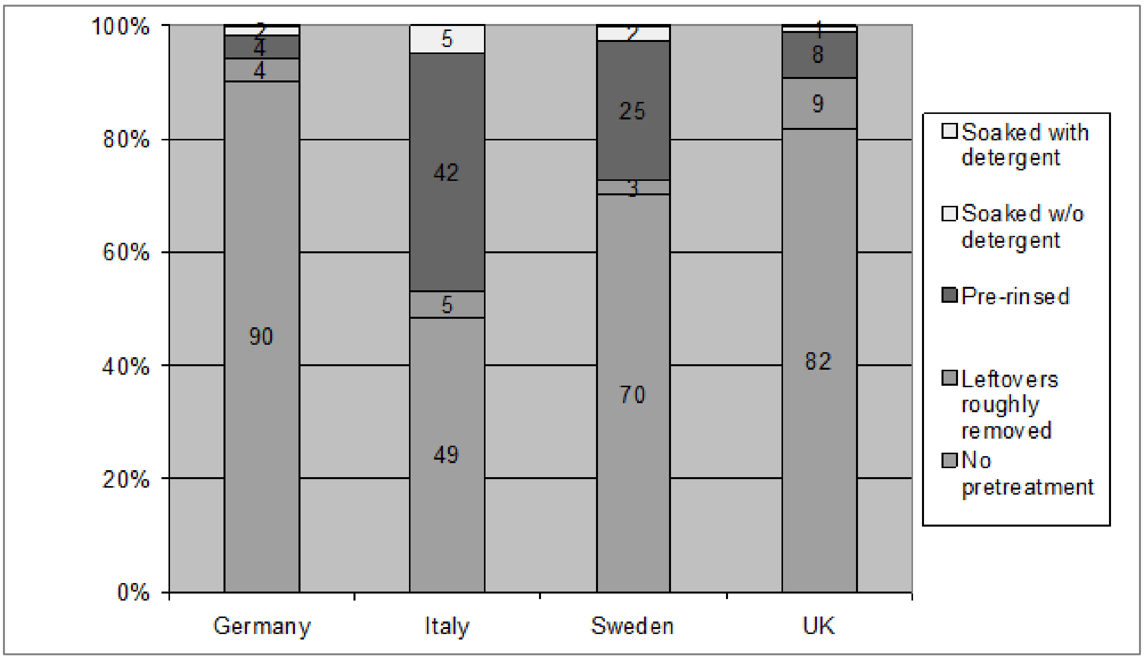


Figure 3.6: **Share of pre-treatment types in total number of dishes cleaned (Richter 2010b)**

"[...] 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

3.1.6.1. In-home study by Richter (2010b)

The in-home observation of 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 per-

formance. 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. (2015). 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). Note that only from 2012 the Ecodesign Regulation (EC) No 1016/2010 requires the Eco programme to be set as default on new machines.

Table 3.5: Usage behaviour in choosing dishwashing programmes in two studies, relative shares; according to Bichler et al. (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. 2015)	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 (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 (ISIS 2007a).

Table 3.6: Distribution of chosen programme temperatures, relative percentage (in %) and absolute number of households in brackets (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

3.1.6.2. Stiftung Warentest

An article of the German consumer journal Stiftung Warentest (Stiftung Warentest 2015a) points out that the Eco and the automatic programme are the most used programmes: 43%, of the participants of an online survey in January and February 2015 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. 24% of the participants never use the 'Eco' programme.

3.1.6.3. Reasons for consumers to not chose 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 could be increased.

> *"[…] for various reasons consumers may not choose these eco programmes […]." (iea-4e 2014)*

Within the in-home study of Bichler et al. (2015) 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 3.7: 89.1% of respondents do not accept programme durations ≥ 3 hours, which relates to the programme duration of actual eco programmes (section 2.2.4). 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)

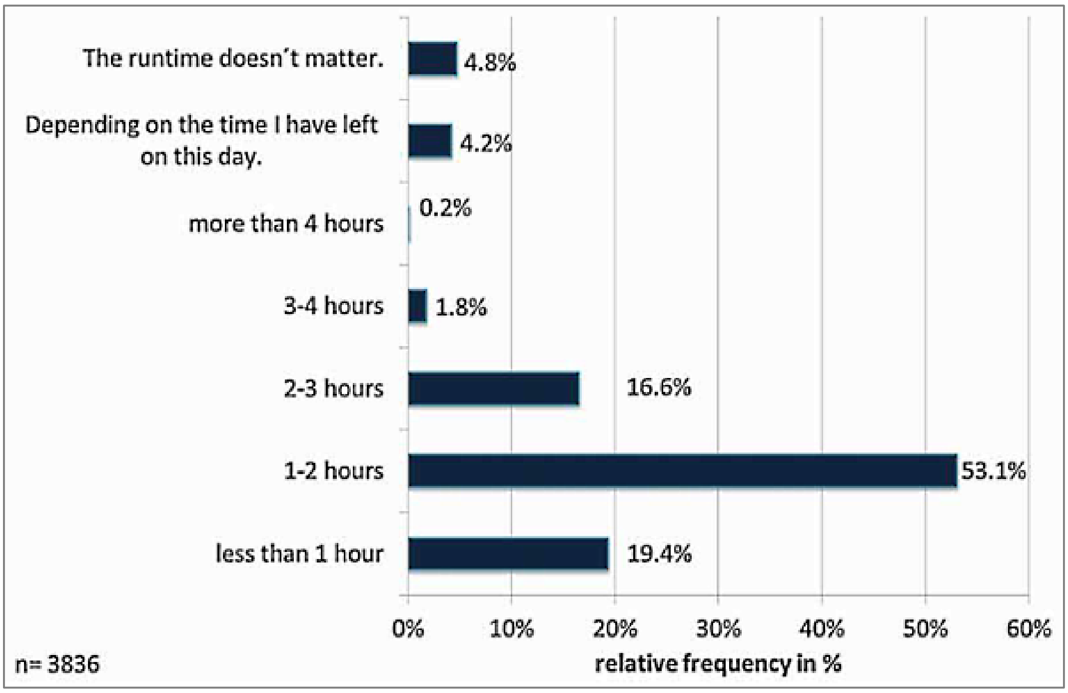


Figure 3.7: Accepted maximum programme durations (Bichler et al. 2013)

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 (cf. section 4.2.2) and why eco programmes have long programme durations and still are the most efficient programme to choose. This led to an increase in acceptance of eco programmes: three months after the study was finished, the share of households that predominantly used 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 collected through the consumer behaviour survey (see 3.2).

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), give 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 3.8).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.

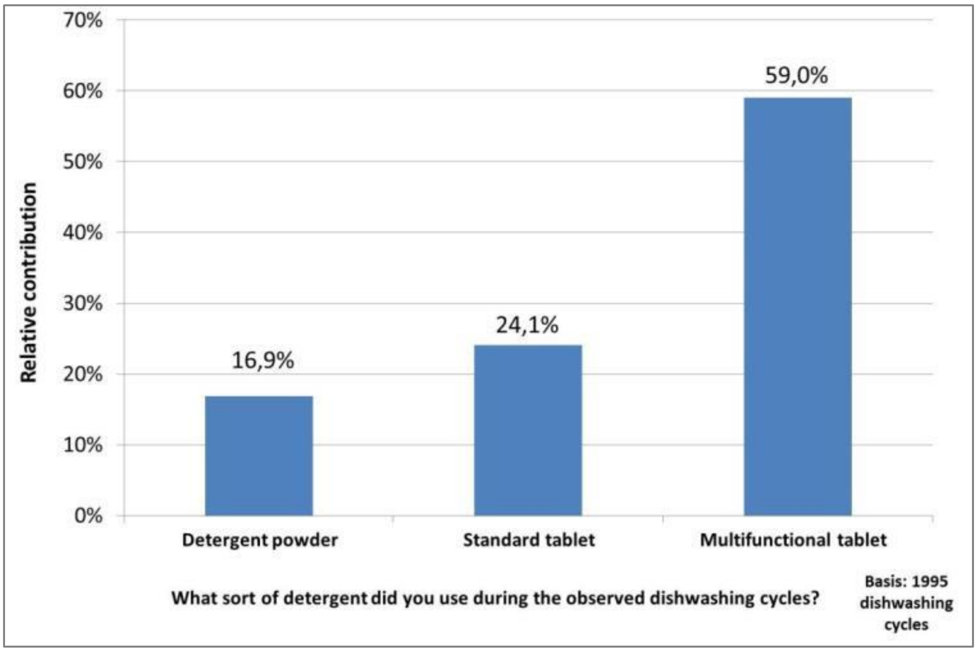


Figure 3.8: Types of dishwasher detergents used in German households, relative shares (Bichler 2014)

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 $CaCO_3$/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 $CaCO_3$/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 3.9).

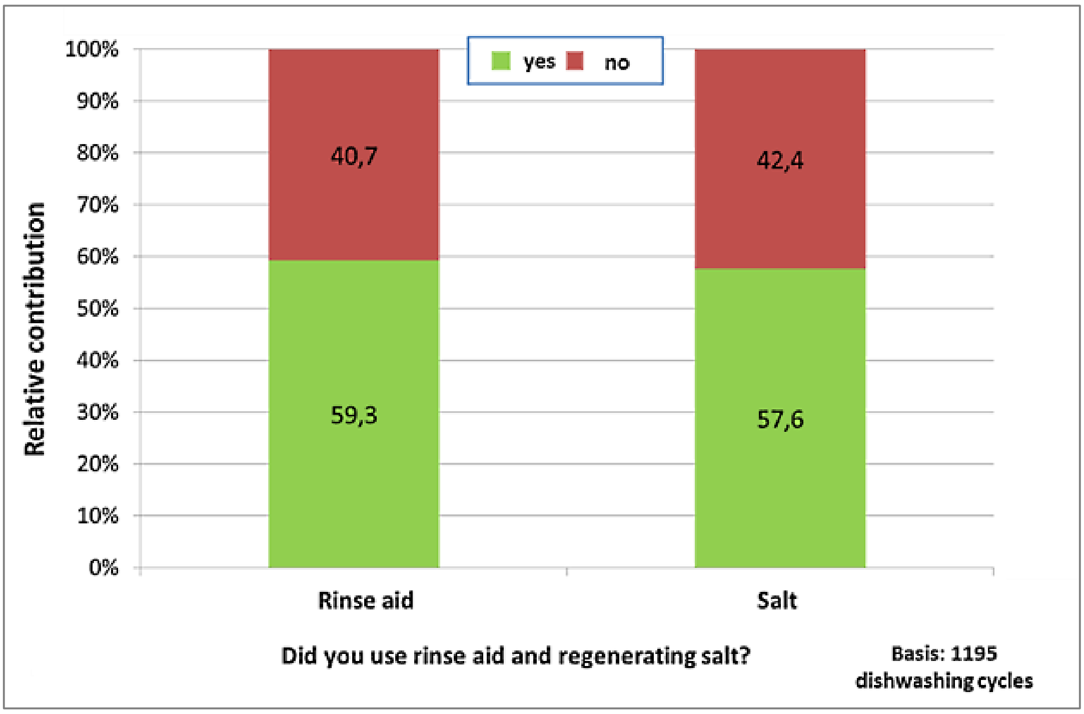


Figure 3.9: Use of rinse aid and regenerating salt (Bichler 2014)

The second German study about consumer behaviour in terms of automatic dishwasher products evaluated 2 567 responses to a questionnaire that have been provided 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)

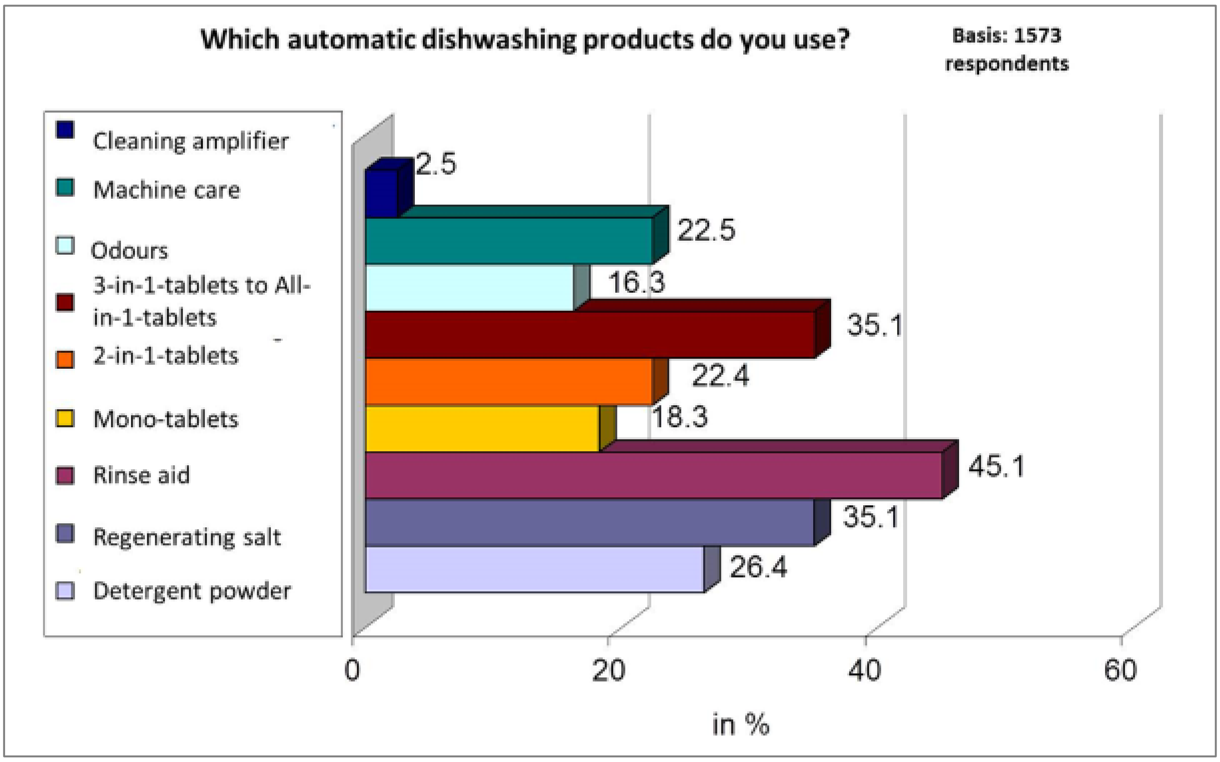


Figure 3.10: **Usage of automatic dishwashing products in German households (Schneider & Stamminger 2011)**

Users of multifunctional tablet products were asked about their usage of additional dishwashing products (Figure 3.11). Answers were compared to those of a former questionnaire from the campaign-day in 2006.

Figure 3.11 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 3.10. 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%).

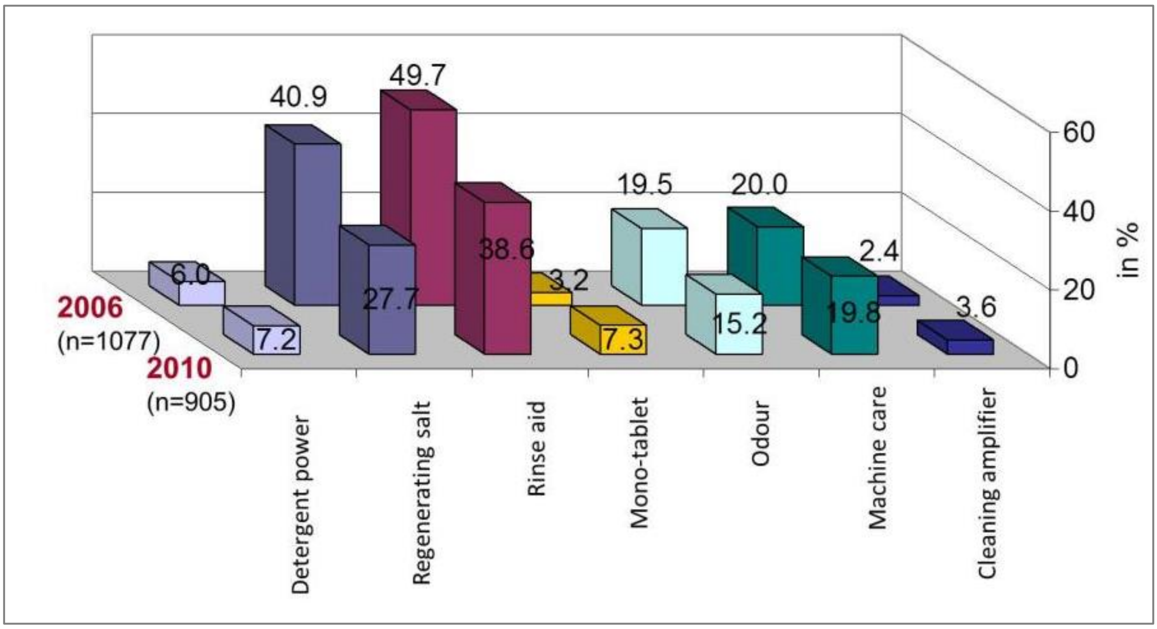


Figure 3.11: **Users of multifunctional tablets: usage of additional automatic dishwashing products (Schneider & Stamminger 2011)**

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 User needs 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 these 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 regarding EU Ecolabel criteria, also dosage requirements of other ecolabels and voluntary schemes were analysed which are presented in the Table 3.8. Note that the dosage levels for the EU

Ecolabel are calculated based on medium water hardness whereas for other ecolabels it is calculated based on soft water. 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 automatic dishwashing (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 3.12): 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 2014)

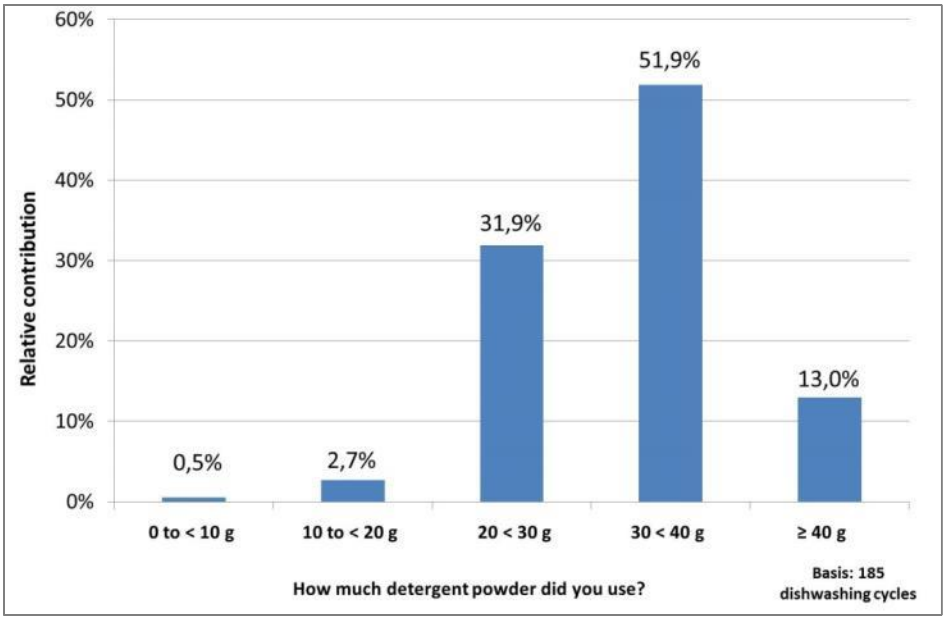


Figure 3.12: Dosing behaviour of detergent powder in German households (Bichler 2014)

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 from the questionnaire (JRC IPTS 2015b), 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 3.13.

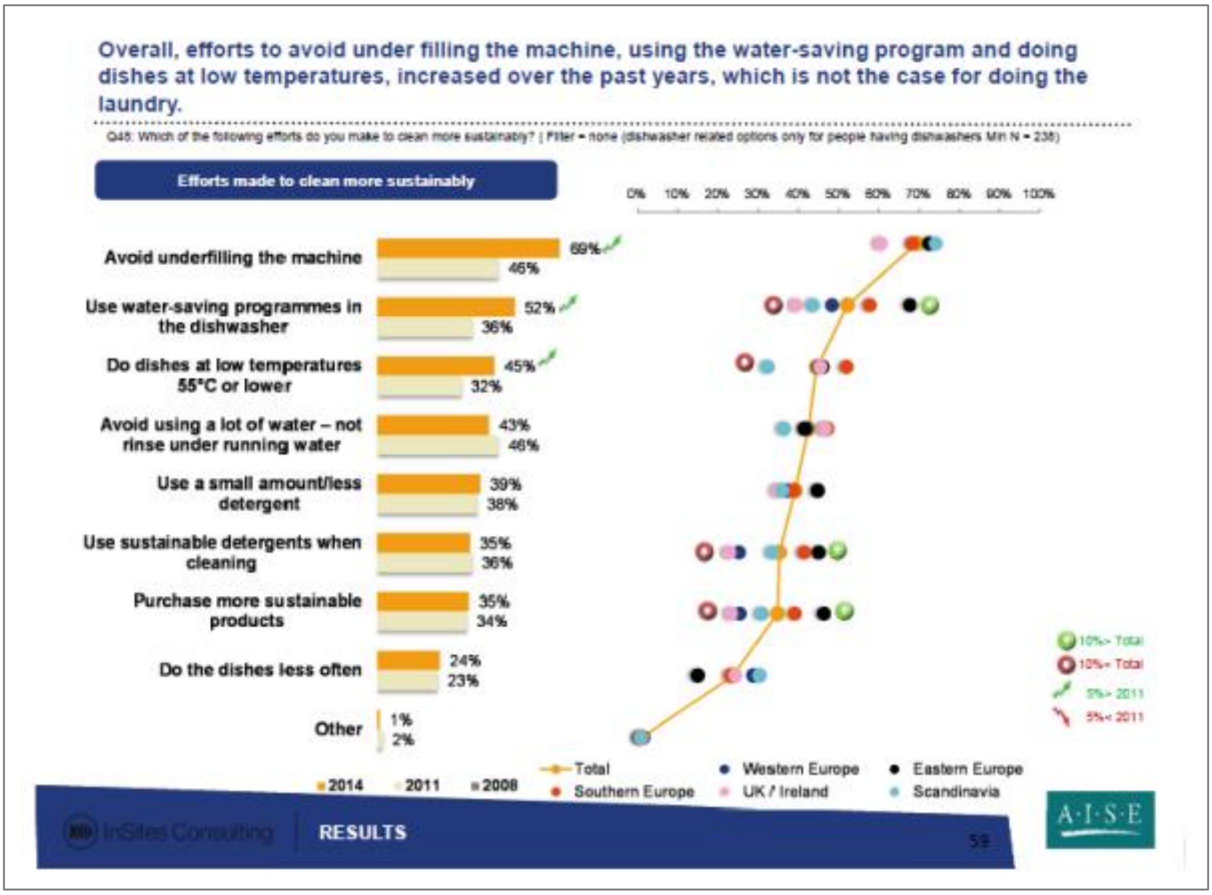


Figure 3.13: Efforts made to clean more sustainable; provided in JRC IPTS (2015b)

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 3.14). 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 n.d.)

Figure 3.14: **IFHE-poster on best practices in automatic dishwashing (IFHE n.d.)**

3.2. Results of the 2015 consumer study on dishwashing

3.2.1. Introduction and methodology

The semi-representative (as only a part of all consumers is surveyed according to the described rules) EU online survey was conducted by the University of Bonn in April–May 2015. The aim of the survey was to assess the dishwashing behaviour of more than 5 000 households in 11 European countries (Czech Republic, Finland, France, Germany, Hungary, Italy, Poland, Romania, Spain, Sweden and the United Kingdom) and obtain information about the wishes and level of consumers' awareness regarding the energy label. These results support standardisation activities and the revision of ecodesign and energy label requirements for household dishwashers.

A professional market research company Toluna, located in Frankfurt (am Main), Germany, was responsible for translating the questionnaires into different languages, recruiting participants from the panel of registered consumers and fulfilling the quotas for each country.

Households were selected following predefined criteria:

- Selected age groups:
  - 20–39 years
  - 40–59 years
  - 60–74 years
- Household size: 1, 2, 3, 4 and > 4 people
- Involvement in dishwashing: substantial
- Distribution of gender: more than 50% female.
  - DW equipped with heat pump. These labelling requirements should be covered by the amended F-Gas Regulation 517/2014.

Furthermore, Eurostat data were used to calculate the distribution of the population in the particular age classes and household sizes in each country. This was then, truly reflected in the selection of the participants for each country panel.

The participants were asked about their automatic and manual dishwashing behaviour, their opinion regarding energy saving issues and their awareness of information reported on the energy label of dishwashers and user manuals. Demographic data were also recorded. Identification and exclusion of outliers has been done as described in Annex 8.1.3. This Annex also includes additional information about how the responses on the survey were handled and interpreted.

3.2.2. Weighting of average values

Weighting according to the number of households of each country compared to the sum of all countries investigated was implemented for calculating EU average results.

Table 3.9 illustrates the contribution of the European countries in the survey. The EU averages represent 82% of all households in EU-28.

Table 3.9 Contribution of European countries in the survey

Country	Panel	Valid data*	Households**	Contribution to total results (in %)
Czech Republic	300	292	4 502 431	3%
Finland	300	290	2 579 781	1%
France	600	582	27 106 517	16%
Germany	600	585	40 656 000	23%
Hungary	300	285	4 105 708	2%
Italy	600	581	2 500 700	14%
Poland	600	570	13 567 999	8%
Romania	300	293	7 470 429	4%
Spain	950	914	18 083 690	10%
Sweden	300	296	4 725 279	3%
United Kingdom	600	589	26 414 000	15%
All households in the sample	5450	5277	174 218 834	100%
Total number of households in EU-28			213 656 847	

* The selection criteria were modified after the first stakeholders meeting held in Seville on 23 June. Therefore, small differences in the data are explained.

** Source: UNECE Statistical Database, compiled from national official sources.

3.2.3. Results

3.2.3.1. Penetration of dishwashers

In the beginning of the survey, participants are asked whether there is an automatic dishwasher in their household. Those who do not have a dishwasher in their household are forwarded to the part of the questionnaire that deals only with manual dishwashing behaviour. It was necessary to recruit Spanish households without a dishwasher additionally, because of misunderstanding translations. Therefore, the results for the ownership rate of Spanish households have been disregarded. For the remaining countries the ownership of dishwashers that has been found in the survey is somewhat higher compared to the rate that has been published by Euromonitor in 2013 (Figure 3.15). Deviations can be explained by the contribution of the survey panel, which only includes people between 20 and 75 years and who have internet access, while Euromonitor takes all households into consideration for their calculations.

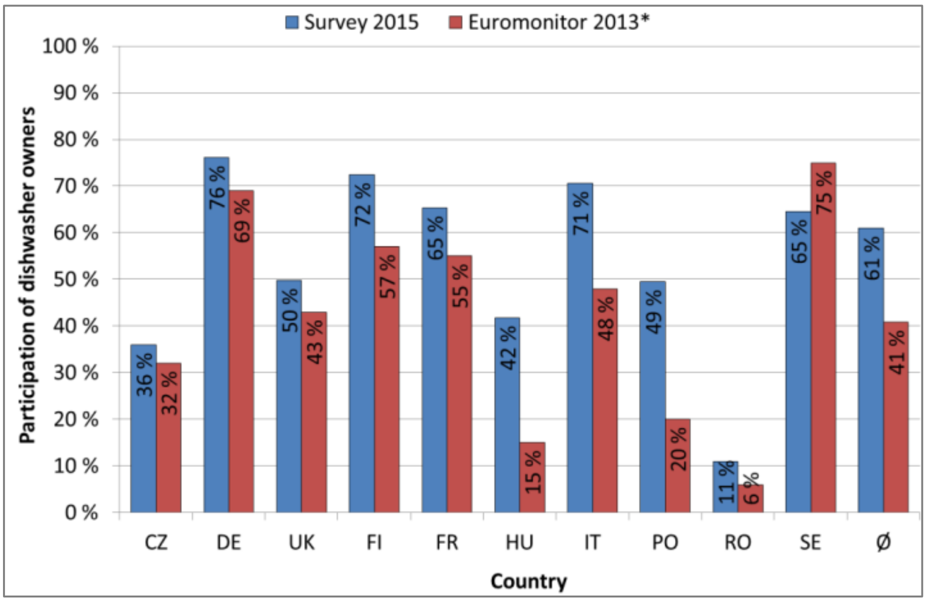


Figure 3.15: Ownership of dishwashers (n = 5277); source: JRC IPTS (2014)

On average, 61% of all households participating own a dishwasher. There is a significant relationship between the household size and the possession of a dishwasher (see Annex 8.1.3). The penetration rate of dishwashers is clearly higher in households with four people (71%) and more than four people (69%), and clearly lower in single-person households with an average of 41% (Figure 3.16).

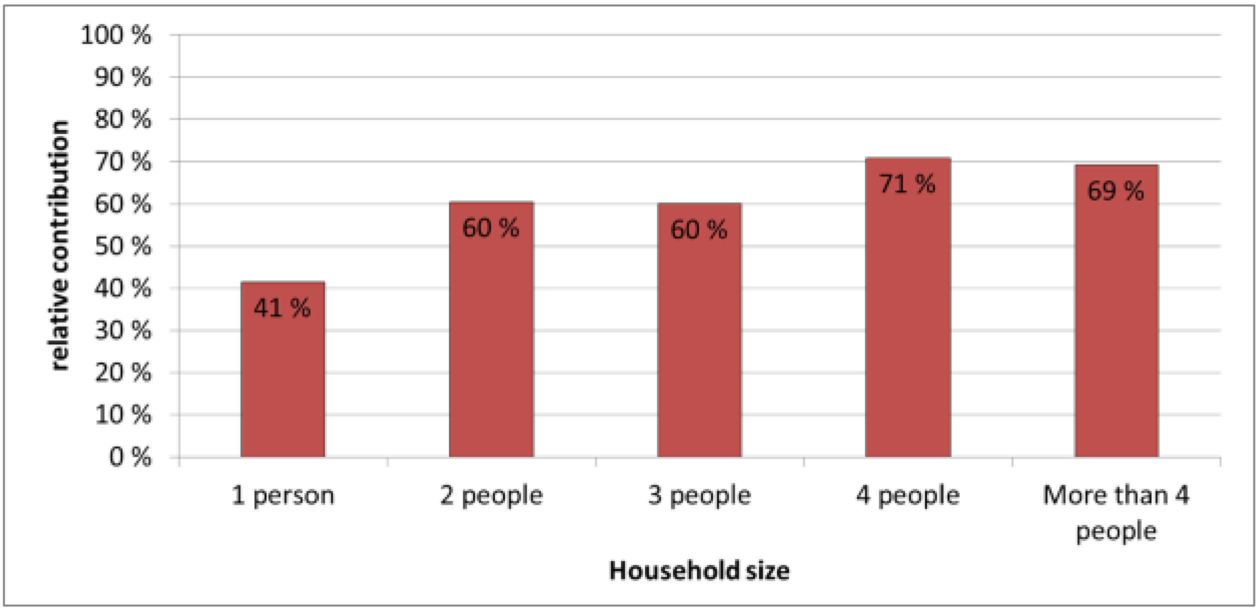


Figure 3.16: Ownership of dishwashers based on household size (weighted n = 3216)

3.2.3.2. Important features of a dishwasher

The participants of the survey were asked for the main features that are taken into consideration when buying a new dishwasher. Nineteen features were given; firstly, six of them should be chosen as the most important ones and, secondly, they should be arranged according to the priorities of the participant. Features that were not chosen, i.e. 13 out of 19 features, received 0 points while the others got 1 to 6 points.

The feature "*low energy and water consumption and associated bills*" is the most important one for the participants of the survey when choosing their future dishwasher. "*Good cleaning performance*" and the " *purchase price*" are the second and third most important features, respectively, followed by a "*long lifetime*", "*low noise emissions*" and "*simple and easy to use*" (Figure 3.17).

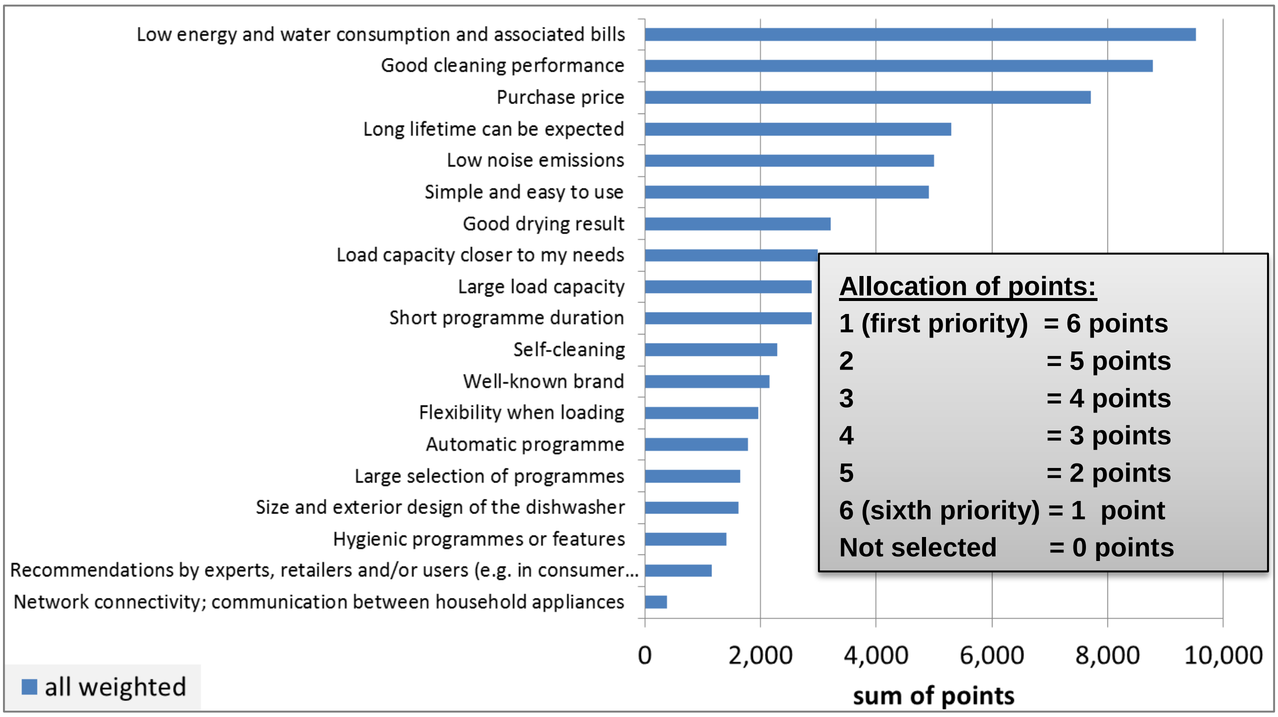


Figure 3.17: Important features for consumers when buying a new dishwasher; 1 [most important] to 6 [least important]) (n = 5277)

3.2.3.3. Types and sources of information supporting purchase decisions

Different sources of information are consulted by the consumers before purchasing a new dishwasher. The most important sources of information are websites of manufacturers (46%) and online product ratings (46%). 34% of the consumers trust the advice of a sales-person in a shop and 30% consider recommendations from relatives, family, friends or neighbours. The product fiche is consulted by 35% of the consumers and the label on the machine by 20% (Figure 3.18). The relative low relevance of the energy label and related data may be explained by asking specifically to the information 'before purchasing'. Furthermore a misunderstanding of the terms 'fiche' and 'label' may have led to the low relevance of the label and higher relevance of the fiche.

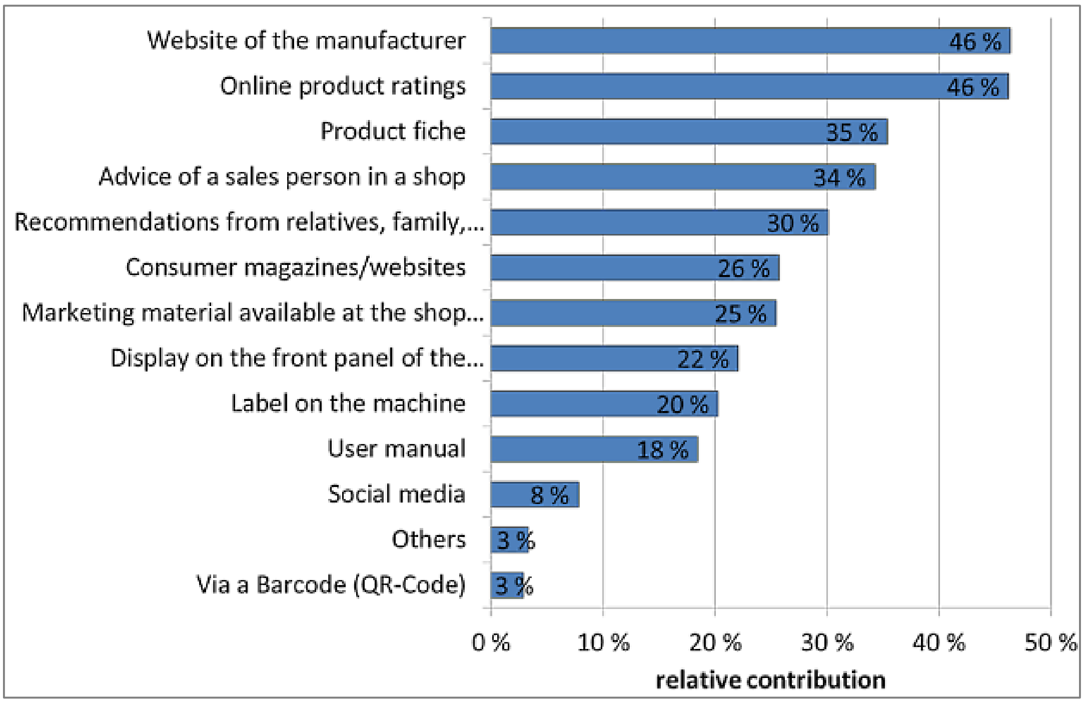


Figure 3.18: **Sources of information before purchasing a dishwasher "Where do you look for information before purchasing a new dishwasher?" (Multiple choice) (weighted n = 3216)**

3.2.3.4. Manual treatment of dishware in households with dishwashers

Although there is an automatic dishwasher in the household, certain items are washed by hand. After summing up all items per day on average over all households (with a dishwasher) 37.1 items are used per day per average household and have to be cleaned afterwards: of these items, 5.0 items are cleaned manually. Generally more than 40% of all pots and pans and 21% of all bowls are in average washed by hand. Even plates, cups, glasses and items of cutlery are washed by hand in households owning a dish-washer (Figure 3.19).

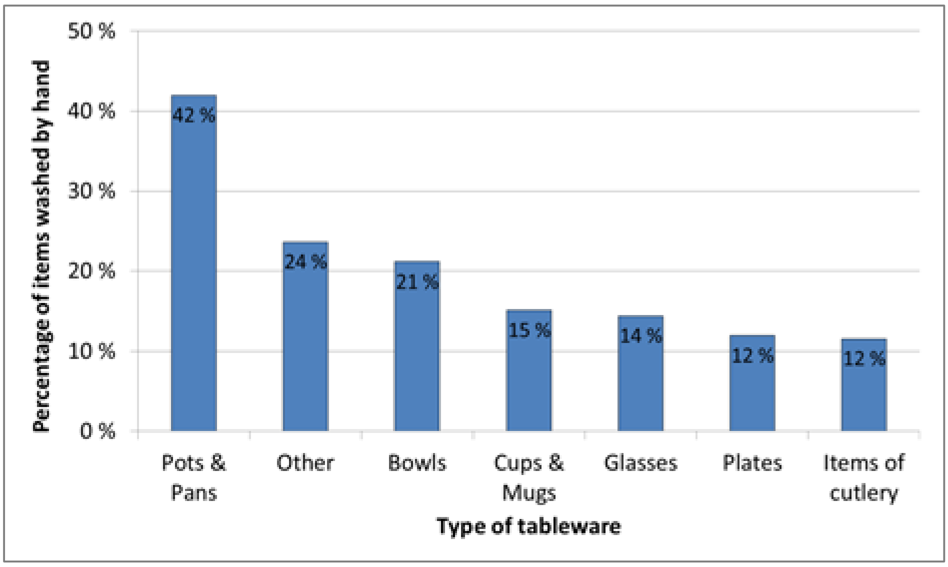


Figure 3.19: **Percentage of items washed by hand (weighted n = 3216)**

Items which are cleaned in the dishwasher are pre-treated in most of the households (Figure 3.20). Only 19% of households indicate that their dishes are not pre-treated at all. The majority of the participants scrape or wipe off left-over pieces of food before washing the items. Each item is pre-rinsed under the tap in almost a third of all households, 10% wash heavily soiled items by hand and 4% state that they only load items into their dishwasher that get clean without pre-treatment. Another 15% only pre-rinse or soak pots, pans and casseroles.

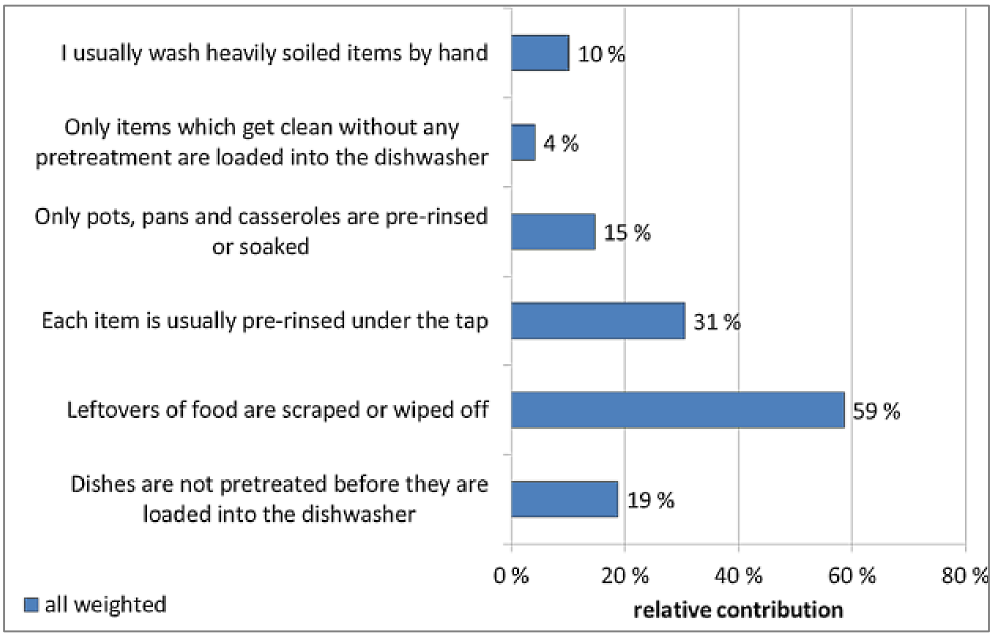


Figure 3.20: Pre-treatment of dishes, multiple choice (weighted n = 3216)

Three aspects were shown as reasons for pre-treating the dishware, being all of them of equal importance (Figure 3.21): Pre-rinse the dishes for preventing bad odour inside the machine (45%), afraidness of not getting clean dishes without pre-rinsing (42%) and concerns that the dishwasher cannot handle the amount of soiling on the dishes (41%)

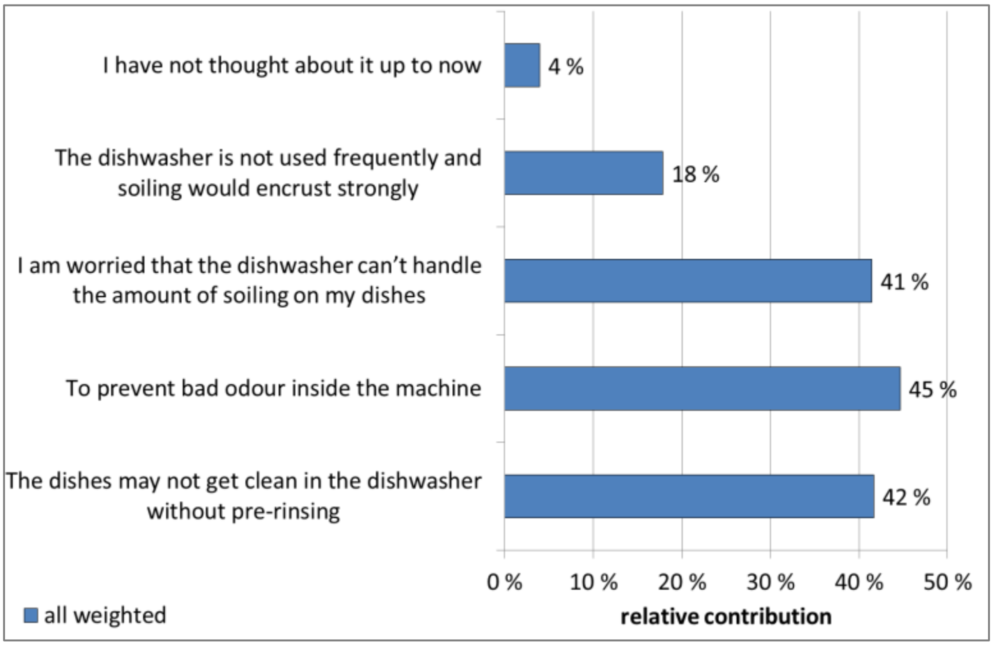


Figure 3.21: Reasons for pre-treating dishware (multiple choice) "You indicated that you usually pre-rinse your dishes. Why do you do this?"

3.2.3.5. Dishwashing frequency and programme choice

An average of 5.1 automatic dishwashing cycles is run per week in all households participating on the survey (Figure 3.22). French and German households are below this average, with only 4.3 and 4.4 cycles per week, while the Hungarian households run their dishwashers 6.9 times per week.

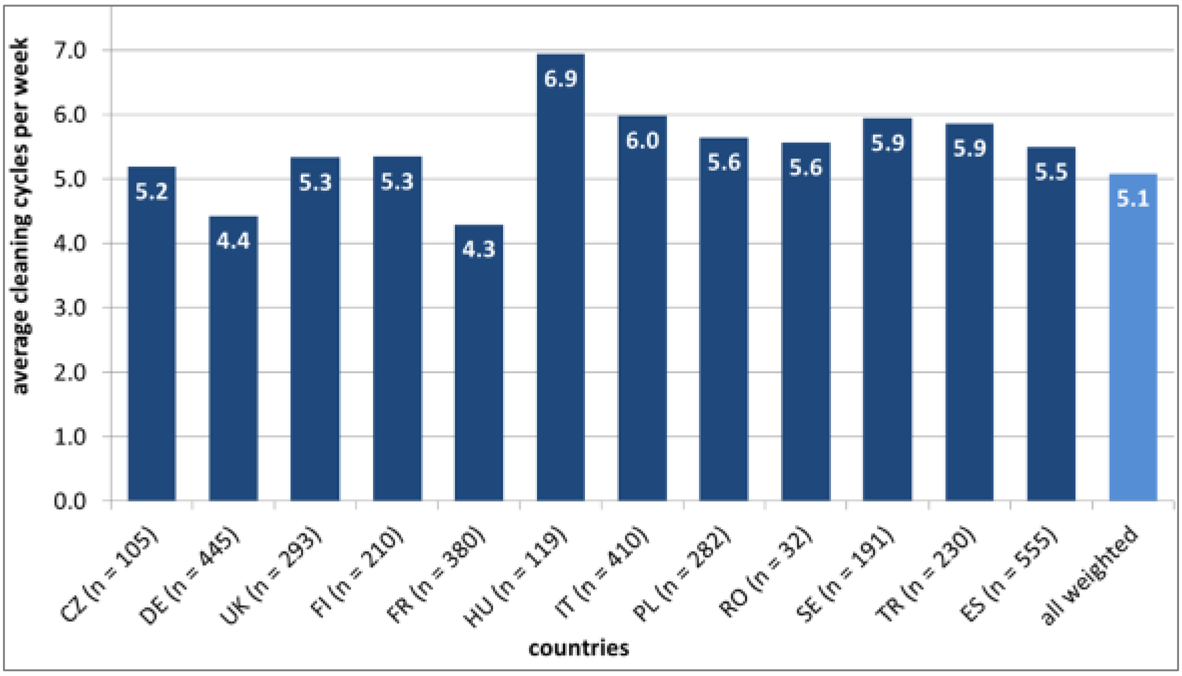


Figure 3.22: Frequency of automatic dishwashing per week (n = 3252)

Regarding the influence of the family size, the data show that the number of dishwashing cycles per week significantly relates to the number of people in the household (see Annex 8.1.3). On average, 2.7 cycles are run per week in a single-person household, while the dishwasher is run 7.2 times per week in households with more than four people (Figure 3.23).

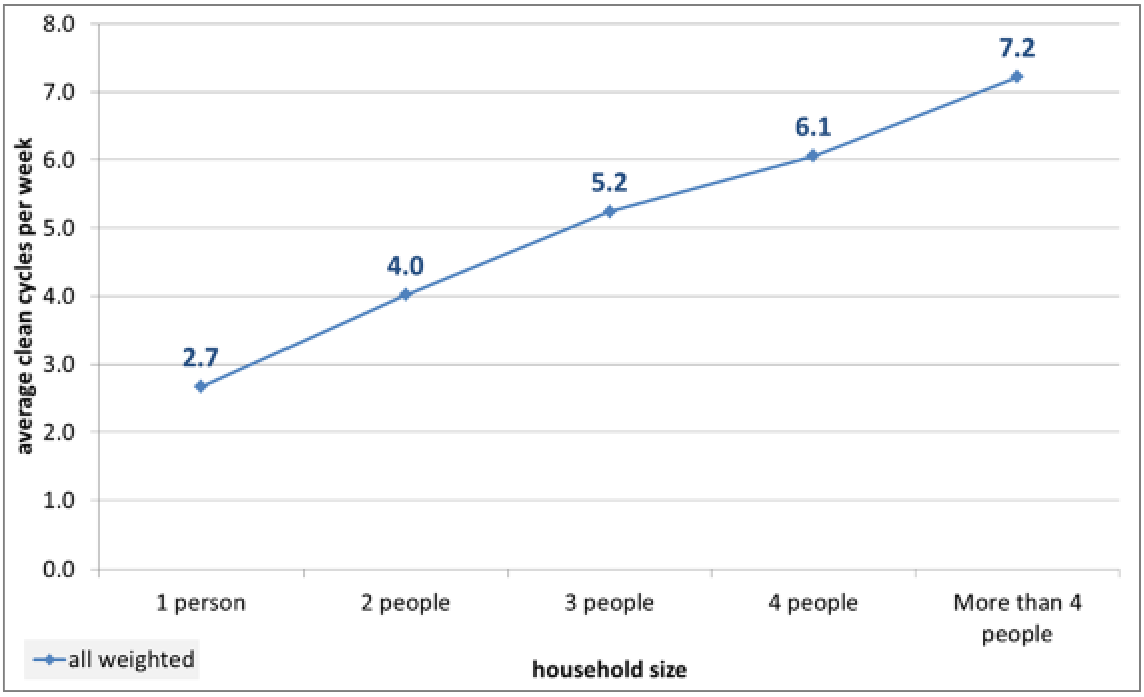


Figure 3.23: Frequency of automatic dishwashing per week based on household size (weighted n = 3216)

According to the results of this survey 39% of all cleaning cycles are run in a normal programme: 22% use a normal programme at 45–55°C and 17% use a normal programme at 60 or 65°C. 19% of all dish-washing cycles are run in Eco or energy-saving programme cycles. The short programme has a contribution of 11%, automatic and intensive programmes have a share of 9% each. The glass and the rinse (and hold) programmes have the lowest relevance and are chosen in only 5% and 7%, respectively, of all cases. The percentages are illustrated in Figure 3.24.

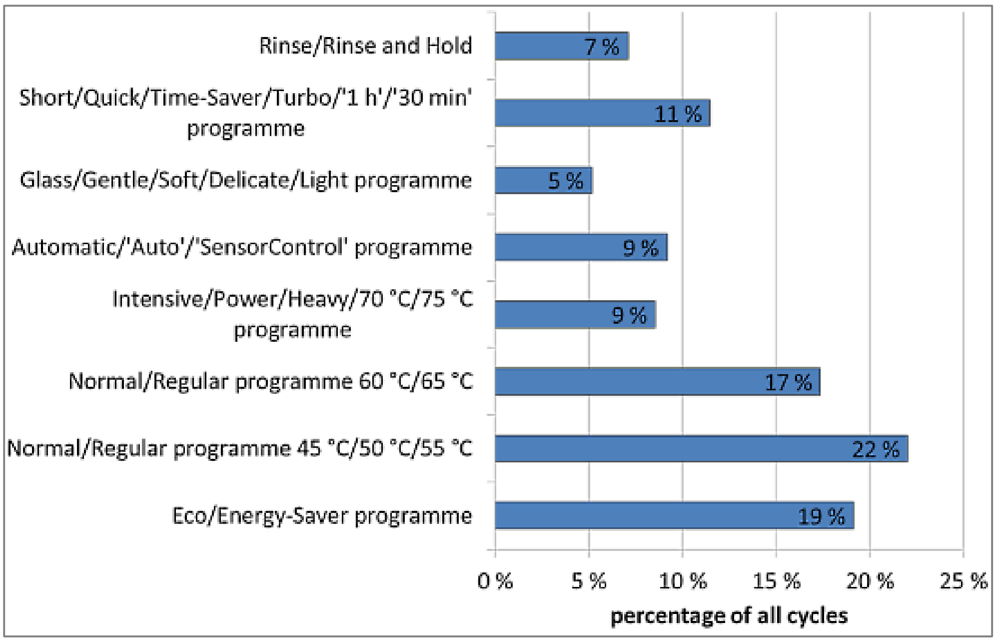


Figure 3.24: **Dishwashing programmes used (percentage of all cleaning cycles) "*Please indicate what kind of programme you use for washing your dishes and how often it is used*." weighted n = 3216**

The programme depends, to a certain extent, on the age of the machine that is available in the household (see Figure 3.25). The percentage of dishwashing cycles with the Eco programme is slightly lower in machines that are older than eight years. There is a significant relationship of the use of the Eco programme and the age of the dishwasher (see Annex 8.1.3). The 'normal/regular' programmes at 45–55°C and at 60–65°C are used more frequently in the machines which are eight or more years old, but not significantly.

A distribution of programme use is applied in section 5.1.1.4 to calculate the energy consumption under real life conditions. A slightly different distribution is used than in Figure 3.24 as the distribution used for the calculation is based on the distribution of programmes observed in dishwashers younger than three years.

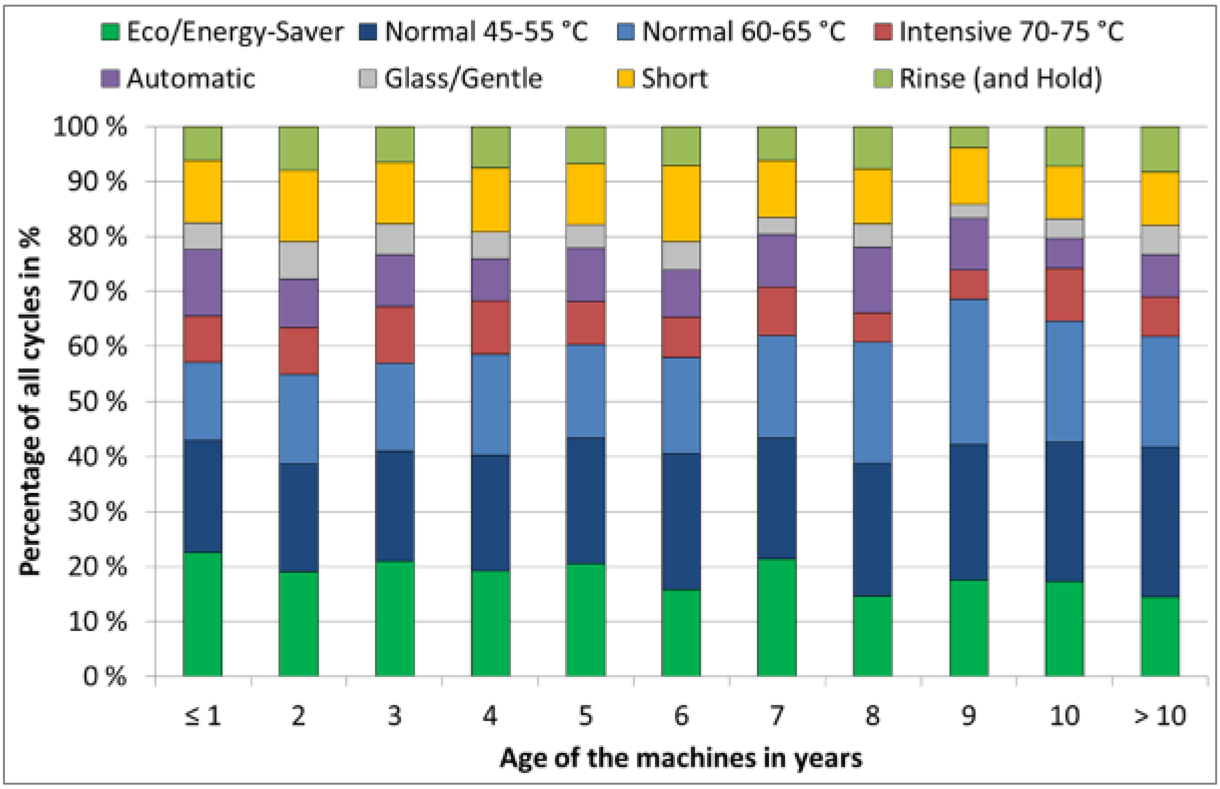


Figure 3.25: **Dishwashing programmes used based on the age of the machine**

Regarding particularly the usage of the Eco programme in households with younger and older machines, the data show that this programme is used more often with younger machines (Figure 3.26). About half of the households with younger machines (0 to 3 years old) use the Eco programme at least once a week., However, in households with older machines, more than 50% percent of the participants do not use it at all and about 30% use it at least once a week. The Eco programme is not used at all in 30% of the households with younger machines (0 to 3 years old).

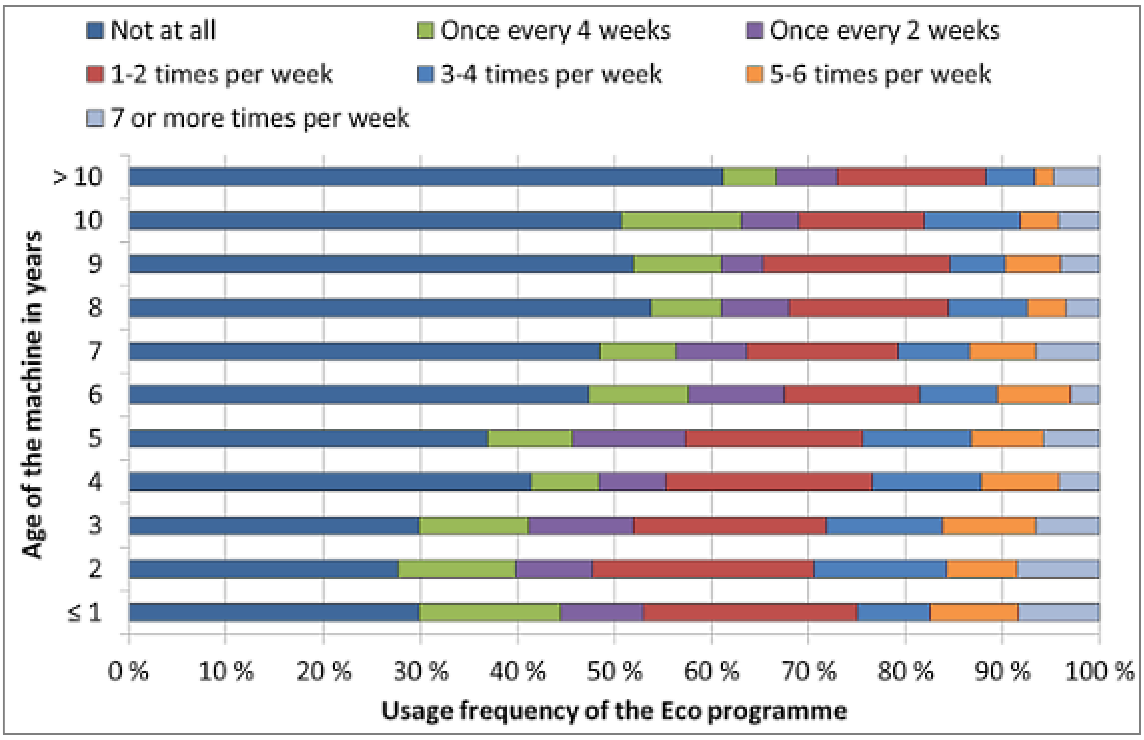


Figure 3.26: **Usage of the Eco programme based on the age the machine**

The reasons for using short programmes were investigated (Figure 3.27). The main reason, chosen by 60% of the consumers was "*to save energy and water*". This answer reveals that most of the people who use short programmes might not know the relationship between energy consumption and duration in dishwashing corresponding to the Sinner circle (see section 4.2.2). In the questionnaire it was not distinguished if the short programme which is chosen by the consumers is a programme for normally soiled dishes or for lightly soiled ones. If people put only lightly soiled dishes in their appliance and then use an appropriate programme for lightly soiled dishes, this indeed usually needs less energy than programmes for normally soiled dishes and thus consumers save energy. In that sense the answer would be correct. If they however choose a short programme for normally soiled dishes thinking it needs less energy because it has a shorter duration, the answer would represent a misunderstanding of the real interdependency of the different factors of the Sinner circle. Unfortunately also on the appliances themselves it is not always clear what the purpose of the short programme is (for lightly soiled dishes and thus with possibly lower energy consumption or for normally soiled dishes and thus with higher energy consumption) making it difficult for the consumer to decide whether he should choose a short or a long programme to save energy, if they know these relationships at all. Additionally, 55% use a short programme because the dishes are slightly dirty. It is not clear if these are the same people that also indicated they would use a short programme to save energy and water. At least there seem to be some overlapping between these two reasons. Only 14% apply the short programme because of its main characteristic and purpose, which is the saving of time.

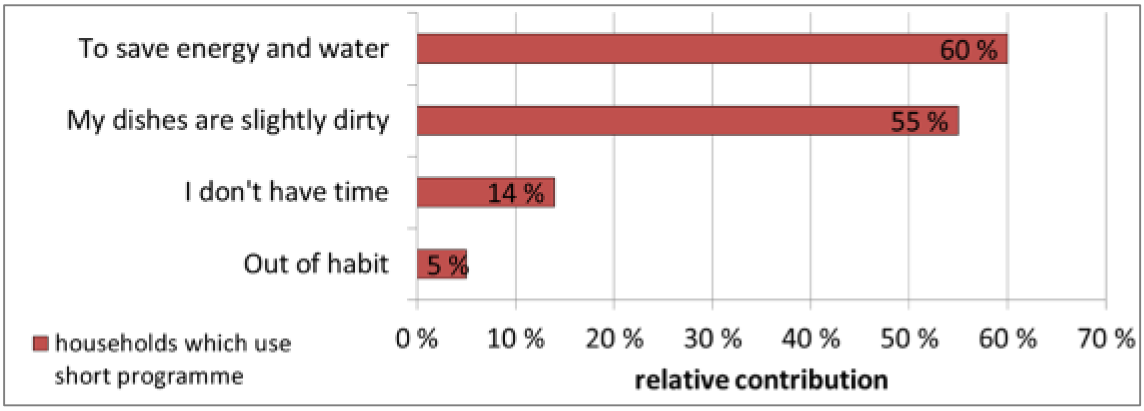


Figure 3.27 **Consumers' motives for using the short programme; multiple choices *("What Figure is your reason for using short programmes?")*, weighted n = 1540**

3.2.3.6. Programme duration

The participants of the survey chose contradictory options concerning programmes with long cycles (Figure 3.28). 34% of them indicated that they have "*no problems with programmes with long cycles*" and 22% even understand "*that long cycle times can be energy efficient*". On the other hand, 28% of the consumers *"do not believe that a programme with a long cycle is energy saving*". 29% of the respondents do not want to run the machine with no-one at home. For a certain percentage of the participants, long cycles are inconvenient as they may disturb people nearby during the day (8%) or night (15%) and also make it impossible to clean all the dishes in the time available (10%).

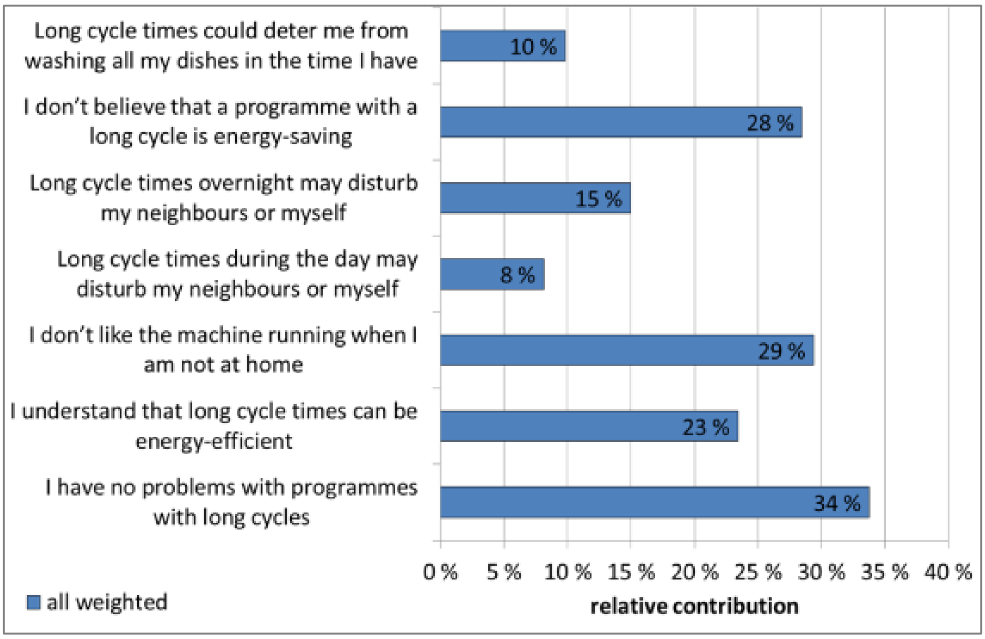


Figure 3.28: **Acceptance of long programme cycles; weighted n = 3216 ("*What is your opinion of cleaning programmes with long cycles?")***

The participants of the survey possessing a dishwasher were introduced to seven activities they could apply to save energy and/or money (Figure 3.29). The most acceptable one for 69% of all households is the use of "*energy-saving programmes offered by the machine*", 28% would take it into consideration and only 3% disapprove the use of energy-saving programmes. Additionally, more than 50% of the households would be willing to "*skip pre-rinsing by hand*" and only 14% refuse to do this. When it comes to long programme cycles, 35% are willing to accept them, 13% refuse to accept them and 52%% of the participants are not confident with long programme cycles.

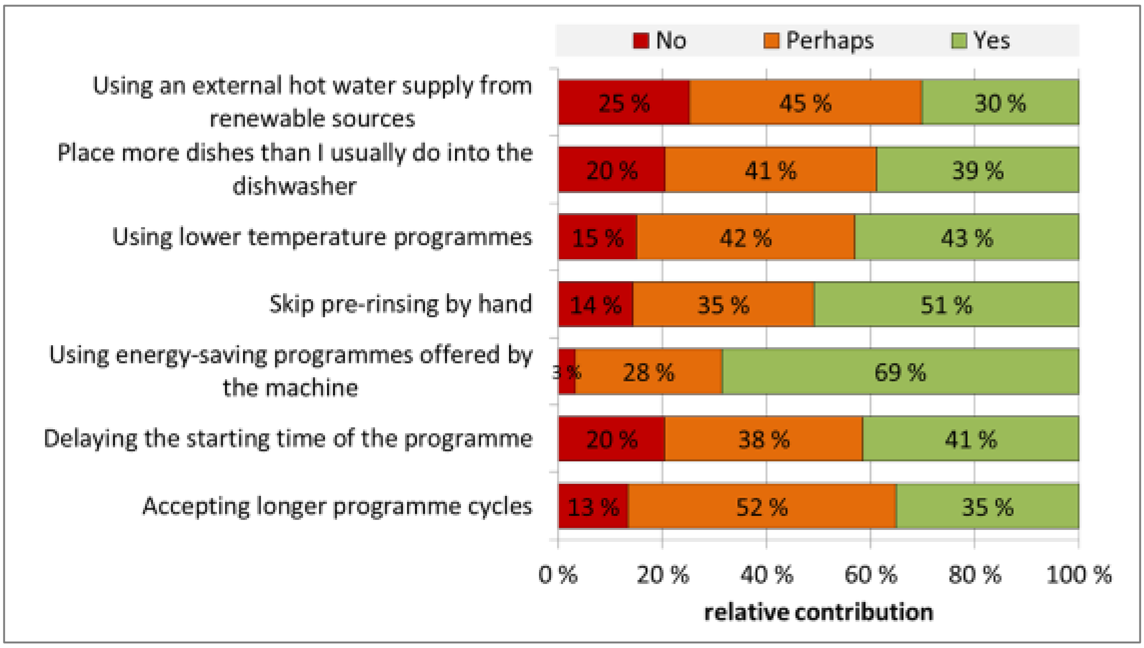


Figure 3.29: **Acceptance of energy-saving activities ("*Which of the following options would you use if doing so would enable you to save energy and/or money?*"); weighted n = 3216**

This is supported by the results concerning the maximum time that is acceptable for a cleaning cycle (Figure 3.30). Almost 70% of all consumers do not accept cycles requiring more than 2 h and 27% accept a maximum duration of 3 h. The acceptance of cycles with 4 h or more during night-time is low, even though it is higher than for programmes running during the day. Less than 20% of the consumers would accept a cycle time of 4 h or more.

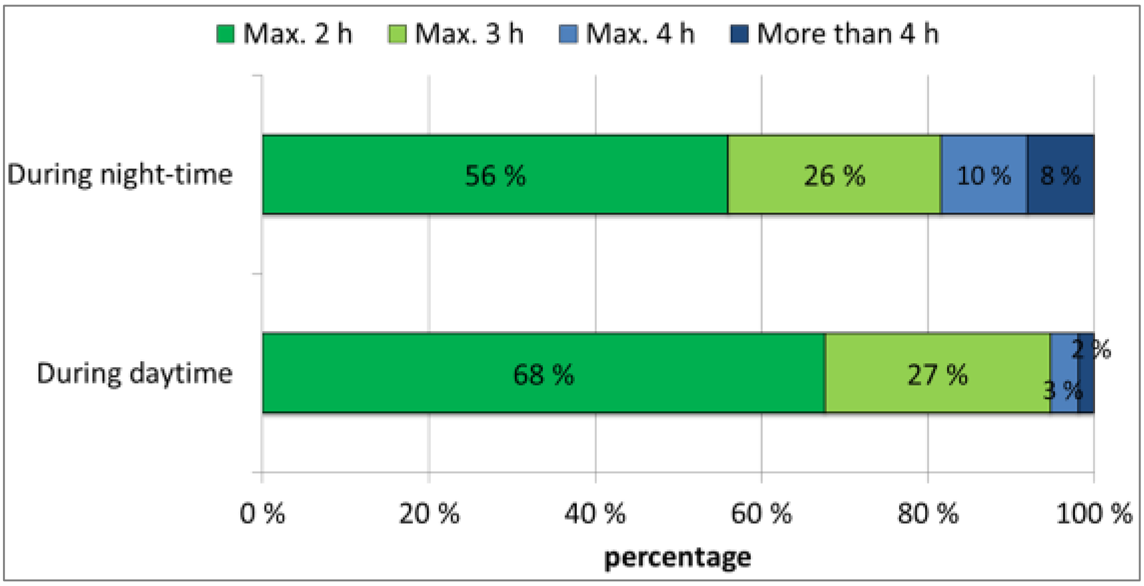


Figure 3.30: Acceptable programme duration for an energy-saving programme, weighted n = 3216 (*"If an energy-saving programme required a longer cleaning time, what is the maximum time you would accept for a cleaning cycle during day and night?"*)

The highest acceptance of longer programme time is found in households with a young machine (Figure 3.31). More than 30% of the participants with machine of 1 year old or less would accept programme time of 3 hours during daytime. During night time, a programme duration of 4 hours is acceptable for 13% and even more than 4 hours for 8% of the participants with young machines (age of 1 year or less). This data shows that the provided eco programmes with long cycle's times are being more and more accepted by the users.

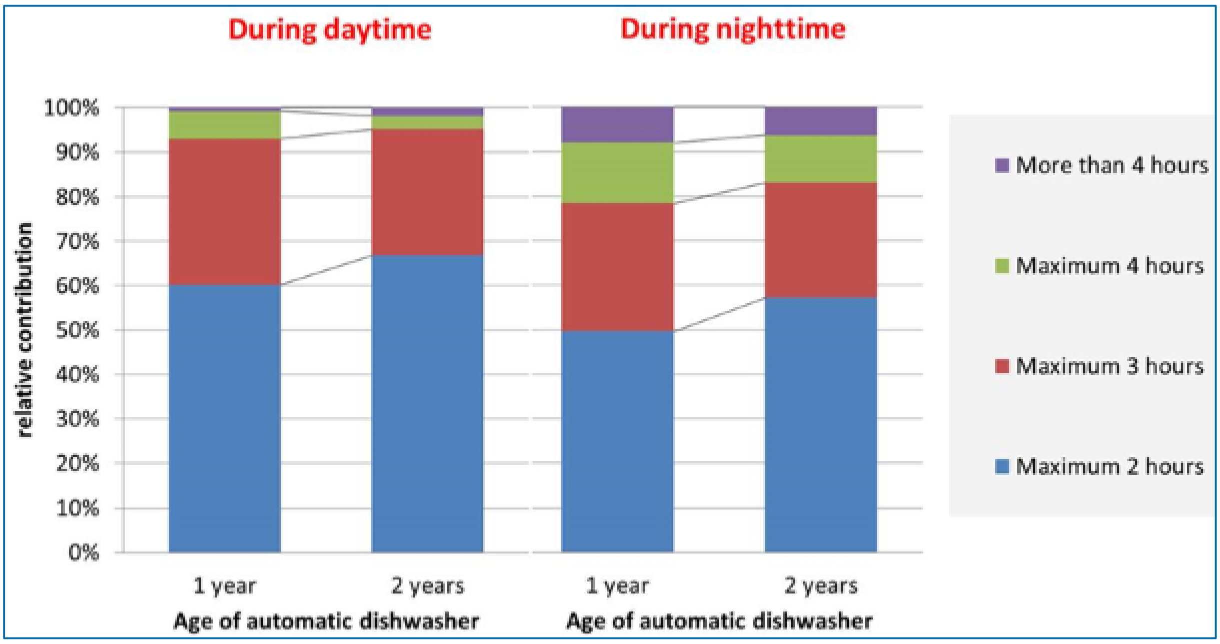


Figure 3.31: Acceptable programme duration for an energy-saving programme of participants owning a new machine (max. 2 years old) (*"If an energy saving programme required a longer cleaning time, what is the maximum time you would accept for a cleaning cycle during day and night?"*)

Participants, who indicated that they would be willing to accept longer programme times to save energy and/or money, tend to accept longer programme times during daytime and night time, than those who are not willing or are indecisive whether to accept longer cycles times. There is a slight association between maximum time participants would accept for a cleaning cycle during day and night and accepting longer programme cycles or not (see Annex 8.1.3).

3.2.3.7. Energy label

The results of the survey (Figure 3.32) reveal that the majority of the consumers owning a dishwasher do not know to which programme the energy efficiency class on the label refers. A total of 65% believe that machines with a high energy efficiency class save energy and water in all of the programmes and 22% believe that only energy is saved in all of the programmes. Only 4% and 9% believe that energy or energy and water, respectively, are saved only in a selected programme.

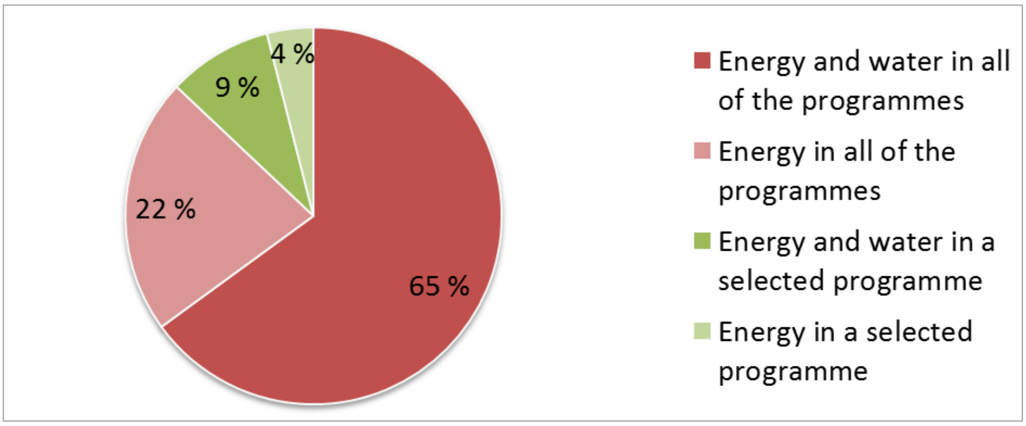


Figure 3.32: Perception of the energy label ("I would expect from a dishwasher with the highest energy efficiency class available in the market that it saves…"); weighted n = 3216

Consumers were asked to tick all the pieces of information that should be indicated on a future energy label (Figure 3.33). The energy-efficiency class is the most important issue that is chosen by 78 % of consumers and 61% want to retain the indication of noise emission on the label. Only 41% and 40 % are interested in energy and water consumption, respectively, per year; 59% and 56% prefer to find values for energy and water consumption per cycle. Cleaning performance is chosen by 54% of the consumers, while the drying efficiency is relevant for only 44%. A total of 53% want to retain the indication of the capacity (in place settings) on the label. Additional aspects that are requested by 47% and 43% of the participants are the duration of the energy-saving programme and the expected lifetime of the machine, respectively.

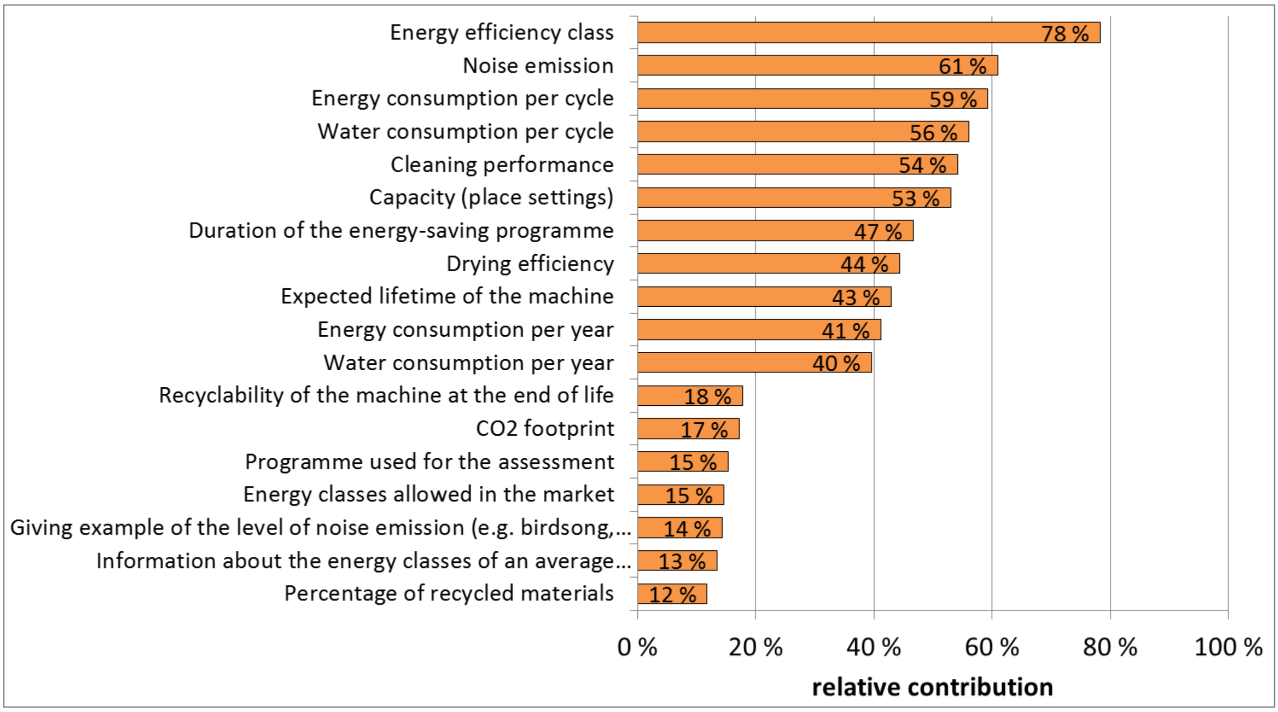


Figure 3.33: **Information on the future energy label ("*In your opinion, which of the following pieces of information is it important to indicate on the future energy label*?"); weighted n = 3216**

3.3. Manual dishwashing compared to automatic dishwashing

Not all of the dishes are washed in a dishwasher for several reasons such as the non-ownership of a dishwasher. Even if the household owns a dishwasher, not all items are cleaned in the dishwasher (between 12 and 42% of the dish items are cleaned by hand (see Figure 3.19). This process consumes a relevant amount of resources, as it was already indicated in the previous preparatory study (Lot 14) (ISIS 2007e). This section reports the new data that have been gathered since, the findings of Lot 14.

Richter (2010b) has investigated the dishwashing resource consumption of 200 households in four European countries (Germany, UK, Italy and Sweden) by direct observation in these households for two weeks. In 82 of those households measurement equipment was installed for detailed recording of the resource consumption for manual and automatic dishwashing. The analysis reveals that households owning a dishwasher consume on average only about half of the water and 28% less energy per item washed up compared to households without a dishwasher (Figure 3.34). This result is even more important when taking into account that in at least two of the countries (IT and SE) many items were still washed by hand and manual pre-rinsing was frequently done even when a dishwasher was present.

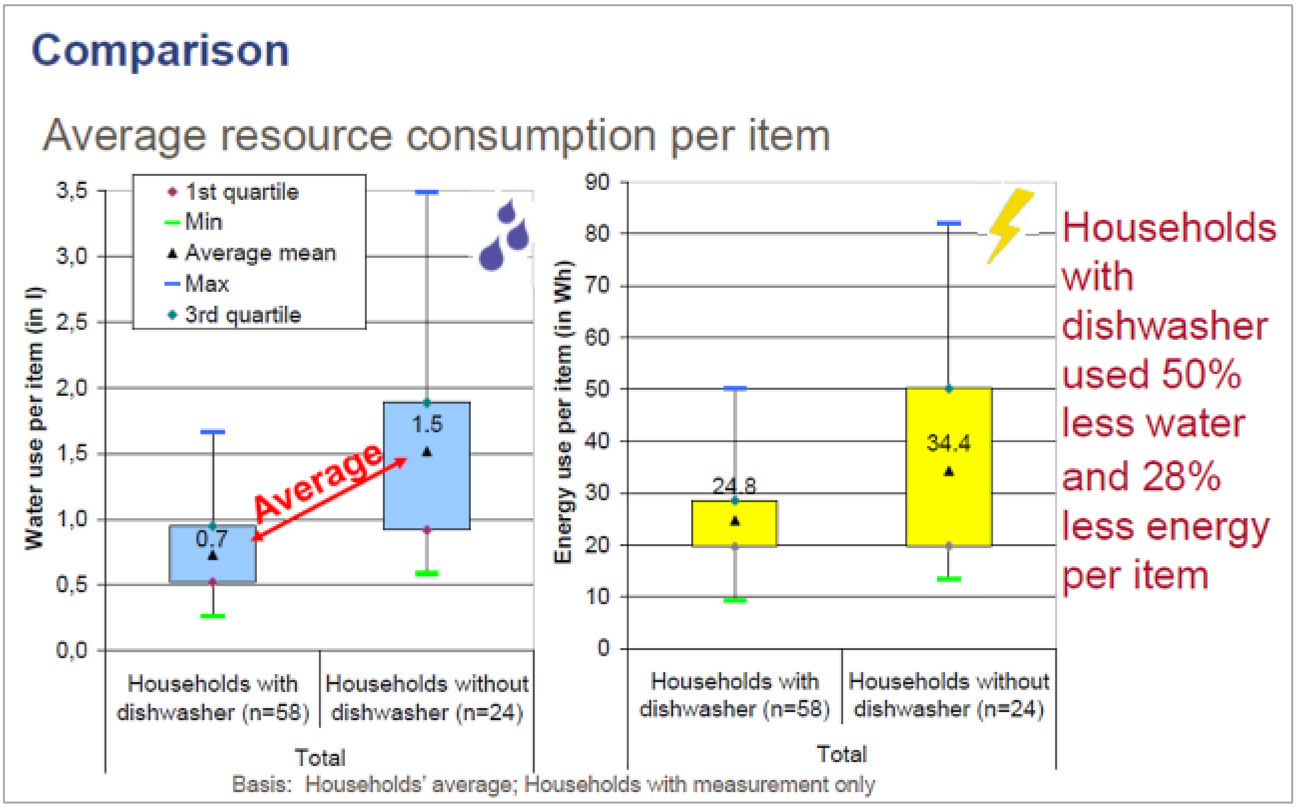


Figure 3.34: **Summary of results comparing energy and water consumption of households with and without dishwasher per item cleaned in a two weeks observation period (data from Richter (2010b))**

According to these results it can be concluded that a high dishwasher penetration leads to an overall reduction in energy and water needed for dishwashing. CECED therefore calculated with the mentioned consumption values per item how much energy could be saved when the dishwasher penetration rate in Europe would be increased from currently 40% to 60% (i.e. by 20%). More detailed calculations can be found in Annex 8.1.2.

From CECED's calculations, the savings sum up to 36-38 TWh per year. These savings results from the lower energy and water consumption when the same amount of dishes is cleaned with a household dish-washer instead of manually. The energy consumption of prewashing items before putting them in the dishwasher is considered in these savings. What is not considered is the fact that, the number of items might increase when a household owns a dishwasher. This would reduce the saving potential.

3.4. End-of-life behaviour

3.4.1. Product use & stock life

Whereas this section describes the *consumer behaviour* with regard to the duration of the product use, in section 4.4.6 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. 2016). 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 4.4.6).

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. 2016).

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%).

3.4.2. 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 machine with a new model instead of repairing it (RReuse 2013):

<u>Lack of access and cost of spare parts and repairs:</u>

- 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 dif-

ficult 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 for 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 related to cleaning and drying performance where the testing for problems is time consuming.

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 (ISIS 2007c) used the following generic input data for the category "Maintenance, repairs, service" of dishwasher models in 2007:

Table 3.10: Average input data for maintenance, repairs and service of dishwasher models used by Lot 14 in 2007; source: 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 2015b), 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, cleaning the drain filter 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 that 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.

Another stakeholder provides results of a study from 2006 analysing what usually breaks in dishwashers (cf. also section 4.4.6). The 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 why about one third of the respondents repair their machines themselves is possibly due to the fact 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.

3.4.3. 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. 2012 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 3.11: Disposal channels for large household appliances used by consumers in Italy in 2012; source: Magalani et al. 2012

	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 2015b), about two-thirds of e-waste is managed by commercial actors without the involvement of producer responsibility schemes.

3.4.4. 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 of 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% is 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).

4. Task 4: Technologies

4.1. Local infrastructure

4.1.1. Energy

Around 70% to 90% of the electric energy supply in dishwashers is used for heating the water, the dishes and the machine. However this heat can also be supplied by other sources apart from electricity. Technical options such as heating by a hot water circulation loop ("heat-fed machines") or hot fill are among those options. (See section 4.2.44.3)

4.1.1.1. 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 cause higher energy consumption in the final rinse.

A better option for dishwashers is to be connected only to a hot water supply. Today, most 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 or renewable water heating sources), this can result in reduced energy consumption and lower greenhouse gas (GHG) emissions.

The hot water supply option is expected to achieve higher market shares in the near future as the installation of renewable energy technologies in the residential sector is supported by the Art.13 (4) of Directive 2009/28/EC on the promotion of the use of energy from renewable sources (European Parliament 2009b). 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. See also technical description in section 4.3.4.

4.1.1.2. Demand-response enabled appliances

As the energy system of the future is getting more and more variable due to fluctuating energy generation from renewable energy sources such as wind power 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, before launching such an energy system a sufficiently large number of appliances need to be on the market. It might therefore be 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. See also description provided in section 4.3.9.

4.1.2. 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 4.3.11.

With regard to infrastructure and system aspects, the following measures of reduced or sustainable use of water are to be mentioned.

4.1.2.1. Changing use patterns

Avoiding manual pre-rinsing of dishes would be the most relevant option to reduce the overall water consumption connected to dishwashing (cf. section 3.1.5).

4.1.2.2. Use of greywater and rainwater

Use of domestic greywater and rainwater can play a role in water efficiency. A rainwater harvesting system can be attached to a tank where the water is stored until needed and by using a pump the water can then be recycled through the water supply for dishwashers. This has additional advantages as rainwater is soft water and therefore causes no lime scale which can often cause problems with filters and elements in such appliances (Claridge 2015). Soft water would also require less or no water softener and therefore no regeneration of the interchange column (water softener).

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 [n.d.]).

4.1.3. 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 washing machines with special smart features (Griffin 2015). It is highly expected that this technology will be applied to dishwashers as well. Other companies such as Miele, BSH and Electrolux announced similar technologies at the international trade fair “IFA” in September 2015.

According to (European Commission 2013c), increased frequency of internet usage, coupled with faster speeds and the growth of mobile access are accelerating recent trends in internet use and induce new and different behaviour patterns by users. In general, the increasing trend to internet via mobile access such as smartphone, tablet, etc. might also drive the trend towards connected household appliances in future.

4.2. Technical product description

4.2.1. Basic product types

According to the definition given by Regulation (EC) No. 1059/2010 (European Commission 2010a) and Regulation (EC) No. 1016/2010 (European Commission 2010b), 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).

Figure 4.2 shows the basic construction principle of a household dishwasher. Dishwashers have a front door to open the cabinet and two or three drawers to put in the crockery. The water is circulated by a circulation, pump that pumps the water into the spray arms, which are rotating due to the pressure by the escaping water. The hydraulic system can be described as the circulation of the water from the sump through the circulation pump, the spray arms over the crockery and then through a filter system back to the sump. During certain phases of the dishwashing programme, e.g. at the end of the programme, the water is drained via the drain pump.

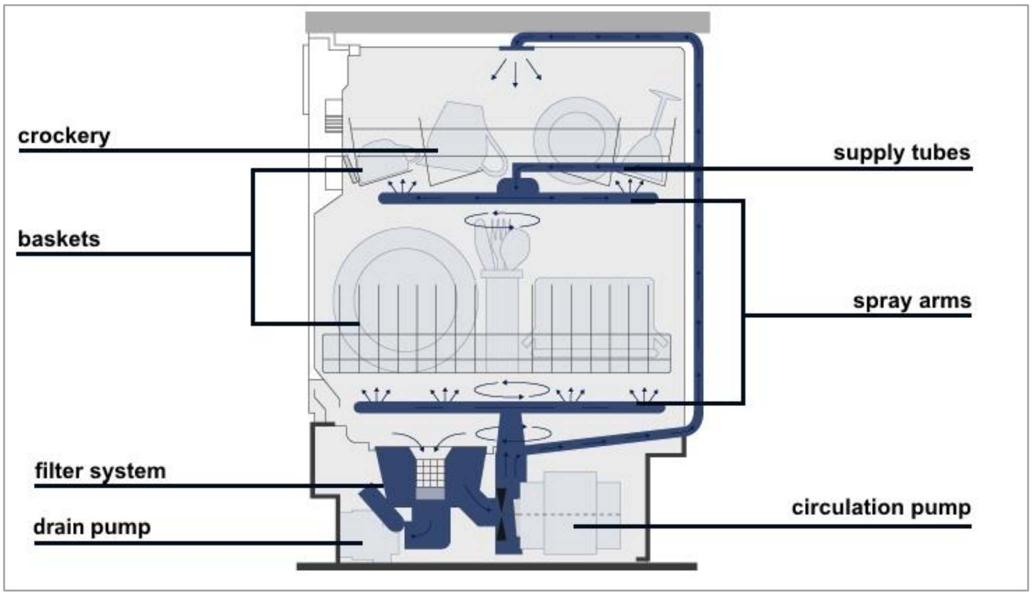


Figure 4.1: Basic construction principle of a household dishwasher (BSH, personal communication)

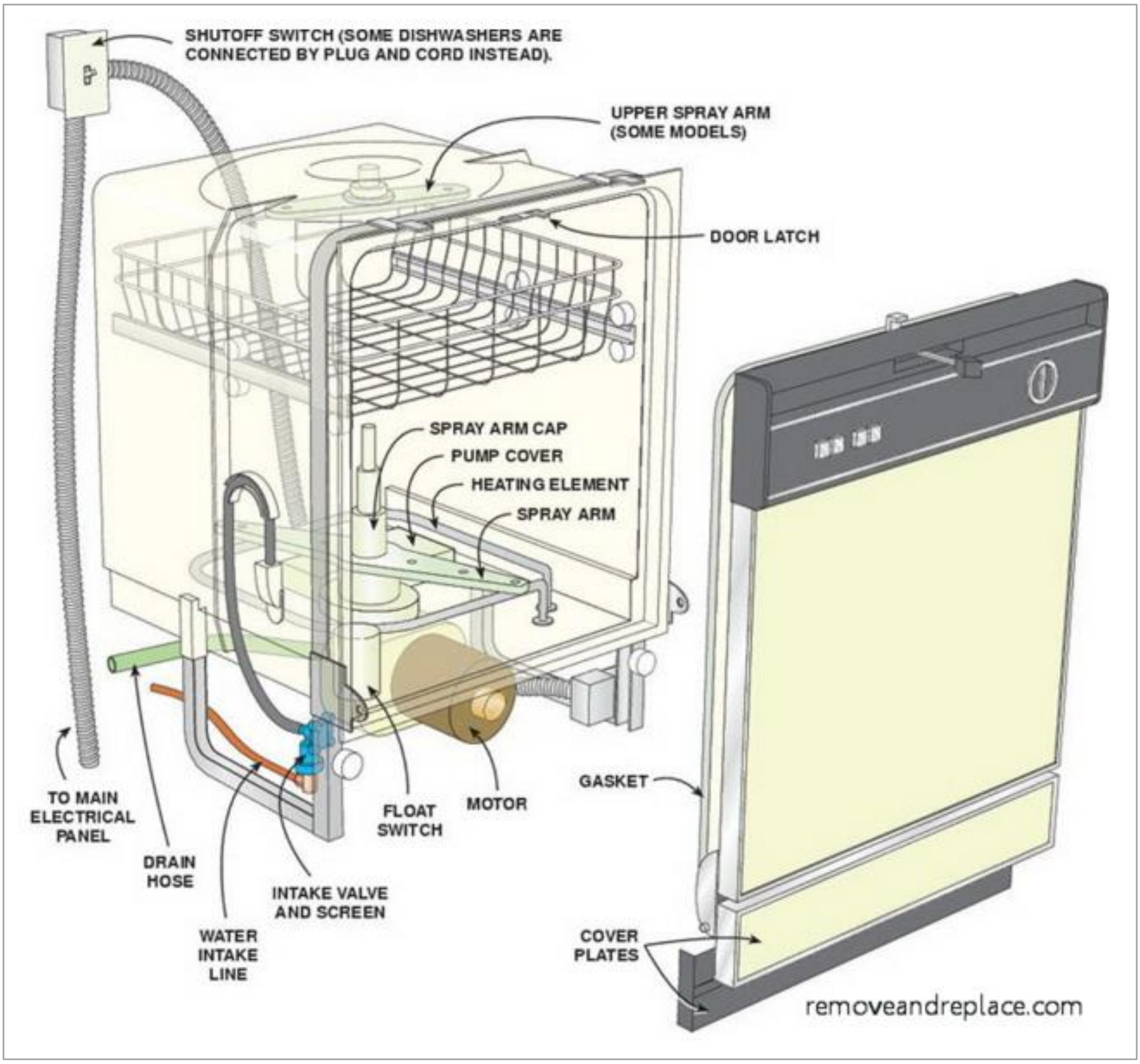


Figure 4.2: Basic construction principle of a household dishwasher (Remove and Replace 2013)

4.2.1.1. 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 or stand-alone 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 counter-top 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.

4.2.1.2. 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. section 2.2.3.2.

- 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. A special product offered by one manufacturer is a full size dishwasher with two separate drawers instead of one door (Fisher & Paykel 2016). This product is, for the time being, not available on the European market and only offered on the Australian market.
- Slim line dishwashers have a standard width of approximately 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.

4.2.2. Sinner Circle

According to the 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 when maintaining the same cleaning efficiency. In comparison to hand dishwashing, in an automatic dishwasher all factors are of similar importance (Figure 4.3). For hand dishwashing, mechanics is by far the most important factor. 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 automatic 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) (cf. also section 3.3).

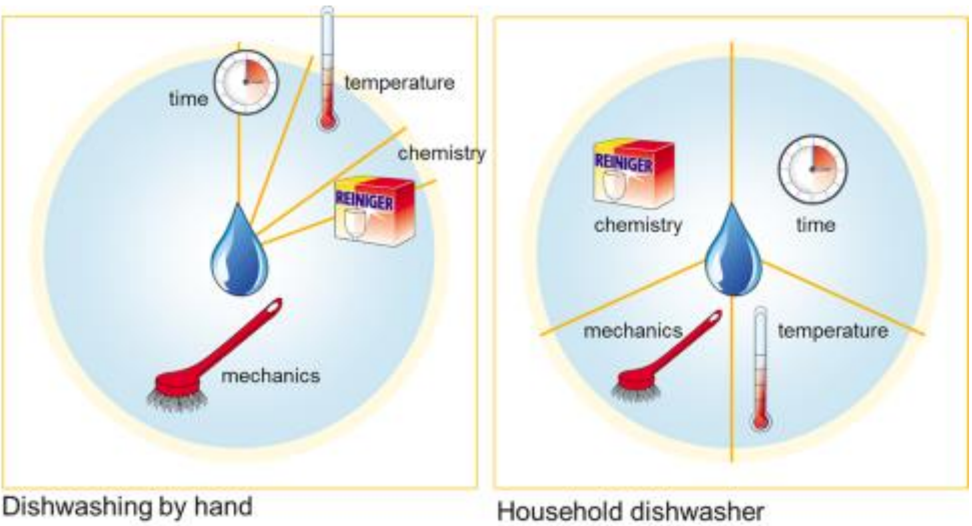


Figure 4.3: Cleaning factors comparing dishwashing by hand and in a household dishwasher source adapted from Miele (2015)

4.2.3. 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 the different phases, the reached temperatures and the water pressure. In some programme types some phases are missing. The following figure gives an overview of a typical temperature profile of a dishwashing cycle (example programme: “normal 55°C”).

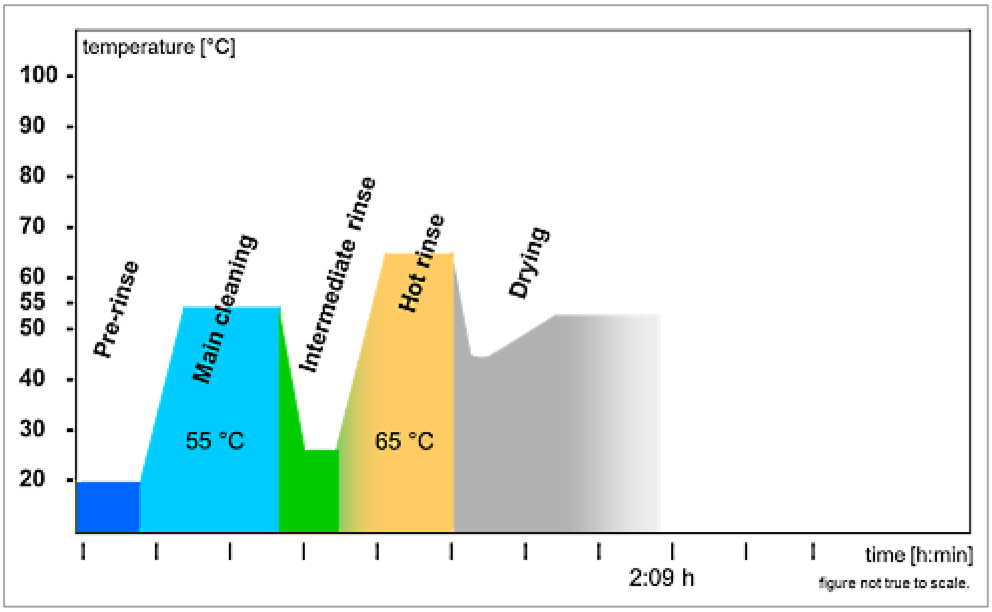


Figure 4.4: Typical temperature profile of a dishwashing programme (example: “normal 55°C”); adapted from Miele (2015)

4.2.4. Best Available Technologies (BAT) (best products on the market)

According to TIG (2015), Topten shows the availability of high efficiency dishwashers, the BAT. This information is regularly updated. All dishwashers currently listed as BAT 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 (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

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 4.5 provides an overview of the EEI of the basic dishwasher models presented on www.topten.eu in June 2014.

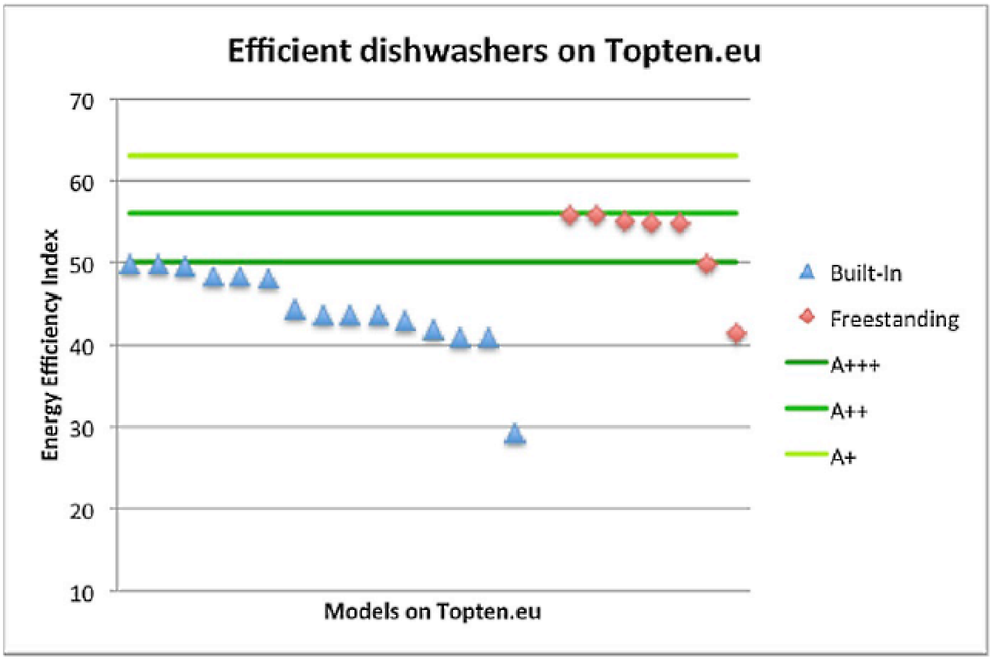


Figure 4.5: Energy efficiency Indices (EEI) of dishwasher models presented on www.topten.eu in June 2014; (TIG 2015)

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 in Table 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 (Eco programme) (kWh/cycle)	0.49 – 0.84
Energy consumption (Eco programme) (kWh/year), based on 280 cycles per year	137 – 237

	Benchmarks: Range of BAT-dishwasher models listed on www.topten.eu
Water consumption (Eco programme) (litres/cycle)	6.0 – 10.0
Water consumption (Eco programme) (litres/year); based on 280 cycles per year	1 680 – 2 800
Noise emissions (dB(A))	40 – 45

4.3. Technology Areas

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 1995), the preparatory study on domestic dishwashers and washing machines (in the following: “Lot 14”) of 2007 (ISIS 2007d) and new information based on the internet, stakeholder feedback and scientific publications. The presented technologies will serve as basis for Task 6.

Table 4.3 provides an overview of the technology areas for household dishwashers that are going to be described in more detail in the following sections.

Table 4.3: Overview of technology areas for household dishwashers

Technology areas	Specific technologies
Technology Area 1: Reduction of thermal losses	• Weight reduction of heated parts • Improved insulation of the appliance • Heat exchanger (water buffering tank) • Cross flow heat exchanger (with storage tank)
Technology Area 2: Improved drying systems	• (Water tank) condenser for drying • Automatic door opening system • Adsorption drying technologies • Fan for better air circulation • Direct heating of the load
Technology Area 3: Time-temperature trade off	• Moderate increase of programme duration
Technology Area 4: Alternative heating systems	• Heat pump system • Heat-fed machines • Hot fill
Technology Area 5: Motor efficiency	• Brushless inverter driven asynchronous DC motor • Brushless, permanent magnet synchronous DC motor
Technology Area 6: Sensors and automatic controls	• Soil sensors • Load sensors • Automatic detergent dosage
Technology Area 7: Alternative spraying / water systems	• Water wall / PowerClean
Technology Area 8: Consumer feedback mechanisms	• Displaying detergent dosage recommendation • Indication of the energy and water demand of the chosen programme
Technology Area 9: Smart appliances	• Internet connectivity • Electronic update of programmes • Smart grid ready (SG-ready)

Technology areas	Specific technologies
Technology Area 10: Material selection	• Use of recycled plastic • Increased durability of the appliance
Technology Area 11: Reduction of water consumption	• Optimisation of the hydraulic system • Partly draining and re-filling (of water) • Avoidance of certain phases of the programme • Fleet reservoir
Technology Area 12: Others	• Hygiene options: UV radiation • Hygiene options: 60-70°C in rinse phase • Noise level: < 44 dB(A) or < 41 dB(A) • Optimised regeneration of softener • Delay start • Voice controlled appliances

4.3.1. Technology area 1: Reduction of thermal losses

During a dishwashing cycle a part of the energy supplied for heating up the water and the dishes is also used to heat up parts of the appliance. This heat is dissipated by radiation to the environment or by draining the heated water without previously recovering its thermal energy. The exact breakdown of the thermal energy 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 than porcelain or crockery), the differences in 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 (JRC IPTS 2015b), the "1/3-rule" can be used as a first estimation, which means 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.

The following measures can be taken to reduce the thermal losses.

4.3.1.1. 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/peak 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.

4.3.1.2. Improved insulation of the appliance

A lower thermal dissipation 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.

4.3.1.3. 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 water tank condenser for (improved) drying described in the following section 4.3.2 uses the same heat exchanger tank. The same technical option can thus lead to energy savings in different phases of the dishwashing programme.

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 and because of possible hygienic problems, and a 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, zeolite drying system, etc.) are more promising approaches to reduce the heat loss in the end of the dishwashing cycle.

Another improvement to the simple heat exchanger is the cross flow heat exchanger (with storage tank). 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 so most of the energy from the waste water can be recovered. This option is not applicable to slim line machines due to the lack of space. Paepe et al. (2003) measured and calculated the possible heat recovery under various conditions. Depending on the temperature of the water leaving the dishwasher and the flow rate of the cold water the heat recovery is between 75 kJ and 365 kJ (corresponding to 0.02 and 0.1 kWh). Regarding the costs, Paepe et al. (2003) assume installation costs of 40 €, which mainly depend on the costs for a 15 m copper tube (25 €). These figures would need to be updated with current cost data (in 2003 the price for copper has been about one half to one third of the current price).

The cross flow heat exchanger was already mentioned in the GEA study (Group for Efficient Appliances 1995) and Lot 14 (ISIS 2007d) but only implemented recently (2015/2016) in the high-end appliances of one manufacturer (Miele 2016). According to stakeholder input the saving potential is rather small compared to the high manufacturing costs. Also, if the waste water is strongly cooled down, the soil is prone to drop out from the fleet and thus block the filter systems requiring new developments of this technology. The savings through the currently implemented cross-flow heat exchanger are estimated to be within the range calculated by Paepe et al. (2003).

4.3.2. Technology area 2: Improved drying systems

The basic principle of automatically drying 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 draining the water of the final rinse, the water on 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 1995). This led to a reduction in energy saving of 40 Wh/cycle. Obviously, back then, with a hot rinse phase of 65°C, additional heating was not necessary for a sufficient drying performance as the dishes contained enough heat to evaporate all remaining water. Drying time was increased however. To shorten the drying time both GEA and Lot 14 describe two possibilities as also shown in the following sections: recirculation of air in the tub with a condensing system (water tank) and ventilation of the moist air by a fan.

4.3.2.1. Heat exchanger (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.

The water tank is identical with the heat exchanger tank described in section 04.3.1.3. The same technical option can thus lead to energy savings in different phases of the dishwashing programme.

4.3.2.2. 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 water temperature during the final rinse 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 the furniture through the escaping steam. Miele for example avoids damaging of the surrounding furniture (especially the countertop) through 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 (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.

4.3.2.3. Adsorption drying technologies (like Zeolith®)

About 1.0 to 1.5 kg of adsorption material (e.g. 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 adsorption material heats up as the adsorption process is an exothermic process. The additional heat helps evaporating the water from the dishes. Also the condensing heat, i.e. the heat that is released when vapour is condensed to liquid water, is captured and used for improving the drying process. The adsorption material 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 are the same. The energy saving compared to dishwashers without this technology is mainly due to the recuperation of the condensing heat of the steam during the drying process which dissipates without being recovered in conventional dishwashers.

The adsorption technology needs an additional fan to circulate the humid air through the fixed bed of adsorption material and to transfer the heat generated into the cabinet.

Currently, the technology is patented by BSH and the models offered on the market are always equipped with an additionally heat exchanger. Together with the fan and the heat exchanger it is supposed to save about 14% of energy compared to similar devices without this technology.

4.3.2.4. Fan for better air circulation

The dishwasher can be equipped with an additional fan to generate an air flow that can be either conducted through a condensing unit or out of the appliance. An additional energy consumption of 4 Wh for the fan is assumed. In Lot 14 it was considered to be applied to approximately 25% of the models on the market.

The "powerDry" technology of Bauknecht (introduced in 2013) belongs to this type of drying. Here the fan is connected to an air-air-heat exchanger. The warm and humid air is sucked into an air-air cross-flow heat exchanger where the air is cooled down and the moisture is condensed and subsequently drained. Both drying performance and drying duration are supposed to improve leading to a lower energy demand during the drying phase.

A fan is also needed for several other technological options, e.g. for the adsorption drying technology, for dishwashers equipped with a heat pump or with an automatic door opening system.

4.3.2.5. 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 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 today’s perspective it seems that manufacturers have chosen different ways of reducing the energy demand of the final hot rinse, e.g. by reducing the water demand to only 3-4 litres for the hot rinse and lower temperatures for the hot rinse phase due to improved drying technologies.

4.3.3. Technology area 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, if the cleaning performance has to be maintained. An increase of the mechanical action is limited by the power that can be achieved by the water jets and the delicateness of the crockery. The factor chemistry cannot be influenced easily by the appliance manufacturers as this is controlled by the detergent manufacturers in real life and defined in the standard for standard test conditions. Thus, the main factor that compensates lower wash temperatures is time. This resulted in dishwashing cycles that became longer during the past decades (see also Figure 4.3).

Lot 14 describes a development of the temperature of the main wash phase which initially (i.e. in the mid-90s) 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 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 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 its 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 around 50°C. According to stakeholder input, 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. According to stakeholders it is not possible to reach an A-rated cleaning performance with cleaning temperatures below 45°C due to the stubbornness and heavy load of the applied standard soiling (especially the fatty soil and the tee stains need temperatures above 45°C to be cleaned sufficiently). Also, longer duration of the main wash phase, i.e. increasing mechanical action, makes it more difficult to remove the soil from the water as the soil particles will become too small to be filtered out.

Second, there was a considerable technological development in the area of drying of the dishes (see section 4.3.2). Through these developments the dishes dry (in a reasonable time) also without high temperatures during the hot rinse phase. This results in a lower energy demand for the hot rinse phase. This reduction in energy demand lowered the pressure on temperature reductions during the main cleaning phase. Another advantage of reducing the temperature of the hot rinse phase, instead of reducing it in 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. This possibility is reached much easier with today’s low water consumption (on average about 10 litres for the whole cycle, but only around 3 to 4 litres for each water intake) – less dishes are cooled down with smaller amounts of fresh cold water.

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 door opening do not need as high temperatures during the hot rinse as dishwashers without automatic door opening. This results in differences in the water temperatures in the cleaning and hot rinse phases for different models on the market depending on the applied drying technology. Altogether, this makes it difficult to determine a certain temperature profile as “base case” and lower temperature as “improvement option”.

Obviously there are models on the market that need more time than others. In general, the programme duration and the energy consumption as “input variables” are correlated with the cleaning and drying efficiency as "results", since they depend on each other. Adding a certain technology influences the energy consumption or the programme duration or both if cleaning and drying efficiency shall fulfil certain minimum requirements. It can also be observed that some appliances have a quite long programme duration and reach, even without a specific technology, low energy consumption values. In these cases the water temperature is lowered, usually in the hot rinse phase, and dishes are given more time to dry while the machine is waiting in standby until the dishes are dry. This can thus be interpreted in a way that a (moderate) increase of the programme duration leads to a certain reduction of energy consumption.

An important aspect to consider is the hygiene, especially with regard to lowering the temperatures during the dishwashing cycle. Consumers do 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 a reaction to this expectation. If the hygiene option is activated the temperatures during the dishwashing cycle are much higher (between 60°C and 70°C) compared to the standard programme (around 50°C). This leads to an increase of the energy demand. On the other hand, it can be supposed that the conditions in a dishwasher with temperatures in the main wash phase between 45 and 50°C and usually higher temperatures in the final rinse phase are still more “hygienic” compared to dishwashing by hand. Therefore special “hygiene” options are seen as rather a marketing aspect than a necessity from a hygienic perspective.

Other than for washing machines, where a trend to washing at lower temperatures than indicated for the (standard) washing programmes can be observed, the temperatures indicated to consumers are reached either in the main wash or during the last rinse. This information was provided by stakeholder feedback from the questionnaire for dishwashers (JRC IPTS 2015b).

4.3.4. Technology area 4: Alternative heating systems

Most dishwashers have integrated electric resistance heating elements to heat up the water. There are currently three possibilities to alternatively generate (part of) this electrical energy.

4.3.4.1. Heat pump system

With heat pumps it is possible to (partly) replace the electric energy used to heat the dishwasher. In the currently applied system the heat pump takes heat from a latent heat storage which is cooled down. The latent heat storage currently used is water which is stored in a tank. The water turns into ice after heat extraction. The latent heat storage could be regenerated (reheated) by the waste heat from the waste water at the end of the cycle. This can be difficult however as the waste water can be dirty and clog tubing systems. The waste water is thus discharged and the latent heat storage is heated with ambient air at room temperature. A small ventilator can be applied to enhance air flow over the system for a better heat exchange and to avoid condensation.

The electricity savings are based on the heat that is extracted from the latent heat storage which is recovered with heat from the ambient air in the surroundings, usually the kitchen. The overall energy balance is positive, meaning that over a complete cycle a small amount of heat is delivered to the kitchen (V-ZUG, personal communication 2016). If other systems would be used, e.g. air-to-air heat pumps, the final energy balance should be taken into account. Measurements and simulations by Bengtsson et al. (2015) show that the electricity consumption can be reduced by 24% through the use of a heat pump. As drawback and according to stakeholder feedback the latent heat storage currently needs up to 12 h to fully recover. A cycle once per day is possible, but it is not possible to use the heat pump for two dishwashing cycles directly after each other. Heat pump equipped dishwashers usually have an electric resistance as well which can be used in combination with the heat pump or alone. The most energy-saving program only uses the heat pump for heating water.

V-ZUG introduced a dishwasher to the market with a heat pump in 2014 (V-ZUG Heat Pump 2014). The model is called Adora SL WP and is currently the only dishwasher on the market which is equipped with a heat pump. This dishwasher uses 8.7 litres of water and 0.49 kWh of electricity in the Eco 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 2014; V-ZUG Website n.d.)

	Adora SL WP	Adora SL	Saving through heat pump
Energy Efficiency Class	A+++ (-40% of the current threshold)	A+++	
Capacity (in ps)	13	13	
Annual energy consumption (in kWh/annum)	137	196	-59 kWh -30%
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%	

The saving potential in the Eco programme compared to an equivalent model without heat pump is quite large (around 30%) whereas, according to the information in the user manual (V-ZUG 2014), the savings in the other programmes are smaller (between 0% and 14%). An energy-saving option can be chosen for all programs which activates the heat pump which then runs in conjunction with the electric resistance. (see Table 4.5)

Table 4.5 Consumption values of the Adora SL dishwasher with and without heat pump in the various programmes (V-ZUG 2014)

	Adora SL WP	Adora SL	Energy Saving
Automatic	0.6-1.1	0.7-1.2	8.3 – 14.3%
Daily quick	0.95	1.05	9.5%
Sprint	0.65	0.75	13.3%
Glass	0.7	0.75	6.7%
Intensive	1.05-1.15	1.15-1.25	8 – 8.7%
Fondue/Raclette	1.25-1.35	1.35-1.45	6.9 – 7.4%
Hygiene	1.5	1.6	6.3%
Pre-rinsing	0.05	0.05	0%
Appliance Hygiene	1.5	1.6	6.3%
Economic programme	0.49	0.69-0.73	28.9 – 32.9%

Included in the dishwashers with heat pump technology are also other technologies which can be considered as improvement options. The Adora SL WP includes a fan, an automatic door opening technology to improve the drying and a fleet reservoir to re-use the water of the final rinse for the subsequent dishwashing cycle. This fleet reservoir saves about 2.5 liters of water. The heat pump equipped dishwasher uses about 2 liter more than the same model without heat pump. This is attributed to the additional amount of water that is filled in the tubing that runs over the heat exchanger.

Manufacturers ask for proper testing of dishwashers equipped with a heat pump technology with regard to all requirements set by energy label and ecodesign directives (e.g. cleaning performance, drying performance, noise) before using it as a benchmark. Test results presented by competitors, show a lower cleaning and drying performance and higher water consumption and noise emissions but also a lower energy consumption as declared by the manufacturer itself. Similar third party tests were performed by an environmental organization. Results confirmed the large reduction in energy consumption in the Eco programme and showed that dishwashers with a heat pump fulfil the minimum requirements of cleaning and drying performances taking tolerances into account.

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 amount of this refrigerant is 175 g. R134a has a specific global warming potential of 1 430 kg CO_2e/kg which could be released in the end-of-life phase if the dishwasher is not properly collected and/or de-polluted (cf. sections 1.3.3.2). Currently it shows to be difficult to appropriately extract the refrigerant as the dishwasher has to be opened to access the heat pump system and tubing. Table 4.6 shows the global warming potential of the refrigerant per appliance.

Table 4.6: 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)	0,175 kg	1 430 kg CO_2e / kg	250 kg CO_2e

In principle also other refrigerants are possible to be used (e.g. R290 (propane) or R600a (isobutane)) with much lower specific global warming potential. However this technology is currently not implemented. If the amount of flammable hydrocarbon gases exceeds 150 g, additional safety measures have to be applied which might be costly.

Slim-line dishwashers (<50 cm width) with heat pump are currently not on the market. It could be difficult to include a heat pump in these appliances due to space limitations.

4.3.4.2. Heat-fed machines: heating by hot water circulation loop

This option describes the possibility to replace the electric heating elements in the dishwasher with a hot water circulation loop using a water-water heat exchanger to transfer the heat from the hot water to the inlet water in the machines. This means that opposite to the "hot fill" option, the dishwashers itself is connected to cold water which is then heated by a hot water heat exchanger instead of an electrical resistance. The hot water heat exchanger is fed by the hot water generated by the hot water delivery of the dwelling (e.g. 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 electricity 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 and the electricity demand can be reduced to about 0.13 kWh. (Persson 2007)

One difficulty in realising this option is that dishwashers are generally located in the kitchen with possible, large distance to the hot water storage. Hot water pipes would therefore be long which would lead to rather big conduction heat losses.

4.3.4.3. Hot fill

In principle it is possible to connect all dishwashers to a hot water line, as shown by the studies carried out by Bush & Nipkow (2005), Gensch et al. (2009) and Saker et al. (2015). In cases where 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 energy savings.

However, there are few scientific studies assessing these savings on a quantitative basis. 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 of which only one of them was specifically designed for hot-water filling. 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 lower 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 8 litres of water are heated (split in two take-ins), the amount of water taken in at the same time is between 3 and 4 litres. This means the pipe 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. This is confirmed in Energyrating Australia [n.d.].

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. Conditions for connection are detailed in a factsheet published by Topten Switzerland (topten.ch 2012). Saker et al. (2015) conclude that the magnitude of electricity savings is higher for dishwashers compared to washing machines due to the following reason: for washing machines, Saker et al. (2015) record 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. In the case of dishwashers, the users regarded in that study prefer 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).

4.3.5. Technology area 5: Increased 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 circulation 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 circulation pump is considered.

The circulation 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 realises 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).

4.3.5.1. Universal motors

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. Their efficiency is low with up to 50% (i.e. only 50% of the power input is effectively used for moving the drum, the rest dissipates), they are prone to wear, and noisier compared to other motors. They are still used in the low-price segment.

4.3.5.2. Brushless, inverter driven asynchronous DC motors

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, i.e. these motors are currently used in most dishwashers. 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.

4.3.5.3. Brushless, permanent magnet synchronous DC motor (PMSM)

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. 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. The motor efficiency of PM 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 inverter driven asynchronous motors).

All dishwasher models of some important (regarding their market share) manufacturers are equipped with PMSM motors.

Permanent magnets might 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) which are light rare earth elements.

Rare earth elements like Neodymium (used in NdFeB with a rather high share of the rare earth element Nd) 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. Pr can substitute Nd by up to 6% in these magnets.

For permanent magnet (PM) motors, if not based on NdFeB, there are further possibilities: SmCo (based on Samarium and Cobalt which is costly and difficult to process); AlNiCo (Aluminium, Nickel and Cobalt, but there is no mass production for this type, i.e. rather unlikely used for dishwashers) and PM motors based on ferrites. The two latter ones do not contain critical raw materials, are cheaper, but also weaker compared to PM motors containing rare earth elements. This weakness can be compensated by using more active material, i.e. larger magnets which leads to heavier motors.

According to stakeholder feedback, in current PM motors of dishwashers, no rare earth elements are used but PM motors based on ferrites.

Dalhammar et al. (2014) assume that the potential of improved energy efficiency of PM motors will result in an increase of market share, resulting in increased supply and a price decrease for such motors. However, it has to be taken into account that the motor efficiency alone does not determine the efficiency of the whole dishwasher.

4.3.6. Technology area 6: Sensors and automatic controls

By the use of sensors several aspects of a dishwashing cycle can be optimised. An improved accuracy of the water level and the temperature by using sensors was already in Lot 14 considered as applied to all models on the market. More enhanced sensors are electronic sensors for the detection of the actual soiling or for the detection of the load weight. These sensors are usually activated in the automatic programmes.

4.3.6.1. Soil sensors

Soil sensors detect the actual soiling, e.g. by a turbidity sensor in the circulated water, 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. The soil sensors can only detect the released soil but not the soil which might be still sticking to the dishes. This increases the risk of wrong conclusions due to the soil detection mechanism, e.g. if the soil sticks very strong to the dishes the soil sensors might, by mistake, detect very low soiling in the water and end the programme while the dishes are not clean. The use of soil sensors in the standard test would call for a randomly applied soiling to mimic real-life conditions which could drastically decrease the repeatability and reproducibility of the measurements. If different "standard" soiling would be applied there is a risk that these sensors would react in a standard way and therefore jeopardize the real saving potential.

4.3.6.2. Load sensors

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. According to stakeholder feedback lower loading does not lead to significant changes in the programme parameters as the water needed only changes slightly. The change in the amount of water is due to, the reduced amount of water needed for the initial wetting of the dishes which is around 0.5 litres for a full load. The water needed for the hydraulic system (sump, spray systems, etc.) remains the same as with a full load. The overall energy consumption of partially loaded cycles thus is only slightly reduced due to the slightly reduced water consumption and less energy needed to heat up the crockery.

4.3.6.3. Combination of sensors

It can be assumed that at least one of these sensor types is applied to dishwasher models on the market that offer an automatic program. Most dishwashers offer an automatic programme these days.

Both soil and load sensors only adapt the programme characteristics under real-life conditions. They do not have an influence on the parameters under current standard conditions as this is measured and tested with standard soiling and full load only. Also according to stakeholder feedback the soil and load sensors are not active in the standard (Eco) programme as this might lead to lower repeatability and reproducibility of the results. This means that the Eco programme does not adapt to cycles with less soiling or partly loading and that the consumption values of the Eco programme remain the same even if the required cleaning performance could have been reached with lower input of water, energy and/or time.

According to Brückner (2013) both the soiling and the amount of items is much lower under real life conditions compared to standard testing conditions. She therefore compared four different dishwasher models with regard to their ability to adapt the programme characteristics of the automatic programme (energy and water consumption, programme duration, cleaning and drying performance) to lower load and soiling. The main outcome was that there are substantial differences in the ability of dishwashers on the market to adapt to those conditions, see e.g. Figure 4.6.

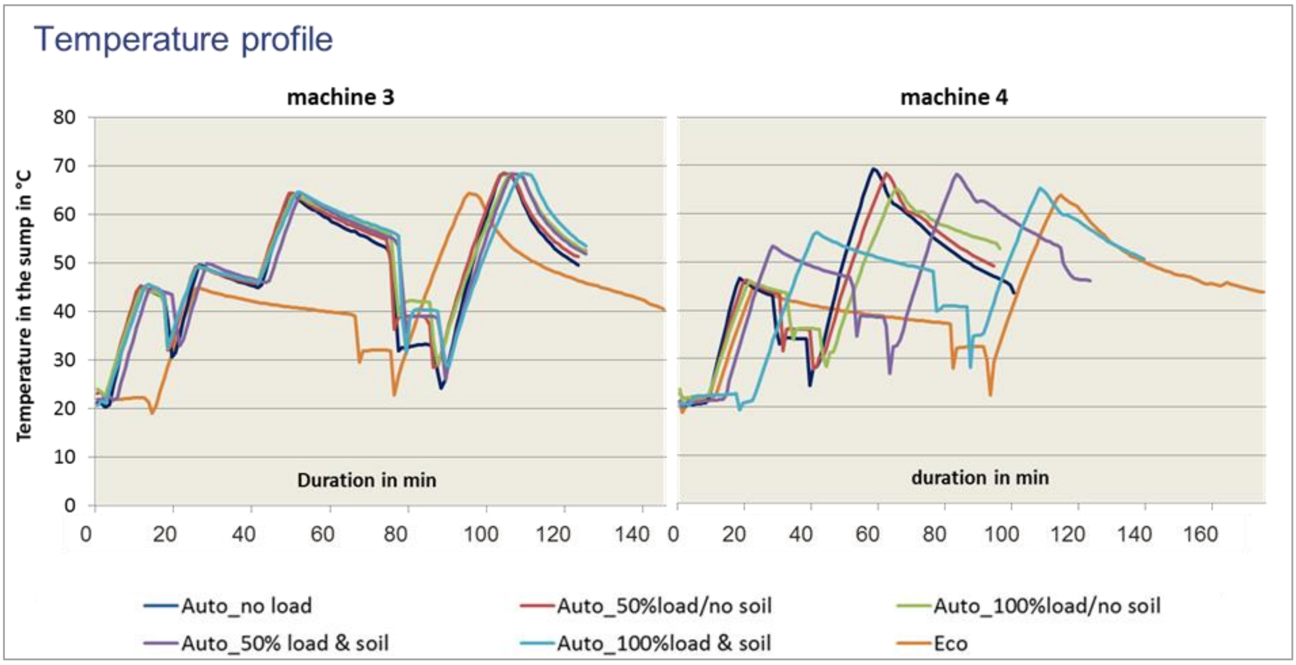


Figure 4.6: **Temperature profiles of two dishwashers tested in the Eco programme and under different load and soil conditions in the automatic programme (Brückner 2013)**

In case of machine 3 all temperature profiles of the automatic programme are nearly the same. The programme does not react to differences in loading or soiling. It seems that the sensors are not working correctly. In contrast, machine 4 shows a strong dependence of the temperature profile at least with regard to “load&soil” (“no load”, “50% load&soil” and “100% load&soil”, represented by the dark blue, violet and light blue profiles respectively), and to a smaller extent with regard to varying the loading only (“no load”, “50%load/no soil” and “100%load/no soil”, i.e. dark blue, red and green profiles, respectively). This result can be interpreted in such a way that the soil sensor is working in case of machine 4 whereas not in machine 3.

This effect can also be seen in the energy consumption of machine 3 and machine 4 in the Eco programme and under the various load and soil conditions in the automatic programme, see Figure 4.7.

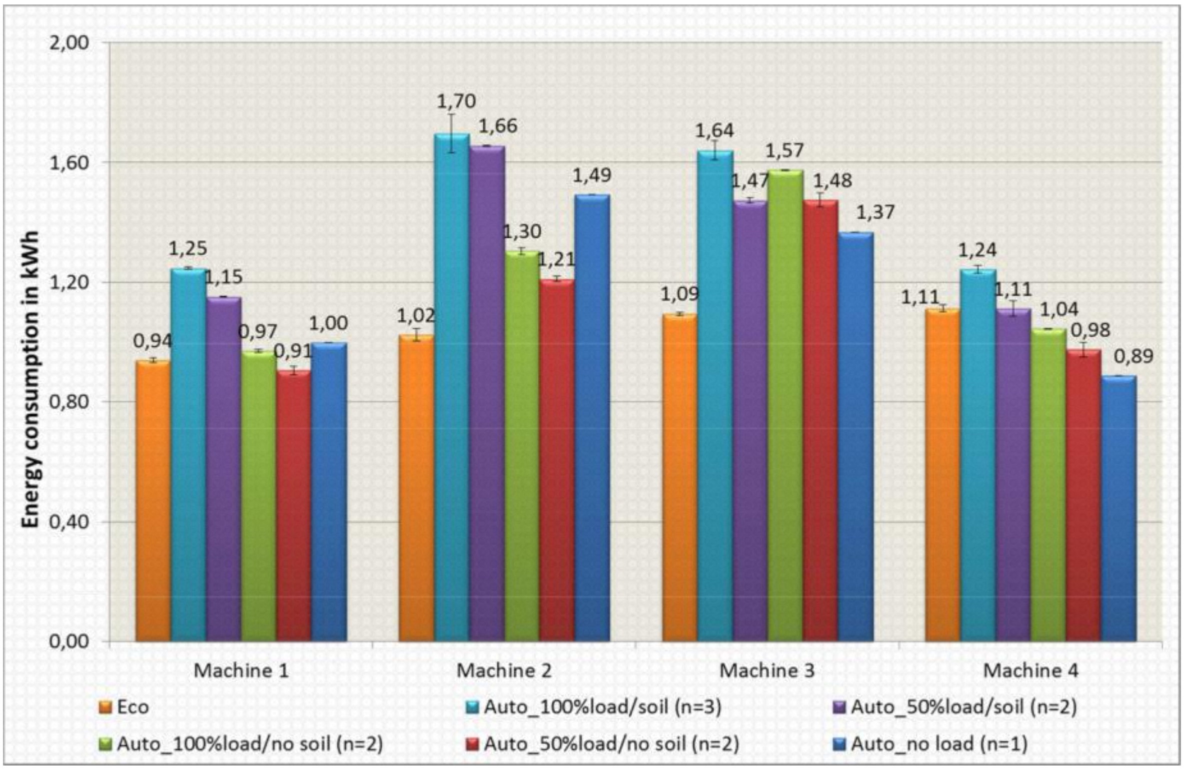


Figure 4.7: Energy consumption of dishwashers tested in the Eco programme and under different load and soil conditions in the automatic programme (Brückner 2013)

In case of machine 3 the automatic programme needs more energy than the Eco programme no matter how it is loaded or soiled. In contrast, the automatic programme of machine 4 only needs more energy than the Eco programme when fully loaded and soiled. Under all other conditions, it needs the same or less energy than the Eco programme. For machine 1 and 2 it seems that the Eco programme is almost always the best choice with regard to energy consumption.

However, the reservation must be made with respect of the results shown above, that the number of appliances tested was very limited (only 4 appliances, i.e. one of each model) and thus the results might not be representative for all appliances on the market. It seems to indicate however that there is a variation in real-life adaption in the automatic programme for different dishwasher models on the market. Some manufacturers might optimize the automatic programme on energy consumption; others might focus more on programme duration.

Currently these differences are not visible on the energy label as the measurements only take place in one programme (the Eco programme) with full load and quite heavy soiling (the standard soiling). Therefore there is no incentive from the energy label point of view to use and/or improve soil or load sensors or to improve other programmes apart from the standard one.

4.3.6.4. Automatic Detergent Dosage for dishwashers

While common for professional dishwashers, an automatic detergent dosage system for household dishwashers is not applied on the market yet. On the international trade fair "IFA" in September 2015 a prototype of a dishwasher with automatic detergent dosage has been presented. 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 both the load and the soiling is often lower than under standard conditions. Users mainly use multifunctional tablets (see section 3.1.7.1, Figure 3.8) and with tablets it is not possible to adapt the amount of detergent accordingly.

The use of multifunctional tablets can have an influence on energy consumption as well. Some machines detect that the rinsing agent container is not filled and will adapt the programme accordingly, e.g. by increasing the final rinse temperature. This aspect is further outlined in section 5.1.1.4.

Stakeholders pronounce the limits of correct load and soil detection and thus the respective adaptation of detergent dosage.

Moreover, according to one stakeholder feedback from the questionnaire for dishwashers (JRC IPTS 2015b) automatic detergent dosage systems could significantly 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.

4.3.7. Technology area 7: Alternative spraying / water systems

New developments in this area are the so called “water wall” by Samsung and the “powerclean” technology by Bauknecht.

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 (for 14 ps), resulting in energy efficiency class A++, which is not an outstanding low consumption.

PowerClean Technology (Bauknecht): dishwashers with this technology dispose of 32 high-pressure nozzles at the rear wall of the appliance. Strongly soiled crockery is supposed to be cleaned effectively at the rear part of the lower basket, while at other places of the dishwasher more delicate crockery can be cleaned. It is not clear if this technology leads to energy and/or water savings.

4.3.8. Technology area 8: Consumer feedback mechanisms

4.3.8.1. Displaying a detergent dosage recommendation

Currently there are on the market washing machines that have load sensors and give a detergent dosage recommendation via the display in accordance with the measured loading of the drum. This technology is in the case of dishwashers not easy to implement as the loaded crockery can have very different specific mass and soiling. Regarding detergent dosage it does not make a difference if a dishwasher is fully loaded with plastic (light weighted) or with china (much heavier). This technology is also difficult to implement as it would require a change in the user behaviour. Currently about 60% of all consumers use tabs that provide the dishwashers with a fixed amount of detergent per cycle, independent of the mass and soiling of the load.

4.3.8.2. Direct feedback mechanism on presumed consumption

Miele offers machines that give a prognosis on the estimated energy and water demand of the chosen programme via a display. The user can directly see differences in the consumption values and might choose a more economic programme. After the cycle exacter 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 Eco programme but enables consumers to make informed choices. This might enhance a more sustainable washing behaviour.

According to stakeholder feedback the display of a prognosis of the consumption parameters is only possible for programmes with a fixed profile, e.g. the Eco programme. For flexible programmes, like the automatic programmes, only averages or ranges could be indicated. This option is only possible for appliances with displays which usually increase the manufacturing costs.

4.3.9. Technology area 9: Smart appliances

4.3.9.1. 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, or be informed when new detergent has to be bought. 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 (EC) No 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 therefore it was considered as a BNAT. For the time being, there are still not many appliances equipped with this feature.

4.3.9.2. 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. In Lot 14 it was assumed that 20% of the models on the market have this option (year 2005). It can be assumed that today the share is higher.

4.3.9.3. 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 in line with the availability of electric energy within a consumer-defined time range. Thus electricity use can be shifted according to availability. Also signals from an on-site PV system can be received to adjust the starting time according to the availability of on-site generated electricity. There are no direct water or energy savings but rather changes in the time when electricity is consumed optimizing the simultaneous generation and consumption. Besides a smart-grid ready appliance the consumers may need a communication module (to be installed at the appliance) and perhaps a central gateway or energy demand manager. 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 can hardly 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). Also the energy consumption while the appliance is in a “ready-to-operate” mode, waiting for a signal to start the cycle, has to be taken into account. This is regulated under Regulation (EU) No 801/2013.

4.3.10. Technology area 10: Material selection

4.3.10.1. Use of recycled plastic

In its Sustainability Report 2013, Indesit Company informs that it has developed technological solutions and recycled materials, biopolymers or materials from renewable sources that can potentially reduce the amounts of bitumen damping material, soundproofing felts and, in certain models, also eliminate metal side panels. 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. (Indesit 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 used since 2001. By combining a high-efficiency metal removal line, high-purity polypropylene (PP) separation and other recovery technologies with quality control technologies, Sharp has been able to recover recyclable plastic, and to find applications for its use such as in the exterior panels of home appliances (base frame and washing tub in washing machines and other similar home appliances sold in Japan which are subject to the Home Appliance Recycling Law) and as flame-retardant materials (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 increasing the use of recycled materials include the risk of contamination, the costs associated with avoidance of such risks, and the 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 recycled material that complies with quality requirements. The companies interviewed in the study foresee 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.

According to manufacturers the amount of recycled plastics in dishwashers is limited as plastic components have to fulfil specific requirements with respect to mechanical, chemical and thermal resistance.

4.3.10.2. Design for durability

Some manufacturers are producing appliances which present increased durability. This is achieved through specific design choices and by the careful selection of materials (e.g. higher amount of metals are sometimes used). More durable products generally tend to be heavier and more expensive for consumers. Environmental impacts embedded in the product might be higher than in case of using cheaper materials, although the lifecycle impacts could be compensated by the possibility of using the appliance for a longer time.

According to one manufacturer feedback, appliances are developed for a minimum lifetime as expected by the customers. All components have to fulfil these requirements so that the choice of materials and product construction is entirely based on criteria to fulfilling this end-user expectation, with the respect of cost aspects in a highly competitive environment.

4.3.11. Technology area 11: Reduction of water consumption

A reduction of the water consumption partly leads to lower energy consumption as less water has to be heated. The current average water consumption per cycle of dishwashers is approximately 10 litres (Figure 2.13), 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). The reduction of water consumption as such is not necessarily seen as an environmental advantage but rather as an important means to reduce the energy necessary to heat up the water. The following options have been evaluated in this sense.

4.3.11.1. 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 are e.g.

- Reduction of the size of the sump,
- Reduction of the diameter of the pipes,
- Reduction of the diameter and exact adjustment of the jet 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),
- 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,
- Differentiation of the water levels (i.e. reduction of the water flow in certain phases of the cycle).

Already in Lot 14 it was considered that the hydraulic system was optimised in all models on the market. Therefore no further optimisation is expected.

4.3.11.2. 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 only draining part of the contained heat and 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. Only the 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 testing conditions as there is too much soil in the water to be drained. It might be applied in programmes for lightly soiled crockery.

4.3.11.3. 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 for pre-rinsing is usually 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.

4.3.11.4. Reuse of last rinsing water (Fleet reservoir)

This option was already discussed in Lot 14 but it was supposed that, due to the very low water consumption of dishwashers, the last rinsing water is too dirty to be stored for many hours without hygiene problems. Back then no machines were equipped with this option.

Today, there are dishwashers on the market that store the water of the final rinse phase in a special tank, the so called fleet reservoir, and re-use it for the pre-rinse of the following dishwashing cycle. The storage duration of the tank is 36 hours. If the water is not used within 36 hours the water is drained. After a certain number of cycles the tank is rinsed with hot water (V-ZUG 2014). 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). This option only leads to a reduction of the water consumption and only a slight reduction of the electricity consumption of the dishwashers. The energy remaining in the water of the final rinse phase dissipates and gets lost for the following dishwashing cycle. A small energy efficiency gain is obtained because the water of the next first rinse is at room temperature instead of the water temperature coming from the tap which usually lower than room temperature.

4.3.12. Technology area 12: Miscellaneous

4.3.12.1. Hygiene options

The hygiene aspect seems to get increasingly important as more and more manufacturers offer certain “hygiene functions”. The demand of more hygiene however may also be encouraged by advertising of corresponding household appliances (e.g. “hygiene plus option” in dishwashers, disinfecting cleaning agents and detergents, cold appliances with silver coating, etc.). This development is thus not purely “consumer driven” but also a result of 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 due to the shadows created by one piece of crockery on the others. Therefore it was not further considered in Lot 14.
- The temperatures during a standard dishwashing cycle usually reach between 45°C and 60°C and are held over a certain period of time. For “hygienic” programs, temperatures increase to 60°C and 70°C leading to an increase in 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%.

According to Stiftung Warentest (2016), there is no problem with the hygienic quality of the dishes, even when using the Eco programme with rather low temperatures. Compared to manual dishwashing, still more bacteria are removed from the dishes (ibid.).

4.3.12.2. 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 by 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 45dB(A)) and the number of models on the market with better noise reduction levels (i.e. lower noise emissions) is higher.

4.3.12.3. Optimized regeneration of softener

The regeneration of the water softener is only run when really necessary which leads to savings in water and regeneration salt. The conductivity of the water is measured with sensors. In Lot 14 it is supposed to be already applied to all models on the market.

4.3.12.4. Delay start

This option allows starting the dishwashing cycle after a certain amount of time (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 because it is 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.

4.3.12.5. 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.

4.4. Production, distribution and end-of-life

4.4.1. 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 4.7 provides a first general average material composition of dishwashers based on 2011 data (UNEP 2013).

Table 4.7: Average composition of dishwashers (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 (ISIS 2007c) used following average production input data for dishwasher models in 2007 (Table 4.8).

Table 4.8: Average production input data for 9 ps and 12 ps dishwasher models used by Lot 14 in 2007 (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

PRODUCTION			
Materials type	Material	DW 9 ps (g)	DW 12 ps (g)
	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 (a detailed BoM can be found in the Annex, section 0):

- If the machine is equipped with a permanent-magnet synchronous motor (PMSM, cf. section 4.3.5.3), the motor weight is reduced from around 6.5 kg to 3.5 kg; further there have been generations of motors with presence of rare earth elements 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. However, as explained further below, in recent years a new generation of permanent magnet motors with ferrite and without rare earths is in use widely, with similar properties to the motors including rare earths.
- The use of zeolites or similar heat storage technology requires additional materials, for the heat exchanger unit itself (zeolite or other appropriate material and metals for encapsulation) as well as for the air venting system (electric motor and fan). Electric motor and fan 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. In addition, a refrigerant is used (e.g. 200-400g of R134a -1,1,1,2-tetrafluoroethane, an HFC with a GWP of 1430 kg CO2-e)
- 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. Valuable 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).

However, these amounts are normally lower than in printed boards from appliances where high speed and performance is required, such as computers.

4.4.2. 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 (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 4.9. 5% of sheet metal scrap is also assumed in this study.

Table 4.9: Average input data for sheet metal scrap of dishwasher manufacturing used by Lot 14 in 2007 (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

4.4.3. Packaging materials

According to WRAP [n.d.], 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 (ISIS 2007c) used following production input data for the packaging of dishwasher models in 2007. The same packaging is assumed in this study.

Table 4.10: Average production input data for packaging of dishwasher models used by Lot 14 in 2007 (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*

4.4.4. Volume and weight of the packaged product

The Ecodesign Preparatory Study Lot 14 (ISIS 2007c) used following input data for the volume and weight of the packaged dishwashers. The same assumptions are kept in this study.

Table 4.11: Input data for volume and weight of packaged dishwashers used by Lot 14 in 2007; (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

4.4.5. 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 (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

In this study the same distance and an average transport mix are assumed.

4.4.6. Technical product life (time-to-failure of critical parts)

4.4.6.1. Data on technical product lifetime of dishwashers

The Ecodesign Preparatory Study Lot 14 (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 / status 2013) applied 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. (2016) 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. (2016) analysed data of GfK for large household appliances in Germany with regard to the developments of the average "first useful service-life" (see also section 3.4.1). 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 (see section 3.4.1).

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. (2016), 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 defect dishwasher replacements between 2004 and 2012.

Very different information has been collected on failure age and replacement rates. According to stakeholder feedback via the questionnaire (JRC IPTS 2015b), one stakeholder provides results of a study from 2006 analysing what usually breaks down in dishwashers (cf. also section 4.4.6). The 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 failures 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. Some companies provide after sales service which is involved in ensuring 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 2015b):

- Warranty by manufacturers is provided according to the national requirements. Sometimes consumers can buy an extended warranty up to 5 years. Some features may have a longer warranty, e.g. at 10 years warranty for a tub against corrosion or an extended warranty for the motor.
- 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.

4.4.6.2. 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.

RReuse study

In 2013, RReuse conducted an investigation into some of the main obstacles its members encounter when repairing products (cf. section 3.4.2), 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:

<u>Design for disassembly for repair</u>

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 lime scale.
- 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.

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 2015b) about results of a study from 2003 (Konsumentverket 2003) that provide some information on what usually breaks in dishwashers. The parts that broke down are the following (with the 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 container (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, drain pump, thermostat, sieve, heater, hinges to the door, lamp, spray arm and touch buttons.

One stakeholder commented via the questionnaire (JRC IPTS 2015b) 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.

4.4.7. Materials flow and collection effort at end-of-life (secondary waste), to land-fill/ incineration/ recycling/ re-use

The following sections provide an overview of European end-of-life management paths of household dishwashers.

4.4.7.1. Collection rates

Dishwashers are classified under category 1 “Large household appliances” of the WEEE-Directive 2012/19/EU (cf. section 1.3.1.2; European Parliament (2012a)). From 15th of 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 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 electric and electronic equipment (EEE) put on 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 2015b) 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 2014). Information from other potential second-hand markets such as Eastern Europe is currently 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 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.

4.4.7.2. 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.

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.

Pre-processing / depollution

The majority of end-of-life dishwashers or washing machines are passed on to the pre-processing stage, which may start 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 would be removed from the devices for separate treatment:

- Power-cables.
- Large accessible printed circuit boards > 10 cm². 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 could result in down cycling.
- Devices containing volatile hydrofluorocarbons (HFC) or hydrocarbons (HC) – which might be the case for 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 of HC 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 appliance would be 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).

In most treatment plants in Europe (likely >95%, although no clear statistics are available), most treatment is purely mechanical, with limited manual treatment intervention. The sequence described above is reversed: the first treatment stage is shredding, followed by mechanical separation, and only in specific cases there would be manual separation of certain components. One of the consequences of this is that the separated fractions have a lower purity (and therefore market value) than the fractions obtained with manual separation. Normally, large-volume treatment plans are essentially mechanical. The few plants in Europe that base their treatment on manual separation operate relatively low flows of appliances.

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.

4.4.7.3. Recycling and recovery rates

The Ecodesign Preparatory Study Lot 14 (ISIS 2007c) used the input data for end-of-life parameters as in Table 4.12.

Table 4.12: Input data for end-of-life handling of household dishwashers used by Lot 14 in 2007 (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, 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 have been raised to 85% since 14 August 2015 (see Table 4.13).

Table 4.13: Re-use and recycling targets specified in Directive 2012/19/EU; source: 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 2015b) 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 (primarily metals) according to WEEE recycling guidelines. According to UNEP (2013), printed circuit boards containing palladium, silver and gold form a very small part of this recycling stream and are mostly lost. If recovered, physics limit the production of clean recyclates from these printed boards, which makes subsequent processing in metallurgical plants difficult. Printed circuit boards 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 these elements.

End-of-life treatment of permanent magnet (PM) motors

According to stakeholder feedback, it seems that dishwasher and washing machine manufacturers have in the last years moved away from motors using rare earth metals because of cost reasons. This might change again in the future as the cost strongly depends on the metal market. (see also section 4.3.5.3)

Dalhammar et al. (2014) conducted a case study in 2012 on the potential inclusion of PM motors in the revision of Regulation (EC) 640/2009 for electric motors. The objective was to see how the ecodesign requirements 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 REE gain 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 4.3.2) is difficult.

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 might 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. By the current Regulation (EC) No 640/2009 for electric motors manufacturers are obliged to provide relevant product information on disassembly, recycling or disposal at end-of-life.

5. Task 5: Environment and economics

The aim of this section is to assess environmental and economic impacts associated to different base cases. The assessment is based on the updated version of the EcoReport Tool (version 3.06), as provided with the MEErP 2011 methodology (COWI and VHK 2011b).

5.1. Product specific inputs

According to MEErP methodology, Base Cases (BC) should reflect average EU products. Different products of similar functionalities, Bill of Materials (BoM), technologies and efficiency can be compiled into a single base case. Therefore, in most of the cases, it does not represent a real product on the shelves. The base cases are used as reference for modelling the stock of products together with their environmental and economic impacts and the available improvement design options.

For the identification of the base cases for household dishwashers, the analyses presented in the previous Tasks 1 (Scope & definition), 2 (Markets), 3 (Users) and 4 (Technologies) have been considered.

5.1.1. Base Cases for dishwashers

The selection of the base case models has been done on the basis of the analysis of the latest technical data developed by CECED (2014). CECED databases for dishwashers have been developed since 1999. This technical database includes the parameters declared for the energy label.

5.1.1.1. Basic description of base cases

Section 2.2.2.2 reveals that the majority of household dishwasher models offered on the market are full-size dishwashers. In this category appliances with larger capacities are increasing in market shares. Dishwasher models with a rated capacity of 12 ps show a downward trend from a market share close to 40% in 2013 to a market share of 25% in 2014. On the contrary, dishwashers with a rated capacity of 14 ps are increasing their market share from 11% in 2013 to 23% in 2014. Full-size dishwashers with a capacity of 13 ps had the highest market share (31%) in 2014.

Regarding slim-line (compact) dishwasher models, those with a rated capacity of 9 ps are still the majority (7.7% in 2014) but also show a downward trend (9% in 2013). Dishwasher models with a rated capacity of 10 ps show on the contrary an upward trend. The market share of 10 ps dishwashers was 4% in 2013 and rose to 6.7% in 2014.

The following base cases have thus been identified and chosen to further assess the environmental and economic impacts over the life cycle of dishwashers:

- Base Case 1 (BC1): Household dishwashers with a nominal rated capacity of 13 place settings.
- Base Case 2 (BC2): Household dishwashers with a nominal rated capacity of 10 place settings (slim-line dishwasher).

Two base cases have been chosen to represent two types of dishwashers on the market, i.e. standard dishwashers with a width around 60 cm and slim-line dishwashers with a width around 45 cm. Such a subdivision has also been followed in the policy measures already in place. Countertop or table-top dishwashers are still a niche market and account for less than 1% of the models on the market in 2014. This kind of dishwashers is therefore discarded as a base case and for further calculations.

Table 5.1 summarises the detailed performance characteristics chosen for the dishwasher base cases including the respective underlying sources and assumptions (a more detailed description of the assumptions can be found in the sections 5.1.1.2 to 5.1.1.5).

Table 5.1: Characteristics of the chosen Base Cases 1 and 2 for dishwashers

	BC1 (13 ps)	BC2 (10 ps)	Sources
Nominal rated capacity (ps)	13	10	BC1 "13ps": 31% 13ps models and 25% 12ps models in 2014; Table 2.11: overall decreasing trend of 12ps models and increasing trend to 13 ps models in the past years* BC2 "10ps": 7.7% 9ps models and 6.1% 10ps models in 2014; choice for 10ps due to Table 2.11: for small DW overall decreasing trend of 9ps models and increasing trend to 10 ps models in the past years
Width (cm)	60	45	BC1 "13ps": most 13ps models with 60 cm width (few models with larger widths from 63 to 68 cm) BC2 "10ps": most 10ps models with 45 cm width (few models with larger widths from 50 to 53 cm)
Manufacturing cost (in €)	205	205	BC1 "13ps": Calculated from the assumed average recommended retail price (RRP) using the following assumptions similar to Lot 14 ISIS (2007d) (see section 5.1.2): Manufacturing costs plus 28% costs for manufacturers' marketing & administration, multiplied by a factor 2.5 to account for the sales margin plus 21.6% for average EU VAT 2015. BC2 "10ps": no difference in manufacturing cost compared to BC1.
Recommended Retail Price (RRP)	800	750	According to own investigations and stakeholder feedback.
Observed Retail Price (ORP)	526	516	Based on analysis of top seller products at mediamarkt national web-sites (IT, BE, DE, ES, PL, SE) (13ps and A++; 9 or 10ps and minimum A+) Obviously many appliances are sold for prices lower than the RRP. However those price reductions do not have a direct relation to the manufacturing costs or the RRP and differ greatly between retailers and trade channels.
Maintenance and repair costs (in €/lifetime)	57	57	BC1 "13ps" / BC2 "10ps": assumption that 37% of the dishwashers are repaired once in their lifetime at 155 Euros (see section 5.1.2)
Energy Consumption			
Annual Energy consumption in Eco programme (kWh/year)	268	245	BC1 "13ps" / BC2 "10ps": CECED database 2014 average annual energy consumption of 13ps DW models (n=1 821) average annual energy consumption of 10ps DW models (n=362)
Annual Energy consumption including other programmes (real-life conditions) (kWh/year)	292	272	Based on the use and energy consumption of other programmes than the Eco programme (see Table 5.4 and Table 5.6)
Energy consumption Eco programme (kWh/cycle)	0.96	0.87	BC1 "13ps" / BC2 "10ps": annual average energy consumption divided by 280 cycles per year (annual energy consumption of left-on and off-mode neglected, estimated around 4kWh/year, i.e. 0.01 kWh/cycle)
Energy consumption including other programmes (real-life conditions) (kWh/cycle)	1.04	0.97	Based on the use and energy consumption of other programmes than the Eco programme (see Table 5.3 and Table 5.5)
Water consumption			
Annual Water consumption in Eco programme (L/year)	2 731	2 877	BC1 "13ps" / BC2 "10ps": CECED database 2014: average annual water consumption of 13 ps DW models (n=1 821) average annual water consumption of 10 ps DW models (n=362)
Annual Water consumption including other programmes (real-life conditions) (L/year)	3 057	3 401	Based on the use and water consumption of other programmes than the Eco programme (see Table 5.4 and Table 5.6)
Water consumption Eco programme (L/cycle)	9.8	10.3	BC1 "13ps" / BC2 "10ps": annual average water consumption divided by 280 cycles

	BC1 (13 ps)	BC2 (10 ps)	Sources
Water consumption including other pro-grammes (real-life conditions) (L/cycle)	10.9	12.1	Based on the use and water consumption of other programmes than the Eco programme (see Table 5.3 and Table 5.5)
Detergent consumption:			
Detergent consumption (g per cycle)	20	20	Assumption as 20 g as mostly tabs are used with on average content of 20 g detergent.
Rinsing agent (g or ml per cycle)	3	3	Data taken from JRC IPTS (2015a)
Regeneration salt (g per cycle)	19	19	Own estimation
Other parameters:			
Noise (dB(A))	45	48	BC1 "13ps" / BC2 "10ps": CECED database 2014: average noise level of 13 ps DW models (n=1 821) and 10 ps DW models (n=362)
Cycle time (min) (Eco programme / real-life conditions)	196 / 124	185 / 123	Based on direct input of stakeholders (see tables Table 5.3 and Table 5.5)
Lifetime (years)	12.5	12.5	BC1 "13ps" / BC2 "10ps": Section 4.4.6.1: First useful service life of dishwashers replaced due to a defect (i.e. technical product lifetime) is 12.5 years

Compared to the base cases used in the ecodesign preparatory study of 2007 ("Lot 14") by ISIS (2007c) the current base cases both have a larger rated capacity. The selected base cases in the ecodesign preparatory study of 2007 were a 12 ps and a 9 ps machine. As far as the energy consumption is concerned, the declared energy consumption for the standard Base Case (BC1) dishwasher is significantly lower while the slim-line dishwasher Base Case (BC2) accounts for a slightly higher value. Compared to the 2007 base cases, both base cases show a remarkable reduction in the water consumption and a reduction in the declared noise levels.

5.1.1.2. Raw materials use and manufacturing of the products: Bill of Materials (BoM)

The manufacturing phase includes the extraction and production of the required materials including the following steps necessary to produce and assemble one product. The MEErP 2011 EcoReport tool contains a detailed list of materials and processes for which defined environmental indicators are provided as default values.

Material input

The Bill of Materials (BoM) of the base case products have been selected based on input provided by stakeholders (mainly personal communication with manufacturers). Manufacturers provided information on 4 models for the 13ps DW (BC1) and 1 model for the 10ps DW (BC2). In order to define the average model for each base case the data collected were analysed and aggregated or averaged regarding the type of material.

To compile the BoM considered for the household dishwasher base cases, it is worth noting that in the data base available in the ErP EcoReport many materials are missing. The materials not mentioned in the data base have been reallocated to the existing material categories. The following correspondences were considered:

- different ferrous metals as steel sheet galvanized

- wiring as Cu wire
- zinc die-casting as CuZn38
- ethylene propylene diene monomer (EPDM) / for process development and control (PDC) as LDPE
- polyoxymethylene (POM) as HDPE
- electronic components as controller board
- composites of some plastics as the main plastic they are made of, for example PC+ABS was classified as PC

For certain other materials no correspondence is possible. In this case the missing materials' weight is reallocated in other material categories, e.g. wood as cardboard and fleeces as PET. Other materials are not considered when the corresponding weight is not relevant, e.g. small pieces made of crepe tape weighting in total 0.7g or adhesive tape weighting in total 0.1g.

The amount of materials that does not exactly correspond to the categories included in the ErP EcoReport data base is around 7% of the total mass.

Table 5.2: Aggregated BoM considered for the current household dishwasher base cases and the base cases used in Lot 14

Component / Material	BC 1 (13 ps)	Base Case 12 ps Lot 14 (2007)	BC 2 (10 ps)	Base Case 9 ps Lot 14 (2007)
	Weight (in kg)	Weight (in kg)	Weight (in kg)	Weight (in kg)
Product				
Bulk Plastics	9 993	7 701	7 668	7 189
TecPlastics	881	637	777	376
Ferro	21 553	27 266	18 922	20 781
Non-ferro	5 831	1 374	5 830	1 080
Coating	0	0	0	0
Electronics	1 382	448	1 206	694
Miscellaneous	8 140	10 732	7 133	10 087
Refrigerant	--	--	--	--
Packaging				
Bulk plastics	926	896	768	780
Miscellaneous	407	1646	305	175
SUM	49 113	50 699	42 609	41 162

Compared to the base case used in the ecodesign preparatory study of 2007 by ISIS (2007c) (see also Table 5.7), the current base cases consist of more plastics (both bulk plastics and tecplastics). Additionally, an increase in the amount of electronics and non-ferrous metals is observed. These increases are compensated to a certain extent by a lower use of ferrous metals. The overall weight of the base case dishwashers in this study are close to the base cases used in the ecodesign preparatory study of 2007 (see also Table 5.7).

Manufacturing process

The manufacturing process is mainly fixed in the EcoReport tool. The only variable which can be edited is the percentage of sheetmetal scrap. The default value is 25%.

According to section 4.4.2, Lot 14 has used 5% as input for the sheet metal scrap, whereas stakeholder feedback in case of washing machines ranged from negligible (0.18%) to 12.2%. For further calculation of the environmental impacts, a value of 5% sheet metal scrap is taken.

5.1.1.3. Distribution phase

This phase comprises the distribution of the packaged product. According to the MEErP Methodology report (COWI and VHK 2011b), the section on Final Assembly and Distribution covers all activities from OEM components to the final customer. The only design variable, however, is the volume of the final (packaged) product.

Regarding the average volume of the final packaged product the same values as in Lot 14 (ISIS 2007c) are assumed (cf. also section 4.2.4 of Task 4):

- 0.400 m^3 for Base Case 1 (13 place settings)
- 0.303 m^3 for Base Case 2 (10 place settings)

It is expected that the volume of the final (packaged) product is based on the width of the machine, i.e. 60 cm (12 ps, 13 ps) or 45 cm (9 ps, 10 ps) and not on the amount of place settings.

5.1.1.4. Use phase

To calculate the environmental impacts of the use phase, the input parameters for the EcoReport tool are set as follows.

General inputs

For the base cases only direct ErP (energy) impacts are considered.

Both for 13 ps and for 10 ps dishwashers, according to data collected in section 4.4.6.1, the product service lifetime is assumed to be 12.5 years (which corresponds to the first useful service-life of dishwashers which are replaced due to a defect according to Prakash et al. (2016), see also section 3.4.1 and 4.4.6).

Regarding refrigerants (refill) it is assumed that no refill of refrigerant is needed during the use phase. This is only an issue for a heat pump equipped appliance which is a technology recently introduced in the market. Therefore this is not taken into account for the base cases as heat pumps are not used in average appliances. A dishwasher equipped with a heat pump is described as a possible design option in section 6.1.

In Lot 14 (ISIS 2007c), the travelling distance of 'maintenance and repair services' over the product life of a dishwasher has been assumed to be 160 km for a 12 ps dishwasher. For the purposes of this report the same distance is assumed for both a 13 ps and a 10 ps dishwasher. The input parameter for the weight of spare parts is automatically fixed in the EcoReport tool at 1% of the total weight of the analysed product.

Electricity consumption

During their use phase, household dishwashers generally consume electricity in on-mode and low-power modes (e.g. left-on-mode and off-mode), as well as consumables (water, detergents, rinsing agents, regeneration salt).

For the electricity consumption two alternatives are regarded for each base case:

- "Eco programme" uses the aggregated annual energy consumption per year in the Eco programme, as stated on the energy label. This includes both the electricity consumption for 280 cycles in the Eco programme and the annual electricity consumption in left-on and off-mode. (CECED database on dishwashers in 2014) (cf. Table 5.3).

- “real-life” uses the annual electricity consumption under real-life conditions. Data on the real-life use of the different programmes and data on the energy consumption of the various programmes are used. The real-life selection of programmes is derived from the latest consumer survey (Hook et al. 2015) and the energy consumption of the different programmes is defined according to direct stakeholder input. The assumptions are outlined in more detail in the following paragraphs.

Programme selection:

The percentage of real-life use of the different programmes is taken from data of machines which are at maximum 3 years old (Hook et al. 2015).

Full load/half load:

The electricity and water consumption of the dishwashers in the different programmes is estimated at full load. Only few data is available for half load energy and water consumption values. The difference from full load energy and water consumption depends on the efficiency of the machine. Differences between full load and half load range from 5% for the most efficient machines to 12% for inefficient machines.

Considering the BC1 and its energy consumption of 268 kWh/year, a half load run would consume between 233 and 254.6 kWh/year, leading to a range between 0.7% and 1.6% less energy consumption per missing ps (VHK 2014 / status 2013). Most people do not fully load there machines from a mass perspective but it is assumed that they do from a volume perspective. Therefore if a loading of 9 ps per cycle is assumed for a 12 ps base case, an average loading of 10 ps could be assumed in a 13 ps. Applying this logic (i.e. 3 ps less) would lead to a reduction of 2.1% to 4.8% in the real-life energy consumption of the base case. The effect of ‘underloading’ is judged to be small and therefore excluded from further calculations.

Consumption in low power modes (left-on mode, off mode):

The consumption in low power modes (left-on mode and off-mode) are not taken into account as the additional energy consumption is very small compared to the total energy consumption (between 0.8 and 4.3 kWh per year, depending on the power consumption in the respective modes, which would increase the annual energy consumption about 1.5% in the worst case). The excluded consumption in low power modes partly compensates the slightly too high energy consumption due to the assumption of full load (see previous point).

Multi-tab mode

Also the type of detergent used under real-life conditions differs from that used under standard conditions. Approximately 60% of all consumers use multifunctional tablets (multi-tabs) (see section 3.1.7). Besides detergent these tabs also include rinsing agent which is used in the end of the programme to enable proper drying of the crockery without stains. If only multi tabs are used and no rinsing agent is additionally dosed in the separate rinsing agent container less rinsing agent is available for the drying process at the end of the programme. This would lead to a worse drying efficiency. Some dishwashers therefore detect an empty rinsing agent container and subsequently modify the programme to ensure proper drying with less rinsing agent. Usually this is connected to higher temperatures during the last rinse to facilitate the drying phase which leads to higher electricity consumption compared to the standard electricity consumption measured under standard conditions. In other dishwashers this setting has to be chosen manually by the consumer. The increase in energy consumption depends on the type of appliance and the technology used. One manufacturer indicates an increase between 40 and 200 Wh per cycle (resulting in 11 to 56 kWh/year). It seems that the higher the energy efficiency of an appliance, the more critical it becomes regarding the drying performance if the rinsing agent is not used. Manufacturers therefore recommend using rinsing agent additionally to (multi-) tabs.

According to the consumer survey conducted by the University of Bonn (unpublished results, personal communication) 44% of the multi-tab-users also use rinsing agent (i.e. 34% of all dishwasher users use multi-tabs and do NOT additionally dose rinsing agent). Stakeholders also informed that rinsing agent sales have not dropped significantly since the introduction of multi-tabs. This aspect supports the previous finding. Additionally it is not clear how large the market share of appliances is that can switch to “multi-tab-mode” (automatically or manually) in those cases when no rinsing agent is used. It can be assumed that not all appliances of the 34% have such a multi-tab-mode or are switched to that mode.

Summing up, it is clear that this effect can increase the energy consumption under real-life conditions, but it is unclear to what extent it affects the real-life consumption

The electricity consumption as assumed is, according to stakeholder feedback, a good value to represent the real-life consumption.

Water consumption

For the water consumption also two alternatives are regarded for each base case:

- “Eco programme” uses the aggregated annual water consumption per year in the Eco programme, as stated on the energy label. The data is taken from the CECED database on dishwashers in 2014 (cf.).
- “real-life” uses the annual water consumption under real-life conditions. The calculations are equivalent to the calculations of the electricity consumption under real-life conditions.

The effect of ‘underloading’ is not manifested in the water consumption. The water consumption does not change or hardly changes at all when washing a full load or a half load. This is because the water consumption to wash a full load is already very low and a minimum of water has to be used to maintain a proper working of the pumps. Also low power modes or the multi-tab mode do not affect the water consumption. The water consumption as assumed is therefore, according to stakeholder feedback, a good value to represent the real-life consumption.

Summary electricity and water consumption

The following tables give an overview of the assumptions with regard to the Eco programme and under real-life conditions. The expected cycle time is presented as well.

Table 5.3: Real-life usage and energy and water consumption values (Eco programme and real-life) – Base Case 1 (13 ps) – full load

		Electricity consumption		Water consumption		Cycle time	
	Real-life usage	Absolute (in kWh)	Relative to Eco programme	Absolute (in litre)	Relative to Eco programme	Absolute (in minutes)	Relative to Eco programme
Eco programme	20.5%	0.96		9.8		196	
Normal programme 45-55°C	19.9%	1.15	121%	13.1	135%	124	63%
Normal programme 60-65°C	15.6%	1.34	140%	13.0	133%	136	69%
Intensive programme 70-75°C	9.1%	1.53	160%	12.9	132%	148	75%
Automatic (average)	9.9%	1.18	124%	10.6	108%	133	68%
Glass/ Gentle/Light programme	5.9%	0.92	96%	11.4	117%	102	52%
Short	12.0%	0.76	80%	9.2	94%	30	15%
Rinse/ Rinse and Hold	7.1%	0.06	6%	4.0	41%	13	7%
Sum/Average 'real-life usage'	100%	1.04	109%	10.9	112%	124	63%

Table 5.4: Annual energy and water consumption values – Base case 1 (13 ps) – full load – 280 cycles p.a.

	Electricity (kWh p.a.)	Water (litre p.a.)	Cycle time (minutes p.a.)
Eco programme	268	2 731	54 880 (= 915 hours)
Real-life usage	292	3 057	34 720 (= 579 hours)

The electricity consumption of BC1 (13 ps) in the Eco programme is 268 kWh/year. This represents almost an A++ appliance (the threshold for 13 ps appliances between A+ and A++ is currently 263 kWh/year).

Table 5.5: Real-life usage and energy and water consumption values – Base Case 2 (10 ps) – full load

	Real-life usage	Electricity consumption		Water consumption		Cycle time	
		Absolute (in kWh)	Relative to Eco programme	Absolute (in litre)	Relative to Eco programme	Absolute (in minutes)	Relative to Eco programme
Eco programme	20.5%	0.87		10.3		185	
Normal programme 45-55°C	19.9%	1.16	132%	14.5	141%	136	73%
Normal programme 60-65°C	15.6%	1.23	141%	15.0	146%	139	75%
Intensive programme 70-75°C	9.1%	1.30	149%	15.6	152%	142	76%
Automatic (average)	9.9%	1.05	121%	12.2	118%	111	60%
Glass/ Gentle/ Light programme	5.9%	0.81	93%	12.8	125%	98	53%
Short	12.0%	0.78	90%	9.7	95%	39	21%
Rinse/ Rinse and Hold	7.1%	0.06	7%	3.7	36%	12	7%
Sum/Average 'real-life usage'	100%	0.97	111%	12.1	118%	123	67%

Table 5.6: Annual energy and water consumption values – Base Case 2 (10 ps) – full load – 280 cycles p.a.

	Electricity (kWh p.a.)	Water (litre p.a.)	Cycle time (minutes p.a.)
Eco programme	245	2 877	51 800 (= 863 hours)
Real-life usage	272	3 401	34 440 (= 574 hours)

The electricity consumption of BC2 (10 ps) in the Eco programme is 245 kWh/year. This represents almost an A+ appliance (the threshold for 10 ps appliances between A and A+ is 238 kWh/year).

Dishwashing detergent

With regard to dishwashing detergent, rinsing agent and regeneration salt the following assumptions are made:

- According to the data outlined in section 3.1.7.2 a detergent consumption of 20 g per dishwashing cycle is assumed for both base cases (most users use tablets with a fixed amount of dishwasher detergent which cannot be reduced even if a smaller dishwasher is used). In case of powder usage, users tend to overdose. Also when using tabs it could be questioned if there is no overdose; the machine is not always completely filled up, neither is the content always very dirty. So even if users could reduce the amount of detergent in smaller dishwashers it is likely that they will use the same amount. Given 280 cycles per year, that results in an amount of 280 tabs per year or 5.6 kg detergent per year. (cf. Lot 14, 9 ps: 6.85 kg p.a.; 12 ps: 7.25 kg p.a.).
- Rinsing agent: 3 ml (=3 g) of rinsing agent per cycle. This assumption is supported by data provided in JRC IPTS (2015c). This report states that although the quantities used of rising agent are variable between the different machines, the standard appears to be setting 3 or 4 ml as default. The majority of the devices examined in that study operated with 3ml resulting in 0.84 kg per year. (cf. Lot 14: 9 ps: 1.16 kg p.a.; 12 ps: 1.02 kg p.a.).
- Regeneration salt: 19 g per cycle (own estimation), resulting in 5.3 kg per year. (cf. Lot 14: 9 ps: 8.33 kg p.a.; 12 ps: 7.835 kg p.a.)

Dishwashing detergent: sensitivity Analysis

An important aspect to consider is that the default values for calculating the impact of the dishwashing detergent in the EcoReport tool are based on a phosphate containing detergent (cf. COWI and VHK (2011a) p. 127: "*Dishwasher detergent, rinsing agent and salt based on EU Ecolabel studies (avg. EU phosphate) and CECED data (energy). Phosphate emissions are considered after Urban Waste Water Treatment (80% removal efficiency)"*).

At present, consumer dishwasher detergents are allowed to contain phosphates. However, from 2017 onwards phosphates will be banned from consumer dishwashing detergents as stated in the Detergent Regulation (EC) No 648/2004 and corroborated by the Commission Communication COM(2015) 229. Thus the impact on eutrophication through the dishwashing detergent discharge will be significantly lower in the future.

A sensitivity analysis has been conducted for the Base Case 1 (standard, 13 ps). For this analysis the specific eutrophication potential of the dishwashing detergent included in the EcoReport tool has been reduced by 90%. The results are shown in the last row of Table 5.13.

- For further results, the whole eutrophication potential is reduced by approximately 90% which means that the main contributor to the eutrophication potential is the discharge of dishwashing detergent. This aspect has to be kept in mind when interpreting the results.

5.1.1.5. End-of-Life (EoL) phase

Recycling of materials can avoid the extraction of raw materials and the production of virgin materials. This is modelled in the EcoReport tool as credits (avoided impacts), i.e. negative impacts.

For the product (stock) life, i.e. the period between when the dishwasher is purchased and discarded, 12.5 years have been assumed, the same as for the product service life, i.e. the period that the product is in use and operational. This assumption is made because consumers do not keep the old dishwasher stocked after buying a new one.

As “unit sales L years ago” the assumption for the year 2002 is taken (5.392 million units) (according to calculations used in CLASP (2013)) with a relative share of large dishwashers of 86% and of slim line dishwashers of 14% (according to the share of models on the market, see also section 5.1.2). The resulting unit sales figures in 2002 are

- 4.637 million units (for standard dishwashers, Base Case 1) and
- 0.755 million units (for slim-line dishwashers, Base Case 2)

The current fraction of materials contained in appliances on the market is calculated by the EcoReport tool based on the material shares of the current BoM (including packaging material), the calculated spare parts for maintenance and repair, and the auxiliary materials consumed during the use phase (detergent, rinse agent and regeneration salt). For comparison the material inputs from Lot 14 are displayed as well in Table 5.7.

It is seen that the fractions of materials of household dishwashers about 10 years ago slightly differ to that of today’s dishwashers. It has to be noted that this effect might be caused by the different data sources and the underlying assumptions.

Table 5.7: Comparison of the current share of materials in household dishwashers with former fractions (including auxiliary materials)

Materials	Base Case 1 13 ps	Base Case Lot 14 12 ps	Base Case 2 10 ps	Base Case Lot 14 9 ps
Bulk Plastics	5.6%	3.4%	4.5%	3.3%
Tecno Plastics	0.5%	0.3%	0.4%	0.2%
Ferro	11.1%	10.8%	10.1%	8.5%
Non-ferro	3.0%	0.5%	3.1%	0.4%
Coating	--	--	--	--
Electronics	0.7%	0.2%	0.6%	0.3%
Miscellaneous	4.4%	4.9%	4.0%	4.2%
Refrigerants	--	--	--	--
Extra	--	--	--	--
Auxiliaries	74.8%	80.0%	77.4%	83.1%
SUM	100%	100%	100%	100%

Further, the EcoReport tool requires input on the destination of the EoL of 5 fractions in mass: re-use, recycling (material), recovery (heat), incineration and landfill/missing/fugitive. In lack of more specific data on the destination of the material fractions of dishwashers the default values of the EcoReport tool have not been changed with the exception of auxiliaries.

For dishwashers, only dishwashing detergents, rinsing agent and regeneration salt are subsumed under the category auxiliaries. As consumables, they are not undergoing any reuse, recycling or recovery process at their end of life but go with the wastewater to the respective treatment; thus, the default values in this EcoReport “Disposal & Recycling” section have been changed to 100% fugitive accordingly. This setting is confirmed by Kemna, personal communication (2015): the impacts of all life cycle stages of this category are accounted for in the use phase of the impacts. The impacts in the EoL-phase only relate to resources/emissions needed for removal of the waste.

Two important parameters for the modelling are recycled content and recyclability of materials. The recycled content is the proportion of material input to the production process that has been recycled in a previous system. The recyclability rate is the proportion of a certain material in the product that will be recycled in a subsequent system. This takes into account any inefficiency in the collection and recycling processes. (Allacker et al. 2014)

The EcoReport tool requires to define qualitatively the 'EoL recyclability'. This relates to the potential of the new products to change the course of the material flows, e.g. due to faster pre-disassembly or other ways to bring about less contamination of the mass to be recycled. In that case, it is likely that the recycled mass at the EoL will displace more virgin material in other applications. The recyclability does not influence the mass balance but it does give a reduction or increase up to 10% on all impacts of the recycled mass. For the calculation of base cases, an average recyclability of the fractions is chosen.

Table 5.8 gives a summary of the assumptions.

Table 5.8: End-of-life destination of material fractions

Per fraction (post-consumer)	Bulk Plastics	TecPlastics	Ferro	Non-ferro	Coating	Electronics	Misc. , excl. refrigerant	Refrigerant	Extra	Auxiliaries
EoL mass fraction to re-use, in %	*1*			*1*		*1*	*1*	*1*	*1*	*0*
EoL mass fraction to (materials) recycling, in %	*29*			*94*		*50*	*64*	*30*	*60*	*0*
EoL mass fraction to (heat) recovery, in %	*15*			*0*		*0*	*1*	*0*	*0*	*0*
EoL mass fraction to non-recov. incineration, in %	*22*			*0*		*30*	*5*	*5*	*10*	*0*
EoL mass fraction to landfill/ missing/ fugitive, in %	*33*			*5*		*19*	*29*	*64*	*29*	*100*
TOTAL, in %	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*
EoL recyclability	avg	avg	avg	avg	avg	avg	avg	avg	avg	avg

5.1.2. Life cycle cost inputs for dishwashers

In the EcoReport tool the Life Cycle Costs (LCC) are calculated according to the following formula:

$$LCC = PP + PWF * OE + EoL \qquad \textbf{Equation 5.1}$$

Eq 5-1)

With:

- LCC is the Life Cycle Costs to end-users in €
- PP is the purchase price (incl. installation costs) in €
- OE is the annual operating expense in €
- EoL is the end-of-life costs for end-users (i.e. costs for disposal)
- PWF is the (Present Worth Factor)

$$\mathbf{PWF = 1 - \left(\frac{1+e}{1+d}\right) \cdot \left[1 - \left(\frac{1+e}{1+d}\right)^N\right]} \qquad (d \neq e)$$

Equation 5.2

Where

- e is the aggregated annual growth rate of the operating expense ('escalation rate')
- d is the discount rate in %

- N is the product life in years.

Discount and escalation rate

To calculate the PWF the discount rate (d) and the escalation rate (e) of the operating expenses has to be defined. For the discount rate (d = interest - inflation) (COWI and VHK 2011b) recommends to apply 4% (which is also the required discount rate of the impact assessment guidelines of the Commission). The 4% results from an assumed MEErP interest rate of 6.5% and an inflation rate of 2.5%. For the base case calculations the recommended discount rate of 4% has been chosen. However, over the period of 1999-2013 the interest rate was on average close to 2% (Eurostat 2016b) and the inflation rate around 2.1% increase per year (Eurostat 2016a). This would result in a discount rate of 0%. Therefore a **sensitivity analysis** with a discount rate of 0% is calculated (for results see section 5.3.2.1)

The escalation rate (e = inflation corrected running cost price increase) shall be the weighted average of the different annual growth rates of the different elements of the operating expenses. (COWI and VHK 2011b) suggest a default value of 4% which is assumed to reflect the situation of dishwashers.

Additionally, end-users in Europe do not have separate costs for the disposal of household dishwashers, so EoL is zero.

In case the discounted rate equals the escalation rate (d = e) the present worth factor is mathematically undefined. It then equals the product life (PWF = N) and the formula can be simplified to

$$LCC = PP + N * OE \qquad \textbf{Equation 5.3}$$

Stock and sales data

For the calculation of the EU totals, data on the annual sales and the stock are taken into account.

Regarding stock data, several figures have been reported. VHK (2014 / status 2013) and CLASP (2013) assumed values of 82.8 million and 82.2 million units of dishwashers in 2010 and they estimate values of 95.0 million units and 95.5 million units of dishwashers in 2014, respectively. The latter value has been considered in the Ecoreport calculations. The estimations can also be validated by taking into account the number of households in EU-28 combined with an average EU household penetration rate. The number of households are 217 million in 2014 (Eurostat 2016d) with an average penetration rate of 44% in 2014 (cf. section 2.2.2) resulting in 95.4 millions of units.

For sales data, VHK (2014 / status 2013) assumes annual sales of 6.9 million units in 2010 and estimates an increase to 7.89 million units in 2014. CLASP (2013) estimates sales figures of 7.37 million units in 2010 and 8.65 million units in 2014. The latter value was selected for further calculations in Ecoreport.

No data is available on the detailed split between standard dishwashers and slim-line dishwashers. Therefore the relative share is estimated according to the CECED database on the models offered in 2014. In 2014, 14% of the models on the market were slim-line models, 86% of the market were standard models with a width of 60 cm.

Table 5.9: Assumptions on stock and sales of slim-line and standard dishwashers (CLASP 2013)

	Share of models on the market 2014	Sales (2014) (in million units)	Stock (2014) (in million units)
Slim-line	14%	1.211	13.377
Standard	86%	7.436	82.170
Total	100%	8.647	95.547

Product prices and installation costs

A price range is observed for appliances that meet the specifications of the base cases. Manufacturers usually assume a recommended retail price (RRP) which usually is higher than the observed retail price (ORP) for which the appliance is sold on the market (both prices include VAT). The difference depends to a large extend on the retailer, the trade channels, the brand and also the local circumstances or sales (e.g. in case of special sales).

Not only is there a difference between the recommended retail price and the observed retail price, but also a variation in the recommended retail price for similar appliances. For example, one brand displays for a standard A^{++} dishwasher (60 cm width, 44 dB noise) recommended retail prices ranging from 670 € to 1 230 € on its website. These price variations might be due to additional features that are not related to energy and/or water consumption or aesthetic options. For an A+ slim-line dishwasher (45 cm width, 46 dB noise) the recommended retail price ranges from 580 to 730 € for the same brand. Stakeholder feedback has shown that the average recommended retail price in 2015 for dishwashers complying with the definition of BC 1 (13ps) can be assumed to be 800 €. This is in line with the example commented above.

In case of slim-line (10 ps) dishwashers, i.e. BC 2, the RRP for A+ appliances seems to be slightly lower. An average RRP of 750 € is assumed based on stakeholder feedback.

In principle there is no fix correlation between the RRP and the ORP. Stakeholder feedback showed that the difference between ORP and RRP can vary between 11% and 56%. For further calculations in section 6 however, a multiplication factor has to be derived to estimate the increase of price related to a specific design option.

The factor between the manufacturing cost and the RRP is derived from the assumptions in ISIS (2007d) (slightly updated with the current EU VAT rate). From the RRP the manufacturing cost was derived assuming that the manufacturing cost

- increases by 28% due to manufacturers' marketing & administration,
- is then multiplied by a factor 2.5 to account for the sales margin and
- is finally increased by 21.6% for accounting for the average EU VAT 2015.

This results in an overall factor of 3.9, i.e.

Recommended retail price (RRP) = Manufacturing cost x 3.9 **Equation 5.4**

Applying the inversed procedure starting from the RRP of BC1, this results in a manufacturing cost of 205 €.

The ORP was estimated to be on average 526 € for BC1 and was based on the analysis of top seller products at six Mediamarkt national websites by the end of 2015 (IT, BE, DE, ES, PL, SE). Applying the same procedure as explained above but starting from the estimated manufacturing cost (205 €), the multiplication factor between the ORP and the manufacturing cost was derived resulting in a factor 2.6 for BC1:

Observed retail price (ORP) = Manufacturing cost x 2.6 **Equation 5.5**

The sales margin is then 1.7 for the ORP.

It is assumed that the manufacturing costs of a slim-line dishwasher are approximately equal to that of a standard dishwasher. This assumption balances the possible slightly lower material costs with the presumably equal or in some cases even higher assembly costs (e.g. two upper spray arms in slim line dishwashers compared to only one in standard dishwashers). Therefore, it is assumed that also for BC2 (slim-line dishwasher) the manufacturing costs are 205 €. For reaching a RRP of 750 €, the overall factor between the manufacturing costs and RRP is therefore estimated as 3.7 instead of 3.9 (slightly lower). With an ORP of 516 €, the overall factor between the manufacturing costs and the ORP is slightly lower as well: 2.5 for slim-line dishwashers compared to 2.6 for standard dishwashers. Table 5.10 gives a summary of the assumptions regarding prices and multiplication factors.

Table 5.10: Summary of product prices and multiplication factors

	Base Case 1	Base Case 2
Manufacturing costs	205	205
Recommended Retail Price (RRP)	800	750
Observed Retail Price (ORP)	526	516
Factor (manufacturing costs – RRP)	3.9	3.7
Factor (manufacturing costs – ORP)	2.6	2.5

Maintenance and repair costs

Maintenance and repair costs are estimated to be 57€ per product service life of 12.5 years. The same cost is considered for both 10 ps and 13 ps dishwashers. The maintenance and repair costs were estimated assuming that 37% of the dishwashers are repaired once in their lifetime and the cost of one repair amounts to approximately 155€, split between labour costs (88€ as an average, i.e. 57%) and cost of the spare parts (average 66€, i.e. 43%) (Deloitte 2016). These assumptions have a relative high uncertainty as no reliable or peer-reviewed data is available. Consumer Reports (2010) reported a repair rate of the dishwasher of 10% which is significantly lower. Stakeholder feedback reported a range of repair rate between 10% and 45% for the dishwashers and Lot 14 estimated 5.5 euros/year that would result in 69€ in 12.5 years of lifetime.

The assumption regarding the repair cost has a relative high uncertainty too. Several reasons can be pointed out such as the difference in labour costs and income across Europe, the lack of identified frequent failures in the machines or the cost of the spare parts. According to stakeholder feedback the average split for repairs in France for washing machines is 40% for the cost of the spare parts and 60% for the cost of the service, while (Que choisir?, 2015) provides an example that showed that the total repair cost for washing machines could even consist of approximately 75% for the cost of the spare parts and 25% for the cost of the service.

The impact of repairs has been analysed by means of a sensitivity analysis. In this study a higher and a lower repair rate is proposed as the effect would be similar to a higher or lower cost per repair respectively. A repair rate of 50%, resulting in repair costs of 77.5 € per dishwasher and a repair rate of 25%, resulting in a repair cost of 38.8€ per appliance is considered in the sensitivity analysis (for results see section 5.3.2).

Consumables (electricity, water, detergent)

The electricity rate has been taken according to (Eurostat 2015a). The EU-28 average electricity price for households was 0.208 € in 2014 (including taxes, levies and VAT). The electricity prices vary between the member states by a factor of three: the highest prices are found in Denmark (0.304 €/kWh) and Germany (0.297 €/kWh), whereas the lowest prices are found in Bulgaria (0.090 €/kWh) and Hungary (0.115 €/kWh). France (0.175 €/kWh) and UK (0.201 €/kWh) have a medium price level.

Regarding the water rate, European Environment Agency (2003) states that there are wide variations in water charges within individual countries and between different countries in Europe. This is because of the wide range of factors that determine local water prices, and whether there is a full recovery of costs, including those for water treatment and supply, for sewage treatment and for environmental damage. COWI and VHK (2011b) proposed 3.70 €/m^3 as European average for the year 2011.

COWI and VHK (2011b) proposed long-term growth rates for electricity rates (5%) and water rates (2.5%). Applying the growth factor of 2.5% to derive the current water rate from the 2011 costs, in 2014 the water rate would be 3.98 €/m³.

For detergent costs, section 2.3.2 shows a range between 0.08 € and 0.24 € for tablets (mono-tabs with and without phosphate) across Europe (Bio by Deloitte 2014). For further calculations, a mean value of 0.16 € per tab of 20 g is taken, which equals 8 € per kg. For the rinsing agent 3 € per litre (with a density of 1 kg/litre) is assumed and for regeneration salt 1 € per kilogram (own assumptions).

Ratio average new appliance vs. stock

Finally the ratio between the energy consumption of the average new product and the energy consumption of the average product installed ('stock') has to be derived. The average product installed approximately equals the average new product a number of years ago. This number of years equals half the product life which is 6.25 years in the case of dishwashers. The ratio therefore has been estimated from the average energy consumption (according to the CECED database) per cycle in 2014 (0.942 kWh/cycle) and the average consumption per cycle in the years 2007 (1.015 kWh/cycle) and 2008 (1.020 kWh/cycle) (see also section 2.2.2.3). The resulting ratio is 92.5%.

Summary

Table 5.11 summarizes the data input for carrying out the economic assessment of the base cases with the Ecoreport tool.

Table 5.11: Inputs for the LCC for dishwashers (data is considered to be representative for EU-28 in 2014)

Input parameter	BC1 (13 ps)	BC2 (10 ps)
Annual sales (million units/year)	7.436	1.211
EU stock (million units)	82.170	13.377
Manufacturing Costs (€)	205	205
Recommended Retail Price (€)	800	750
Observed Retail Price (€)	526	516
Installation costs*	-	-
Indicative maintenance and repair costs (€), referred to the total product service life	57 (sensitivity analysis: 77.5 and 38.8)	57
Product service life (years)	12.5	
Electricity rate (€/kWh) $_{2014}$ / long-term growth rate per year	0.208 / 5%	
Water rate (€/m³) $_{2014}$ / long-term growth rate per year	3.98 / 2.5%	
Costs for detergents: • Detergent costs • Rinsing agent • Regeneration salt	 0.16 €/mono-tablet (= 8 €/kg; 44.8 € p.a.) 3 €/liter (2.52 € p.a.) 1 €/kg (5.32 € p.a.)	
Discount rate d Escalation rate e	4.0% (sensitivity analysis: 0%) 4.0%	
Ratio (energy consumption) average new vs. average product installed ('stock')	0.925	

*Installation costs for consumers are not relevant for dishwashers.

5.2. Environmental Impact Assessment of base cases

The environmental impacts have been calculated with the MEErP EcoReport tool and the data inputs presented in the previous section. This section shows the results of these calculations in the MEErP format for

- Raw materials use and manufacturing,
- Distribution,
- Use phase
- End-of-life phase.

5.2.1. Base Case 1: Standard dishwasher, 13 place settings

Table 5.12 shows the material consumption of a household dishwasher with 13 place settings over the whole life cycle of 12.5 years. The material consumption during the production equals the input values of the bill of materials. The materials consumed during the use phase correspond to the materials consumed for maintenance and repair that account for 1% of the bill of materials, and the sum of detergents (= auxiliaries) used over the life cycle. The material consumption during the End-of-Life phase is split in disposal, recycling and the stock. The latter value results from the effect that the mass discarded seldom equals the mass of new products sold.

Table 5.12: Life cycle material consumption of a standard household dishwasher with 13 place settings

Life Cycle phases -->		Production	Distribution	Use phase	End-of-Life		
Material	Unit				**Disposal**	**Recycling**	**Stock**
Bulk Plastics	g	10 919	-	109	2 292	1 875	6 861
TecPlastics	g	881	-	9	170	139	581
Ferro	g	21 553	-	216	661	12 555	8 553
Non-ferro	g	5 831	-	58	33	633	5 224
Coating	g	0	-	0	0	0	0
Electronics	g	1 382	-	14	106	111	1 178
Misc.	g	8 547	-	85	2 040	3 960	2 633
Extra	g	0	-	0	0	0	0
Auxiliaries	g	0	-	147 000	98 024	0	48 976
Refrigerant	g	0	-	0	0	0	0
Total weight	g	49 113	-	147 491	103 326	19 273	74 005

Table 5.13 shows the environmental impacts of a household dishwasher with 13 place settings over the whole lifecycle of 12.5 years under real-life conditions, i.e. assuming that all programmes are used according to real-life consumer behaviour.

The results are also shown in Figure 5.1 in terms of relative contributions (%) of each life cycle phase (i.e. manufacturing, distribution, use and end of life) to the overall results. The results are presented for each impact category as the sum of the contributions (%) of all the phases in absolute value summing up to 100%. Negative values in the end-of-life phase represent credits, i.e. avoided impacts.

Table 5.13: Life cycle environmental impacts of a standard household dishwasher with 13 place settings (real-life conditions)

Life Cycle phases -->		Production			Distri-bution	Use phase	End-of-Life			Total (of absolute values of impacts)
	Unit	Mate-rial	Manufac-turing	Total			Disposal	Recycl.	Total	
Resources & Waste										
Total Energy (GER)	MJ	5 641	829	6 470	590	35 652	164	-439	-276	42 437
of which, electricity (in primary MJ)	MJ	2 740	497	3 236	1	33 073	0	-114	-114	36 196
Water (process)	ltr	1 442	7	1 449	0	53 114	0	-199	-199	54 365
Water (cooling)	ltr	971	232	1 202	0	1 478	0	-51	-51	2 630
Waste, non-haz./ landfill	g	34 005	2 750	36 755	346	20 326	718	-7 140	-6 422	51 005
Waste, hazardous/ incinerated	g	204	0	204	7	582	0	-7	-7	786
Emissions (Air)										
Greenhouse Gases in GWP100	kg CO2 eq.	314	46	360	39	1 525	1	-30	-29	1 895
Acidification, emissions	g SO2 eq.	2 543	199	2 743	118	6 924	6	-216	-210	9 575
Volatile Organic Compounds (VOC)	g	54	0	55	8	740	0	-9	-9	794
Persistent Organic Pollutants (POP)	ng i-Teq	531	11	542	2	99	0	-95	-95	549
Heavy Metals	mg Ni eq.	2 445	27	2 472	18	359	2	-385	-383	2 465
PAHs	mg Ni eq.	156	0	156	20	84	0	-6	-6	255
Particulate Matter (PM, dust)	g	2 674	31	2 704	1 368	173	38	-322	-284	3 961
Emissions (Water)										
Heavy Metals	mg Hg/20	1 166	1	1 166	1	170	0	-218	-218	1 120
Eutrophication	g PO4	36	0	36	0	3 759	813	-7	807	4 601
Sensitivity analysis: reduction of 90% in the eutrophication input data for dishwashing detergent										
Eutrophication	g PO4	36	0	36	0	382	83	-7	76	494
Reduction of eutrophication by		0%	--	0%	--	90%	90%	0%	91%	89%

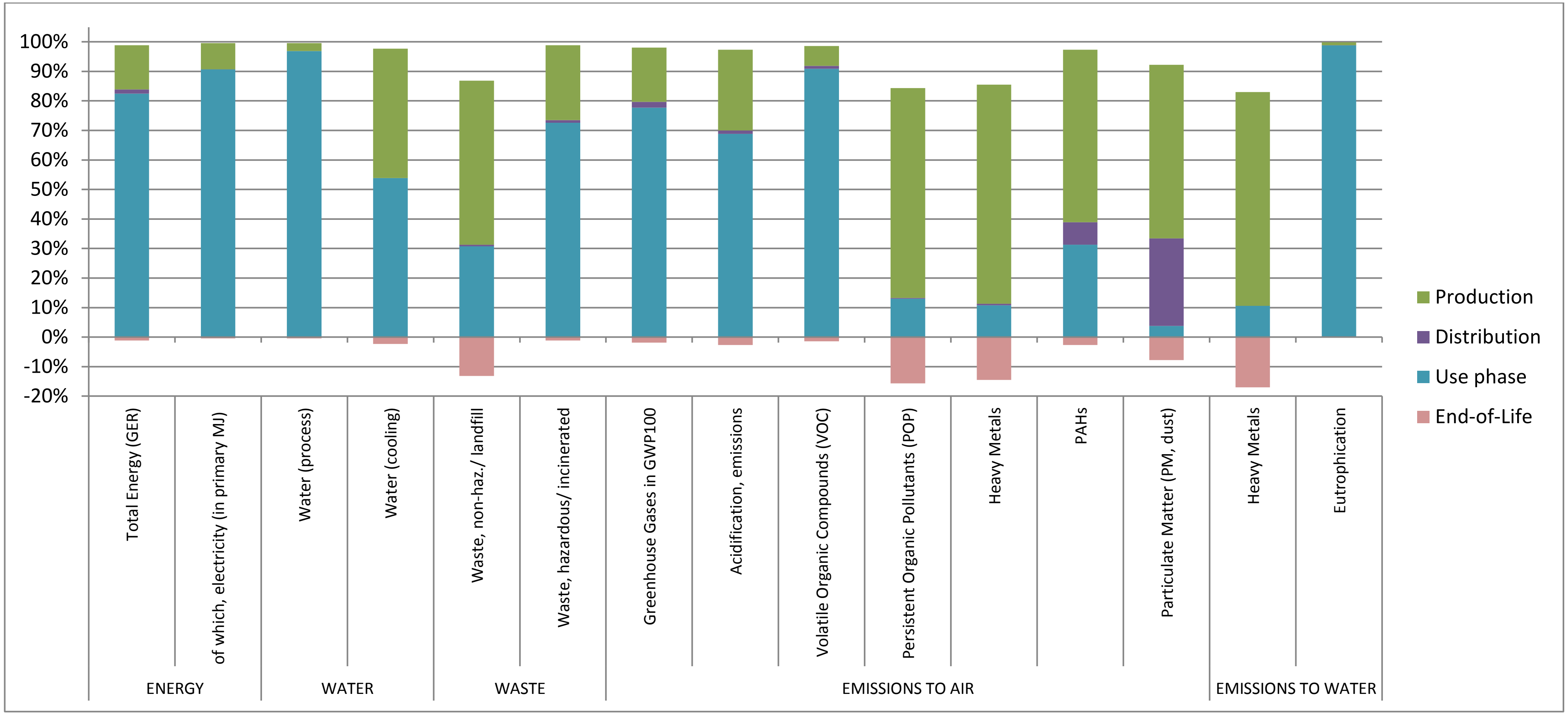


Figure 5.1: **Contribution of different life cycle phases to the environmental impacts of a standard household dishwasher with 13 place settings (real-life conditions)**

Figure 5.1 shows that the use phase clearly dominates the consumption of energy (>80%) and water (>95% of water process and > 50% of water cooling) and the generation of waste (especially hazardous/incinerated waste) along the life cycle. Besides process water, which is essentially related to the consumption of water by the cleaning and drying cycle, consumption of electricity is the main contribution to all the other indicators of these three macro categories (see also Table 5.13).

Regarding the emissions to air and water, the use phase also dominates four impacts categories, namely global warming potential (GWP100) (≈ 80%), acidification potential (AP) (≈ 70%), volatile organic compounds (VOC) (≈ 90%) and eutrophication potential (EP) (≈80%). For persistent organic pollutants (POP), heavy metals to air (HM air), polycyclic aromatic hydrocarbons (PAHs), particulate materials (PM, dust) and heavy metals to water (HM water) the use phase has a contribution ranging from 5% to close to over 30% from the total of each category. This is mainly caused by the consumption of electricity (see also Table 5.13).

The contribution of the production phase scores significantly in the following impacts categories: non-hazardous waste (≈ 55%), POP (≈ 70%), HM air (≈ 75%), and PAHs and PM, dust scoring both approximately 60% and finally HM water getting approximately 70% of the total of this category. This is mainly due to the extraction of raw materials such as minerals and the further manufacturing to steel or processing of raw materials to get the different types of plastics.

The distribution phase is relevant only for the generation of PAHs (<10%) and PM (>30%) due to the transport of the packaged products.

The EoL presents significant negative impacts in some categories. This is due to the credits (avoided impacts) that EcoReport tool assigns to the recycling of materials. For instance, the contribution of the EoL for non-hazardous waste, POP, HM air and HM water is close to -15%.

Figure 5.2 shows data normalized against share in the EU totals as given in the EcoReport for the Base Case 1 (13ps) and assuming the use of phosphate-free detergents according to section 5.1.1.4. This gives an idea of the relative share or relative significance of each impact category in the EU (at EU level). The basis for this calculation (index 100) is the attributed impact to the electricity, which for dishwashers is the highest accounting for 1.025%.

The second most significant environmental impact is particulate matter (PM, dust) with an index 71, which means 0.71*1.025 = 0.73% of the EU total.

Both categories total energy and eutrophication (even considering the entering the use of phosphate-free detergents) scored around 0.39 and 0.38% and are followed by a group of several categories that scored approximately 0.30% such as acidification (0.29%), Greenhouse Gases in GWP100 (GHG, 0.26%) and heavy metals in air (0.26%). The share of other impacts categories are smaller ranging below 0.20%.

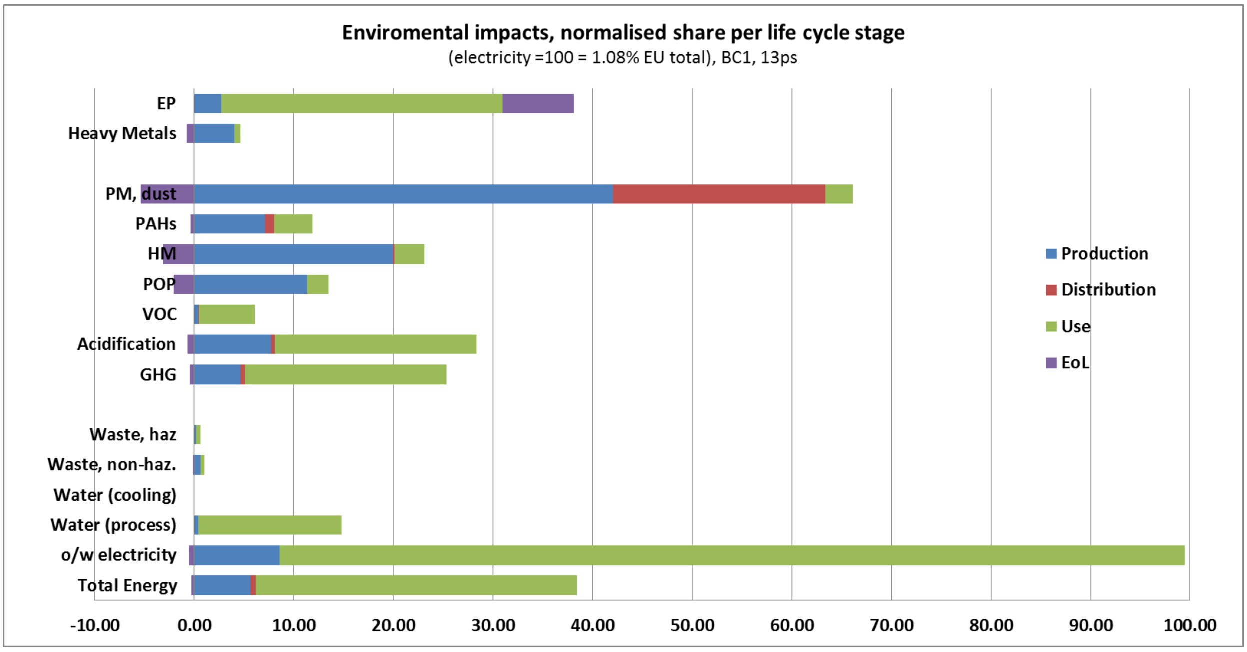


Figure 5.2: **Environmental impacts, normalised share per life cycle stage (electricity = 100) for the base case 1, 13ps under the assumption of using phosphate-free detergents**

5.2.2. Base Case 2: slim-line dishwasher, 10 place settings

Table 5.14 shows the material consumption of a household dishwasher with 10 place settings over the whole life cycle of 12.5 years.

Table 5.14: **Material consumption of a household dishwasher with 10 place settings**

Life Cycle phases ->		Production	Distribution	Use phase	End-of-Life		
Material	Unit				Disposal	Recycling	Stock
Bulk Plastics	g	8 436	-	84	2 134	1 746	4 639
TecPlastics	g	777	-	8	101	82	602
Ferro	g	18 922	-	189	506	9 614	8 991
Non-ferro	g	5 830	-	58	26	500	5 362
Coating	g	0	-	0	0	0	0
Electronics	g	1 206	-	12	166	172	880
Misc.	g	7 439	-	74	1 699	3 298	2 516
Extra	g	0	-	0	0	0	0
Auxiliaries	g	0	-	147 000	98 480	0	48 520
Refrigerant	g	0	-	0	0	0	0
Total weight	g	42 609	-	147 426	103 112	15 413	71 511

Table 5.15 shows the environmental impacts of a household dishwasher with 10 place settings over the whole lifecycle of 12.5 years under real-life conditions.

Please take into account the considerations made with regard to the Eutrophication Potential in section 5.2.1. It can be assumed that the Eutrophication Potential can be reduced by 90% through use of phosphate free dishwashing detergent.

Table 5.15: Life cycle environmental impacts of a standard household dishwasher with 10 place settings (real-life conditions)

Life Cycle phases -->		Production			Distribu-tion	Use phase	End-of-Life			Total (of absolute values of impacts)
	Unit	Mate-rial	Manufac-turing	Total			Disposal	Recycl.	Total	
Resources & Waste										
Total Energy (GER)	MJ	4 873	682	5 555	474	33 416	172	-422	-250	39 195
of which, electricity (in primary MJ)	MJ	2 379	409	2 787	1	30 841	0	-151	-151	33 478
Water (process)	ltr	1 221	6	1 227	0	59 080	0	-161	-161	60 146
Water (cooling)	ltr	782	191	973	0	1 377	0	-41	-41	2 309
Waste, non-haz./ landfill	g	30 091	2271	32 362	288	19 138	680	-5 602	-4 922	46 866
Waste, hazardous/ incinerated	g	173	0	173	6	547	0	-9	-9	716
Emissions (Air)										
Greenhouse Gases in GWP100	kg CO2 eq.	272	38	310	32	1 429	1	-27	-26	1 745
Acidification, emissions	g SO2 eq.	2 235	164	2 398	96	6 500	7	-197	-191	8 803
Volatile Organic Compounds (VOC)	g	49	0	49	6	690	0	-8	-8	738
Persistent Organic Pollutants (POP)	ng i-Teq	491	10	501	2	94	0	-75	-75	521
Heavy Metals	mg Ni eq.	2 119	23	2 143	15	333	2	-298	-296	2 194
PAHs	mg Ni eq.	136	0	136	16	78	0	-6	-6	224
Particulate Matter (PM, dust)	g	2 393	25	2 418	1036	161	39	-304	-266	3 350
Emissions (Water)										
Heavy Metals	mg Hg/20	999	1	1 000	0	159	0	-164	-163	996
Eutrophication	g PO4	30	0	31	0	3 758	817	-5	812	4 601

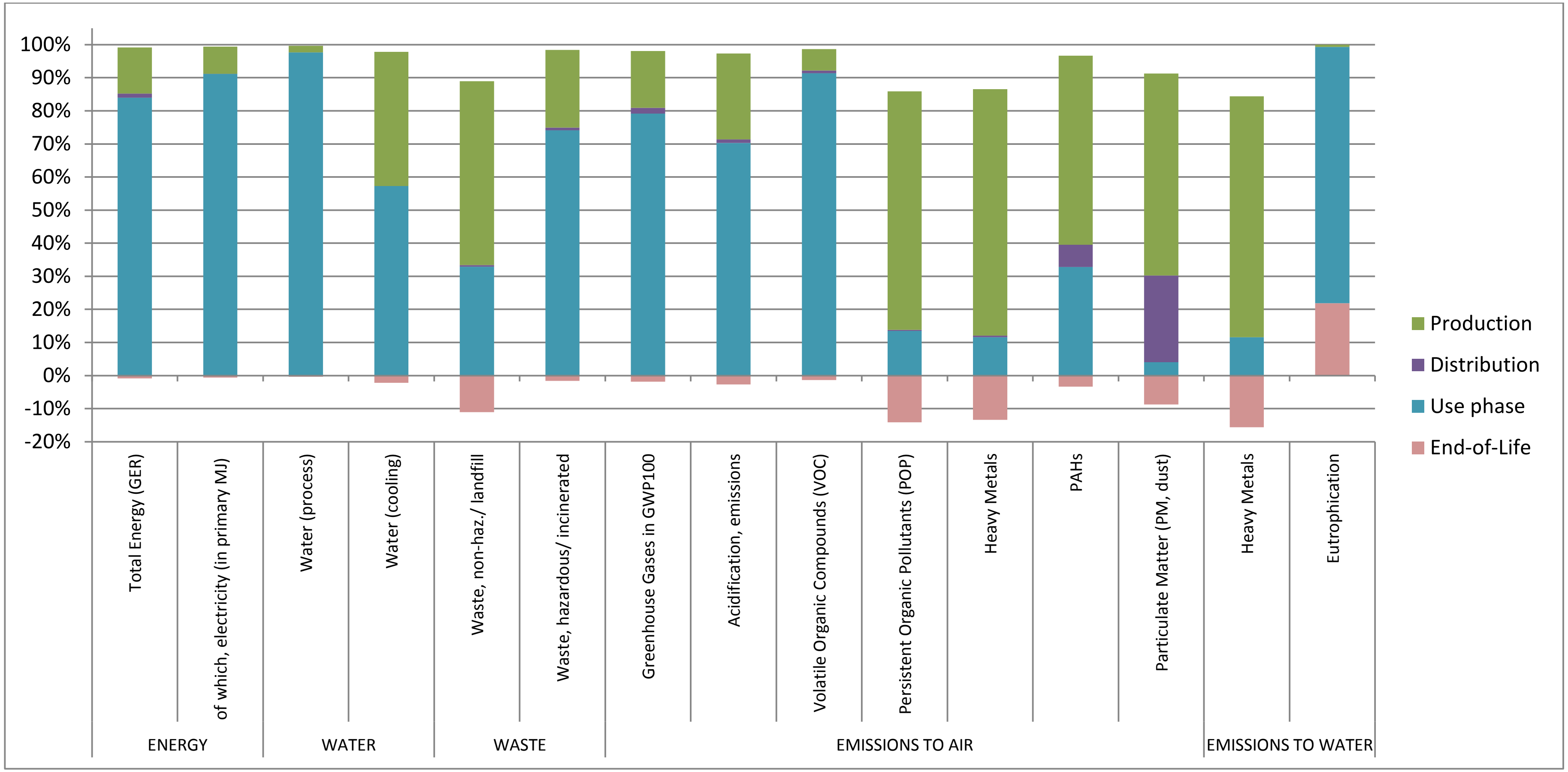


Figure 5.3: **Contribution of different life cycle phases to the environmental impacts of a slim-line household dishwasher with 10 place settings (real-life conditions)**

Figure 5.3 (BC2) shows very similar results to Figure 5.1 (BC1). The use phase clearly dominates the consumption of energy (>80%) and water (>95% of water process and close to 60% of water cooling) and the generation of waste (especially hazardous/incinerated waste with a value close to 75%) along the life cycle of the base case. Once again, besides process water, which is essentially related to the consumption of water of the dishwashing cycles, consumption of electricity is the main contribution to all the other indicators of these three macro categories.

Regarding the emissions to air and water, the use phase also dominates the same four impacts categories, namely GWP100, AP, VOC and EP. For POP, HM air, PAHs, PM and HM water the use phase has a contribution ranging from 5% to close to 35% from the total of each category. This is mainly caused by the consumption of electricity, as commented previously.

The contribution of the production phase scores significantly in the same impacts categories as in the Base Case 1 (13ps) and with similar relative values: POP, HM air, PAHs, PM and HM.

The distribution phase is relevant only for the generation of PAHs (<10%) and PM (>20%) due to the transport of the packaged products.

The EoL presents significant negative impacts in some categories. This is due to the credits (avoided impacts) that EcoReport tool assigns to the recycling of materials. For instance, the contribution of the EoL for POP, for HM air and for HM water is close to -15%, being in line with Base Case 1 (13 ps).

The differences observed between both base cases are not significant. For example the exact percentages of each impact category for each lifecycle phase may vary among 1 and 5 percentage points in most of the cases.

5.2.3. Comparison of the environmental impacts using the Eco programme vs. real-life conditions

Table 8.16 and Table 8.17 in the Annex show the environmental impacts of both base cases when using only the Eco programme.

Compared to the environmental impacts under real-life conditions, the changes in the environmental impacts mainly occur during the use phase. The end-of-life phase only is affected through a slightly higher amount of waste water in the case of the real-life conditions.

Table 5.16 therefore directly compares the environmental impact in the use phase of Base Case 1 (real-life conditions vs. only use of the Eco programme). The environmental impacts in most impact categories when only using the Eco programme are about 6 to 11% lower compared to real-life conditions. This corresponds well to the higher electricity consumption under real-life conditions (see section 5.1.1.4). Only the eutrophication potential does not change significantly as this mainly comes from the use of dishwashing detergents and there is no difference between the two scenarios.

Table 5.16: Comparison of environmental impacts during the use phase (use of Eco programme vs. real-life programme choice) (BC1)

		Use phase		Difference
	Unit	Real-life conditions	Use of Eco programme	
Resources & Waste				
Total Energy (GER)	MJ	35 652	32 943	-8%
of which, electricity (in primary MJ)	MJ	33 073	30 364	-8%
Water (process)	ltr	53 114	47 458	-11%
Water (cooling)	ltr	1 478	1 358	-8%

		Use phase		Difference
	Unit	Real-life conditions	Use of Eco programme	
Waste, non-haz./ landfill	g	20 326	18 930	-7%
Waste, hazardous/ incinerated	g	582	539	-7%
Emissions (Air)				
Greenhouse Gases in GWP100	kg CO_2 eq	1 525	1 409	-8%
Acidification, emissions	g SO_2 eq	6 924	6 412	-7%
Volatile Organic Compounds (VOC)	g	740	679	-8%
Persistent Organic Pollutants (POP)	ng i-Teq	99	93	-6%
Heavy Metals	mg Ni eq.	359	331	-8%
PAHs	mg Ni eq.	84	77	-8%
Particulate Matter (PM, dust)	g	173	162	-6%
Emissions (Water)				
Heavy Metals	mg Hg/20	170	159	-6%
Eutrophication	g PO4	3 759	3 758	0%

5.3. Life cycle costs of the base cases

The life cycle costs have been calculated with the EcoReport tool. The methodology and the assumptions (regarding product price, energy and water costs, repair and maintenance costs as well as costs for detergents) are described in section 5.1.2 (see also Table 5.11).

The life cycle costs per appliance over a lifetime of 12.5 years are summarised for both base cases in Table 5.17. The costs are given both under the assumption of the recommended retail price (RRP) and the observed retail price (ORP).

Table 5.17: Life cycle costs for the base cases under real-life conditions over the whole product life cycle (in euro) (with RRP and ORP)

	Unit	**Base Case 1 (13 ps)** Real-life conditions		**Base Case 2 (10 ps)** Real-life conditions	
		RRP	**ORP**	**RRP**	**ORP**
Product price	€	800	526	750	516
Electricity	€	758	758	706	706
Water	€	152	152	169	169
Dishwashing detergent	€	560	560	560	560
Rinsing agent	€	32	32	32	32
Regeneration salt	€	67	67	67	67
Repair & maintenance costs	€	57	57	57	57
Total	€	2425	2151	2340	2106

5.3.1. Life cycle costs of base case 1 (13 place settings)

The contribution of the different cost elements are shown in Figure 5.4 for Base Case 1 (13 ps), both for the RRP and the ORP. The largest contributions to the overall costs are coming from the purchase price and the expenditures in electricity and dishwashing detergents. If the LCC is calculated with the RRP the product price contributes 33% to the overall LCC and is thus the biggest contributor. In case of calculation with the ORP, the product price only contributes 25% to the overall LCC. The share of the other cost elements is increased accordingly. In the latter case the costs for electricity consumption have the largest share at the overall LCC, i.e. 35%.

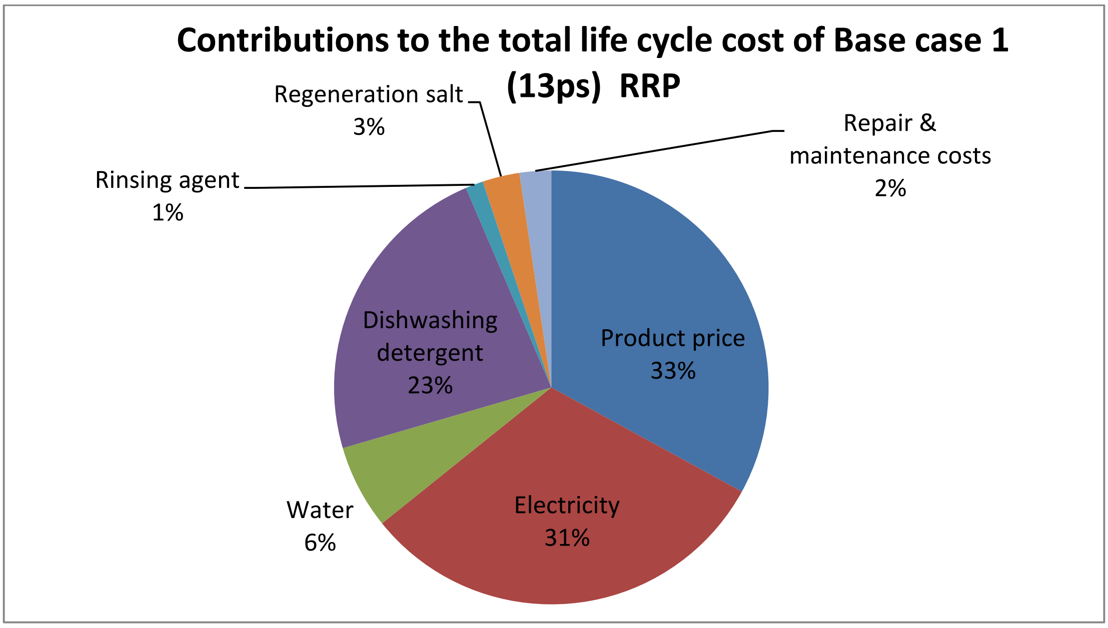


Figure 5.4: Relative contributions of costs to the total life cycle cost of Base Case 1 (13 ps) – RRP

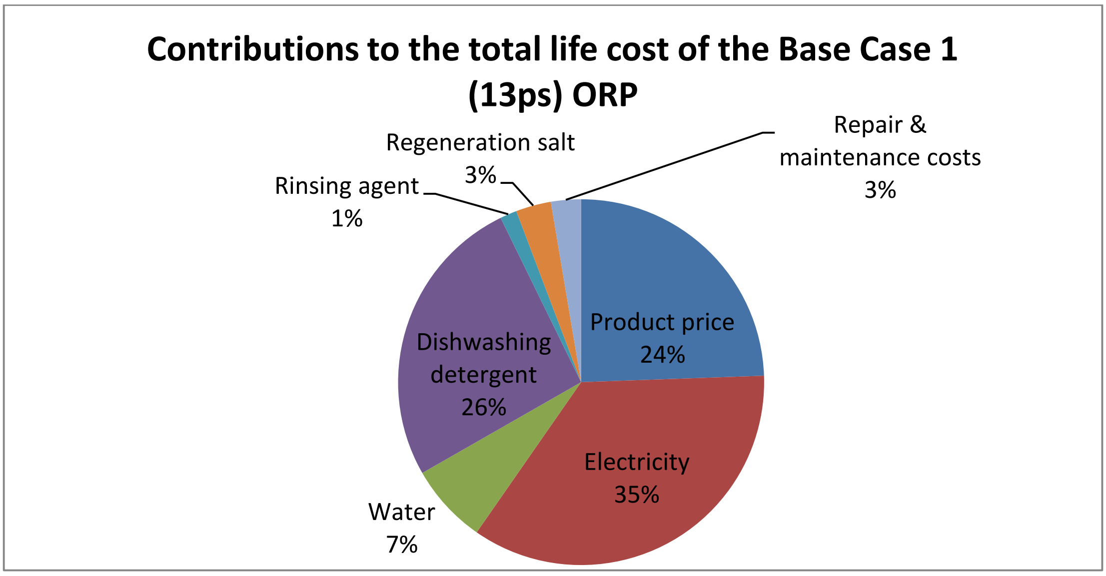


Figure 5.5: Relative contributions of costs to the total life cycle cost of Base Case 1 (13 ps) – ORP

5.3.2. Sensitivity Analyses

5.3.2.1. Discount rate = 0%

Table 5.18 shows the results of the sensitivity analysis for Base Case 1.

The life cycle costs when applying a discount rate of 0% are higher compared to the base case. This results from the fact that in the base case both the discount and the escalation rate have the same value (4%), thus both effects compensate each other. By setting the discount rate to 0% only the escalation rate is effective, i.e. the operating expenses are increased over the time (the resulting present worth factor (PWF) is 16.45 years).

Two main effects can be seen:

- the overall LCC is higher compared to the base case, and
- the relative contribution of the purchase price at the overall LCC is lower (reduced from 33% to 27%) while the relative contribution from the utilities and auxiliaries is increased.

Similar results are obtained (not shown) if the observed retail price is considered. The overall LCC would be higher and the relative contribution of the purchase price at the overall LCC would be reduced (from 25 to 18%). The relative contribution from the utilities and auxiliaries are increased too.

As a result from the latter effect, the additional costs of design options would payoff quicker if a discount rate of 0% is applied.

Table 5.18: Life cycle costs – sensitivity analysis "discount rate = 0%" (over the whole product life cycle, in euro) – calculated with the RRP

	Base Case 1 (13 ps) discount rate = 4%		Sensitivity: discount rate = 0%	
	Absolute LCC (**€**)	Relative contribution	Absolute LCC (**€**)	Relative contribution
Product price	800	33%	800	27%
Electricity	758	31%	998	34%
Water	152	6%	200	7%
Dishwashing detergent	560	23%	737	25%
Rinsing agent	32	1%	41	1%
Regeneration salt	67	3%	88	3%
Repair & maintenance costs	57	2%	75	3%
Total	2 425	100%	2 939	100%

5.3.2.2. Higher repair frequency

Table 5.19 shows the results of the sensitivity analysis for Base Case 1.

When considering higher costs for maintenance and repair, i.e. a repair rate of 50% resulting in repair costs of 77.5 € per appliance (instead of a repair rate of 37% resulting in repair costs of 57 € per appliance) the share of the costs for maintenance and repair slightly increases from 2.35% to 3.17% (for the RRP). When considering lower costs for maintenance and repair, i.e. a repair rate of 25% resulting in a repair costs of 38.75 € per appliance the share of the costs for maintenance and repair slightly decreases (from 2.35 to 1.61%). This indicates that the uncertainty of the repair costs does not have a significant impact on the overall LCC of the machine.

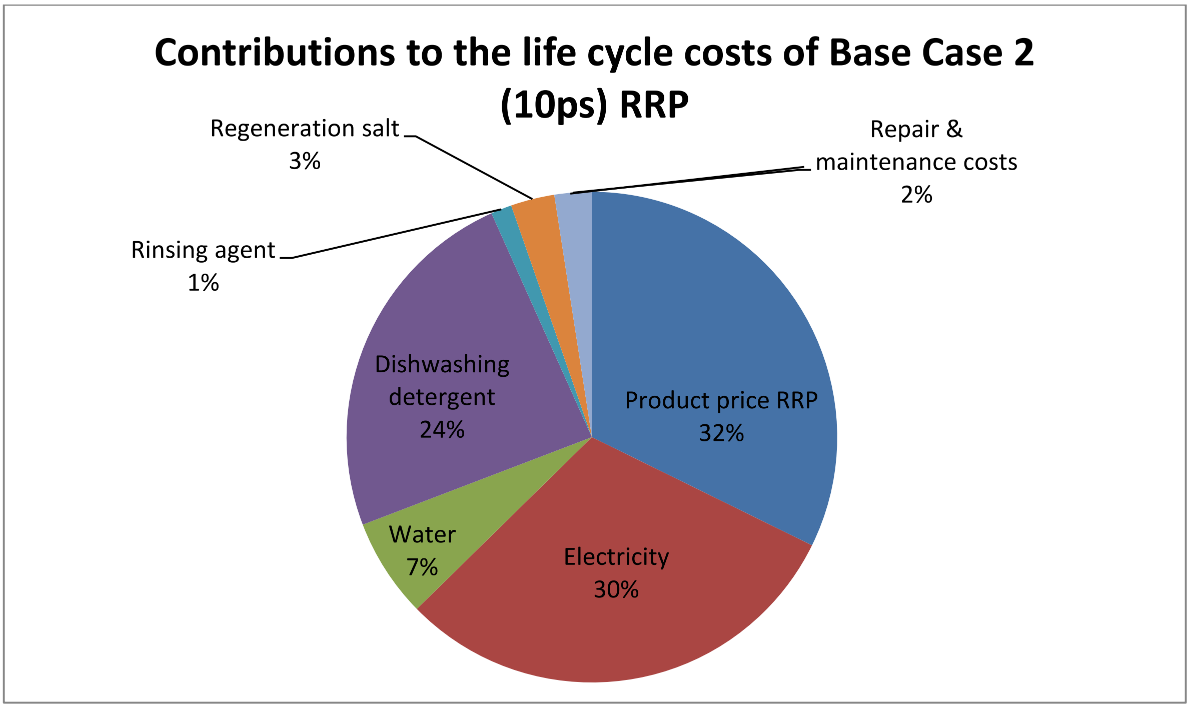
Similar results are obtained if the observed retailed prices (ORP) instead of the recommended retail prices (RRP) are considered (not shown).

Table 5.19: Life cycle costs – sensitivity analysis "higher repair rate/cost" (over the whole product life cycle, in euro)

	Sensitivity: lower repair rate		Base Case 1 (13 ps)		Sensitivity: higher repair rate	
	Absolute LCC (**€**)	Relative contribution	Absolute LCC (**€**)	Relative contribution	Absolute LCC (**€**)	Relative contribution
Product price (RRP)	800	33.2%	800	33.0%	800	32.7%
Electricity	758	31.5%	758	31.3%	758	31.0%
Water	152	6.3%	152	6.3%	152	6.2%
Dishwashing detergent	560	23.3%	560	23.1%	560	22.9%
Rinsing agent	32	1.3%	32	1.3%	32	1.3%
Regeneration salt	67	2.8%	67	2.7%	67	2.7%
Repair & maintenance costs	39	1.6%	57	2.4%	78	3.2%
Total	2 407	100%	2 425	100%	2 446	100%

5.3.3. Life cycle costs of Base Case 2 (10 place settings)

The contribution of the different cost elements are shown in Figure 5.6 for the Base Case 2 (10ps). The largest contributions to the overall costs are again the purchase price and the expenditures in electricity and dishwashing detergents. As for Base Case 1 the costs for electricity consumption and dishwashing detergent exceed the investment costs. Compared to Base Case 1 the share of electricity costs and the shares of dishwashing detergent and water consumption are slightly higher. These differences are however negligible.



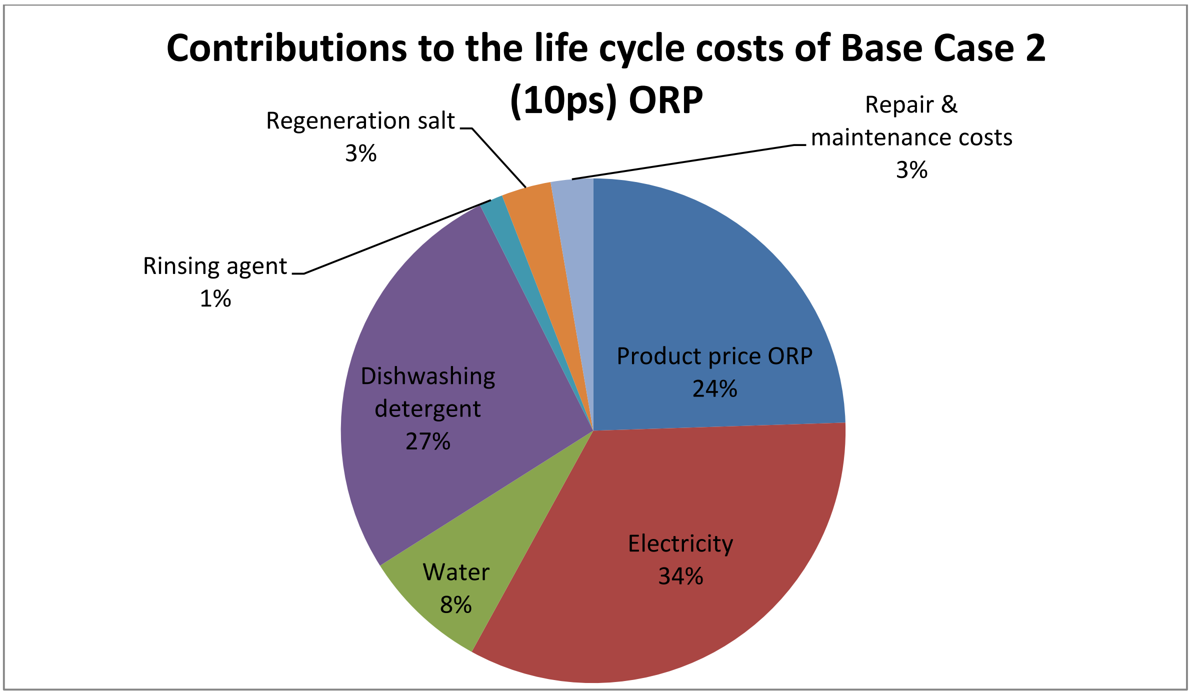


Figure 5.6: Relative contributions of costs to the life cycle cost of Base Case 2 (10 ps)

5.3.4. Comparison of the LCC using the Eco programme vs. real-life conditions

Table 8.18 in the annex shows the LCC per product both when using only the Eco programme and under real-life conditions (calculations based on the RRP as the purchase price).

The electricity and water costs when using only the Eco programme are lower compared to the real-life conditions. The electricity costs are 8% (BC1) and 10% (BC2) lower when assuming a 100% Eco programme scenario than under real-life conditions. The water costs are 11% (BC1) and 15% (BC2) lower in that case. This difference is due to the higher electricity and water consumption under real-life conditions (see section 5.1.1.4). Equal or similar results are obtained if the calculations are based on the ORP since the costs of the utilities remain constant.

The differences between the total LCC in the 100% Eco programme scenario and under real-life conditions are rather small (around 3% for both base cases).

5.4. EU totals

The environmental impacts and the LCC under real-life conditions are aggregated using stock and market data indicating

- the life cycle environmental impact of all new products designed in 2014 (reference year),
- the annual environmental impacts of the stock of dishwashers in 2014 (including production, use and end-of-life),
- the annual monetary costs for consumers (also for 2014) (including acquisition, use and maintenance and repair).

Table 5.20 shows the environmental impacts of all new dishwashers produced in 2014 over their lifetime under real-life conditions.

Table 5.20: Life cycle environmental impacts of all new dishwashers reflected for both base cases (real-life usage) produced in 2014 (over their lifetime)

	Unit	Base Case 1 (13 ps, real-life)	Base Case 2 (10 ps, real-life)	Total
Resources & Waste				
Total Energy (GER*)	PJ	315.6	47.4	363.0
of which, electricity (in primary PJ)	PJ	269.2	40.5	309.7
Water (process)	mln. m^3	404.3	72.8	477.1
Water (cooling)	mln. m^3	19.6	2.8	22.4
Waste, non-haz./ landfill	Kt	379.3	56.7	436.0
Waste, hazardous/ incinerated	Kt	5.8	0.9	6.7
Emissions (Air)				
Greenhouse Gases in GWP100	mt CO_2 eq.	14.1	2.1	16.2
Acidification, emissions	kt SO_2 eq.	71.2	10.7	81.9
Volatile Organic Compounds (VOC)	Kt	5.9	0.9	6.8
Persistent Organic Pollutants (POP)	g i-Teq	4.1	0.6	4.7
Heavy Metals	ton Ni eq.	18.3	2.7	21.0
PAHs	ton Ni eq.	1.9	0.3	2.2
Particulate Matter (PM, dust)	Kt	29.5	4.1	33.5
Emissions (Water)				
Heavy Metals	ton Hg/20	8.3	1.2	9.5
Eutrophication	kt PO_4	34.2	5.6	39.8

*GER stands for Gross Energy Requirement

Table 5.21 shows the annual environmental impact of the stock of dishwashers in the reference year (2014). The stock refers to

- the environmental impact through the production of the annual sales of DW in the reference year
- the environmental impact of 1 year use of the whole stock

- the end-of-life treatment of the amount of dishwashers discarded in that year (according to the EcoReport tool: "simplified model assuming produced = EoL")

Table 5.21: EU Total Impact of STOCK of Dishwasher in reference year 2014 (produced, in use, discarded) (real-life conditions)

	Unit	Base Case 1 (13 ps, real-life)	Base Case 2 (10 ps, real-life)	Total
Resources & Waste				
Total Energy (GER)	PJ	304	46	349
of which, electricity (in primary PJ)	PJ	258	39	297
Water (process)	mln. m^3	387	70	456
Water (cooling)	mln. m^3	19	3	22
Waste, non-haz./ landfill	Kt	373	56	428
Waste, hazardous/ incinerated	Kt	6	1	6
Emissions (Air)				
Greenhouse Gases in GWP100	mt CO_2 eq.	14	2	16
Acidification, emissions	kt SO_2 eq.	69	10	79
Volatile Organic Compounds (VOC)	Kt	6	1	7
Persistent Organic Pollutants (POP)	g i-Teq	4	1	5
Heavy Metals	ton Ni eq.	18	3	21
PAHs	ton Ni eq.	2	0	2
Particulate Matter (PM, dust)	Kt	29	4	33
Emissions (Water)				
Heavy Metals	ton Hg/20	8	1	9
Eutrophication	kt PO_4	33	5	38

Table 5.22 shows the total annual consumer expenditure of all EU consumers for 2014.

Table 5.22: Annual consumer expenditure of all EU consumers for 2014 under real-life conditions (in Euro) (including annual sales of 2014 (product price) and annual usage of stock (electricity, water, detergents, repair + maintenance)) (assuming RRP)

	Unit	Base Case 1 (13 ps)	Base Case 2 (10 ps)	Total	Total %
Product price	Million €	5 949	908	6 857	36
Electricity	Million €	4 984	756	5 741	30
Water	Million €	1 000	181	1 181	6
Dishwashing detergent	Million €	3 681	599	4 280	22
Rinsing agent	Million €	207	34	241	1
Regeneration salt	Million €	437	71	508	3
Repair & maintenance costs	Million €	375	61	436	2
Total	Million €	16 633	2 610	19 243	100

6. Task 6: Design options

As outlined in section 5.1.1 the electricity consumption of the Eco programme of BC1 (13 ps) is 268 kWh/year which represents almost an A++ appliance (the threshold for 13 ps appliances is 263 kWh/year). In this task different design options to improve the energy efficiency and their impacts are discussed.

In case of BC2 (10 ps) the electricity consumption of the Eco programme is estimated 245 kWh/year. This represents almost an A+ appliance (the threshold for 10 ps appliances between A and A+ is 238 kWh/year). Compared to standard dishwashers (BC1), slim line dishwashers face greater challenges to reach the same energy efficiency class due to their worse surface to volume ratio, space restrictions and a different basis for the calculation of the standard annual energy efficiency. The technical configuration of A+ slim line dishwashers can therefore be considered as equivalent to that of A++ standard dishwashers.

6.1. Options

6.1.1. Selection of single design options

In Task 4, several technologies that are applied or can be applied to dishwashers in the future have been described in detail. Those that are not yet widely applied are considered as design options for household dishwashers. These options are further analysed in this section and applied to the BC. Table 6.1 summarizes and clusters the initial design options and provides rationales for being further analysed or not in the following sections.

Table 6.1: Overview of design options for household dishwashers

Improvement options	Description	Rationales for the selection of design options for further follow-up
Option 1: Reduction of thermal losses	During a dishwashing cycle a part of the energy used for heating up the water and the dishes is lost. Examples to reduce those thermal losses are: 1a) Improved insulation of the appliance 1b) Heat exchanger (water buffering tank) 1c) Cross flow heat exchanger (with storage tank)	1a) Not chosen as considered to be fully optimised. 1b) integrated in option 2a 1c) integrated in option 2a
Option 2: Improved drying systems	Usually, the dishes are heated at the end of the cycle in a final hot rinse phase for drying. For reducing the energy demand in that phase, alternative drying technologies have been developed. Examples are: 2a) Heat exchanger (water tank) fostering the condensing of the hot vapour at the tub walls and thus the drying of the dishes 2b) Automatic door opening systems facilitating the hot air escaping from the dishwasher (partly including a fan) 2c) Fan for better air circulation (partly including condensing unit) 2d) Adsorption drying technologies (like Zeolith®, or others); 2e) Direct heating of load that avoids the last hot rinse, i.e. avoiding rinse water to be heated up additionally	1b) + 1c)+ 2a) chosen as "heat exchanger" 2b) chosen 2c) chosen 2d) chosen 2e) not chosen. The last rinse takes place with warm water to remove remaining soil from the dishes. Thus, apart from the difficulties in heat transfer to the dishes without water, the cleaning performance could be worse if the last rinse would be with cold water only.

Improve-ment options	Description	Rationales for the selection of design options for further follow-up
Option 3: Time-tempera-ture - trade off	Using lower temperatures in dishwashers, e.g. in the final hot rinse phase, combined with increasing cycle times. This ensures the same cleaning and drying performance with lower energy consumption for heating. Examples are: 3a) Extension of programme duration and lowering of the final hot rinse temperature - moderate scenario (e.g. 4 hours) 3b) Extension of programme duration and lowering of the final hot rinse temperature - extreme scenario (e.g. 6 hours)	3a) chosen 3b) Currently the average duration of the Eco programme is 196 min (see Table 5.3), which has not changed during the past 2 years (see section 2.2.3.1). Therefore it seems that for the current standard conditions (mainly regarding soil-ing), it is not an option to increase the time up to e.g. 6 hours.
Option 4: Alternative heating systems	Alternative heating systems to reduce the electricity demand of the dishwasher for heating up the water by external heating sources. Examples are: 4a) Heat pump technology: 4a1) either with common refrigerant R134a or 4a2) with alternative refrigerant with lower GWP (e.g. pro-pane, isobutane) 4b) Heat-fed machines: the electric heating elements of the appliance are replaced by a hot water circulation loop that, using a heat exchanger, transfers the heat from the hot water circulation to the machine. The appliance itself is connected to the cold water tap. The cleaning water is not heated up by an electric resistance heater but by a hot water heat exchanger which is fed by the hot water delivery by the dwelling generat-ed e.g. by central or district heating. 4c) Hot fill (connection of the appliance to a hot water supply), i.e. the machine is directly fed with external hot water that is used as the wash water and less water has to be heated up internally by the machine itself.	4a1) chosen as BAT for BC 1. 4a2) considered as BNAT 4b) not chosen as dishwashers are usually located in the kitchen with a large distance to a possible hot water storage. 4c) discussed separately: almost all dishwashers on the market can be connected to hot water without any modification. Therefore the technol-ogy can be considered as standard. However, in real-life it does not take place very often and it is advanta-geous only under certain conditions. Moreover, this option cannot be combined with other options, e.g. heat exchanger for better drying (with cold water) or the adsorption drying technologies. For compara-tive reasons the potential will be discussed based on existing de-tailed research (see section 6.1.3).
Option 5: Increased motor efficiency	Compared to universal commutator motors with brushes, more energy efficient motors become common in household dish-washers. Advantages are also claimed in terms of lower noise, partly less volume and weight, and longer lifetime due to the absence of brushes which are more prone to wear. Examples are: 5a) Brushless, inverter driven asynchronous DC motors 5b) Brushless, permanent magnet synchronous DC motors (PMSM)	5a) and 5b) not chosen as assumed that most appliances on the market already have a brushless DC motor (BLDC).
Option 6: Sensors and automatic controls	Certain electronic controls might support the adaptation of energy, water and detergent consumption to specific loads and soiling. Examples are: 6a) Soil sensor 6b) Load sensor 6c) Automatic detergent dosage systems which is supposed to reduce misdosing (under- or overdosing)	6a) and 6b) chosen: advanced sensor technology (turbidity sensor, water level measurement, tempera-ture measurement) to adapt the wash programme to the different loads and soiling levels. 6c) Not considered as there are currently no automatic detergent dosage systems on the market. Beko has shown a prototype on IFA 2015, but this is not yet available on the market and the performance

Improvement options	Description	Rationales for the selection of design options for further follow-up
		is not yet verified. It is also not considered as BNAT as automatic detergent dosage is not assumed to bring further benefits in terms of energy and/or water savings.
Option 7: Alternative spraying / water systems	Examples are: 7a) "Water wall" (a line of spray jets that move back and forth along the bottom of the tub) instead of rotating spray arms 7b) "Powerclean technology" (high-pressure nozzles at the rear wall of the appliance). It allows different treatments in the same cycle, e.g. for pre-cleaning, delicate dishes or heavily soiled dishes).	7a) not chosen, so far no effect on energy efficiency has been detected. Explicitly developed to improve cleaning performance (e.g. in the edges of the lower basket). 7b) not chosen as no benefits in terms of energy savings were documented
Option 8: Consumer feedback mechanisms	Feedback to consumers via LCD display on certain parameters might lead to optimized consumer behaviour in terms of e.g. loading and dosage. Examples are: 9a) Displaying a detergent dosage recommendation 9b) Indication of the energy and water demand of the chosen programme	9a) not chosen as most people use tabs and therefore this has no influence on detergent consumption. Moreover, in the standard testing protocol the amount of detergent is fixed. 9b) chosen. Providing information could influence consumer behaviour to some extent.
Option 9: Smart appliances	Examples are: 10a) Internet connectivity 10b) Electronic update of the programmes / diagnostics in case of failures 10c) Smart grid ready (SG-ready)	10a), 10b) and 10c) not chosen as they do not provide direct improvement potential on energy efficiency
Option 10: Material selection	The choice of materials might not have direct impacts on the energy or water consumption of dishwashers but might improve the overall resource efficiency or durability of the appliances. Examples are: 11a) Use of recycled plastic 11b) Increased durability of the appliance (e.g. increasing the durability of the materials and components used)	11a) not chosen, currently no possibility to systematically use recycled plastic 11b) chosen and discussed in section 6.1.4.2

6.1.2. Assumptions regarding the selected design options

Based on a questionnaire, manufacturers were asked to provide specific technical and cost data of the above listed design options and combinations thereof. To assess the design options, stakeholders were also asked to estimate the current and likely future market penetration of certain improvement options as well as to give an indication of which of the single options are compatible with other options. No information on the market penetration has been provided.

Comparisons are made to the base cases (BC1 and BC2) which are defined in section 5.1.1. Stakeholders were asked to provide information about changes induced by the design options compared to the base cases with regard to:

- Performance parameters (energy and water consumption, noise, cycle time)

- Variation of material resources (compared to the BoM of the base cases)
- Manufacturing costs, maintenance and repair costs
- Product lifetime

Based on this input and additional expert knowledge, the project team has assumed the input for further calculations as described in the following sections.

6.1.2.1. Environmental saving potential

In case of the single design options, *average values* for the saving potential of the different options have been taken into account. This results from the fact, that there is a variety of technical realizations of some options (e.g. heat exchangers). Also the "longer programme duration" seems to be a design option that cannot be realised as such, but that comes along with certain single design options. The degree of prolongation and the resulting saving potential therefore might vary.

These average saving potentials have been derived as follows:

1. Where applicable and taking into account respective stakeholder feedback, the absolute and relative saving potential (in terms of energy and water) was determined for the Eco programme of the Base Case 1 (13 ps).
2. The relative saving was applied to the other programmes, sometimes with exceptions: e.g. it is assumed that in the rinse/rinse & hold programme some of the technologies are not applied, that the moderate increase of programme duration only affects the Eco programme or that the savings through more advanced sensors are not relevant for the Eco programme as this programme is running without active sensors.
3. In case of appliances equipped with a heat pump, the savings of the various programmes compared to the equivalent appliance without a heat pump (as outlined in the user manual) are taken as saving potential of the heat pump as single design option (the appliance currently on the market comprises also other design options, e.g. automatic door opening and a fan, see also section 4.3)
4. For estimating the savings through consumer feedback mechanisms no savings in the Eco or other programmes are established. Savings result from a shift in programme usage under real-life conditions. 10% more use of Eco programme is assumed and 5% less use of normal 45-55°C and normal 60-65°C each.
5. The changes in material composition are an estimation based on the additional components.
6. In case of Base Case 2 (10 ps)
    a. Where no specific data were available, it is assumed that the relative saving potential derived for Base Case 1 can be applied to Base Case 2.
    b. Other assumptions are the same as for Base Case 1 (e.g. for which programme the savings are valid, shift in real-life programme usage, etc.).
    c. The changes in material composition are slightly adapted (reduction by 20% due to the smaller size).

All percentage values are given in rounded values – the calculations are made with the exact figures.

6.1.2.2. Additional costs

Obviously, the assumptions regarding the price increase due to the implementation of certain design options are characterized by a level of uncertainty:

- Usually for each design option there are several versions/models on the market (with slightly differing properties regarding reachable energy saving, durability or convenience for the consumer) which results in different manufacturing costs for this option.
- A certain increase in manufacturing cost does not necessarily result in a fix increase of the retail price. As already outlined in section 5.1.2 there is no fix correlation between the recommended retail prices (RRP) and the observed retail prices (ORP). The difference between both prices depends, to a large extend on the retailer, the trade channels, the brand and also the time (e.g. in case of special sales).
- the price itself is variable in time (see e.g. Ecofys (2014); Siderius (2014)) and
- the price assumption can be derived differently either based on the manufacturing costs (bottom-up calculation) or according to the price differences which are achievable / apparent on the market.

The last two bullet points usually go hand in hand and result in higher prices for the consumers for design options at the beginning of their market introduction and lower prices after a certain time.

Usually only few models are equipped with an option that is only recently introduced in the market. This can result in higher manufacturing costs, e.g. because certain manufacturing steps are done manually or with a lower degree of automation. At that moment, often only a limited number of manufacturers offer the design option that is incorporated in high-end machines (the new design option is a unique selling proposition). Additionally the new design option is often combined with other high-end features and manufacturers can follow a product differentiation strategy. Altogether this allows manufacturers to request higher purchase prices which often results in higher margins for those newly developed products. This means that at the beginning of market introduction the price is high and will depend on the price achievable on the market.

After a certain time, when the design option becomes more popular and is implemented in a larger number of models, the manufacturing costs and consequently the purchase prices tend to decrease. This is mainly due to two effects: the escalation factor and the learning curve. The first one involves the cost savings due to the production of a large number of items and the decrease in the proportional fix costs. The learning curve includes the effect of improving the production process due to the gained experience. Additionally, the new design option is no longer a unique selling proposition as other manufacturers offer products with that option as well and manufacturers tend to apply a differentiation cost strategy. Therefore the purchase price achievable on the market decreases. The price is now similar to the bottom up calculated price (starting from the manufacturing costs).

Most design options at hand already reached a certain maturity level and it can be assumed that the additional purchase price is close to the bottom-up calculation starting from the manufacturing cost. For example, BC 1 has an annual energy consumption of 268 kWh which is only slightly below the threshold to energy efficiency class A++. To reach this class at least one out of the three design options “D1 – heat exchanger”, “D2 – automatic door opening” or “D3 – fan for better air circulation” has to be incorporated into the dishwasher. This means that these three design options are mature enough to be massively manufactured and included in (almost) any average dishwasher. The additional costs attributed to the design options can therefore be assumed to be competitive and approximately equal to the increase in costs calculated by means of a bottom up method that starts from the manufacturing costs.

Further cost estimations only take into account the increase of costs related to the design options due to the manufacturing cost. Other features that can raise the purchase price and which usually go together with premium models (e.g. better aesthetics, market positioning, etc.) are not taken into account. Therefore the calculated purchase price could be lower than the real market price of machines equipped with certain improvement options. This is especially true for the heat pump as design option as this option has been implemented only recently (in 2014) and by one manufacturer only.

The changes in material composition and the additional material costs are estimated based on the additional needed components. The assumptions on the cost increase of the design options combine both any additional material costs and any additional costs for the manufacturing process itself. Starting from the estimated manufacturing costs and following the bottom-up approach, the increase of the purchase price is calculated with the same assumptions as outlined in section 5.1.2.

Regarding the costs for repair and maintenance, it is assumed that small incremental changes in product energy efficiency produce no changes in repair and maintenance costs compared to that of the base case. However, dishwashers having significantly higher energy efficiencies (such as those equipped with heat pumps) are more likely to incur higher repair and maintenance costs, because their increased complexity and higher part count typically increases the cumulative probability of failure. In case of D6 (heat pump) therefore additional repair costs are assumed. Following the same reasoning as in case of the base case assumptions (see section 5.1.2) of having 37% of dishwashers to be repaired once per lifetime, it is assumed that the reparation of heat pump equipped dishwashers will cost 200 Euros instead of 155 Euros, leading to an additional cost of 17 Euros for every dishwasher equipped with a heat pump (resulting in 74 euros for repair and maintenance instead of 55 Euros).

The manufacturing costs of the design options are assumed to be the same both for Base Case 1 and for Base Case 2, in contrast to the additional material consumption which is assumed to be 20% lower compared to BC1.

6.1.3. Hot fill

“Hot fill” was not included as regular design option due to two reasons. First, it is possible to connect most dishwashers on the market to a hot water tap (i.e. to use the dishwasher with hot water, which is heated up by another water heating system). In contrast to washing machines, it is not necessary to have two inlet valves therefore the existing valve can be used either for the cold or for the hot water tap. Second, it is not clear and easily quantifiable with the EcoReport tool how beneficial the hot water connection is. The project team therefore decided to discuss the pros and cons of the hot water connection of dishwashers based on existing literature.

If the dishwasher is connected to hot water, it needs less electricity than if it was connected to cold water. The water has to be heated by another system however (e.g. usually district heating or central hot water generation systems) that also needs energy. The energy source of this alternative heating system is usually not electricity and therefore the energy consumption cannot be summed up easily. It should be done by using other indicators (like the primary energy consumption or the global warming potential) to enable a possible comparison.

The hot water has to be led through the building to the dishwasher. Thus conduction losses occur e.g. in the water storage tank, in the circulation pipe and in the water stub line. Usually only the losses in the water stub line are attributed to the dishwasher use if it is connected to hot water.

According to Bush & Nipkow (2005) and Gensch et al. (2009), the environmental and cost savings through hot water connection of a dishwasher depend on various framework parameters. Gensch et al. (2009) conducted a detailed study to analyse the saving potential with regard to these parameters. They took into account

- different electricity and hot water generation systems of four different European countries (Germany, France, Spain and Sweden),
- differences in pipe lengths and insulation,
- five dishwasher types (models) with different technology.

The main results are:

- It is not possible to draw general conclusions with regard to possible environmental advantages of hot water connection of dishwashers. The conclusions are only valid under certain framework conditions.
- The savings in electricity consumption vary depending on the technology used in the dishwashers. The relative savings lie between -18% and -44% (corresponding to 0.14 and 0.52 kWh/cycle). If the dishwasher already includes other energy saving technologies (e.g. heat exchanger or adsorption technology), further energy savings are smaller compared to less optimised dishwashers.
- The differences due to the type of electricity or the type of warm water generation used for heating up the wash water (e.g. green electricity or not, country specific differences) are bigger than the differences due to the cold or hot water connection of the dishwasher within a given system.
- The saving potential regarding the GWP and primary energy consumption indicators depends on
- The type of electricity generation: For example, if the electricity generation has a low GWP (as it is the case in France and Sweden due to their high share of nuclear power), the hot water connection only leads to savings regarding the GWP indicator if:
- 1) the dishwashers are not otherwise optimised, e.g. by design options like heat exchanger or adsorption drying technology
- 2) the water stub line is at most 5 m long and
- 3) the water is heated by solar thermic warm water generation.
- The type of warm water generation: e.g. in Germany the hot water connection results in savings in the GWP indicator in all scenarios if the warm water is generated by solar thermic or biomass generation.
- The dishwasher technology: if the dishwasher already includes other energy saving technologies, further savings are smaller compared to less optimised dishwashers.
- The length and insulation of the water stub line: the difference in the saving potential (GWP, primary energy consumption) between stub lines with a length of 0 and 10 meter vary between 5 and 13% (depending on indicator and dishwasher technology).

The following examples illustrate the differences between the electricity and warm water generation and the dishwasher type (Legend: green shadow means a decrease of GWP score of more than 10%, and red shadow means an increase of GWP score of more than 10% compared to cold water connection of the respective dishwasher in the given system).

Example 1 (high GWP savings): Germany, conventional electricity generation, medium pipe length (5 m)

Table 6.2: Relative GWP through hot water connection (example 1)

Type of warm water generation	Cold water connection	District heating	Natural gas	Oil	Biomass	Solar thermic (combined with natural gas)
Dishwasher Type “M1 (GV640)”	100%	88%	92%	97%	76%	80%
Dishwasher Type “EuP reference (GV 600)”	100%	77%	82%	89%	62%	67%
Dishwasher “M3” (with zeolite technology)	100%	96%	101%	107%	82%	88%

Source: Gensch et al. (2009)

Example 2 (low GWP savings): Sweden, conventional electricity generation, medium pipe length (5 m)

Table 6.3: Relative GWP through hot water connection (example 2)

Type of warm water generation	Cold water connection	District heating	Oil	Bio-mass	Solar thermic (combined with biomass)
Dishwasher Type "M1 (GV640)"	100%	209%	240%	99%	90%
Dishwasher Type "EuP reference (GV 600)"	100%	235%	276%	92%	80%
Dishwasher "M3" (with zeolite technology)	100%	239%	276%	110%	99%

Source: Gensch et al. (2009)

In light of the results of this study, it is questionable to encourage consumers to use hot fill for dishwashers in general. Not only does the saving potential of the hot fill vary to a great extent, it even might result in an overall increase of energy consumption. Thus, if a measure is to be proposed, it would have to accommodate all the installation variables described, and be conditional to the combination of variables that can ensure a net energy and financial benefit.

6.1.4. Durability

6.1.4.1. Cycle time and life time of dishwashers

Given the average dishwasher durability, and the durability of brushless motors, it is assumed that longer programme cycle times do not lead to a shorter life time of a dishwasher. Longer operating hours of motors do not lead to more wear and tear in case of brushless motors which are currently the most used motor technology. In addition, in the Eco programme the motor usually does not work in full power mode for most of the time, as for example the spray arms are used alternatingly. Also, the reached temperatures are lower. All these aspects lead to lower strain on the motor and other parts of a dishwasher. Moreover, a longer cycle time is usually related to a longer drying phase where the machine is basically waiting for the dishes to dry and not in operating mode.

6.1.4.2. More durable materials/products

Durability is not included as a design option, as the necessary calculations would be too complex to be performed by the EcoReport tool. This would imply not only taking into account alterations at current dishwashers but also forecasting future efficiency gains. Environmental impact benefits due to a life time extension strongly depend on the energy consumption of future dishwashers. Therefore this aspect is discussed separately and based on existing literature.

Ardente & Talens Peirò (2015) report on the benefits and costs/impacts of options for different potential material efficiency requirements for dishwashers. They first conduct a literature review on the available environmental impact assessments of dishwashers. The main conclusion drawn is that design for disassembly and recycling is very important in case of dishwashers as the possibility of the extraction of valuable materials (mainly copper and printed circuit boards containing other precious metals) differs significantly depending on the design of the dishwasher.

Secondly, they conduct an LCA analysing the environmental impacts of four life cycle stages (production of materials, manufacture, use and disposal) with respect to 13 environmental impact categories. For the use phase the electricity and water consumption are taken into account, but not the detergent, regeneration salt consumption and the rising agent consumption. The use phase has the highest impact in 10 out of the 13 the impact categories. The production of materials dominates the categories "abiotic depletion", "freshwater eutrophication" and "ecotoxicity". The disposal mainly contributes only to "freshwater eutrophication" due to the impact of landfilling plastic parts. The manufacturing process has only very low environmental impacts (below 1% in all categories).

Finally, they apply the REAPro method to dishwashers (Resource Efficiency Assessment of Products, see Ardente & Mathieux (2012) aiming at estimating the best option for increasing the resource efficiency in this product. Two end-of-life scenarios are distinguished: scenario 1 is a shredding based scenario with little manual treatment, scenario 2 consists of a preliminary manual disassembly followed by one or two shredding phases (combined treatment). The two scenarios are compared with regard to several indicators:

- Reusability/Recyclability/Recoverability index (in mass): No relevant differences between the scenarios with regard to these indicators were found. In both cases the majority of material losses results from landfill of bitumen and wood parts and to the partial recovery of ferrous metals.
- Reusability/Recyclability/Energy Recoverability benefit rate indexes: only with regard to the recyclability benefit rate relevant differences between the scenarios were found. Due to the higher recycling rates of some precious metals and copper in scenario 2, the impacts on abiotic resource depletion and ecotoxicity are significantly lower.
- Recycled content rate / recycled content benefit index: The main conclusion is that the use of recycled plastic parts for the manufacturing of a dishwasher has lower relevance in its environmental impact from a life-cycle perspective.

With regard to the use of hazardous substances, printed circuit boards and LCD screens are seen as relevant components.

Ardente & Talens Peirò (2015) also calculate a durability index: the savings due to a possible 1 to 4 years life time extension of a dishwasher were calculated by taking into account differences in the energy efficiency of the new appliance (the use of a new possibly more energy efficient appliance is postponed by the same period of time that the life time extension of the old one). The most important findings are:

- The extension of the life time of the dishwashers saves up to 30% of the environmental impacts that are mostly influenced by the material production (abiotic resource depletion, freshwater eutrophication and ecotoxicity). The improvement is only slightly influenced by the change in the energy efficiency of the new dishwasher.
- The possible savings with regard to the other impact categories strongly depend on the efficiency of the new appliance. The impact of life cycle extension is ambivalent with regard to the GWP. If the new dishwasher is at least 10% more efficient than the old one the overall GWP score increases due to the life time extension. If the new dishwasher has the same energy efficiency than the old one, the GWP score can be reduced by 3%.
- This means, that depending on the future development of the energy efficiency, it can be beneficial, from an environmental point of view, to extend the life time of a dishwasher as it will decrease the environmental impacts dominated by the use phase. For the other three impact categories, dominated by the other life cycle stages, the life time extension is beneficial in any case.
- The components most frequently subject to failures are identified to be the motor (circulation and drain pump), the piping equipment, electric and electronics and structural and interior parts.

Finally, Ardente & Talens Peirò (2015) identify and address potential measures for resource efficiency of dishwashers. These are measures to facilitate reparability, extended product warranties or better information for after sales service providers. It has to be noted that Ardente & Talens Peirò (2015) have based their investigation on the information provided in Lot 14 (see e.g. (ISIS 2007c)).

An updated work of Ardente & Talens Peirò (2015) was carried out by Tecchio et al. (2016). The updated study considers the same environmental impacts categories as the previous study but based their investigation on updated input from this preparatory study. The BoM, energy consumption and lifetime of the dishwasher are those considered for Base Case 1 (see Table 5.1 and Table 5.2) and they included in the analysis the detergents and regeneration salt consumption. The study points out again that the use and repair phase are the most relevant followed by the production phase. The first one is dominated by the energy consumption of electricity while the detergent consumption affects the majority of freshwater eutrophication, ozone depletion and marine eutrophication. The production phase contributes to more than 50% to freshwater toxicity, human toxicity, ozone depletion and abiotic depletion of elements (ADP elements). It is mainly the electronic components that are responsible for the environmental impacts in the production phase.

Tecchio et al. (2016) draw similar conclusions to Ardente & Talens Peirò (2015):

- Prolonging the lifetime of the dishwashers is environmentally beneficial for the GWP indicator in the large majority of the considered scenarios. Regarding GWP, it is convenient to prolong the lifetime of the dishwashers when the newer product replacing the old dishwasher is less than 15% more energy efficient In other words, it is better in terms of GWP to replace the old dishwasher after the average lifetime of 12.5 years than to prolong the lifetime if the new dishwasher is at least 15% more energy-efficient. As an example, it is calculated that "*prolonging the lifetime by 6 years would produce a decrease in the GWP indicator by about 2.7% compared to the replacement with a new machine which is 10% more energy efficient*"
- Regarding the ADP indicator, which is mainly affected by materials used during the production phase, it is shown beneficial to prolong the lifetime of the DW in any case. The ADP indicator can be reduced by about 45% when the operating life is extended by 6 years and about 7% for when the lifetime is extended with 1 year.

6.1.5. Assumptions regarding the combinations of design options

The selection of combinations of single design options is explained in detail in section 6.4.1. The selection of combinations is based on the simple payback periods of the single design options, stakeholder feedback on their combinability and a market research on existing appliances on the market. The following combinations were selected:

- C1: D3+D2 (fan, automatic door opening)
- C2: D3+D2+D1 (fan, automatic door opening, heat exchanger)
- C3: D5+D3+ D2+D7 (longer programme duration, fan, automatic door opening, improved sensors)
- C4: D5+D3+D2+D7+ D1 (longer programme duration, fan, automatic door opening, improved sensors, heat exchanger)
- C5: D5+D3+D2+D7+ D1+D8 (longer programme duration, fan, automatic door opening, improved sensors, heat exchanger, consumer feedback mechanisms)
- C6: D5+D7+D8+D1+ D4 (longer programme duration, improved sensors, consumer feedback mechanisms, heat exchanger, adsorption technology)
- C7: D5+D3+D2+D7+D8+D6 (longer programme duration, fan, automatic door opening, improved sensors, consumer feedback mechanisms, heat pump)

In this section the assumptions regarding the environmental saving potential and the additional costs are outlined.

The combination of the design options is considered as a second degree of interaction between the single design options. When implementing multiple design options in the same dishwasher, the resulting environmental improvement is expected to be smaller than the sum of the environmental improvements per individual option. In other words, if a dishwasher has been already improved with one design option, every consequent design option will only realize a part of its individual potential. This is one of the reasons why the energy savings are not the direct sum of the single design options that the combination consists of.

Additionally, in case of the single design options, *average values* for the saving potential of the different options were considered (see section 6.1.2). In case of the combinations, however, where available the consumption values of existing appliances equipped with the combination of design options, are used. This partly results in higher savings of the combinations than the sum of the savings of the combined single design options as these appliances might combine the best available types of the respective design options.

For example, combination C4 consists of the single design options D5, D2, D7, D3 and D1 (i.e. longer programme duration, automatic door opening, improved sensors, fan and heat exchanger). The sum of the average savings of these single options would result in a saving potential of 28% (in the Eco programme). In reality, there is a dishwasher on the market containing all these options. Its saving compared to the base case is 29%, i.e. even higher than the sum of the average savings of the single options. One possible explanation is that in that particular appliance for example a very efficient heat exchanger is included that results in higher savings than the average heat exchanger accounted for in the single options.

In summary, the savings of the single design options are average savings of the different variants of a certain design option, whereas the savings of the combinations are based on the saving of real appliances on the market that rather represent the best available variant of the respective single design option on the market.

The following concrete assumptions were made:

- Where available the electricity consumption values of existing appliances, equipped with the combination of design options, are used. This is especially the case for the combinations C1, C3, C4, C5 and C6.
- Stakeholder feedback on saving potential was taken into account,
- C7 (the combination containing the heat pump) is a hypothetical combination that, compared to the real appliance currently on the market, additionally includes the options D5 (longer programme duration), D3 (fan for better air circulation) and D8 (consumer feedback mechanisms). The assumed electricity saving is therefore slightly higher than that of the appliance currently on the market.
- The water consumption is only changed by combinations that include D7 (improved sensors) and D6 (heat pump). The reduction through the improved sensors is not applied to the Eco programme as no soil or load sensors are activated in the Eco programme. The change through the heat pump (which in fact is an increase) equals the differences of the water consumption between the dishwasher with heat pump and the equivalent appliance without heat pump (as outlined in the user manuals).
- The changes in material composition, the additional manufacturing costs and changes in maintenance and repair are assumed to be the sum of the changes of the single design options.
- It is assumed that the combinations of options do not result in changes in detergent consumption and life time.

The assumptions regarding the saving potential, the material composition, the manufacturing and the maintenance and repair costs of both single and combined design options are summarised in Table 6.4 and Table 6.6 (for BC1 and BC2 respectively).

The resulting absolute values of the energy and water consumption and the purchase prices are then outlined in Table 6.5 and Table 6.7 (for BC1 and BC2 respectively).

6.1.6. Summary: Assumptions regarding the single design options and combinations

Table 6.4: Selected design options (BAT) and estimation of alterations compared to the Base Case 1 (13 ps)

Improvement options BAT (NOTE: new numbering)	Alterations compared to BC 1 (%)				
	Energy consumption (Eco programme/ Real-life)	Water consumption (Eco programme/ Real-life)	Main changes in material composition	Manufacturing costs	Maintenance and repair costs
Base Case 1 (standard, 13 ps)	**0.96 kWh/cycle** (Eco) **1.04 kWh/cycle** (Real-life)	**9.8 liter/cycle** (Eco) **10.9 liter/cycle** (Real-life)	**n.a.**	**205 €**	**57 €**
Single design options					
D1: Heat exchanger for pre-warming incoming water and fostering the condensation in the drying phase	-0.05 kWh (=-5%) -5%*	n.a.	+ 0.5 kg PP	+10 € (water tank)	n.a.
D2: Automatic door opening system	-0.09 kWh (=-9%) -9%*	n.a.	Negligible	+8 € (special door lock with spacing actor)	n.a.
D3: Fan for better air circulation	-0.09 kWh (=-9%) -9%*	n.a.	Negligible	+5 €	n.a.
D4: Improved drying through adsorption technology	-0.12 kWh (=-12%) -12%*	n.a.	+ 1.3 kg zeolite + 1.5 kg steel + 0.25 kg plastics (PP)	+30 € (zeolite + tank + fan+ heating element)	n.a.
D5: Moderate increase of programme duration	-0.05 kWh (=-5%) -1%*	n.a.	n.a.	0 €	n.a.
D6: Heat pump with common refrigerant (R134a)***	-0.3 kWh (=-31%) -14%*	+2.2 L (= +23%) +12%*	+ 175 g R134a + 3.5 kg plastics + 3.0 kg copper + 9.5 kg steel	+150 € (compressor, 2 heat exchanger, phase change material, fan, control)	+17 €

Improvement options BAT (NOTE: new numbering)	Alterations compared to BC 1 (%)				
	Energy consumption (Eco programme/ Real-life)	Water consumption (Eco programme/ Real-life)	Main changes in material composition	Manufacturing costs	Maintenance and repair costs
D7: Advanced sensor technology	0% -4%*	0% -4%*	Negligible	+5 € (digital pressure sensor, digital temperature sensor)	n.a.
D8: Consumer feedback mechanisms	n.a. shift in programme choice: +10% Eco programme -5% normal 45-55°C -5% normal 60-65°C	n.a. like for energy consumption	Negligible	+5 € (sensors + display elements)	n.a.
Combinations of single design options					
C1: D3+D2 (fan, door opening)	-11% -11%	n.a.	Negligible	+13 €	n.a.
C2: D3+D2+D1 (fan, door opening, heat exchanger)	-16% -16%	n.a.	Negligible	+23 €	n.a.
C3: D5+D3+D2+D7 (programme duration, fan, door opening, improved sensors)	-20% -20%	n.a. -4%	Negligible	+18 €	n.a.
C4: D5+D3+D2+D7+D1 (programme duration, fan, door opening, improved sensors, heat exchanger)	-29% -29%	n.a. -4%	+ 0.5 kg PP	+28 €	n.a.
C5: D5+D3+D2+D7+D1+D8 (programme duration, fan, door opening, improved sensors, heat exchanger, feedback mechanisms)	-29% -31%	n.a. -7%	+ 0.5 kg PP	+33 €	n.a.
C6: D5+D7+D8+D1+D4 (programme duration, improved sensors, feedback mechanisms, heat exchanger, adsorption technology)	-21% -23%	n.a. -7%	+ 1.3 kg zeolite +1.5 kg steel +0.25 kg plastics (PP)	+50 €	n.a.

Improvement options BAT (NOTE: new numbering)	Alterations compared to BC 1 (%)				
	Energy consumption (Eco programme/ Real-life)	Water consumption (Eco programme/ Real-life)	Main changes in material composition	Manufacturing costs	Maintenance and repair costs
C7: D5+D3+D2+D7+D8+D6 (programme duration, fan, door opening, improved sensors, feedback mechanisms, heat pump)**	-52% -34%	n.a. +7%	+ 0.5 kg PP + 175 g refrigerant + 3.5 kg plastics (PP) + 3.0 kg copper + 9.5 kg steel	+173 €	+ 17 €

n.a.: not affected;

* average saving potential over all programmes under real-life conditions. Depending on the option not all programmes are affected, e.g. increase of programme duration is only applied to the Eco programme, advanced sensor technology is applied to all programmes except the Eco programme, etc. (see also section 6.1.2). Please note that all percentage values are given in rounded values. The calculations are made with the exact figures.

** heat pump dishwashers: a) the data on material composition is based on direct input by stakeholders, b) costs for maintenance and repair: following the same reasoning of 37% of dishwashers to be repaired, but now at 200 Euros instead of 155 Euros, thus plus 17 Euros for every dishwasher.

Note: As we state above "*It is assumed that the combinations of options do not result in changes in detergent consumption (20 g/per cycle) and life time (12.5 years)*." (See section 6.1.4.1 on cycle time and life time of dishwashers)

Table 6.5 shows the absolute values of the energy and water consumption for the base case and the selected design options. Both the values for the Eco programme and the real-life conditions are shown. The variation in purchase price is also shown.

Table 6.5: Overview of the purchase prices and absolute values of the energy and water consumption for Base Case 1 (13 ps) and the selected design options

	RRP/ORP*	Eco programme		Real-life conditions	
		Energy consump-tion	Water consump-tion	Energy consump-tion	Water Consump-tion
Unit	Euro	kWh/cycle	l/cycle	kWh/cycle	l/cycle
Base Case 1 (13 ps)	**800/526**	**0.96**	**9.8**	**1.04**	**10.9**
Single design options					
D1: Heat exchanger	839/552	0.91	9.8	0.99	10.9
D2: Automatic door opening system	831/547	0.87	9.8	0.95	10.9
D3: Fan for better air circulation	820/539	0.87	9.8	0.95	10.9
D4: Improved drying through adsorption technology	917/603	0.84	9.8	0.91	10.9
D5: Moderate increase of pro-gramme duration	800/526	0.91	9.8	1.03	10.9
D6: Heat pump with common refrigerant (R134a)	1385/911**	0.66	12.0	0.90	12.2
D7: Advanced sensor technology	820/539	0.96	9.8	1.00	10.5
D8: Consumer feedback mecha-nisms	820/539	0.96	9.8	1.01	10.6
Combinations of single design options					
C1: D3+D2 (fan, door opening)	851/559	0.85	9.8	0.92	10.9
C2: D3+D2+D1 (fan, door ope-ning, heat exchanger)	890/585	0.80	9.8	0.88	10.9
C3: D5+D3+D2+D7 (programme duration, fan, door opening, improved sensors)	870/572	0.76	9.8	0.83	10.5
C4: D5+D3+D2+D7+D1 (pro-gramme duration, fan, door opening, improved sensors, heat exchanger)	909/598	0.68	9.8	0.74	10.5
C5: D5+D3+D2+D7+D1+D8 (programme duration, fan, door opening, improved sensors, heat exchanger, feedback mecha-nisms)	929/611	0.68	9.8	0.72	10.2
C6: D5+D7+D8+D1+D4 (pro-gramme duration, improved sensors, feedback mechanisms, heat exchanger, adsorption technology)	995/654	0.75	9.8	0.80	10.2

	RRP/ORP*	Eco programme		Real-life conditions	
		Energy consump-tion	**Water consump-tion**	**Energy consump-tion**	**Water Consump-tion**
Unit	**Euro**	**kWh/cycle**	**l/cycle**	**kWh/cycle**	**l/cycle**
C7: D5+D3+D2+D7+D8+D6 (programme duration, fan, door opening, improved sensors, feedback mechanisms, heat pump)	1475/970	0.46	12.0	0.69	11.6

* RRP = Recommended Retail Price / ORP = Observed Retail Price

** The RRP and ORP of the heat pump equipped DW are lower than the purchase price observed on the market now. The prices presented here are the prices in a market where other manufacturers would also implement this design option. Currently, there is only one manufacturer providing this option resulting in a higher purchase price. Moreover, this manufacturer is based in Switzerland were prices for household appliances are usually higher than in EU28 (see also section 6.1.2.2).

Table 6.6: Selected design options (BAT) and estimation of alterations compared to the Base Case 2 (10 ps)

Improvement options BAT (NOTE: new numbering)	Alterations compared to BC 2 (%)				
	Energy consumption (Eco programme/ Real-life)	Water consumption (Eco programme/ Real-life)	Main changes in material composition	Manufacturing costs	Maintenance and repair costs
Base Case 2 (10 ps)	**0.87 kWh/cycle** (Eco) **0.97 kWh/cycle** (Real-life)	**10.3 liter /cycle** (Eco) **12.1 liter/cycle** (real-life)	**n.a.**	**133 €**	**57 €**
Single design options					
D1: Heat exchanger for pre-warming incoming water and fostering the condensation in the drying phase	-0.05 kWh (=-5%) -4%*	n.a.	0.4 kg PP	+10 €uro	n.a.
D2: Automatic door opening system	-0.08 kWh (=-9%) -8%*	n.a.	Negligible	+8 €	n.a.
D3: Fan for better air circulation	-0.08 kWh (=-9%) --8%*	n.a.	Negligible	+5 €	n.a.
D4: Improved drying through adsorption technology	-0,11 kWh (=-12%) -11%*	n.a.	+ 1.0 kg zeolite + 1.2 kg steel + 0.2 kg plastics (PP)	+30 €	n.a.
D5: Moderate increase of programme duration	-0.04 kWh (=-5%) -1%*	n.a.	n.a.	+0 €	n.a.
D6: Advanced sensor technology	0% -4%*	0% -4%*	negligible	+5 €	n.a.
D7: Consumer feedback mechanisms	n.a. shift in programme choice: +10% Eco programme -5% normal 45-55°C -5% normal 60-65°C	n.a. like for energy consumption	negligible	+5 €	n.a.

Improvement options BAT (NOTE: new numbering)	Alterations compared to BC 2 (%)				
	Energy consumption (Eco programme/ Real-life)	Water consumption (Eco programme/ Real-life)	Main changes in material composition	Manufacturing costs	Maintenance and repair costs
Combinations of single design options					
C1: D3+D2 (fan, door opening)	-11% -11%	-0% -0%	Negligible	+13 €	n.a.
C2: D3+D2+D1 (fan, door opening, heat exchanger)	-16% -16%	-0% -0%	+ 0.4 kg PP	+23 €	n.a.
C3: D5+D3+D2+D7 (programme duration, fan, door opening, improved sensors)	-20% -20%	-0% -4%	Negligible	+18 €	n.a.
C4: D5+D3+D2+D7+D1 (programme duration, fan, door opening, improved sensors, heat exchanger)	-29% -29%	-0% -4%	+ 0.4 kg PP	+28 €	n.a.
C5: D5+D3+D2+D7+D1+D8 (programme duration, fan, door opening, improved sensors, heat exchanger, feedback mechanisms)	-29% -32%	-0% -7%	+ 0.4 kg PP	+33 €	n.a.
C6: D5+D7+D8+D1+D4 (programme duration, improved sensors, feedback mechanisms, heat exchanger, adsorption technology)	-21% -24%	-0% -7%	+ 0.4 kg PP + 1.0 kg zeolite +1.2 kg steel +0.2 kg plastics	+50 €	n.a.

n.a. not affected;

* Average saving potential over all programmes under real-life conditions. Depending on the option not all programmes are affected, e.g. increase of programme duration is only applied to the Eco programme, advanced sensor technology is applied to all programmes except Eco programme etc. (cf. also section 6.1.2)
Note: As we state above "It is assumed that the combinations of options do not result in changes in detergent consumption (20 g/per cycle) and life time (12.5years)." (See section 6.1.4.1 on cycle time and life time of dishwashers)

Table 6.7: **Overview of the purchase prices and absolute values of the energy and water consumption for Base Case 2 (10 ps) and the selected design options**

	RRP/ORP*	Eco programme		Real-life conditions	
		Energy consumption	Water consumption	Energy consumption	Water consumption
Unit	**Euro**	**kWh/cycle**	**L/cycle**	**kWh/cycle**	**L/cycle**
Base Case 2 (10 ps)	**750/516**	**0.87**	**10.3**	**0.97**	**12.1**
Single design options					
D1: Heat exchanger	787/541	0.83	10.3	0.92	12.1
D2: Automatic door opening system	779/536	0.80	10.3	0.88	12.1
D3: Fan for better air circulation	768/529	0.80	10.3	0.88	12.1
D4: Improved drying through adsorption technology	860/592	0.77	10.3	0.85	12.1
D5: Moderate increase of programme duration	750/516	0.83	10.3	0.96	12.1
D6: Advanced sensor technology	768/529	0.87	10.3	0.93	11.6
D7: Consumer feedback mechanisms	768/529	0.87	10.3	0.94	11.7
Combinations of single design options					
C1: D3+D2 (fan, door opening)	798/549	0.77	10.3	0.86	12.1
C2: D3+D2+D1 (fan, door opening, heat exchanger)	834/574	0.73	10.3	0.82	12.1
C3: D5+D3+D2+D7 (programme duration, fan, door opening, improved sensors)	816/561	0.70	10.3	0.77	11.6
C4: D5+D3+D2+D7+D1 (programme duration, fan, door opening, improved sensors, heat exchanger)	852/586	0.62	10.3	0.69	11.6
C5: D5+D3+D2+D7+D1+D8 (programme duration, fan, door opening, improved sensors, heat exchanger, feedback mechanisms)	871/599	0.62	10.3	0.66	11.3
C6: D5+D7+D8+D1+D4 (programme duration, improved sensors, feedback mechanisms, heat exchanger, adsorption technology)	933/642	0.69	10.3	0.74	11.3

*RRP = Recommended Retail Price / ORP = Observed Retail Price

6.1.7. Best Not Yet Available (BNAT) design options

Best Not yet Available Technologies (BNAT) have to be identified and their potential to reduce environmental impacts has to be estimated. So far the following technological options have been identified as possible in principle but so far not yet installed in any dishwasher on the market.

6.1.7.1. Heat pump with alternative refrigerant

Currently the heat pump installed in a dishwasher works with R134a (tetrafluroroethane) as refrigerant. R134a has a high specific global warming potential (see Table 6.8). The choice of this refrigerant is because of its excellent technical performance. However, in principle it is possible to construct heat pumps with other refrigerants with lower environmental damage potential (lower GWP) but most likely lower technical performance. This development already takes place in case of tumble dryers, where first appliances with R290 (propane) as refrigerant are already on the market. A challenge that has to be considered is that R290 is flammable. Therefore due to safety issues the manufacturer would probably limit the amount of R290 to 150 g per appliance due to the extra costs of additional safety measures. Table 6.8 compares the GWP of currently used refrigerant (R134a) with the possible substitute (R290).

Table 6.8: Global Warming Potential (GWP) of refrigerants used in heat pumps

	Used amount per dishwasher	Specific GWP (IPCC 2007; UNEP 2014)	Total GWP in case of 100% loss per dishwasher
	g	kg CO_2e/kg	kg CO_2e
R134a (tetrafluroroethane)	175	1 430	250
R290 (propane)	150	3.3	0.5

According to stakeholder feedback the safety limit on the amount of alternative refrigerant is supposed to lead to a lower efficiency compared to using R134a (i.e. longer cycle times and/or additional electric heating would be necessary to reach the target temperatures).

6.1.7.2. Slim-line dishwasher with heat pump

Currently there is no slim-line dishwasher with a heat pump on the market.

Already in the standard dishwasher with a width of 60 cm the heat pump is packed extreme compactly. The heat pump addition uses all the bottom of the dishwasher and adds around 15-20 cm in height to the dishwasher. This is done in order not to take space from the washing cabinet, which is still constructed for 12-14 place settings. Due to space restrictions it is presumably very difficult to integrate a heat pump into a slim-line dishwasher.

6.1.7.3. Automatic detergent dosage system

Beko presented on the trade fair “IFA” in September 2015 a prototype of a dishwasher with automatic detergent dosage system. One advantage of such an appliance could be a reduction in detergent consumption, if the automatic dosage system would adapt the dosing in accordance with the real soiling. Such an adaptation is currently for most consumers not possible as they use tabs with a fix amount of detergent (e.g. 83% of the German households use tabs, see section 3.1.7.1) which cannot be adjusted to the degree of soiling. As the standard soiling is a rather strong soiling and under real-life conditions the soiling is expected to be lower an adjustment of the detergent dosage would thus result in a reduction of detergent consumption.

However, there could also be a saving potential in electricity consumption which results from the fact that most people (60%, see section 3.1.7.1) use multifunctional tabs (instead of mono-tabs or powder and separate dosing of rinsing agent and regeneration salt). The so called “multi-tab mode”, which might lead to higher electricity consumption under real-life conditions, is described in detail in section 5.1.1.4. If automatic detergent dosage is installed, it can be expected that also the rinsing agent is dosed separately and the necessity to ensure a proper drying through higher temperatures is not needed. This additional electricity consumption under real-life conditions could be saved. As outlined in detail in section 5.1.1.4 this might amount to 11 to 54 kWh per appliance per year in those cases where

- multi-tabs are used (60% of all users) and
- no additional rinsing agent is used (44% of the multi-tab users) and
- where the dishwasher switches automatically or is switched manually to “multi-tab-mode”.

The first two conditions mean, that at most 34% of all users (60% times 44%) use multi-tabs and at the same time do not use additional rinsing agent. From these 34% only an unknown fraction is supposed to switch or to be switched in the multi-tab mode. The average additional energy consumption would therefore result in at most 3.7 to 18 kWh per year which could possibly be saved. If, for illustration, the last condition is assumed to be 50%, then the savings would be 1.9 to 9 kWh per year.

6.1.7.4. Slim-line dishwasher with cross flow heat exchanger

Currently there is no slim-line dishwasher with a cross-flow heat exchanger on the market.

In 60 cm dishwashers this is a very recent development (see section 4.3.1.3) and, according to stakeholder feedback, it is not possible to be implemented it in slim-line dishwashers due to space restrictions. However, as in case of the heat pump, it might be possible in the future.

6.1.8. Additional modelling aspects

The additional materials of the design options outlined in Table 6.4 and Table 6.6 have been included in the EcoReport tool. The materials were assigned to the following materials of the tool:

- Plastics and PP (polypropylene): Bulk plastics – PP
- Steel: ferrous metals – Stainless 18/8 coil
- R134a: miscellaneous – refrigerant (R134a; HFC; 1430)
- Copper: non-ferrous materials – Cu tube/sheet

For the adsorption material for option D4 no suitable material is available in the EcoReport tool. Therefore the data set “zeolite, powder” of the EcoInvent database (version 3.1) has been included. The following calculation methods for the indicators were chosen:

- Primary energy: total cumulative energy demand (renewable, non-renewable, geothermal, nuclear etc.)
- Electric energy, waste: these indicators accounted for in the EcoReport tool are no input or output parameters of LCA datasets but are corresponding processes are modelled themselves. The resulting inputs and emissions are accounted for in the other impact categories.
- Feedstock energy: no feedstock energy contained in the material
- GWP: GWP 100 in CO2-equivalents (using ReCiPe Midpoint)*
- PM: in PM10-equivalents (using ReCiPe Midpoint)**
- AP: terrestrial acidification in SO2-equivalents (using ReCiPe Midpoint)**
- VOC: as NMVOC according to COWI and VHK (2011b)

- Eutrophication: eutrophication potential in PO4-equivalents (using CML 2001)**
- Water (process, cooling), POP, HMa, PAH and HMw: modelled from the inventory data with the characterisation factors as outlined in COWI and VHK (2011b).

* equivalent to the characterisation factors as outlined in COWI and VHK (2011b).
** slightly deviating from MEErP characterisation, but not impacting the results.

6.2. Impacts

6.2.1. Impacts of single design options Base Case 1 (13 place settings)

Figure 6.1 depicts the relative environmental impacts of the single design options compared to Base Case 1 (13 ps) under real-life conditions. Table 6.9 shows the respective absolute figures of the total environmental impacts of the base case and the single design options. For better comparison, also the decrease (or increase) per option and impact category is given in percentage.

The biggest differences to the base case can be observed in the design options D6 (heat pump) and D4 (adsorption technology). These design options cause relatively high savings in the impact categories total energy and electricity consumption, hazardous waste, GWP, partly acidification (only D4) and VOC emissions that range from 5% to 13%. However especially option D6 (heat pump) has a high additional impact in the categories process water, non-hazardous waste, POPs and heavy metals (both to air and to water) of between 13 and 74%. Option D4 (adsorption technology) has a medium additional impact in cooling water and heavy metals (both to air and to water) of between 6 and 18%. The increase of the impacts can be attributed to the additional efforts in the production phase (higher material consumption).

The options D2 (automatic door opening) and D3 (fan) cause medium savings between 5 and 8% in the impact categories total energy and electricity consumption, cooling water, hazardous waste, GWP, acidification and VOC emissions. The differences in the other impact categories are small to negligible. No additional impacts can be observed.

Small savings of 2 to 4% can be observed for the options D1 (Heat exchanger), D7 (advanced sensors) and D8 (consumer feedback mechanisms) for the impact categories total energy and electricity consumption, hazardous waste, GWP, acidification and VOC emissions. The differences in the other impact categories are small to negligible. No additional impacts can be observed.

The differences observed for option D5 (moderate increase of programme duration) cannot be considered as significant as they do not exceed 1%.

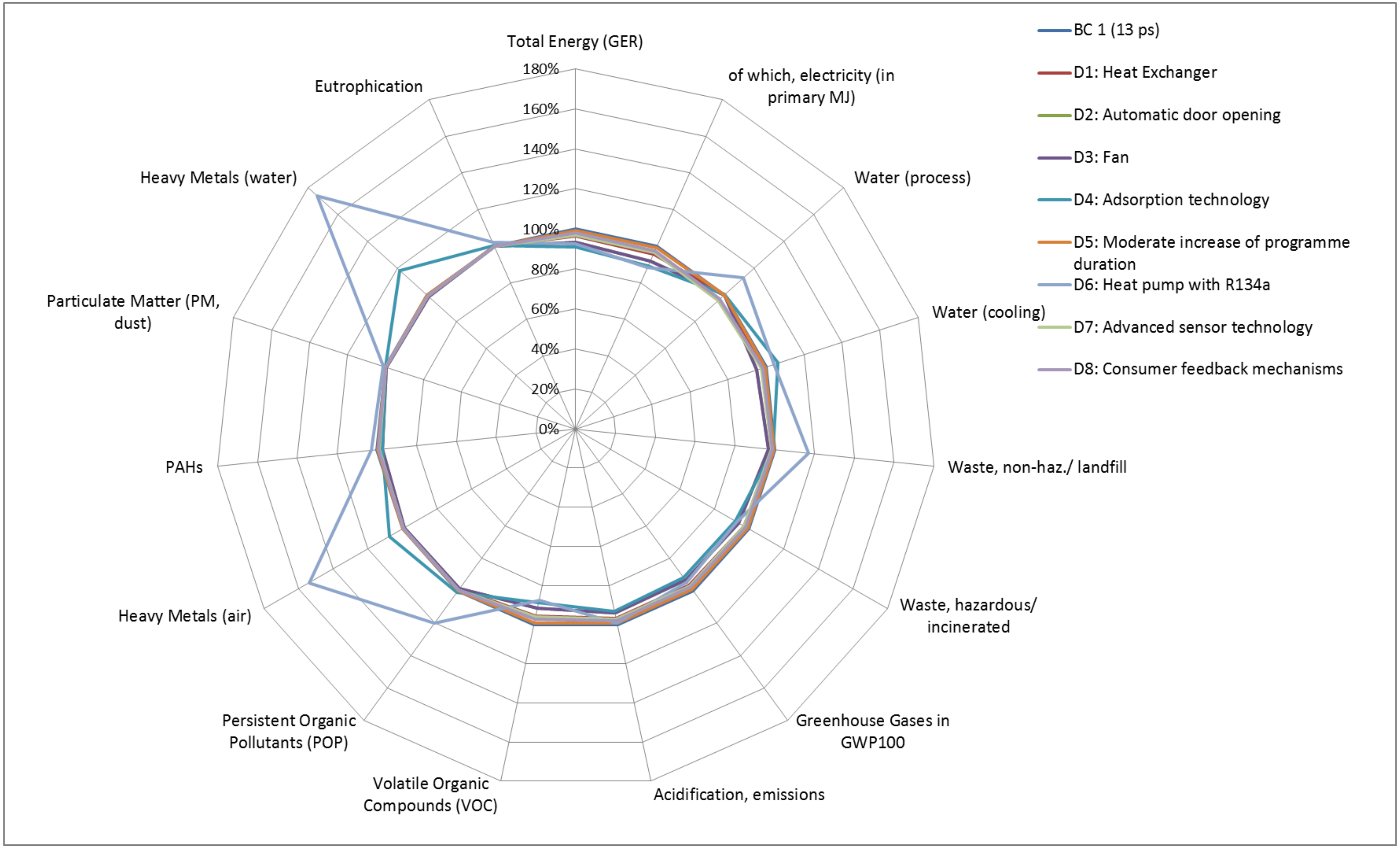


Figure 6.1: **Relative environmental impacts of the single design options compared to the standard Base Case 1 (13 ps)**

Table 6.9: Environmental impacts of a standard household dishwasher with 13 place settings (Base Case 1) and its single design options

		BC 1 (13 ps)	D1: Heat Exchanger	D2: Automatic door opening system	D3: Fan	D4: Adsorption technology	D5: Moderate increase of programme duration	D6: Heat pump (R134a)	D7: Advanced sensor technology	D8: Consumer feedback mechanisms
Resources & waste										
Total Energy (GER)	MJ	**42 437**	**40 940**	**39 512**	**39 512**	**38 633**	**42 133**	**39 253**	**41 099**	**41 506**
			-4%	**-7%**	**-7%**	**-9%**	**-1%**	**-8%**	**-3%**	**-2%**
of which, electricity (in primary MJ)	MJ	**36 196**	**34 660**	**33 271**	**33 271**	**32 214**	**35 893**	**32 020**	**34 859**	**35 267**
			-4%	**-8%**	**-8%**	**-11%**	**-1%**	**-12%**	**-4%**	**-3%**
Water (process)	ltr	**54 365**	**54 367**	**54 365**	**54 365**	**54 521**	**54 365**	**61 393**	**52 196**	**52 751**
			0%	**0%**	**0%**	**0%**	**0%**	**13%**	**-4%**	**-3%**
Water (cooling)	ltr	**2 630**	**2 587**	**2 500**	**2 500**	**2 797**	**2 616**	**2 737**	**2 571**	**2 589**
			-2%	**-5%**	**-5%**	**6%**	**-1%**	**4%**	**-2%**	**-2%**
Waste, non-haz./ landfill	g	**51 005**	**50 267**	**49 498**	**49 498**	**50 599**	**50 849**	**59 685**	**50 315**	**50 525**
			-1%	**-3%**	**-3%**	**-1%**	**0%**	**17%**	**-1%**	**-1%**
Waste, hazardous/ incinerated	g	**786**	**764**	**740**	**740**	**723**	**781**	**730**	**765**	**771**
			-3%	**-6%**	**-6%**	**-8%**	**-1%**	**-7%**	**-3%**	**-2%**
Emissions (Air)										
Greenhouse Gases in GWP100	kg CO2 eq.	**1 895**	**1 831**	**1 770**	**1 770**	**1 739**	**1 882**	**1 792**	**1 838**	**1 855**
			-3%	**-7%**	**-7%**	**-8%**	**-1%**	**-5%**	**-3%**	**-2%**
Acidification, emissions	g SO2 eq.	**9 575**	**9 289**	**9 022**	**9 022**	**8 934**	**9 517**	**9 495**	**9 322**	**9 399**
			-3%	**-6%**	**-6%**	**-7%**	**-1%**	**-1%**	**-3%**	**-2%**
Volatile Organic Compounds (VOC)	g	**794**	**759**	**728**	**728**	**706**	**787**	**694**	**764**	**773**
			-4%	**-8%**	**-8%**	**-11%**	**-1%**	**-13%**	**-4%**	**-3%**
Persistent Organic Pollutants (POP)	ng i-Teq	**549**	**545**	**542**	**542**	**556**	**548**	**660**	**546**	**547**
			-1%	**-1%**	**-1%**	**1%**	**0%**	**20%**	**-1%**	**0%**
Heavy Metals	mg Ni eq.	**2 465**	**2 448**	**2 435**	**2 435**	**2 648**	**2 462**	**3 796**	**2 451**	**2 455**
			-1%	**-1%**	**-1%**	**7%**	**0%**	**54%**	**-1%**	**0%**
PAHs	mg Ni eq.	**255**	**251**	**248**	**248**	**247**	**254**	**262**	**251**	**252**
			-1%	**-3%**	**-3%**	**-3%**	**0%**	**3%**	**-1%**	**-1%**

		BC 1 (13 ps)	D1: Heat Exchanger	D2: Automatic door opening system	D3: Fan	D4: Adsorption technology	D5: Moderate increase of programme duration	D6: Heat pump (R134a)	D7: Advanced sensor technology	D8: Consumer feedback mechanisms
Particulate Matter (PM, dust)	g	**3 961**	**3 956**	**3 950**	**3 950**	**3 966**	**3 960**	**4 011**	**3 956**	**3 958**
			0%	**0%**	**0%**	**0%**	**0%**	**1%**	**0%**	**0%**
Emissions (Water)										
Heavy Metals	mg Hg/20	**1 120**	**1 112**	**1 107**	**1 107**	**1 324**	**1 118**	**1 948**	**1 114**	**1 116**
			-1%	**-1%**	**-1%**	**18%**	**0%**	**74%**	**-1%**	**0%**
Eutrophication	g PO4	**4 601**	**4 603**	**4 601**	**4 601**	**4 621**	**4 601**	**4 689**	**4 601**	**4 601**
			0%	**0%**	**0%**	**0%**	**0%**	**2%**	**0%**	**0%**

6.2.2. Impacts of combinations of design Options Base Case 1 (13 place settings)

Figure 6.2 depicts the relative environmental impacts of the combinations of design options compared to Base Case 1 (13 ps). Table 6.8 shows the respective absolute figures of the total environmental impacts of the base case and the combinations of design options. For better comparison, also the decrease (or increase) per combination and impact category is given in percentage.

All combinations lead to savings in the total primary energy and electricity demand, hazardous waste, GWP, acidification and VOC emissions of 7% and more. The highest savings can be found for combination C4, C5 and C7.

Combinations C6 and C7 are the only combinations where, besides relevant savings in many impact categories (total energy, hazardous waste, GWP, Acidification, VOC, PAHs) also a relevant increase of impacts in some impact categories occurs.

In case of C6 which includes the design option “adsorption technology” a significant increase takes place in heavy metal emissions (to air: +6%, to water +17%). Compared to the other combinations the decrease in cooling water consumption is much lower (only -1% instead of -6% to -16%). As was already described in the previous section on the single design options, this can partly be attributed to the use of zeolite material in the dishwasher.

In case of C7, which includes the design option “heat pump” a significant increase takes place in process water consumption (+8%), POP (+17%) and Heavy Metals (to air: +51%, to water: +71%). As the analysis of the single design options show this can be attributed to the inclusion of extra material for the heat pump in the dishwasher.

For all other combinations (C1 to C5) only savings or non-significant changes of the impacts in all impact categories occur. The impact categories with the highest savings are: total energy consumption (-9% to -24%) and the corresponding electricity consumption (-10% to -30%), cooling water consumption (-6% to -16%), hazardous waste generation (-8% to -20%), GWP (-8% to -23%), acidification (-7% to -20%) and VOC (-11% to -31%).

Comparing the environmental impacts of the different combinations it can be seen that (with the exception of those impact categories that show an increase in C6 and C7) the savings increase from C1 to C5 (e.g. total energy from -9% (C1) to – 24% (C5), similar for electricity, hazardous waste, GWP, acidification, VOC and PAHs). Combination C6 then shows a slightly lower saving potential (similar to that of C3) and combination C7 is comparable with combination C5 (i.e. showing higher savings again). For both combinations C6 and C7 there are impact categories however where the potential savings are partly or fully compensated for by the additional impacts through additional material consumption, resulting in significant lower savings or even additional overall impacts.

In the impact categories PM and eutrophication no significant saving or increase occurs.

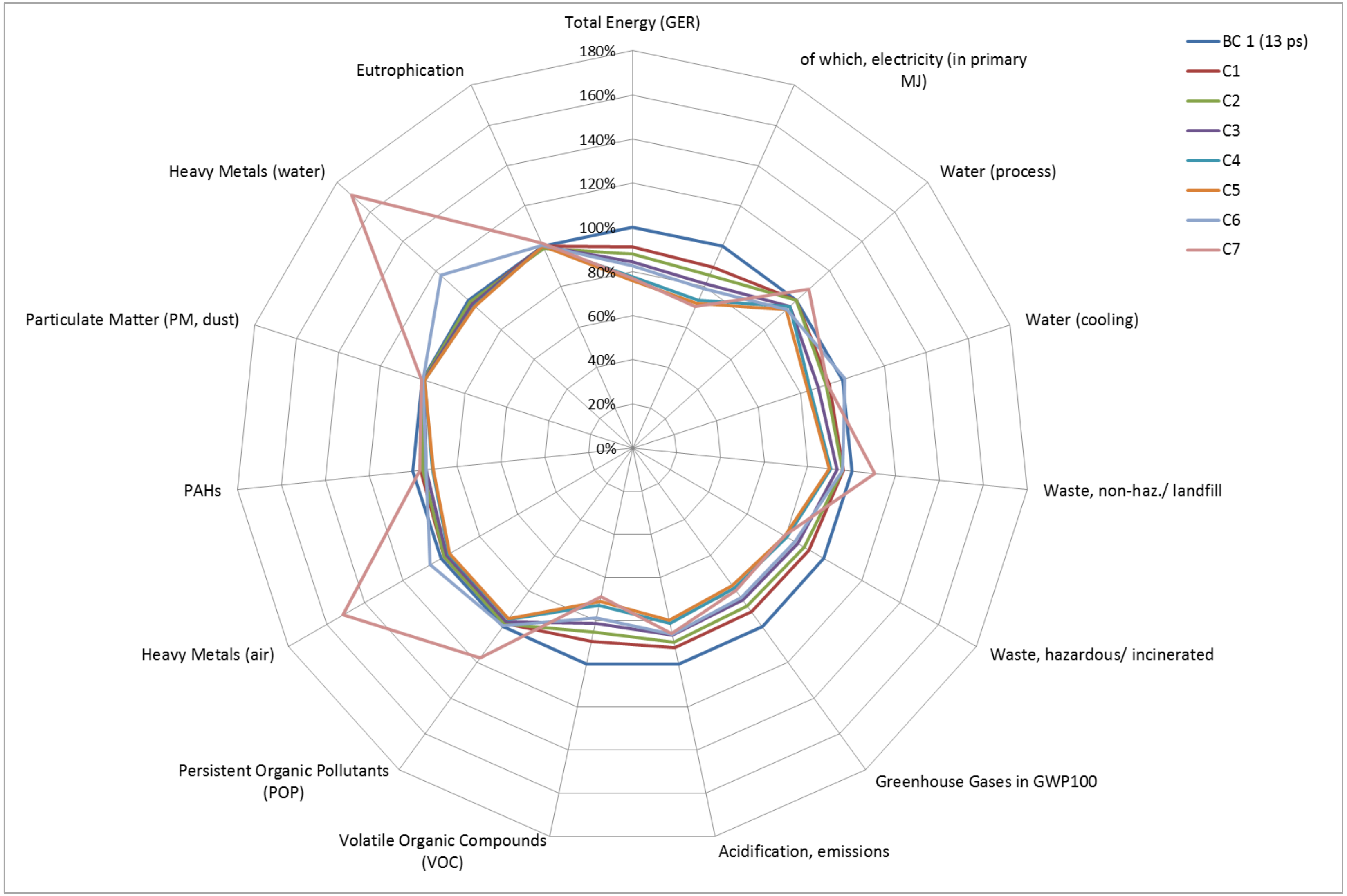


Figure 6.2: Relative environmental impacts of the combinations of design options compared to the standard Base Case 1 (13 ps)

Table 6.10: Environmental impacts of a standard household dishwasher with 13 place settings (Base Case 1) and the combinations of design options

		BC 1 (13 ps)	C1*	C2*	C3*	C4*	C5*	C6*	C7*
Resources & waste									
Total Energy (GER)	MJ	42 437	38 690	37 278	35 744	32 875	32 217	35 040	32 624
			-9%	-12%	-16%	-23%	-24%	-17%	-23%
of which, electricity (in primary MJ)	MJ	36 196	32 450	30 987	29 504	26 595	25 936	28 580	25 391
			-10%	-14%	-18%	-27%	-28%	-21%	-30%
Water (process)	Ltr	54 365	54 365	54 378	52 196	52 198	50 914	51 071	58 495
			0%	0%	-4%	-4%	-6%	-6%	8%
Water (cooling)	Ltr	2 630	2 463	2 427	2 333	2 229	2 199	2 661	2 443
			-6%	-8%	-11%	-15%	-16%	1%	-7%
Waste, non-haz./ landfill	g	51 005	49 075	48 746	47 556	46 110	45 770	48 779	56 268
			-4%	-4%	-7%	-10%	-10%	-4%	10%
Waste, hazardous/ incinerated	g	786	727	706	680	636	626	668	626
			-8%	-10%	-13%	-19%	-20%	-15%	-20%
Emissions (Air)									
Greenhouse Gases in GWP100	kg CO2 eq.	1 895	1 735	1 675	1 609	1 487	1 458	1 586	1 509
			-8%	-12%	-15%	-22%	-23%	-16%	-20%
Acidification, emissions	g SO2 eq.	9 575	8 867	8 606	8 311	7 765	7 641	8 251	8 243
			-7%	-10%	-13%	-19%	-20%	-14%	-14%
Volatile Organic Compounds (VOC)	g	794	710	677	644	579	564	625	546
			-11%	-15%	-19%	-27%	-29%	-21%	-31%
Persistent Organic Pollutants (POP)	ng i-Teq	549	540	542	533	526	524	547	644
			-2%	-1%	-3%	-4%	-4%	0%	17%
Heavy Metals	mg Ni eq.	2 465	2 427	2 433	2 397	2 367	2 360	2 610	3 729
			-2%	-1%	-3%	-4%	-4%	6%	51%
PAHs	mg Ni eq.	255	246	243	239	232	231	239	246

		BC 1 (13 ps)	C1*	C2*	C3*	C4*	C5*	C6*	C7*
			-3%	-5%	-6%	-9%	-9%	-6%	-3%
Particulate Matter (PM, dust)	g	3 961	3 946	3 957	3 935	3 923	3 921	3 952	3 984
			0%	0%	-1%	-1%	-1%	0%	1%
Emissions (Water)									
Heavy Metals	mg Hg/20	1 120	1 103	1 109	1 091	1 078	1 075	1 308	1 919
			-1%	-1%	-3%	-4%	-4%	17%	71%
Eutrophication	g PO4	4 601	4 601	4 556	4 600	4 602	4 602	4 622	4 688
			0%	-1%	0%	0%	0%	0%	2%

* C1: D3+D2 (fan, automatic door opening)
C2: D3+D2+D1 (fan, automatic door opening, heat exchanger)
C3: D5+D3+ D2+D7 (longer programme duration, fan, automatic door opening, improved sensors)
C4: D5+D3+D2+D7+ D1 (longer programme duration, fan, automatic door opening, improved sensors, heat exchanger)
C5: D5+D3+D2+D7+ D1+D8 (longer programme duration, fan, automatic door opening, improved sensors, heat exchanger, consumer feedback mechanisms)
C6: D5+D7+D8+D1+ D4 (longer programme duration, improved sensors, consumer feedback mechanisms, heat exchanger, adsorption technology)
C7: D5+D3+D2+D7+D8+D6 (longer programme duration, fan, automatic door opening, improved sensors, consumer feedback mechanisms, heat pump)

6.2.3. Impacts of single design options Base Case 2 (10 place settings)

Figure 6.3 depicts the relative environmental impacts of the single design options compared to Base Case 2 (10 ps). Table 6.11shows the respective absolute figures of the total environmental impacts of the base case and the seven design options. For better comparison, also the decrease (or increase) per option and impact category is given in percentage.

The changes through the design options for Base Case 2 (10 ps) are very similar to those of Base Case 1 (13 ps) with the exception that in case of slim-line dishwashers the heat pump is not an option:

The biggest differences to the base case can be observed in the design option D4 (adsorption technology). This design option cause relative high savings in the impact categories total energy and electricity consumption, hazardous waste, GWP, acidification and VOC emissions that range from 7% to 11%. However option D4 has a small to medium additional impact in cooling water and heavy metals (both to air and to water) of between 4 and 13%. The increase of the impacts can be attributed to the additional efforts in the production phase (higher material consumption).

The options D2 (door opening) and D3 (fan) cause medium savings between 5 and 8% in the impact categories total energy and electricity consumption, cooling water, hazardous waste, GWP, acidification and VOC emissions. The differences in the other impact categories are small to negligible. No additional impacts can be observed.

Small savings of 3 to 4% can (partly) be observed for the options D1 (Heat exchanger), D6 (advanced sensors) and D7 (consumer feedback mechanisms) for the impact categories total energy and electricity consumption, process water, hazardous waste, GWP, acidification, VOC emissions POP and heavy metals (to air and to water). The differences in the other impact categories are small to negligible. No additional impacts can be observed.

The differences observed for option D5 (moderate increase of programme duration) cannot be considered as significant as they do not exceed 1%.

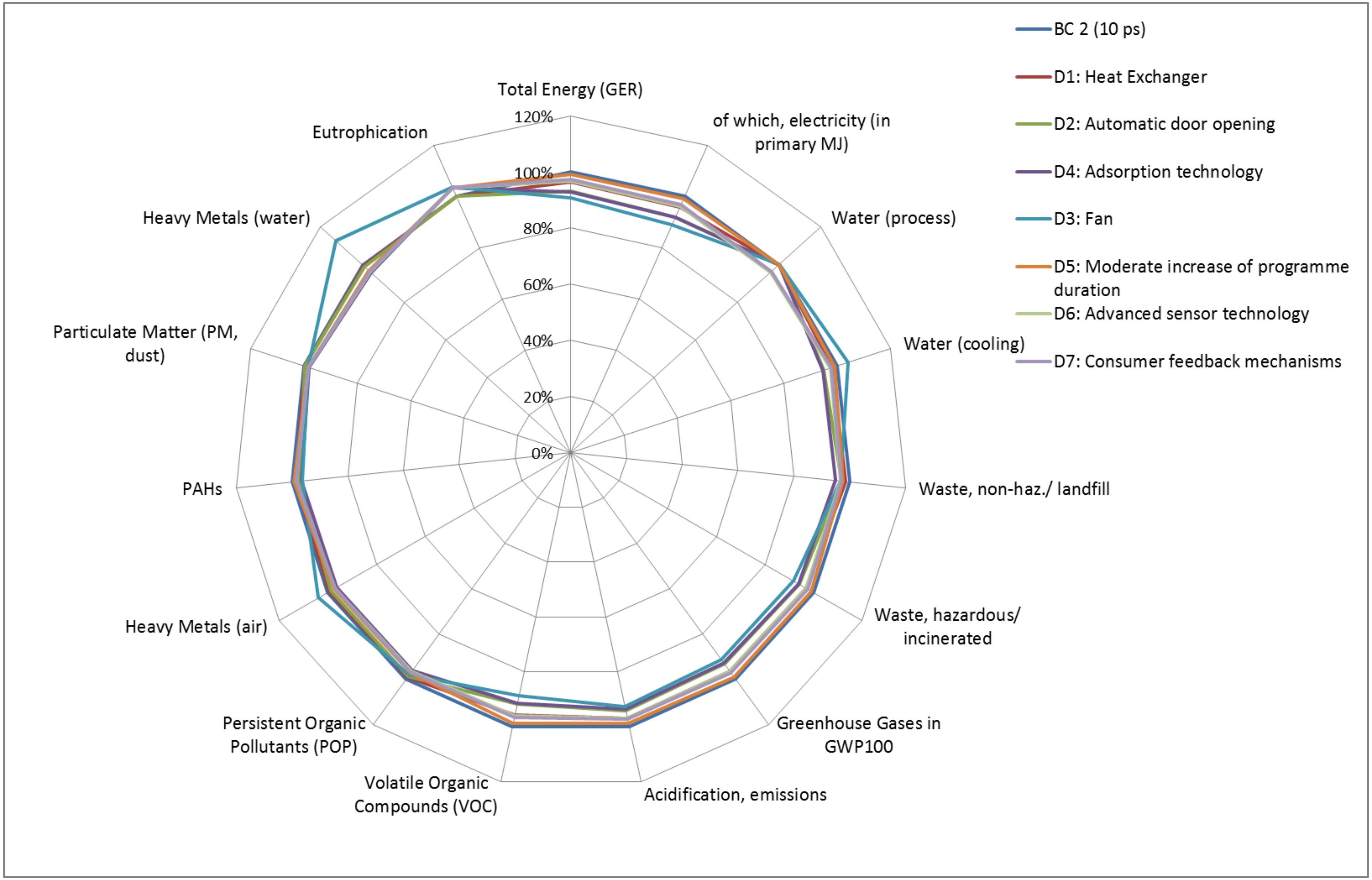


Figure 6.3: **Relative environmental impacts of the single design options compared to the slim-line Base Case 2 (10 ps)**

Table 6.11: Environmental impacts of a standard household dishwasher with 10 place settings (Base Case 2) and its single design options

		BC 2 (10 ps)	D1: Heat Ex-changer	D2: Automatic door open-ing system	D3: Fan	D4: Adsorption technology	D5: Moderate increase of programme duration	D6: Advanced sensor technology	D7: Consumer feedback mechanisms
Resources & waste									
Total Energy (GER)	MJ	39 195	37 806	36 467	36 420	35 575	38 861	37 893	38 131
			-4%	-7%	-7%	-9%	-1%	-3%	-3%
of which, electricity (in primary MJ)	MJ	33 478	32 056	30 750	30 722	29 735	33 163	32 196	32 433
			-4%	-8%	-8%	-11%	-1%	-4%	-3%
Water (process)	ltr	60 146	60 148	60 146	60 116	60 239	60 116	57 670	57 930
			0%	0%	0%	0%	0%	-4%	-4%
Water (cooling)	ltr	2 309	2 267	2 188	2 180	2 402	2 289	2 246	2 256
			-2%	-5%	-6%	4%	-1%	-3%	-2%
Waste, non-haz./ landfill	g	46 866	46 179	45 460	44 541	45 364	45 799	45 300	45 422
			-1%	-3%	-5%	-3%	-2%	-3%	-3%
Waste, hazardous/ incinerated	g	716	695	673	672	656	710	695	699
			-3%	-6%	-6%	-8%	-1%	-3%	-2%
Emissions (Air)									
Greenhouse Gases in GWP100	kg CO2 eq.	1 745	1 685	1 628	1 623	1 593	1 728	1 686	1 696
			-3%	-7%	-7%	-9%	-1%	-3%	-3%
Acidification, emissions	g SO2 eq.	8 803	8 538	8 288	8 253	8 153	8 714	8 531	8 576
			-3%	-6%	-6%	-7%	-1%	-3%	-3%
Volatile Organic Compounds (VOC)	g	738	705	677	675	654	730	708	713
			-4%	-8%	-8%	-11%	-1%	-4%	-3%
Persistent Organic Pollutants (POP)	ng i-Teq	521	518	515	501	512	506	504	505
			-1%	-1%	-4%	-2%	-3%	-3%	-3%
Heavy Metals	mg Ni eq.	2 194	2 179	2 167	2 111	2 278	2 136	2 126	2 129
			-1%	-1%	-4%	4%	-3%	-3%	-3%

		BC 2 (10 ps)	D1: Heat Ex-changer	D2: Automatic door open-ing system	D3: Fan	D4: Adsorption technology	D5: Moderate increase of programme duration	D6: Advanced sensor technology	D7: Consumer feedback mechanisms
PAHs	mg Ni eq.	224	221	217	216	216	222	220	220
			-1%	-3%	-3%	-4%	-1%	-2%	-2%
Particulate Matter (PM, dust)	g	3 350	3 345	3 340	3 290	3 302	3 300	3 296	3 297
			0%	0%	-2%	-1%	-2%	-2%	-2%
Emissions (Water)									
Heavy Metals	mg Hg/20	996	990	984	954	1 123	964	960	961
			-1%	-1%	-4%	13%	-3%	-4%	-4%
Eutrophication	g PO4	4 601	4 602	4 600	4 752	4 769	4 752	4 752	4 752
			0%	0%	3%	4%	3%	3%	3%

6.2.4. Impacts of combinations of single design options Base Case 2 (10 place settings)

Figure 6.4 depicts the relative environmental impacts of the combinations of design options compared to Base Case 2 (10 ps). Table 6.12 shows the respective absolute figures of the total environmental impacts of the base case and the combinations of design options. For better comparison, also the decrease (or increase) per combination and impact category is given in percentage.

It can be seen that the changes through the combinations of design options for Base Case 2 (10 ps) are very similar to those of Base Case 1 (13 ps): All combinations lead to savings in the total primary energy demand of 12% and more. The highest saving comes from combination C4 and C5 (-23 to -25%).

Combination C6 which includes the design option "adsorption technology" is the only combination where, besides relevant savings in many impact categories (total energy, hazardous waste, GWP, Acidification, VOC, PAHs) also a relevant increase of impacts in some impact categories occurs: a significant increase takes place in Heavy Metal emissions (to air: +5%, to water + 14%). Compared to the other combinations the decrease in cooling water consumption is much lower (only -1% instead of -8% to -18%). As was already described in the previous section on the single design options, this can partly be attributed to the use of zeolite material in the dishwasher.

For all other combinations (C1 to C5) only savings or non-significant changes of the impacts in all impact categories occur. The impact categories with the highest savings are: total energy consumption (-12% to -25%) and the corresponding electricity consumption (-14% to -29%), cooling water consumption (-8% to -18%), hazardous waste generation (-11% to -21%), GWP (-12% to -24%), acidification (-10% to -21%) and VOC (-15% to -29%).

As for Base Case 1, it can be seen that the savings increase from C1 to C5 (e.g. total energy from -12% (C1) to – 25% (C5), similar for electricity, water (cooling), non-hazardous waste, hazardous waste, GWP, Acidification, VOC and PAHs). In the impact categories process water, POPs and Heavy Metals (both to air and to water) the savings are much smaller but still show an increase from C1 to C5. In the impact categories PM and eutrophication no significant saving or increase occurs.

The savings of combination C6 are smaller than those of combination C5 again (in the range of combinations C3 and C4).

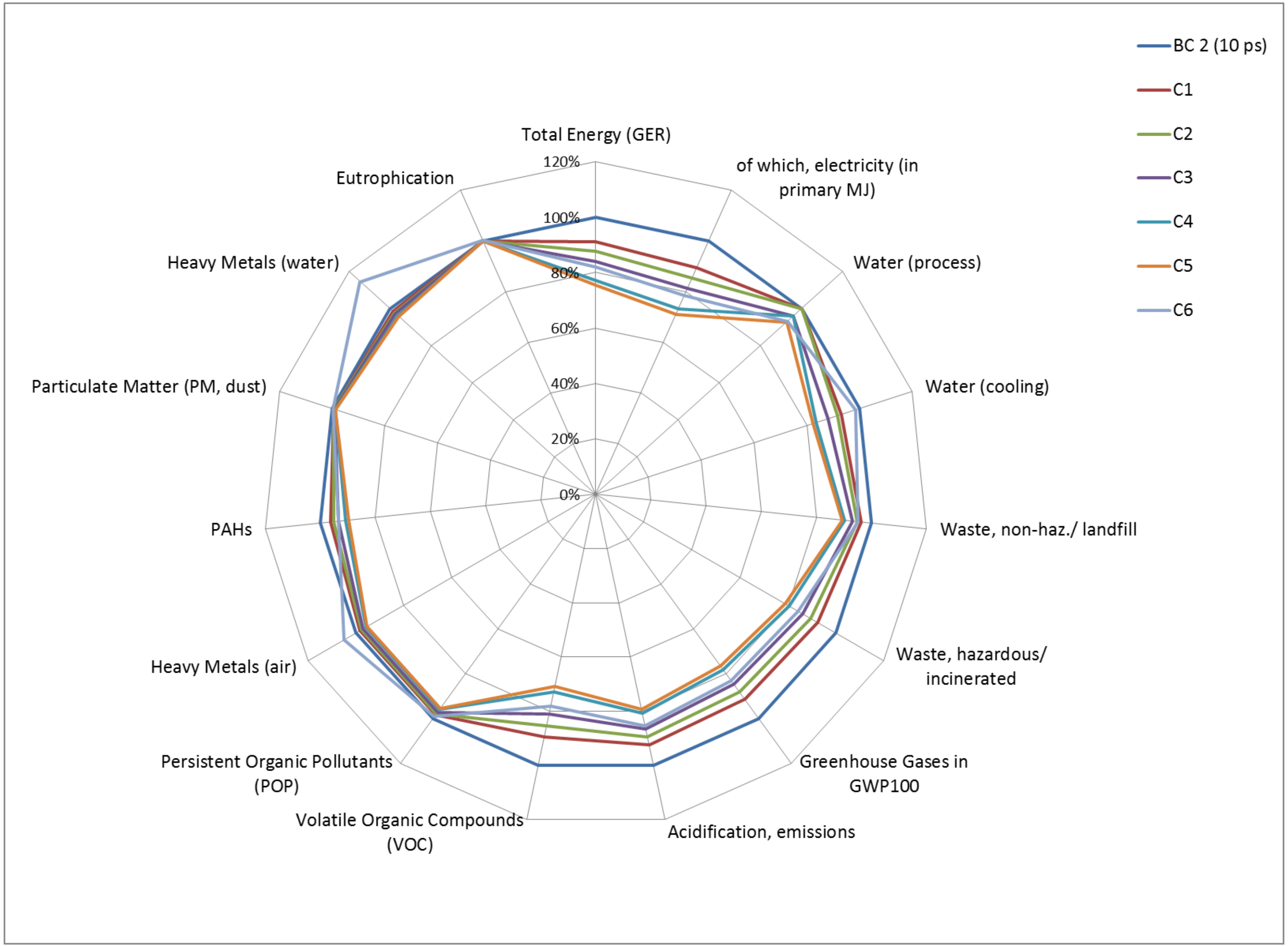


Figure 6.4: **Relative environmental impacts of the combinations of design options compared to the slim-line Base Case 2 (10 ps)**

Table 6.12: Environmental impacts of a standard household dishwasher with 10 place settings (Base Case 2) and the combinations of design options

		BC 2 (10 ps)	C1*	C2 *	C3*	C4*	C5*	C6*
Resources & Waste								
Total Energy (GER)	MJ	39 195	35 702	34 374	32 968	30 279	29 573	32 149
			-9%	-12%	-16%	-23%	-25%	-18%
of which, electricity (in primary MJ)	MJ	33 478	29 985	28 625	27 251	24 530	23 824	26 258
			-10%	-14%	-19%	-27%	-29%	-22%
Water (process)	ltr	60 146	60 146	60 148	57 700	57 702	55 880	56 005
			0%	0%	-4%	-4%	-7%	-7%
Water (cooling)	ltr	2 309	2 154	2 114	2 033	1 932	1 901	2 275
			-7%	-8%	-12%	-16%	-18%	-1%
Waste, non-haz./ landfill	g	46 866	45 066	44 411	43 656	42 300	41 935	44 515
			-4%	-5%	-7%	-10%	-11%	-5%
Waste, hazardous/ incinerated	g	716	661	641	618	577	566	604
			-8%	-11%	-14%	-19%	-21%	-16%
Emissions (air)								
Greenhouse Gases in GWP100	kg CO2 eq.	1 745	1 596	1 539	1 479	1 364	1 334	1 449
			-9%	-12%	-15%	-22%	-24%	-17%
Acidification, emissions	g SO2 eq.	8 803	8 144	7 890	7 627	7 117	6 983	7 532
			-7%	-10%	-13%	-19%	-21%	-14%
Volatile Organic Compounds (VOC)	g	738	659	629	598	537	522	577
			-11%	-15%	-19%	-27%	-29%	-22%
Persistent Organic Pollutants (POP)	ng i-Teq	521	513	510	506	500	498	517
			-2%	-2%	-3%	-4%	-4%	-1%
Heavy Metals	mg Ni eq.	2 194	2 159	2 144	2 131	2 103	2 096	2 301
			-2%	-2%	-3%	-4%	-4%	5%
PAHs	mg Ni eq.	224	216	213	209	203	201	209
			-4%	-5%	-7%	-9%	-10%	-7%

		BC 2 (10 ps)	C1*	C2 *	C3*	C4*	C5*	C6*
Particulate Matter (PM, dust)	g	3 350	3 336	3 331	3 326	3 315	3 312	3 338
			0%	-1%	-1%	-1%	-1%	0%
Emissions (water)								
Heavy Metals	mg Hg/20	996	981	975	969	957	954	1 140
			-2%	-2%	-3%	-4%	-4%	14%
Eutrophication	g PO4	4 601	4 600	4 601	4 599	4 601	4 601	4 617
			0%	0%	0%	0%	0%	0%

* C1: D3+D2 (fan, automatic door opening)
C2: D3+D2+D1 (fan, automatic door opening, heat exchanger)
C3: D5+D3+ D2+D7 (longer programme duration, fan, automatic door opening, improved sensors)
C4: D5+D3+D2+D7+ D1 (longer programme duration, fan, automatic door opening, improved sensors, heat exchanger)
C5: D5+D3+D2+D7+ D1+D8 (longer programme duration, fan, automatic door opening, improved sensors, heat exchanger, consumer feedback mechanisms)
C6: D5+D7+D8+D1+ D4 (longer programme duration, improved sensors, consumer feedback mechanisms, heat exchanger, adsorption technology)

6.3. Costs

6.3.1. Life Cycle Costs of design options Base Case 1 (13 place settings)

Table 6.13 shows the life cycle costs of the single design options compared to the life cycle costs of Base Case 1 (13 ps) with reference to a unit of product and the considered lifetime of 12.5 years.

The life cycle costs for all the single design options except the heat pump option are very similar. They range from -3% to +1% of the LCC of the base case (both in case of the RRP and the ORP). Taking into account the uncertainties especially of the cost data, the differences are not considered to be significant. The single design option with the highest LCC is D6 (heat pump), which mainly results from the high purchase price (73% higher than base case). The LCC are increased by 15 to 21% (depending on the assumption regarding the purchase price). The high purchase price is to some extent compensated for by the savings in the electricity costs (electricity costs are reduced by 14%). The reduction of the electricity consumption and the respective costs would be higher if only the Eco programme was considered. Here the savings are around 30%.

Table 6.14 shows the life cycle costs of the combination of the design options compared to the life cycle costs of the Base Case 1 (13ps) with reference to a unit of product and the considered lifetime of 12.5 years.

The life cycle costs of combinations C1 to C6 are very similar. They range from 2 306 to 2 434 euros (RRP), representing a cost saving compared to the base case of -5% to 0%. When taking into account the ORP instead of the RRP the cost savings are slightly higher, i.e. between -2% and -8%.

An exception are the LCC of combination C7 which are, depending on the assumption regarding the purchase price, 10 to 18% higher than those of the base case (2 870 and 2 365 euros). This can be attributed to the high purchase price due to the inclusion of a heat pump. The purchase price of C7 is almost twice as high as that of the base case. In contrast the electricity costs are reduced by approximately 35% which results in an overall increase of the LCC of only 10 and 18% (around 450 euros over the whole life cycle).

The life cycle costs of the combinations C1 to C5 are nearly the same: they vary only between -1% and -5% (RRP) and -2% and -8% (ORP) (maximum absolute difference: 88 / 109 euros). From C1 to C5 the purchase price is more or less increasing whereas the electricity costs are decreasing by basically the same amount, resulting in similar LCC. The combinations with the lowest life cycle costs are C4 or C5, including basically all design options except D4 (adsorption technology) and D6 (heat pump) which are more expensive design options.

By inclusion of D4 (adsorption technology) in C6 or D6 (heat pump) in C7, the life cycle costs increase slightly (C6) or considerably (C7) compared to the previous combinations.

Table 6.13: LCC of single design options referred to a unit of product over its lifetime and compared to the base case (BC1) (RRP and ORP)

	BC 1 (13 ps)	D1: Heat Exchanger	D2: Automatic door opening system	D3: Fan	D4: Adsorption technology	D5: Moderate increase of programme duration	D6: Heat pump (R134a)	D7: Advanced sensor technology	D8: Consumer feedback mechanisms
in EUR									
Product price (RRP)	800	839	831	820	917	800	1385	820	820
Electricity	758	722	691	691	665	751	654	727	737
Water	152	152	152	152	152	152	170	146	147
Dishwashing detergent	560	560	560	560	560	560	560	560	560
Rinsing Agent	32	32	32	32	32	32	32	32	32
Regeneration salt	67	67	67	67	67	67	67	67	67
Repair & maintenance costs	57	57	57	57	57	57	74	57	57
Total LCC	2 425	2 428	2 389	2 378	2 449	2 418	2 941	2 408	2 419
Relative difference of the LCC with respect to the base case		*-0%*	*-1%*	*-2%*	*+1%*	*0%*	*+21%*	*-1%*	*0%*
Product price (ORP)	526	552	547	539	603	526	911	539	539
Total LCC	2 151	2 141	2 105	2 097	2 135	2 144	2 467	2 127	2 138
Relative difference of the LCC with respect to the base case		*0%*	*-2%*	*-3%*	*-1%*	*0%*	*+15%*	*-1%*	*-1%*

Table 6.14: LCC of combinations of design options referred to a unit of product over its lifetime and compared to the base case (BC1)

	BC 1 (13 ps)	C1*	C2*	C3*	C4*	C5*	C6*	C7*
in EUR								
Product price(RRP)	800	851	890	870	909	929	995	1475
Electricity	758	672	637	604	536	521	581	501
Water	152	152	152	146	146	142	142	162
Dishwashing detergent	560	560	560	560	560	560	560	560
Rinsing Agent	32	32	32	32	32	32	32	32
Regeneration salt	67	67	67	67	67	67	67	67
Repair & maintenance costs	57	57	57	57	57	57	57	74
Total	2 425	2 390	2 394	2 335	2 306	2 307	2 434	2 870
Relative difference of the LCC with respect to the base case		*-1%*	*-1%*	*-4%*	*-5%*	*-5%*	*0%*	*+18%*
Product price (ORP)	526	559	585	572	598	611	654	970
Total LCC	2 151	2 098	2 089	2 037	1 995	1 989	2 093	2 365
Relative difference of the LCC with respect to the base case		*-2%*	*-3%*	*-5%*	*-7%*	*-8%*	*-3%*	*+10%*

* C1: D3+D2 (fan, automatic door opening)
C2: D3+D2+D1 (fan, automatic door opening, heat exchanger)
C3: D5+D3+ D2+D7 (longer programme duration, fan, automatic door opening, improved sensors)
C4: D5+D3+D2+D7+ D1 (longer programme duration, fan, automatic door opening, improved sensors, heat exchanger)
C5: D5+D3+D2+D7+ D1+D8 (longer programme duration, fan, automatic door opening, improved sensors, heat exchanger, consumer feedback mechanisms)
C6: D5+D7+D8+D1+ D4 (longer programme duration, improved sensors, consumer feedback mechanisms, heat exchanger, adsorption technology)
C7: D5+D3+D2+D7+D8+D6 (longer programme duration, fan, automatic door opening, improved sensors, consumer feedback mechanisms, heat pump)

6.3.2. Life Cycle Costs of design options Base Case 2 (10 place settings)

Table 6.15 shows the life cycle costs of the single design options compared to the life cycle costs of Base Case 2 (10 ps) with reference to a unit of product and the considered lifetime of 12.5 years.

The life cycle costs are very similar. They range from -2% to +1% of the LCC of the base case, which is an identical range compared to the single design options of Base Case 1 (except single design option D6 heat pump). Taking into account the uncertainties especially of the cost data, like in case of BC1, the differences are not considered to be significant.

Table 6.16 shows the life cycle costs of the combination of the design options compared to the life cycle costs of the Base Case 2 (10ps) with reference to a unit of product and the considered lifetime of 12.5 years.

As in the case of Base Case 1, the life cycle costs of all combinations are very similar. They range from 2 226 to 2 394 euros (RRP), representing a cost saving/increase compared to the base case of +2% to -5%. When taking into account the ORP instead of the RRP the cost savings are slightly higher, i.e. between -2% and -7%.

The LCC of all combinations are lower than those of the base case, except the LCC of combination C6 in case of taking into account the RRP. This can be attributed to the relative high purchase price due to the inclusion the adsorption technology. The purchase price of C6 is increased by 31% compared to that of the base case. In contrast the electricity costs are reduced by approximately 25% resulting in an overall increase of the LCC of 2% (54 € over the whole life cycle)..

The LCC are decreasing from combination C1 to combination C5. The inclusion of the (relative expensive) adsorption technology leads to slightly increasing LCC compared to the previous options. All in all the change in LCC compared to the base case is rather small (+2% to -5% in case of RRP, -2% to -7% in case of ORP).

Table 6.15: LCC of design options referred to a unit of product over its lifetime and compared to the base case (BC2) (RRP and ORP)

	BC 2 (10 ps)	D1: Heat Ex-changer	D2: Automatic door opening system	D3: Fan for better air circulation	D4: Adsorption technology	D5: Moderate increase of programme duration	D6: Advanced sensor technology	D7: Consumer feedback mechanisms
in EUR								
Product price (RRP)	750	787	779	768	860	750	768	768
Electricity	706	673	643	643	620	699	677	683
Water	169	169	169	169	169	169	162	163
Dishwashing detergent	560	560	560	560	560	560	560	560
Rinsing Agent	32	32	32	32	32	32	32	32
Regeneration salt	67	67	67	67	67	67	67	67
Repair & maintenance costs	57	57	57	57	57	57	57	57
Total	2 340	2 344	2 306	2 295	2 364	2 334	2 322	2 329
Relative difference of the LCC with respect to the base case		*0%*	*-1%*	*-2%*	*1%*	*0%*	*-1%*	*0%*
Product price (ORP)	516	541	536	529	592	516	529	529
Total LCC	2 106	2 098	2 063	2 056	2 096	2 100	2 083	2 090
Relative difference of the LCC with respect to the base case		*0%*	*-2%*	*-2%*	*0%*	*0%*	*-1%*	*-1%*

Table 6.16: LCC of combinations of design options referred to a unit of product over its lifetime and compared to the base case (BC2)

	BC 2 (10 ps)	C1*	C2*	C3*	C4*	C5*	C6
in EUR							
Product price (RRP)	750	798	834	816	852	871	983
Electricity	706	625	594	562	499	483	539
Water	169	169	169	162	162	157	157
Dishwashing detergent	560	560	560	560	560	560	560
Rinsing Agent	32	32	32	32	32	32	32
Regeneration salt	67	67	67	67	67	67	67
Repair & maintenance costs	57	57	57	57	57	57	57
Total	2 340	2 307	2 312	2 256	2 228	2 226	2 394
Relative difference of the LCC with respect to the base case		*-1%*	*-1%*	*-4%*	*-5%*	*-5%*	*2%*
Product price (ORP)	516	549	574	561	586	599	642
Total LCC	2 106	2 058	2 052	2 001	1 962	1 954	2 053
Relative difference of the LCC with respect to the base case		*-2%*	*-3%*	*-5%*	*-7%*	*-7%*	*-3%*

* C1: D3+D2 (fan, automatic door opening)
C2: D3+D2+D1 (fan, automatic door opening, heat exchanger)
C3: D5+D3+ D2+D7 (longer programme duration, fan, automatic door opening, improved sensors)
C4: D5+D3+D2+D7+ D1 (longer programme duration, fan, automatic door opening, improved sensors, heat exchanger)
C5: D5+D3+D2+D7+ D1+D8 (longer programme duration, fan, automatic door opening, improved sensors, heat exchanger, consumer feedback mechanisms)
C6: D5+D7+D8+D1+ D4 (longer programme duration, improved sensors, consumer feedback mechanisms, heat exchanger, adsorption technology)

6.4. Analysis LLCC and BAT

6.4.1. Selection of the combinations of design options

To select the combinations, first the single design options have been ranked according to their Simple Payback Period (SPP) (see also COWI and VHK (2011b). The SPP has been calculated as follows:

$$SPP = dPP / dOE$$

With

dPP: extra investment in purchase price (both RRP and ORP) of the design option compared to base case

dOE: reduction in annual operating expense of the design option compared to the base case

Table 6.17 shows the simple payback periods for the design options for Base Case 1 (calculated both with the recommended and the observed retail price (RRP and ORP)) in increasing order. It can be seen that, when calculating with the ORP the simple payback periods are shorter, however the resulting order of the options is the same.

The payback periods for Base Case 2 differ slightly, however the resulting order of the options is the same.

Table 6.17: Simple Payback Periods (SPP) of the design options (BC1) (RRP and ORP)

Design option	SPP (years) (RRP)	SPP (years) (ORP)
D5*: Moderate increase of programme duration	0.0	0.0
D3: Fan	3.7	2.4
D2: Automatic door opening	5.8	3.9
D7: Advanced sensor technology	6.6	4.4
D8: Consumer feedback mechanisms	9.4	6.3
D1: Heat Exchanger	13.5	9.0
D4: Adsorption technology	15.6	10.3
D6: Heat pump with R134a	104.8	69.7

* "longer programme duration" seems to be a design option that cannot be realised as such, but that comes along with certain single design options. The degree of prolongation and the resulting saving potential therefore might vary (see also section 6.1.2.1). Additionally, as "single option" it is considered to be an undesirable option as it might deviate the consumer from using the Eco programme.

RRP = Recommended retail price / ORP = Observed retail price

The results show that for the single design options D5, D3, D2, D7, and D8, the initial investment is recovered in a shorter time than the expected lifetime, i.e. that their estimated SPP values are lower than 12.5. These design options are therefore considered as economically favourable.

In case of D1 (heat exchanger) and D4 (adsorption technology) it depends on taking the RRP or the ORP if the initial investment is recovered within the expected lifetime. Taking the RRP it is not recovered, taking the ORP it is recovered.

Option D6 is neither taking the RRP nor the ORP economically favourable for the consumer regarding the payback period.

A second step in this study is to consider the combination of single design options. Obviously the combinations of single design options have better performance from the efficiency point of view than the implementation of a single option. However, as commented in section 6.1.5, the improvements of the combinations of single design options are not the direct sum of the single design options since it depends on the interaction among the design options.

Therefore, taking into account

- the ranking of SPP of single design options,
- stakeholder input on possible or impossible combinations (see below) and
- market research on existing appliances and the respective implemented design options

the following combinations have been defined (order of design options according to SPP ranking, see Table 6.17):

- C1: D3+D2 (fan, automatic door opening)
- C2: D3+D2+D1 (fan, automatic door opening, heat exchanger)
- C3: D5+D3+ D2+D7 (longer programme duration, fan, automatic door opening, improved sensors)
- C4: D5+D3+D2+D7+ D1 (longer programme duration, fan, automatic door opening, improved sensors, heat exchanger)
- C5: D5+D3+D2+D7+ D1+D8 (longer programme duration, fan, automatic door opening, improved sensors, heat exchanger, consumer feedback mechanisms)
- C6: D5+D7+D8+D1+ D4 (longer programme duration, improved sensors, consumer feedback mechanisms, heat exchanger, adsorption technology)
- C7: D5+D3+D2+D7+D8+D6 (longer programme duration, fan, automatic door opening, improved sensors, consumer feedback mechanisms, heat pump). Combination C7 is not possible for slimline dishwashers (BC2).

According to stakeholder feedback the following combinations are not possible

- Adsorption drying system (D4) with automatic door opening (D2) as this would disturb the proper functioning of the system.
- As the adsorption drying system (D4) already includes a fan, an additional fan for better air circulation (D3) is not necessary.
- Heat pump technology (D6) with heat exchanger (D1)
- Heat pump technology (D6) with adsorption drying system (D4).

The assumptions regarding the saving potential and additional costs of these combinations of options can be found in section 6.1.5.

Table 6.18 shows the simple payback periods (SPP) of the combinations of design options. In accordance to the life cycle cost results (see section 6.3.1) it can be seen that only combination C7 has a payback time which is longer than the assumed life time of dishwashers of 12.5 years (both for RRP and ORP). In case of combination C6 it depends if the RRP or the ORP is regarded if the simple payback period is shorter or around the assumed life time of dishwashers. All other combinations have shorter SPP which correspond to lower life cycle costs than the base case.

Table 6.18: Simple Payback Periods (SPP) of the combination of design options (BC1)

Combination of design options	SPP (years) (RRP)	SPP (years) (ORP)
C1	7.4	4.8
C2	9.3	6.1

Combination of design options	SPP (years) (RRP)	SPP (years) (ORP)
C3	5.5	3.6
C4	6.0	3.9
C5	6.5	4.3
C6	13.0	8.6
C7	36.7	24.1

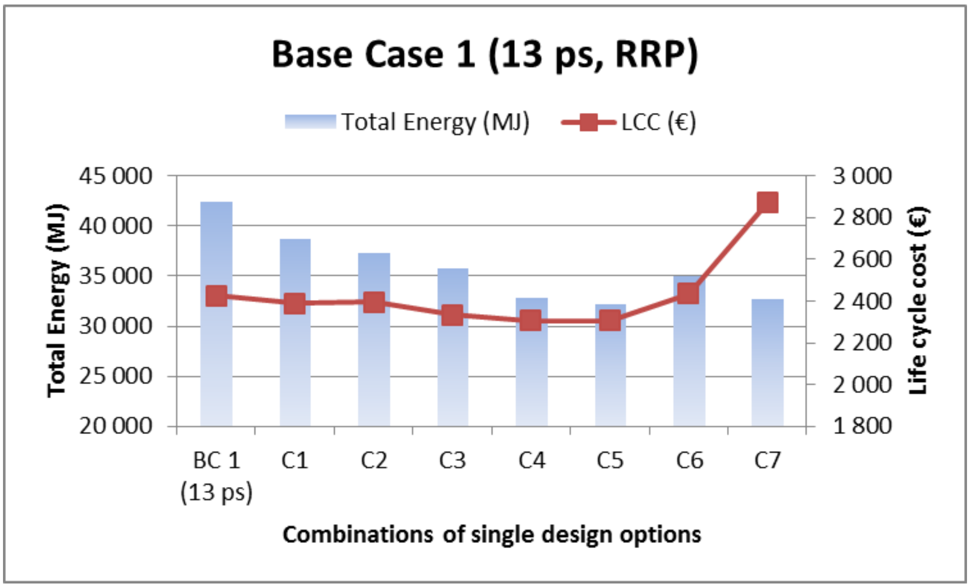
RRP = Recommended retail price / ORP = Observed retail price

6.4.2. Least Life Cycle Cost calculations

The life cycle costs and the environmental impacts of the base case and the combinations of the single design options are plotted in one graph to give the least life cycle curve. Figure 6.5 and Figure 6.7 show these graphs for base case 1 taking into account the recommended retail price (RRP) and the observed retail price (ORP). Figure 6.7 and Figure 6.8 show these graphs for base case 2 (also both taking into account RRP and the ORP). As environmental impact indicator the total energy consumption (MJ) over the lifecycle is chosen (the absolute impacts/costs and the savings are already outlined in the previous sections 6.2 and 6.3 on the impacts and costs of the combinations).The only difference between the two graphs of each base case are on the LCC results, the environmental impacts are identical.

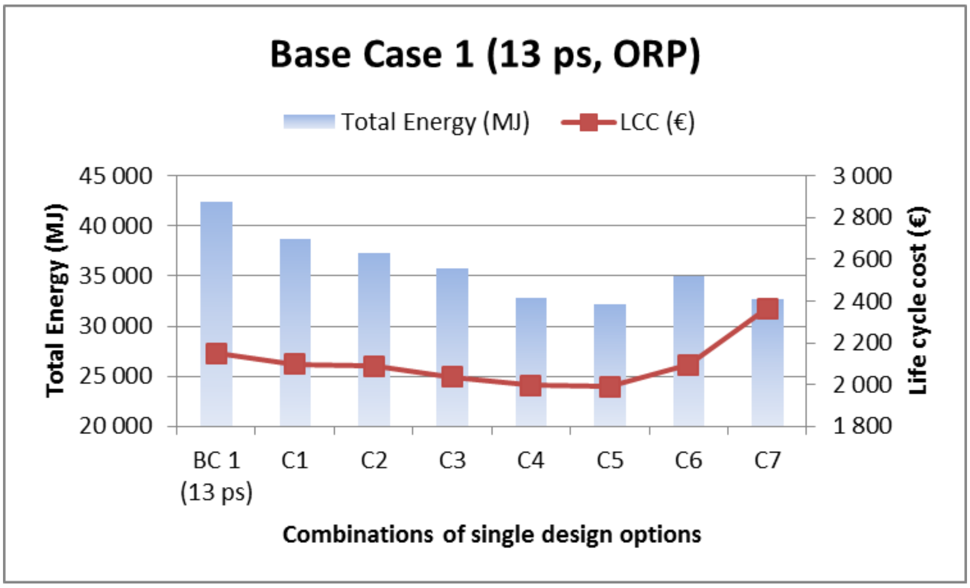
From the figures it can be seen that the shape of the graphs for base case 1 and base case 2 is nearly identical, with the exception that combination C7 does not exist in case of base case 2 as heat pumps (currently) cannot be included in slim line dishwashers. For both base cases the total energy consumption decreases from combination C1 to combination C5. Combination C6 shows a slightly higher energy consumption again (consumption is between that of C3 and C4), whereas the consumption decreases again from C6 to C7 (the value of C7 is between those of C4 and C5). As outlined in sections 6.2.2 and 6.2.4 this decrease would be in principle the same or at least very similar for the impact categories electricity consumption, hazardous waste, GWP, acidification and VOC. For the impact categories PM and eutrophication no significant change occurred, therefore the combinations neither lead to savings nor increase in impact in these categories. For the impact categories water (process), water (cooling), non-hazardous waste, POP, heavy metals (both to air and to water) and PAHs the impacts decrease from the base case to combination C5 and then increase again for the combinations C6 and C7.

The shape of the LCC curve is basically the same for the RRP and the ORP case: the life cycle costs of combinations C1 to C5 of base case 1 are slightly decreasing. When taking into account the RRP the LCC decrease from -1% (C1) to -5% (C5). When taking into account the ORP the LCC decrease from -2% (C1) to -8% (C5). Both for RRP and for ORP the LCC increase then again to 0%/-3% (combination C6) compared to the base case and to +18% /+10% (combination C7). The absolute value of the LCC curve is different however. The LCC curve calculated with the RRP is obviously higher than that calculated with the ORP. It has to be considered however, that all differences between the life cycle costs of combinations C1 to C6 are rather small. Note that the vertical axes in Figure 6.5 and Figure 6.7 do not start from zero).



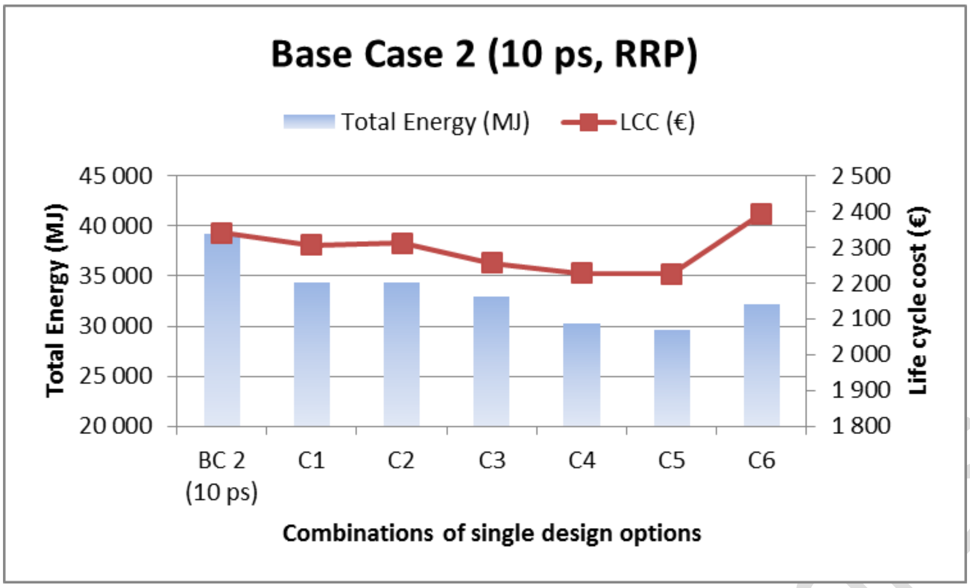
Note that the vertical axes do not start from zero.

Figure 6.5: **LCC for the combinations of design options together with the total energy consumption over the lifetime for Base Case 1 (13 ps) taking into account the recommended retail price (RRP)**



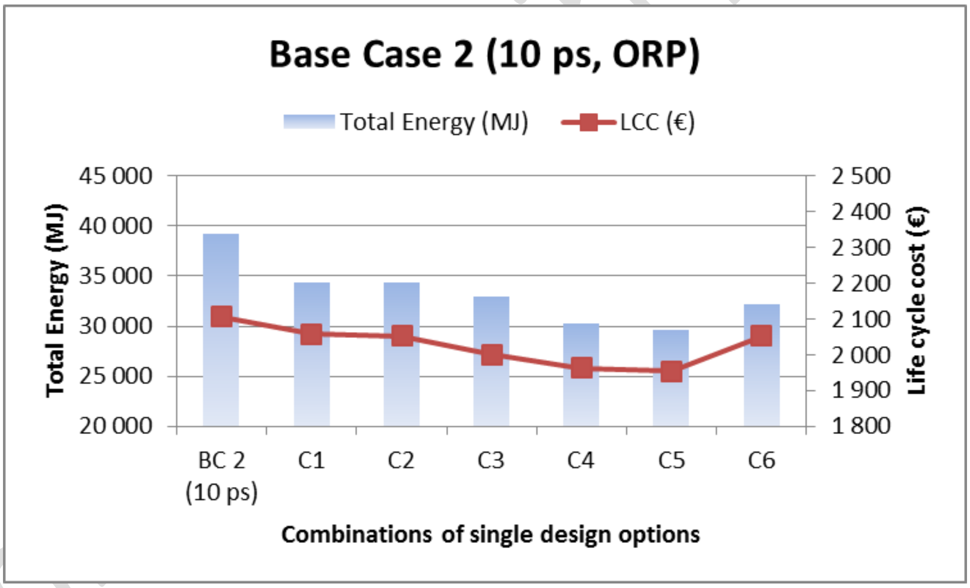
Note that the vertical axes do not start from zero.

Figure 6.6: **LCC for the combinations of design options together with the total energy consumption over the lifetime for Base Case 1 (13 ps) taking into account the observed retail price (ORP)**



Note that the vertical axes do not start from zero

Figure 6.7: **LCC for the combinations of design options together with the total energy consumption over the lifetime for Base Case 2 (10 ps) taking into account the recommended retail price (RRP)**



Note that the vertical axes do not start from zero.

Figure 6.8: **LCC for the combinations of design options together with the total energy consumption over the lifetime for Base Case 2 (10 ps) taking into account the observed retail price RP)**

7. Task 7: Policy analysis and scenarios

Building on the information gathered and produced in the previous tasks, this task aims at describing potential policy measures which could be proposed for household dishwashers. In general, these measures relate to generic and specific ecodesign requirements, the energy label and/or possible resource efficiency requirements, standards and measurement methods as well as consumer information and education. Self-regulation or voluntary agreements by industry (as set out in the Ecodesign Directive 2009/125/EC) are not seen as alternative to the existing ecodesign measures, however might be supportive for example in terms of consumer information campaigns.

A full list of potential policy options is provided in Annex 8.2.5 and Annex 8.2.6. After discussion with stakeholders a short-list of selected policy measures is discussed more in detail in the following sections. The expected benefits of these measures, possible drawbacks for the environment as well as for the consumers, industry and other stakeholders are described.

7.1. Policy analysis

7.1.1. Stakeholder consultation during the preparatory study

During the preparatory work for developing this report a continuous stakeholder consultation has taken place. Stakeholders have been contacted bilaterally for information exchange and two technical working group (TWG) meetings have been organised. Each TWG meeting was public and composed of experts from Member States' administration, industry, NGOs and academia. The first TWG meeting took place in Seville on 23 June 2015 and focused on tasks 1-4. The second TWG meeting was organised in Brussels on 17 November 2015 and was dedicated to tasks 5-7.

Additionally, the project team has visited different manufacturers, test labs, recyclers and a trade fair to investigate the products in detail and to stay up to date with the latest developments. Two questionnaires have been distributed to the stakeholders along the process, addressing information and data updates, and gathering opinions on scope, definitions, and performance parameter specifications like electricity and water consumption, programme duration, etc. An online communication system BATIS has been set-up for easy exchange of documents between registered stakeholders. A website was made available to have the final working documents in the public domain.

More specifically regarding policy options, a comprehensive list of potential policy options including expected benefits and potential disadvantages, challenges and / or drawbacks was developed and circulated to stakeholders for further detailed feedback during summer 2015, cf. Annex 8.2.5 (energy and water) and Annex 8.2.6 (material resource efficiency).

7.1.2. Current status of household dishwashers in the policy landscape of ecodesign and energy label

Household dishwashers already have a history when it comes to ecodesign and energy label. The first ecodesign and energy label requirements were published in 1997. The outcome of the first revision was published in 2010 with requirements reaching into 2016.

Given the fact that this is the second revision of ecodesign and energy label requirements for household dishwashers, industry indicates in general that not much improvement potential on the energy consumption side is still to be harvested with current technologies. The market and sales data in Task 2 indeed show a slowing down of energy efficiency improvement for household dishwashers in the last years.

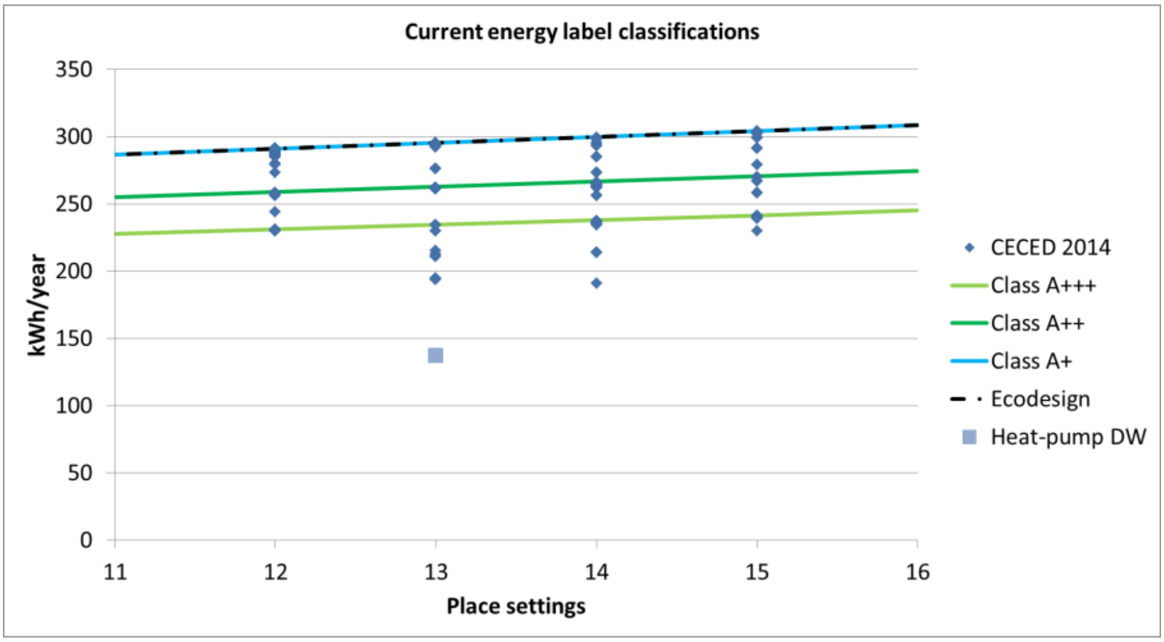
However, in Task 6 different design options are identified and described which still can improve the energy efficiency of household dishwashers.

Table 7.1 shows that only three label classes (i.e. A+, A++ and A+++) are allowed on the market for dishwashers with ps ≥ 11 since December 2013 and for dishwashers with ps ≤ 10 from December 2016. Only for dishwashers with ps ≤ 7, the label class A will still be available. In 2013 about 10% of the dishwashers that were sold on the market were classified as A+++. Altogether, this calls for a revision of the energy label classes, especially in view of the upcoming revision of the framework energy label directive.

Table 7.1: Overview of the current requirements, which classes are phased out

Class	EEI	Tier Dec 2011	Tier II Dec 2013	Tier III Dec 2016
A+++	EEI < 50			
A++	50 ≤ EEI < 56			
A+	56 ≤ EEI < 63			
A	63 ≤ EEI < 71		Allowed for ps = 10 and width < 45cm Allowed for ps ≤ 10	Only allowed for ps ≤ 7
B	71 ≤ EEI < 80	Allowed for ps = 9, 10 and width < 45 cm	Banned for all machines	Banned for all machines
C	80 ≤ EEI < 90	Banned for all machines	Banned for all machines	Banned for all machines
D	EEI ≥ 90	Banned for all machines	Banned for all machines	Banned for all machines

A sample of dishwashers sold in the EU in 2014 (CECED database) with ps ≥ 11 is shown in Figure 7.1 together with the current labelling classes and ecodesign requirements. It shows improvement potential in energy performance, especially comparing the heat pump dishwashers with the other models. Please note that the figure shows the yearly energy consumption under standard conditions, i.e. in the Eco programme. As shown in Task 6, under real-life conditions the improvement potential through the application of a heat pump is smaller. Also, the heat pump dishwasher comprises also other design options (e.g. automatic door opening, etc.). Therefore, for a final evaluation of the heat pump technology the outcomes of the environmental assessment and LCC analysis performed in the previous section (see section 6) should be taken into account.



Note that the energy consumption is based on the standard (Eco) programme only.

Figure 7.1: **Yearly energy consumption of dishwasher models on the market in 2014 in function of their place settings for ps ≥ 11 together with the current labelling classes and ecodesign requirement. A heat pump equipped dishwasher is shown as reference for the most efficient dishwasher on the market.**

Due to the history of ecodesign and energy label requirements for dishwashers, the minimum energy performance requirements are seen to be at a high level. Therefore, it might not be necessary to make these minimum performance requirements stricter in a next revision. The energy label classes however might be revised to provide an incentive to manufacturers to continue improving their appliances.

Further, due to the relatively small improvement potential with current technologies regarding the energy performance of the dishwashers, other areas of improvement might become of higher importance. This can be the case for material efficiency and end-of-life management. Relevant information about these two areas has been commented along this study. The following list is a summary of this information:

- in general, there is an increasing need for finding feasible, operational metrics for implementing resource efficiency aspects into product policies, as reflected in a number of European Union strategic policy documents, including the revision of the ecodesign and energy label directives, and the drafts of the Action Plan on the Circular Economy.
- there is an increasing number of examples of integration of resource efficiency matters (such as durability and facilitating end-of-life management of products) into specific product policy instruments like mandatory ecodesign regulations (e.g. ecodesign requirements for vacuum cleaners) or voluntary ecolabels.
- there seems to be still a gap between the already implemented requirements/criteria in other product policies (e.g. EU Ecolabel) related to resource efficiency and the ongoing research in this field. The ongoing research highlights the potential beneficial impacts of resource related criteria.
- there is an absence of proper standards for testing and measuring resource-related criteria and procedures for verification and market surveillance. Currently, a number of standards are somehow related to material efficiency (e.g. safety standards for durability, standards for recycling in end-of-life management), but they are primarily developed for other purposes (product safety, management at recycling operations) and are not directly addressing resource efficiency in the design phase.
- reparability of dishwashers seems to become more difficult for reuse and repair centres due to lack of access and costs of spare parts, lack of access to service manuals, software and hardware

as well as due to product design which hinders disassembly of the appliances to repair. Also for the users, the repair of the machines becomes less attractive due to the relatively high costs (depending on the defective component between 100-300 euros) compared to decreasing prices for the purchase of a new appliance.

- regarding EoL-management, there are currently well established recycling processes in place in accredited WEEE installations. Appliances with heat pumps would have to be processed separately for depollution (extraction and incineration) of the F-gas refrigerants. Permanent magnet motors in dishwashers had been highlighted as relevant subject of manual disassembly to recover rare earth and copper content. However, recent stakeholder feedback indicates that newer permanent magnet motors do not contain rare earths and copper is replaced by aluminium, both because of lower cost and equal performance of the alternative.
- the collection rate of waste dishwashers through the accredited WEEE collection systems, mostly in connection with producer responsibility systems, and its treatment in accredited installations is in some Member States (e.g. IT, ES, PT, GR) only around 1/3 of the appliances sold on the market. In other Member States, this share is around 2/3. In both cases, large flows are apparently not treated following WEEE prescriptions. Pathways of appliances not collected and registered in official statistics might be prolonged storage in households, recycling within the EU but in non-accredited installations that do not report to official Member State statistics, or export as used EEE or end-of-life equipment to non-European destinations. The revised WEEE Directive has set specific measures to try to address these enforcement issues. The upcoming Action Plan on a Circular Economy may likely address how to improve producer responsibility systems, by imposing minimum operation rules (e.g. transparency of fees and costs, non-profitability) and proposing fees to manufacturers based on the recyclability of their appliances (for which clear definitions and measurement of recyclability will be needed).

Against this background a list of different potential policy options on material efficiency and EoL management of household dishwashers are investigated. The options are split into two main sections: durability (including reparability) and EoL management.

7.1.3. Policy options related to energy and water consumption

Table 7.2 shows an overview of selected policy options for further discussion related to water and energy consumption. The options are discussed more in detail in the sections below.

Table 7.2: Summary overview of the pre-selected policy options to be discussed in this section

Pre-selection of policy options for DW on energy and water consumption	Options	Expected benefits	Possible drawbacks and risks
TEST CYCLE	Changing the test cycle for better alignment with consumer behaviour (inclusion of other programmes or inclusion of partial load and partial soiling)	Better alignment with real-life conditions	Less transparency, higher test burden
CYCLE TIME	Cap on the maximum programme time for the standard programmes	Unrealistic cycle times will be avoided	Less market differentiation
	Adding the programme time of the standard programmes on the energy label	Manufacturers will try to reduce the time	One cannot be sure that shorter programme times will indeed be realized by this measure and how

Pre-selection of policy options for DW on energy and water consumption	Options	Expected benefits	Possible drawbacks and risks
			consumers will react
WATER CONSUMPTION	Cap on water consumption per cycle	Lower water consumption	Less performance, worse rinsing
ENERGY LABEL CLASSES and ECODESIGN REQUIREMENT	Review of label class limits	Incentive for energy efficiency improvement	Energy improvement might be at the expense of other environmental impacts
	Review of energy efficien-cy ecodesign requirement	More efficient appliances	Less market differentiation
LOW-POWER MODES	Integration in the AEC calculation	Alignment with real-life consumption	Test burden, less transpar-ency
	Specific cap for certain low-power modes	Avoidance of increasing consumption	
ENERGY LABEL INFORMATION	Cycle time, cleaning per-formance, hot fill, energy per year or per cycle	Better information for consumer, more targeted consumer choice	Information overload, unclear consumer reaction
RINSING	Include a rinsing perfor-mance minimum ecodesign requirement	Rinsing performance guaranteed and controlled	No proven measurement standard available; Test burden

7.1.3.1. Programme responsible for the energy label and ecodesign requirements

According to the ecodesign requirement introduced in the last revision and implemented since 2013 a so called ‘standard’ programme shall be used for the calculation of the energy consumption and other parameters for household dishwashers. According to the last revision the standard programme shall be

(i) a programme recommended for normal use, to clean normally soiled tableware,

(ii) the most efficient programme in terms of its combined energy and water consumption for that type of tableware,

(iii) the default machine programme for dishwashers equipped with an automatic programme selection/function or with the capability to maintain the selection of a given programme. In addition it shall be declared in the booklet of instructions along with information that this programme is to clean normally soiled tableware and that it is the most efficient programme.

The definition of this programme makes it suitable for daily housework and this is reflected in the ecodesign requirement of setting it as the default programme option.

According to the measurement standard EN 50242/ EN 60436 the standard programme shall be clearly identifiable on the appliance programme selection device and named ‘Eco’. New dishwashers that appear on the EU market since 2013 are therefore equipped with the ‘Eco programme’ as default option.

The conditions under which the standard / Eco programme is measured include full loading with mainly porcelain items and cutlery and quite harsh soiling. Both aspects are not fully representative for the usage conditions under real-life conditions, where more often plastic items are loaded into the machine and the soiling is usually not that strong. The revision of the test standard (cf. section 1.2.5.1) is expected to consider at least the first aspect and changed the standard load items accordingly (new load items are for example stainless pots, coffee mugs and melamine plastic items). The strong soiling ensures that the dishwasher is performing its function well and that there is a differentiation between the dishwashers.

Different options can be hypothesized with regard to the programme that has to be measured and the measurement conditions.

a) Keep the Eco programme

This proposal would keep the Eco programme as the basis for energy label and ecodesign requirements. According to (Alborzi et al. 2015) 19% of all dishwashing cycles are Eco programme cycles. Given the fact that this has been implemented only recently, it is difficult to fully quantify the effect of having the Eco programme as default consumer choice. However, it seems that the share of consumers that choose the Eco programme as the daily used programme is increasing. According to the user behaviour survey results (cf. Figure 7.2) an increased use of the Eco programme is noticed for machines which are younger than three years. This could be related to the implementation of the Eco programme as default programme in the previous revision. Manufacturers claim even a bigger increase of the use of the Eco programme. This is an indication that the measure has still potential to deliver better results in the coming years.

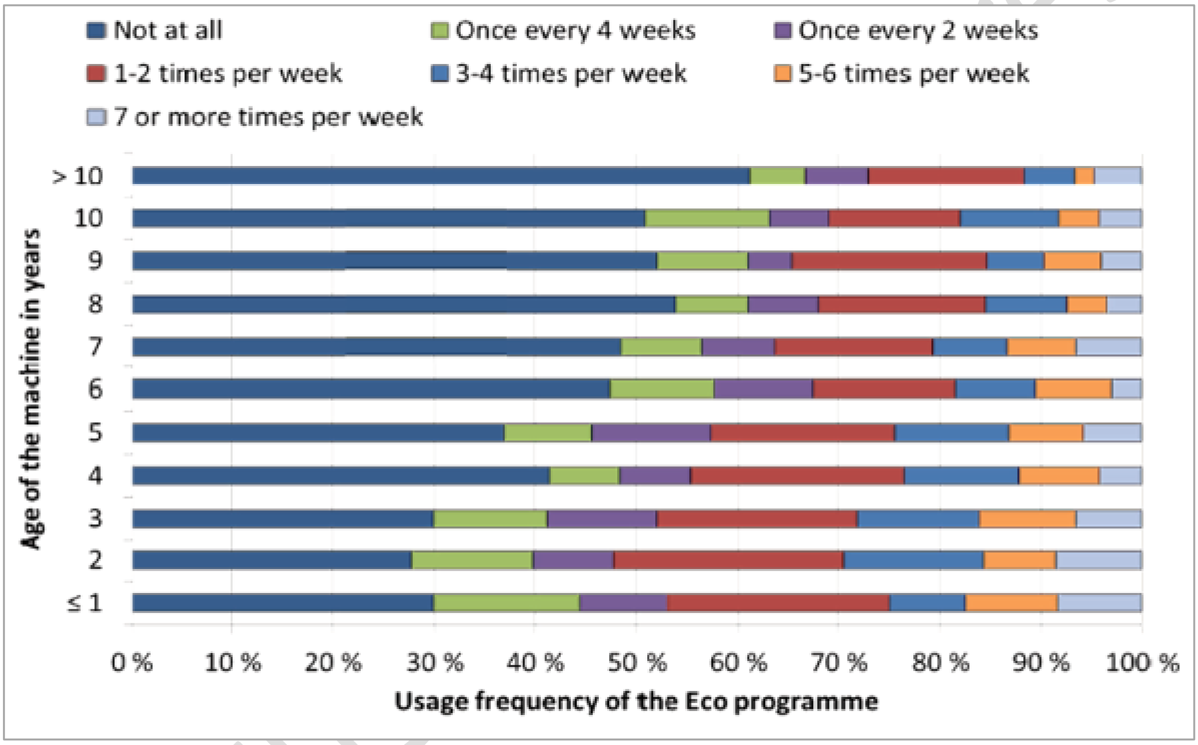


Figure 7.2: Usage of Eco programme based on the age of the machine

Several advantages have been identified in case of a continuation of the current situation, such as the existence of a recently updated standard, simpler test procedures compared to the following options and a fair comparison of the energy and water consumption values of the dishwashers by the consumers (as the values reported on the energy label are based on a single programme and under the same conditions for all the products).

On the other hand, this option has as drawbacks the provision of a possibly unrealistic picture of the consumption values of the appliance since consumers also use other programmes. The current deviation of the consumption under real-life conditions is not so large however, see Table 5.3 and Table 5.5. Another risk could be that, especially if the duration of the Eco programme becomes too long, consumers increasingly prefer other programmes, i.e. programmes that deliver the same function but with shorter programme duration and higher energy consumption. This would be a development which equals the current, unsatisfying situation in the case of washing machines.

Currently there is a mismatch between the measurement standard and the regulation regarding the naming of the programme to be measured. The regulation speaks of 'standard programme', while the standard states that the programme that is mentioned in the regulation as 'standard' programme should be named 'Eco'. In case of keeping the Eco programme as the basis for energy label and ecodesign requirements this could be aligned.

b) Eco vs. 'normal' programme

Currently the standard programme, named 'Eco programme', which per definition is the most efficient programme, has to be measured. Some stakeholders are in favour of using a 'normal' programme. Several reasons have been put forward by stakeholders and are summarized below.

- The 'Eco programme' is per definition the most efficient programme. This requirement could prevent manufacturers to introduce other, more efficient programmes.

As the energy label is a competitive factor, manufacturers will always try to make the 'standard programme' (i.e. the programme which is to be measured for the energy label classification and for ecodesign compliance) as efficient as possible. This means, even if a programme, which is currently not the most efficient one, would be used as standard programme, it would most presumably soon become the most efficient programme "for cleaning normally soiled tableware" (i.e. with a performance necessary to reach an A-class cleaning efficiency when cleaning the dishes which are soiled according to the standard). This would bring the situation back to as it stands now and only a change in wording would really have happened, i.e. from 'standard' or 'Eco' programme to 'normal' programme. On the other hand, manufacturers can offer, and some already do, programmes that, under specific conditions, use less energy than the Eco programme, e.g. programmes for lightly soiled tableware or 'glass only' programmes.

- The name 'Eco' might not seem suitable for everyday use to the consumer which therefore might choose other programmes that seem more appropriate (but might have higher energy consumption). Moreover, in some machines an additional programme can be indicated as 'normal' or 'daily' which might guide the consumer away from the 'Eco' programme.

The discussion of the wording has taken place in the standardization organisation and a compromise has been found, agreed and implemented in 2013. The name 'Eco' has been agreed after wide stakeholder discussion during the standardization work and is a good compromise between translation issues and good information to the consumer. Indeed, the question could be asked if the word 'Eco' is considered to be most suitable for everyday use. Changing to another (language-specific) wording might put a burden on the manufacturers who have to change the panels and provide different translations for different countries. Applying an icon instead of a word might also be less informing to the consumer. One stakeholder has suggested contouring the word 'Eco' with the arrow used for the energy label. If the wording 'Eco' will be continued to use, stakeholders suggest to explicitly mention this in the regulation to avoid confusion.

It might be considered as policy option, to prohibit the use of names like 'daily', 'normal', etc. for other programmes than the Eco programme. This could further encourage the consumer to use the 'Eco' programme for daily use.

c) Introduction of additional programmes or test conditions (i.e. not keeping the Eco programme or include the Eco programme in a combination of test programmes)

Even if the Eco programme is designed to clean normally soiled dishes, most consumers have the need of washing dishes with different programmes (e.g. intensive, automatic, shorter cycle times, etc.). Therefore, some stakeholders call for a change in programme testing related to the energy label classification and ecodesign requirements. Further, it is observed that the real-life energy consumption of the dishwashers is not fully reflected in the energy label and ecodesign requirements. It is estimated that the energy consumption of the Eco programme differs around 10% from the real-life energy consumption (see section 5.2.3).

Testing a combination of programmes (e.g. automatic and Eco or full and half loads) might be a solution to this issue. However, it would complicate testing, verification and market surveillance. This option implies more complicated and costly testing as several programmes should be measured for each model. Transparency to the consumer could be lost as well since the final energy and water consumption values will have to be calculated from different programmes (e.g. by an arithmetic or weighted average). Moreover, a change to other programmes could invite manufacturers to be creative with the names of the programmes and circumvent the goal of this measure.

Some stakeholders would like to see a *testing of the most used programme*. This would be difficult to follow up as it can change in the future. Moreover, it might well be that in the future the Eco programme will be the most used given the recent (from 2013 on) requirement for having the Eco programme as default option. Better consumer information could also help to increase the use of the Eco programme.

Some machines have automatic programmes that might adapt the programme to real-life conditions, e.g. to a low soiling level. The current situation is criticized because people today often buy a sophisticated dishwasher with developed sensor technology, but if they use it as recommended (i.e. Eco programme for everyday use), they do not benefit from these sensors as they are not active in the Eco programme (they are usually switched off to increase repeatability and reproducibility while testing). Also, the dishwasher might need more energy than necessary when it is run in the Eco programme as this has a fix setting which is designed for a load and soiling that is usually more demanding compared to the real-life situation. Therefore, some stakeholders are in favour of *testing the automatic programme*. This could be done in the following ways:

- introduce a new “standard” soil and loading for testing the automatic program, e.g. half load, half soiling, etc. like in the US and defined in IEC 60436:2015, Annex P. Manufacturers could however tune their automatic programme to these new “standard” conditions which will lead to automatic programs that are “standardised” and thereby losing much of its capacity to adapt to each situation of the real-life.
- introduce a random soiling and test the automatic program. This will be very difficult or even impossible to verify by market surveillance authorities.

Both options of testing the automatic programme have drawbacks regarding implementation. Moreover, the automatic programme is nowadays used only in 10% of the cycles and contributes to the real-life consumption about 12%.

The saving potential of automatic programmes mainly results from the adaptation to different soil levels:

- the loading sensors can contribute to a lesser extend to the total energy saving potential because even if a dishwasher detects a smaller load, it will still use about the same amount of water and the same amount of energy to heat that water. Possible savings result from the fact that less energy is needed to heat up the load and the cycle duration might be shortened as well. If the dishwasher employs a temperature sensor to detect the point when the heater should be switched off the energy consumption is automatically lower in case of partial loading.
- the soiling sensors are more efficient but are more difficult to employ in a reliable way. The additional burden to manufacturers and market surveillance could therefore be out of balance compared to the possible savings.

Another aspect that can bring energy savings is that sensor using programmes are currently not tested for the energy label or ecodesign requirements and therefore there is no incentive to design these programmes in a way that they need less energy when run with lower load and/or soiling. Such less demanding conditions might therefore just result in shorter programme duration and, depending on the soiling, still the same or even higher energy consumption as it is currently the case. Currently automatic programmes indeed do not use less energy than the Eco programme even when run with lower load and/or soiling compared to the standard conditions (see e.g. (Brückner 2013; Stiftung Warentest 2016)). The values given in (Stiftung Warentest 2016) show that with the same load and soiling compared to the standard conditions the automatic programmes use between 10% and 56% more energy than the Eco programme.

It can therefore not finally be evaluated if the inclusion of automatic programmes in the testing would result in lower energy consumption, neither under standard nor under real-life conditions. Additionally, some manufacturers have automatic programmes that adapt well to changing load and soil conditions while others have programmes that adapt less.

Finally, one stakeholder suggested staying with *testing the Eco programme but with full and half load* as is the case currently for washing machines (e.g. 3 runs with full load and 4 runs with half load). It is supposed that then the soil sensors of the appliances would be activated in the Eco programme (which currently is not always the case) and thus real-life conditions are better met. This solution would be similar to the suggestion to test the automatic programme.

7.1.3.2. Cycle time

From Figure 2.1 in section 2.2.4.1, a tendency on the market towards longer cycle times especially of the Eco programme of dishwashers can be seen from 2010 to 2014. This seems to have stabilized in 2015. The increase in cycle times can be explained by the Sinner cycle where time is among the variables that affect the cleaning results and the energy consumption. In other words, and considering the conditions set up for a dishwasher, for a certain cleaning performance level, an extension of the cycle time leads to a reduction of the energy consumption (see also section 4.2.2).

The incentive of increasing the cycle time for reducing the energy consumption has led to longer programme cycles that average 196 minutes for the Eco programme. From the last user behaviour survey it is not 100% clear how consumers react to long cycles (see Figure 7.3). The survey revealed that one of the reasons for not using the Eco programme is the long duration of this cycle but at the same time, it seems that consumers are not aware of the relation between longer cycle times and lower energy consumption for the same cleaning performance.

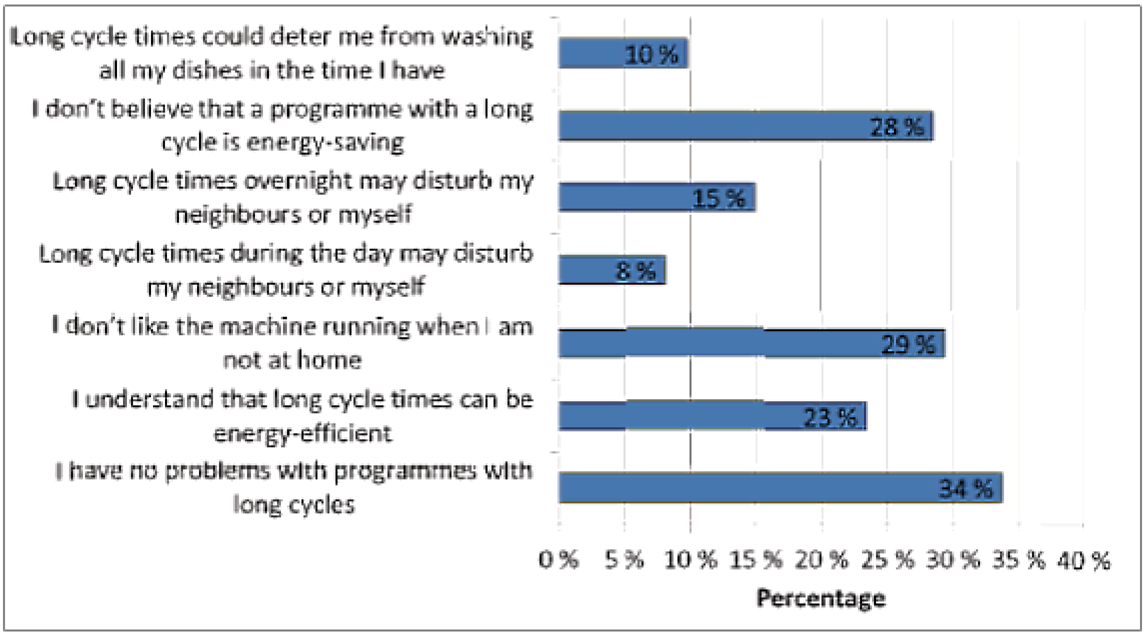


Figure 7.3: Acceptance of long programme cycles ("What is your opinion of cleaning programmes with long cycle times?")

This revision should prevent that programmes are developed with long cycle times which are finally not used by the consumer. This is what has happened in the washing machine case where the most efficient programmes may last up to 6 hours. However, as discussed before, for technical reasons this might not be the case (see Table 6.1, design option 3). In order to prevent this situation, several measures could be hypothesized:

a) A cap on programme time as an ecodesign requirement

The inclusion of a cap (e.g. Eco programme duration no longer than x min) that limits the duration of the Eco programme could be included as an ecodesign requirement. There are several possibilities on the level of strictness and how to specifically apply this. As a preventive measure, a cap that avoids the development of unrealistic long cycle times could be set e.g. at 210 min. A step further would be a stricter cap, e.g. 120 min, to encourage consumers to use more often the Eco programme.

A cap on programme time as an ecodesign requirement may prevent manufacturers from innovation and new developments (e.g. efficient heat pumps need longer programme durations). Moreover, it would prevent consumers who would generally accept longer programme times to go for the most efficient washing cycle, thereby limiting the energy saving potential. Additionally, this measure would reduce differentiation among the machines on the market.

If a cap on timing would be introduced, the regulation could refer to a 'standard' programme which is recommended for normally soiled dishes, but which not necessarily is the most efficient one as is currently the case. The manufacturer should be given the choice to still add a more efficient programme for normally soiled dishes. A change in definition of the standard programme would thus be needed for the implementation of this measure.

b) Cycle time information on the label

Another possibility is to provide information about the Eco programme duration on the label. This information is already provided to the consumers in the user manual and product fiche. The main aim of this measure is to help consumers to take a well-informed decision prior to the purchase of the machine.

As commented before, programme time is an important parameter for balancing the information on the energy efficiency of a dishwasher since consumers want quicker programmes but at the same time lower energy consumption levels. According to the user behaviour research, the most accepted programme duration by average users was 60 -120 min (cf. Figure 7.3) while most of the Eco programmes of machines on the market last longer than 120 min. However, communication plays a role, and consumer research also indicates that better informed consumers with regard to the role of duration in cleaning (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 could be proposed to include cycle time information on the label. Additionally, the cycle time information on the label might stimulate innovation and competition and shift the market towards machines with shorter cycle times (even more than with a cap) without preventing others from reaching better energy performances.

On the other hand, such a measure might be counterproductive as consumers might start to focus on the cycle time instead of the energy efficiency. Improvement potential could get lost. Previous experience on providing the information of the cycle time could be found in the energy label requirements for household tumble driers Regulation (EU) No 392/2012.

In order to implement this idea successfully, a better definition of how this information should be included in the label should be developed. Consumer organizations support the indication of the cycle time on the label and in the user manual, supported by an awareness-raising campaign on the Eco programme in order to prevent the misconception that shorter programmes consume less energy than longer ones. As environmental arguments might not work with all consumers, such an information campaign should highlight in the first place the economic benefits for consumers when using primarily the Eco programme.

7.1.3.3. Water consumption

Water consumption is addressed in the current regulation by the indication of the water consumption per annum on the label. An additional step could be a cap on water consumption as an ecodesign requirement.

However, since the water consumption in the dishwashers is already low a further reduction of the water consumption seems difficult from a technical point of view. Water consumption is related to the cleaning performance and the rinsing performance. Both performances may be affected by a further reduction in water use. The introduction of a water cap should therefore be carefully evaluated in terms of effective benefits and potential negative impact on consumers.

Technically, the energy consumption is related to the water consumption, since part of the energy consumption is used to heat up the washing and rinsing water. Therefore, setting incentives to decrease the energy consumption will probably lead to an overall decrease in water consumption, as already happened as a result from previous implementing measures.

7.1.3.4. Adaptation of the energy label classes and ecodesign requirements

The existing specific ecodesign requirements and the energy label classes are defined as a function of the machine capacity (in terms of place settings) and a difference is made between small (e.g. table top and slim-line machines) and standard machines. Two standard annual energy consumption (SAE_C) reference lines are used for the calculation of the EEI, different for dishwashers with 10 or more place settings and a width of more than 50 cm, and for dishwashers with 9 or less place settings and with 10 or 11 place settings and a width of 50 cm and below. The SAE_C of dishwashers is currently a linear function of the place setting, as shown in Table 7.3.

Table 7.3: Calculation of the SAE_C of dishwashers

Place settings	Width	SAEC formula	SAEC (kWh/year)	SAEc per ps (kWh/year/ps)
8		$SAE_C = 25.2 \times ps + 126$	327.6	41.0
9			352.8	39.2
10	≤ 50 cm		378.0	37.8
11	≤ 50 cm		403.2	36.7
10	> 50 cm	$SAE_C = 7.0 \times ps + 378$	448.0	44.8
12	> 50 cm		462.0	38.5
13	> 50 cm		469.0	36.1
14	> 50 cm		476.0	34.0
16	> 50 cm		490.0	30.6

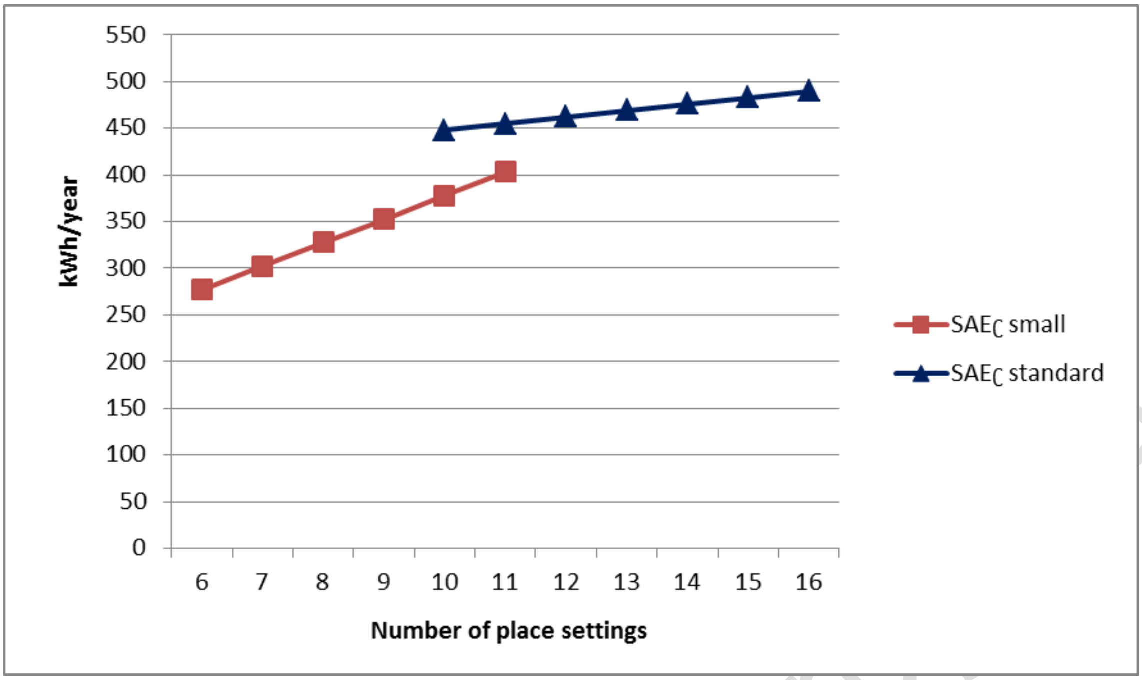


Figure 7.4: **Reference lines (SAEC) of small (table-top and slim line) and standard dishwashers and current minimum requirements (A, A+)**

Table 7.3 shows that larger machines have to be more efficient per place setting to reach a certain energy label classification as the SAEc per place setting is decreasing with increasing capacity. They do however consume more energy in absolute terms. This can also be seen in Figure 7.4: the reference lines are rather flat, especially in case of the standard dishwashers.

The machines with the highest capacity now have 15-16 place settings and this seems to be the limit given the fixed outer volume of the dishwasher. The outer volume is standardised according to kitchen requirements. Moreover, with the update of the new standard, the number of place settings might change as some types of dishes are expected to be changed e.g. some of the plates are changed for pots and pans.

An alternative would be to adopt reference lines independent of capacity. However, as outlined before, the reference lines, especially the one for standard dishwashers, are quite flat already. A differentiation between slim-line (45 cm) and standard (60 cm) dishwashers is probably still necessary. These types of dishwashers have different dimensions and are therefore more or less restricted when it comes to implementing improvement options. The difference in surface-volume ratio also influences the energy efficiency.

a) Rescale the current labelling scheme to A-G

According to the current regulation only those products classified under the three top levels can be found on the market, as described in detail in Table 7.1. A new set of energy label classes going from class G to class A could be created in accordance with the outcomes of the revision of the energy label directive (European Commission 2015c).

Care has to be taken in the redesign of the energy label classes. Strong ambitions in energy saving might lead to an increase of appliances on the market which are equipped with a heat pump. However, this might not be the best choice regarding life cycle costs for the consumers (see Figure 6.5) neither regarding the environmental profile (see Figure 6.1). Moreover, it would presumably increase the purchase price of this kind of dishwashers considerably which might hamper their penetration in countries where dishwashers are not that much in use (mainly Eastern Europe) and therefore prevent the environmental benefits associated with a wider use of this appliance compared to manual dishwashing (see section 3.3).

Different types of rescaling of the energy label should be assessed by looking to energy and water consumption and the cost for the consumer.

In general, changes in the tested programme and/or the test conditions (e.g. through the introduction of the new EN 50242 / EN 60436) have to be taken into account when defining the new label classes (see also section 1.2.5.1).

b) Update of the existing minimum energy performance standard (MEPS)

As most of the dishwashers already perform well (the worst class is now A+ for standard dishwashers), it might not be necessary to adjust the minimum energy performance standards (MEPS).

Adaptations in the case that the test programme and/or the test conditions change, might be necessary.

7.1.3.5. Low power modes

Currently, to evaluate the annual energy consumption (AEC) of a DW, the energy consumption per cycle is multiplied by an agreed number of cleaning cycles (280 cycles/year) and the energy consumption of low-power modes is added. The AEC formula consists of three parts: the energy consumption of the dishwashing cycle, the left-on mode and the off-mode.

These kinds of low power modes are in general regulated by the Standby Regulation (EC) No 1275/2008. A review study of this regulation has been launched in June 2015 (see http://www.ecostandbyreview.eu).

Currently, the *stand-by mode* is, in accordance with the Standby Regulation, a condition where the equipment is connected to the mains power source, depends on energy input from the mains power source to work as intended and provides only the following functions, which may persist for indefinite time:

- reactivation function or reactivation function and only an indication of enabled reactivation function (being the maximum power consumption 0.50W), and/or
- information or status display or combination of reactivation function and information and status display (being the maximum energy consumption 1.00W)

Additionally, the standby regulation requires that when an equipment is not providing the main function, or when other energy-using products are not dependent on its function, equipment shall, unless inappropriate for the intended use, offer a power management function that switches equipment after the shortest possible period 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 of the off mode and /or standby mode when the equipment is connected to the mains power source.

The *left-on mode* is, according to the Regulation (EC) No 1016/2010, 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. Since January 2013 a power management system is mandatory for all household dishwashers according to the Standby Regulation. When a power management system is implemented, the left-on mode reverts to off mode "*after the shortest possible period of time appropriate for the intended use of the equipment*" (cf. also section 1.2.1.1). The exact timing of what means "*after the shortest possible period of time appropriate for the intended use of the equipment*" is not clearly defined for dishwashers. Manufacturers state that in general dishwashers revert to off mode after maximum 30 minutes.

The *off-mode* is, according to the Standby Regulation, a condition in which the equipment is connected to the mains power source and is not providing any function. The off mode is regulated by that regulation and shall not exceed 0.50 W.

Specifically in the dishwasher the *off-mode* means a condition where the household dishwasher is switched off using appliance controls or switches accessible to and intended for operation by the end-user during normal use to attain the lowest power consumption that may persist for an indefinite time while the household dishwasher is connected to a power source and used in accordance with the manufacturer's instructions. Where there is no control or switch accessible to the end-user, 'off-mode' means the condition reached after the household dishwasher reverts to a steady-state power consumption on its own.

Other low power modes that for the time being are not included in the AEC formula, but are present or start being common in this type of machines, are the *delay start mode* and the *smart connectivity/smart ready mode.*

Smart connectivity of appliances to the internet is seen as an upcoming trend. It could help for better communication between manufacturer, consumer and appliance. Appliances with this function have been presented at the IFA 2015 fair in Berlin. This kind of smart connectivity/smart ready mode might fall under networked standby as defined in Regulation (EU) No 801/2013 amending the Standby Regulation. If not, however, a specific cap on the energy consumption of this mode could be introduced.

The *delay start mode* is similar to a standby mode regarding its function but, according to Regulation (EC) No 1275/2008, it is not considered as a standby mode because it has a limited duration. Currently the delay start mode can last up to 24 hours having an energy consumption that varies between 0.3 W and 3.0 W per hour (Stiftung Warentest, personal communication 2015). In practice, these kinds of modes normally do not exceed 8 hours and are not used for every cycle. In the current standard EN 50242/60436, the delay start mode is proposed to be measured for 3 hours.

Assuming the highest power consumption (3 W, representing current worst case), an assumed average duration of 8 hours and as option a) use in half of the dishwashing cycles (140 cycles) and as option b) use in all dishwashing cycles (280 cycles) the annual consumption of the delay start mode for Base Case 1 (13 ps) would amount to 3.4 or 6.7 kWh per year which equals a contribution of 1.2% and 2.4% to the overall energy consumption (see table in Annex 8.2.7.1). These assumptions represent rather a worst-case scenario on a per appliance basis. According to the consumer survey (Alborzi et al. 2015) consumers do not use the delay start that often (9% use it often, 13% use it sometimes) and for a lower duration (43% less than 3 hours, 40% between 3 and 6 hours, 7% more than 6 hours, 10% for varying times) resulting, as CECED provided in a detailed calculation, in an average additional energy consumption per appliance of 0.84 kWh/a (cf. Annex 8.2.7). This consumption represents 0.3% of the annual energy consumption of BC1 (13 ps).

On the basis of these grounds, the policy options to regulate the low power modes could be:

a) Keep on calculating AEC as it is done in the current regulation and add additional low power modes, e.g. the delay start function

This option would leave the calculation as it is currently and add further low power modes which are actually not included, like the delay start function.

It has to be noted however that the currently included low power modes (left-on and off-mode) were introduced in the AEC calculation before the Standby Regulation (EC No. 1275/2008) went into force. The mandatory prescriptions for standby, in place since 2013, seem to have made 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.

The delay start function might also be understood as a reactivation function. However Regulation (EC) No 1275/2008 would have to be adapted to include also standby modes which do not persist for an indefinite time.

b) Introduce a specific cap on the energy consumption of the delay start and/or the smart connectivity mode

Some stakeholders support setting an ecodesign requirement on the energy used by the 'delay start' function. Although the impact of this function on the energy bill on individual households might not be significant, they point out that dishwashers are broadly used in the EU and that the energy that could be saved cumulatively by restricting the energy use of this setting could become significant. Additionally, this function might become even more relevant in the future when smart appliances become more common.

The smart connectivity mode is supposed to fall under networked standby as defined in Regulation (EU) No 801/2013 amending the Standby Regulation. If not, however, a specific cap on the energy consumption of this mode could be introduced.

As these functions exist in various household appliances a horizontal approach might be appropriate or at least a certain degree of harmonization among the requirements included in each specific product regulation.

c) Delete the energy consumption of the low power modes from the AEC calculation

Given that the low power modes generally contribute little to the overall energy consumption, most stakeholders would like to see these modes taken out of the AEC calculation to account for more simplicity and reduce the complexity in testing and the associated market surveillance.

In Australia, New-Zealand and the US, the delay start mode is left out from the calculation to avoid penalization of this mode which was recognized to have an overall positive impact by allowing the delay of the cleaning cycle to off-peak hours.

Keeping the low power modes outside of the EEI calculation makes the formula simpler and more transparent. Therefore, an alternative to the existing EEI formulae would be to define a new one considering only the product's primary function, i.e. cleaning dishes.

7.1.3.6. Communicating the consumption (energy and water) per cycle or per year

The information regarding the energy and water consumption is provided to the consumers to allow them to compare among the different models in the market. The question is if this information should be provided on a per cycle basis or on an annual basis. In the first case, the information is more transparent but the displayed numbers could be too low and close to each other making the comparison more challenging for the consumer. In the annual basis option, 280 cycles/year are assumed as basis for the calculation. This assumption does not reflect each specific consumer situation. During this revision study, it has also been mentioned that not all consumers understand the expression "per annum", as also reported in Dünnhoff & Palm (2014).

Stakeholder feedback regarding the question if the consumption shall be given per cycle or per year is controversial.

While some stakeholders are in favour of "per cycle" as

- surveys show that more than 70% did not understand correctly or did not understand at all the meaning of "per annum" on the energy label,
- the 280 cycles which are currently the basis for the calculation of the annual energy consumption does not correspond to the user pattern of all households and
- the consumer survey that has been conducted under this study reveals consumers prefer an indication per cycle.

Other stakeholders are in favour of an annual indication as

- this would be more coherent with the energy labels of other products and
- the per cycles values are very small and thus also the differences between appliances. Yearly consumption values deliver greater numbers, where differences between appliances become more obvious and easier to quantify by users (in favour of energy efficient appliances).

Another alternative could be to provide the consumption per a certain number of cycles, e.g. 100 cycles, which does not necessarily represent annual consumption but increases the displayed numbers.

7.1.3.7. Rinsing performance

Some stakeholders advocate for an ecodesign requirement on the rinsing performance of the dishwasher. A protocol for measuring the rinsing performance has not been standardised yet. Moreover, different interpretations can be given to rinsing performance. Rinsing can be interpreted as related to left-overs of chemical components from the dishwasher detergent on the tableware or related to stains that are left on the tableware. Tracking down left-overs of detergent on the tableware to prevent e.g. allergic reactions could be a difficult task as all the tableware should be checked with specific characterisation techniques. IEC 60436 Annex Q describes 'Additional rinse performance evaluation' which is targeting left-overs on glass. However, it is not widely tested and proven as a reproducible measurement procedure and it would in any case increase the test burden. Therefore, it would be difficult to set requirements in this revision.

Stakeholders also indicated that the amount of chemical components that might be left on the dishes is very small and that detergents are already regulated and have to comply with food contact requirements (any possible remaining of the detergent can be considered as non-harmful for the consumers).

7.1.4. Policy options regarding information requirements

Given the large amount of information already provided to consumers, any proposal of additional information has to be carefully analysed as not to overload the consumer with information.

7.1.4.1. Additional information on the label

The energy label is a powerful communication tool among producers and consumers. Moreover, it is a kind of marketing channel that helps manufacturers to differentiate their products.

Information provided on the energy label should be clear and should allow consumers to make informed purchase decisions. Several aspects have been highlighted as candidates to be included in a revised energy label for dishwashers, for example:

- *Cycle time of the Eco programme*: this information will provide an idea of the cycle duration of the recommended programme for normally soiled dishes (The pros and cons are discussed in section 7.1.3.2).
- *Cleaning performance*: this information would not make any difference among the products as all dishwashers have to reach the highest cleaning performance class A as an ecodesign requirement. Further differentiation in this highest cleaning performance class is believed not to be feasible as one would have to differentiate between clean and cleaner. Clean is clean and the current thresholds seem to be set in an appropriate way. Having this information on the label would not differentiate between products as they all would carry class A for cleaning performance. It could however show to the consumer that cleaning performance is an ecodesign requirement and that they can be sure that the dishwasher, and especially the Eco programme, is functioning well.
- *Hot fill*: in principle all dishwashers can be connected to a hot tap. However, this is not beneficial for all households (see section 6.1.3). The general information on the label that connection to a hot water tap is possible seems therefore not appropriate as it might suggest that this is environmental beneficial in any case. More specific information about those cases where the hot fill should be used seems to be too complicated due to the limited dimensions and space on the label.

7.1.4.2. Consumption values of all programmes

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, make better programme selections, it could be recommendable that the appliances provide information on the consumption values of other programmes. Regarding the provision of information related to the energy and water consumption for all offered programmes in the dishwasher, two options can be considered:

a) Information for all programmes in the user manual

One possibility is that the user manual shall contain, besides the information on the Eco programme, also detailed information on energy, water consumption, programme time and the recommended usage for each individual programme. Currently, the ecodesign regulation (EC) No 1016/2010 for household dishwashers requires that the booklet of instructions includes '*indicative information on the programme time, energy and water consumption for the main cleaning programmes.*'

Similarly, the functioning of options could be described visually, e.g. diagrams showing how much more or less energy is used when activating certain functions.

b) Information for all programmes shown in the display

Another possibility is to put information about all programmes on the machine/the display (e.g. before it starts the programme and/or once the programme has finished). By doing this, the consumer has easy access to the information at any time the machine is used. This would encourage consumers to choose the most suitable programme for their needs. This option requires a display on the machine which could increase the purchase price.

7.1.4.3. Additional information in the user manual

Some stakeholders are in favour of including advice on how to use the dishwashers while ensuring low environmental impacts. Some stakeholders propose to obligatory include the following information in the user manual:

- *Advices to decrease the energy and water consumption*, as for example: use full load whenever possible; programs at lower temperatures save energy, use the pre-wash programme only when needed, recommendations on the best use of rinse and hold options if applicable.
- *Advice on the installation procedure* as for example how to correctly install the appliance in order to minimise the noise emitted or whether the machine can be operated with hot-fill water or not and under which circumstances this leads to lower environmental impacts.
- *Advice on correct maintenance of the dishwasher* such as cleaning of the filter or how to adjust salt dosing with regard to the local water hardness
- *Advice on how to operate the dishwasher*. As commented in more detail in section 7.1.8.1, a certain percentage of breakdowns of dishwashers are related to the mis-operation of the appliance by the users. A longer life of the dishwashers can be achieved if consumers are informed on how to properly use, install and maintain the machine.
- *Information on manufacturers' take back procedure*.

Many of these points are already included in the user manual even though they are not obligatory.

7.1.5. Tolerances

EN 50242/EN 60436:2016, which introduced the combined cleaning and drying evaluation into the European standard for measuring dishwashers, has included in Annex ZB values for expanded uncertainties. In 2014, a round robin test was performed with 17 laboratories participating from all over Europe. One of the objectives was to check the robustness and precision of the Combined Cleaning and Drying (CCD) evaluation. Four samples of two types of automatic dishwashers were tested in two different cleaning cycles. These machines under test were calibrated to be as identical to each other as possible and delivered to all participating laboratories. Following IEC/TR 61923 *"Household electrical appliances – Method of* *measuring performance – Assessment of repeatability and reproducibility*", the expanded uncertainties for measurements according to this European standard as shown in Table 7.4 may be assumed.

Table 7.4: Table ZB.1 from EN 50242/EN 60436:2016 showing the relative expanded uncertainties of measured values for the EU standard for different parameters

Measured parameter	Relative expanded uncertainty of measure value (k=2)[b]
Cleaning performance index I_c	16%
Drying performance index I_D	10%
Total energy consumption	5%
Total water consumption	4%
Total programme time	2%
Low power mode energy consumption	[c]
Noise (in re 1pW)	[c]

[a] the expanded uncertainty only describes the uncertainty of the measuring method while the variance of the product is not included

[b] these values are the average of measurement figures taken from a low and a high end machine

[c] not measured in this ring test

The values of the newly assumed tolerances differ from those reported in the standard with separate cleaning and drying performance tests in both the tolerance for the cleaning performance index and the tolerance for the drying performance index. The first one has been increased in 2 percentage points (pp) while the second one has been significantly decreased in 6 pp. All other values remain constant.

7.1.6. Mismatch of standards and regulations

7.1.6.1. Standard vs Eco programme

Currently there is a mismatch between the measurement standard and the regulation regarding the naming of the programme to be measured. The regulation speaks of '*standard programme'*, the standard states that the programme that is mentioned in the regulation as '*standard*' programme should be named 'Eco'. In case of keeping the Eco programme this should be aligned. (see also section 7.1.3.1)

7.1.6.2. Rounding methods

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 current 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 litres, 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, p. 30, 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.

Rounding should be carefully aligned between the regulation and the standard. Therefore, it can be proposed to refer to Rule B of the Annex B.3 of the *ISO 80000-1:2009 'Quantities and units - Part 1: General'* and to apply it only to the final value of any calculation. If rounding rules are given in the regulation they should be used only in the last step of any calculation and follow a clear and well defined procedure, e.g. for rounding purposes, the standard EN 50242 is referring to ISO 80000-1:2012 B.3, rule B. Additionally, there should be no other definition used, like ‘rounding’, ‘rounding up’, ‘rounding to the next integer’, etc.

7.1.6.3. 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 1059/2010 within the range defined as outlined in Annex V of that regulation. Currently, for airborne acoustical noise emissions Annex V requires that that mean value “*shall meet the rated value*”, i.e. there is no range defined.

A stakeholder has commented that the verification should require noise declaration to be verified ‘*according to EN 60704-3’*. The use of the term ‘*meet rated value’* is not precise and allows misinterpretation.

In the current regulation it is not prescribed that the noise declaration should be according to EN 60704-3 which describes the ‘*Procedure for determining and verifying declared noise emission values’*. However, the new EN50242/EN60436:2016 describes in paragraph 9 ‘*Airborne acoustical noise’* that “*Where an airborne acoustical noise measurement is required, it shall be measured according to EN 60704-2-3 and shall be determined according to EN 60704-3*”. This ensures that declared values include already some factor taking into account the verification tolerance. It is therefore sufficient to maintain this link in a future standard and to clarify the requirement in the verification procedure to “*shall meet the regulated value or be lower”,* as less noisy values are beneficial to the consumer.

7.1.7. Demand-response enabled appliances

As the energy system of the future is getting more and more variable due to fluctuating energy production by mainly renewable energy 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/function. However, the demand-response function of the appliances 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 was discussed if support to the demand-response enabled appliances should be introduced, and what would be the best tool to set up the general requirements, e.g. user settings, information and capabilities. Both industry and consumer organisations do not support using the EU energy label as a marketing tool to promote the use of smart appliances. Also the EU ecodesign regulation is not seen as suitable place for such requirements.

7.1.8. Policy options related to end-of-life

Since 2009, EU ecodesign and energy labelling are gradually introducing requirements on material efficiency, initially of informational character only (water consumption, noise level, etc), but lately also including specific thresholds (e.g. durability of lighting, durability of two components in vacuum cleaners).

Material efficiency requirements are also present in a number of examples of voluntary agreements (e.g. imaging equipment) and labels such as EU Ecolabel, German Blue Angel or the Nordic Swan.

This development has been accompanied by increasing importance of research on the feasibility of implementing resource efficiency aspects into product policies, as reflected in at least six European research studies published since 2013 (Ardente & Talens Peirò 2015; Benton et al. 2015; Bobba et al. 2015; Deloitte 2016; Prakash et al. 2016; Ricardo-AEA 2015).

A recent study (Tecchio et al. 2016) reviewed a database regarding the frequent failure modes, diagnosis and repairs of dishwashers and washing machines. Data were collected by Reparatur- und Service-Zentrum (RUSZ) in Vienna, Austria. The database contains approximately 3 500 records collected from 2009 to 2015. According to these data, most of the failure modes identified concerned the circulation and drain pumps (approximately 1 100) and electronics (control electronics, relays, sensors, programme selectors and control panels, approximately 750).

There are various causes for the slower uptake of requirements in mandatory policies, including for instance the lack of enforceable and relevant metrics, the lack of proper standards to measure the requirements, and the lack of data demonstrating the benefits of minimum material efficiency requirements, to justify the thresholds.

It is widely accepted that any new resource efficiency requirement should be measurable, enforceable, and relevant and should not hinder innovation and competitiveness. Additionally, 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). However, for the time being, the absence of proper standards for testing and measuring resource-related criteria seems to have hindered a practicable implementation of the criteria, including procedures for verification and market surveillance. Solid evidence for feasibility, proper measurability and environmental benefit should be taken into account when developing such standards.

Manufacturers have also stressed the need to make sure that ecodesign product measures do not overlap with other existing regulations that are already imposing end-of-life provisions and material/resource provisions, such as REACH, RoHS, WEEE and F-Gas.

Regarding currently existing standards, there are a number of harmonised EU standards that include material efficiency aspects (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 covers 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 and not with the products that are currently being manufactured.

National standards on durability and reparability do exist. An example is the Austrian "sustainability label for electric and electronic appliances designed for easy repair (white and brown goods)'' of 2006, followed by the 2014 "label of excellence for durable, repair-friendly designated electrical and electronic appliances" (ONR 192102).

The "*Sustainability label for electric and electronic appliances designed for easy repair (white and brown goods) 2006*'' is a combination of mandatory and optional criteria (from which a minimum number of points should be reached) related to general criteria and service documents. Examples of criteria are the accessibility of sub-assemblies for the purpose of repair, resource savings, ensuring long product life, keeping repair periods to a minimum, simplification of repair and broader range of spare parts, ensuring faultless production, etc. After fulfilment of the conditions the product may be ranked and marked with one of the labels that show the level of satisfaction of the criteria

The "*label of excellence for durable, repair-friendly designated electrical and electronic appliances (2014)*" includes, following the same structure as described before, two lists of requirements: one for white goods and another for brown goods. The lists focus on those aspects that guarantee the ability of the appliance to be repaired as for example the accessibility of the parts to be repaired, the reduction of the repair time, the reduction of the repair costs and the enhancement of the durability of the appliances. (see also section 1.3.3.1).

Following M/543 (2015) from the European Commission, EU standardisation bodies (CEN and CENELEC) begun in September 2016 to develop generic standards for resource efficiency metrics for use in energy labelling and ecodesign requirements.

The section below describes an array of policy options for extending the durability of appliances and facilitating reparability, as well as a proper management of the appliance during the end-of-life stage, and the outcome of the discussions with stakeholders.

7.1.8.1. Durability and reparability

The improvement of energy efficiency in the future years is expectedly limited for household dishwashers, with current technologies. In the context of ecodesign, durability and reparability measures might become more relevant, compared to measures to improve further energy efficiency. Improved durability can be understood as an extension of the lifetime of the machine under the same performance conditions. Such an extension of lifetime can be established either by increasing the technical lifetime of the product (during design), or by extending the real lifetime of products, e.g. through repair activities.

However, while lifetime and durability tests are undertaken on a systematic basis by many manufacturers, standardisation of these procedures or methods is not yet in place, nor harmonised.

The following reasons that decrease the durability of products or the use time by the consumer have been identified:

- Unsatisfactory mechanical robustness or durability of certain components and/or the whole appliance, which lead to early failure rates
- Wrong user behaviour leading to defects of appliances (e.g. incorrect use, insufficient maintenance).

The Austrian repair and service centre RUSZ (Tecchio et al. (2016)) observed that inappropriate use by the customers leads to a large number of early device failures. The repair centre listed a series of behaviour patterns that should be avoided, in order not to compromise the proper functioning of a device:

- the extensive use of low temperature programs, as well as the insufficient use/no use of detergents, leading to fat deposition;
- excessive leftovers/scraps on the dishes that block filters and drain pumps;
- broken/damaged glasses and/or dishes that block filters and pumps;
- cutlery and big dishes, if not well-positioned inside the device, block or even damage the spray arms;
- Lack of proper maintenance by the users (e.g. regular cleaning of the filters, an operation of high temperature programmes and decalcification).
- Early replacement of appliances due to changes in consumer preferences and needs (e.g. larger or newer products, modern design, etc.).

RUSZ indicates additionally that better communication to consumers and preventive measures in this context may help prolonging the lifetime of a device.

The overall number of repairs (per inhabitant) is decreasing. In case of a defect, appliances are increasingly discarded although a repair might have increased the real lifetime. Reasons for discarding the products might be e.g. intrinsic product design impeding repairs, missing and/or no access to spare parts, or high costs for repairs compared to purchase of a new product.

Tecchio et al. (2016) classified the reasons for not repairing a device into three groups: *too expensive for consumers* (the repair is technically possible but considered too expensive by the consumer), *not viable* (the repair is technically possible but considered economically not feasible by the technician) and *technically not feasible* (the repair is technically not possible, mainly because the spare parts are not available or the cause of failure is not identifiable).

The distribution of the cases into these three categories varies depending on the failure. For example, for the most frequent failure types (failures in the pumps or electronics), the main reason for not repairing the dishwasher is that the repair was considered too expensive by the consumer. This reason accounts for approximately 76% of the cases. The second most important reason was that it was technically not feasible (17.5%), while '*economically not viable (by the repairer)*' only accounted for 6.5%.

Tecchio et al. (2016) provide additionally some data regarding the early replacement of the appliances because the consumers by mistake consider that the appliance fails. The study reported that approximately 10% of the machines that reached the repair services had no failures or no failure was found. However, these machines did not perform well likely due to blocked drainage (outside the device/in the wall), the water tap was closed or defect, the power plug off, activated child safety lock, electronics that became wet and dried out in the meantime, or other reasons.

A list of policy options on durability and reparability has been shared with the stakeholders. The stakeholder feedback received reflects the natural divergent opinions between environmental / consumer NGOs, Member States representatives, and industry. There is however general agreement on the need for requirements that improve durability, such as information about the technical lifetime of the products, of spare part availability, or of design for upgrades and repairs. The lack of practicability of some of these approaches is often mentioned as an obstacle, due to missing definitions and standardised metrics or the cost and duration of the required measurements.

Table 7.5 and Table 7.5 below present respectively the policy options discussed. Table 7.5 presents the options seen as least feasible according to stakeholder feedback.

The policy options that have are seen as most feasible by stakeholders deal with reparability of products, and are presented in Table 7.6. The full list of policy options can be found in Annex 8.2.6.

Table 7.5: Durability and reparability policy options seen by stakeholders as least feasible

Option	Policy option	Reasons for the option to be less feasible
Component level		
1a	Requirement on performing durability tests of certain components which are known to be prone to early failures	• No standard / test available for all components; existing safety standards cannot be taken to measure durability • Such requirements have been proposed for vacuum cleaners, essentially consisting of 2 components. DW are more complex appliances and there is a large group of 5-10 components that fail most often, effective measures would have to be set to all these main components (defining "main"). • Definition of components difficult due to different designs – a too wide definition would make consistency checks complicated; a too narrow definition would be easy to circumvent • Durable components do not lead to durable products automatically, especially in complex appliances. • High effort / costs for testing, also for market surveillance , long-time

Option	Policy option	Reasons for the option to be less feasible
		needed for tests or accelerated tests
1b	– e.g. by means of Requirements on minimum operational lifetime of certain components	• No standard / test available; no definition of “operational lifetime” against different usage patterns in EU
1c	- e.g. by providing consumer information about the operational lifetime of certain components (motor, pumps, electronic components, other)	• Might misguide consumers as e.g. the lifetime of a single component cannot be taken as indication for the overall quality of the product
Whole product level		
2a	Requirement on performing durability tests of the whole product (e.g. endurance tests, accelerated tests under extreme conditions), where manufacturers declare the durability values.	• Market surveillance issues: endurance tests take long, for WM and DW about 9-12 months, and are expensive (~minimum 50 000 EUR/test). The results of non-compliance would only be available 1 year after the product is on the market, making the removal conflicting. The mechanism would work more on the brand reputation, if several cases of non-compliance are found.
2b	Requirements on minimum operational lifetime of the whole appliance (e.g. machines to run a certain minimum number of cycles). Several sub options are possible: lifetime set by the manufacturer (see option 2a and option 2c in table 7-6), or by the regulator. If by the regulator also sub options are possible, such as fixed minimum values (5 years, or fixed fractions of the average lifetime (e.g. 50%, 75%), or flexible: e.g. 50% of the value declared by the manufacturer.	• For long-living products such as DW a minimum operational lifetime must be quite high to be meaningful. Even if it would be set at 50% of the Average Expected Product Lifetime (AEPL), it is more crucial that it can be repaired if it fails after the minimum operational lifetime has expired. • Alternatives exist that are less burdensome to producers and to MSAs, like regulation of spare part availability, or guarantee systems.
General information of consumers		
3b	Compulsory direct feedback on necessary maintenance intervals via the machine’s display	• If the feedback mechanism is compulsory, this forces producers to install displays or LED mechanisms, increasing appliance costs, especially for low-price machines without display so far. The requirement can however be made conditional to the presence of a display, but this would not ensure market uptake.
3c	Consumer information about the environmental (and economic) benefits of prolonged product use	• Long lasting DW are usually rather not replaced due to fashion and design • Possibly better option: proper information on disposal and more efficient WEEE collection / recycling • Educational effects might be limited • Work with second hand market might be more effective
Reparability		

Op-tion	Policy option	Reasons for the option to be less feasible
4d	Information requirements on reparability (e.g. repair label); indicating if the machine can be repaired or not; indicating which components are not repairable	• Many stakeholders considered the idea of a reparability scoring attractive, but reparability and after-sales services are market differentiation / competition issues, and therefore self-declared claims are prone to market distortion, unless clearly ruled • Requires a comprehensive standard similar to ONR 192102, and broad agreement on any internal weighting mechanisms, which are better addressed at a horizontal level • No certainty that repairs will be done/commissioned by consumers in the end (e.g. depending on the costs for repairs compared to the purchase price for a new product) • Needs investigation of consumer acceptance and understanding
4e	Consumer information about access to professional repairs	• Common practice of most (all?) manufacturers, although a standard format might help the enforcement of such requirements • It might be better that such requirements are not set on a product by product case, but on a horizontal, and widely accepted level • Reparability and after-sales services are market differentiation / competition issues, and therefore the ruling must also be clear and transparent, and shall ensure the operation of independent repairers
4j	Mandatory provision of information to consumers about commercial guarantees, i.e. the number of months/years the producer guarantees the full functioning of the appliance on top of the legal 2yr warranty, without passing the burden of proof to the consumer	• Cf. arguments under option 4i (see Table 7.6) • Needs investigation of consumer acceptance and understanding • Requires broad agreement on any internal weighting mechanisms, which are better addressed at a horizontal level

Table 7.6: Durability and reparability policy options for follow-up

Op-tion	Policy option	Pros	Cons/Challenges / drawbacks
Component level			
No feasible requirements were identified on specific components			
Whole product level			
2c	Consumer information about the expected operational lifetime of the whole product (e.g. label, manual)	• When buying new appliances, consumers are not informed about the lifetime expectancy of the product, if used and maintained properly. With such information, consumers are enabled to favour manufacturers who produce long-lasting and/or repairable goods. Some consumer surveys indicate a certain willingness to pay for more durable and repairable products, if this information is clearly conveyed.	• While still controversial and generally opposed, the most supported sub option would be one where, based on a harmonised standard, manufacturers declare the durability of their appliances. • Liability declarations and implications would have to be clarified in detail • No existing definition / standard yet (work is in progress on a horizontal level in CEN/CENELEC TC10) • Market surveillance is still a challenge. Surveillance effect would work out via brand reputation, rather than affecting/leaving out specific models

Op-tion	Policy option	Pros	Cons/Challenges / drawbacks
			on the market.
General information of consumers			
3a	Consumer information about correct use and maintenance of appliances, to ensure durability	• Often available in the documentation from manufacturers, this information should additionally be promoted to extend it to the manufacturers not currently including it • Use of further dissemination possibilities, e.g. NGOs and test institutes	• A standard format needs agreement and could help enforcement of such requirements • better enforced as a consumer information campaigns than as an ecodesign / energy label requirement
Reparability			
4a	Design for upgrades and repairs: components being prone to early failures should not be designed in a manner prohibiting repairs (e.g. high integration of different components)	• Independent repairers and consumer organisations see this as very important • The market of repair shall be as transparent and as open as possible to reduce the cost of repair for the consumers	• No clear evidence of which components usually fail more often, although pumps and electronics seem to be the most delicate parts • The formulation of how design for disassembly shall be has to be defined (e.g. avoidance of permanent fastening not using gluing, soldering or welding) • Sometimes there are trade-offs, and certain designs might favour energy efficiency and durability at the expense of reparability.
4b	Design for upgrades and repairs: components prone to early failures should be easily accessible and exchangeable using universal tools	• Seen as very important by some stakeholders, including independent repairers and consumer organisations • Already applied by some manufacturers	• Cf. arguments under option 4a • Early failures are covered by the warranty and defects liability regulation, but not covered after 2 years • In exceptional cases, the use of non-universal tools can save time in repairing. However, affordable access to such tools should be mandatory.
4c	Provision of Repair and Maintenance Information Appliance internal failure diagnosis systems to report error specific messages to the user. Diagnostic tools should also be made available to independent repair operators to make them understand the error codes.	• Seen as very important by some stakeholders, including independent repairers and consumer organisations • Already applied by some manufacturers, but not by others • Particular relevant for electronic failures, for which identification of defects is difficult for repairers	• Some manufacturers make it difficult and/or expensive to provide diagnostic tools to independent repairers.
4f	Information about the availability (and price) of spare parts (current practice: from 0 to 10-15 years after production) and maximum	• Seen as very important by some stakeholders • Already applied by some manufacturers, which have open access websites for purchase of spare parts	• Risk of market distortion if claims are not backed up by harmonised testing procedures and market surveillance • It shall be clarified if other legislation (e.g. REACH, RoHS, ecodesign on

Op-tion	Policy option	Pros	Cons/Challenges / drawbacks
	delivery time	• Cf. French decree 2014-1482 about the time for which spare parts will be available	certain components being integrated in appliances such as motors or fans) would ex post restrict the availability of spare parts, and deploy special exemptions where appropriate
4g	Guarantee of public availability of spare parts for a certain period following the end of the production of the model; ensure original and backwardly compatible spare parts	• Seen as very important by some stakeholders • Already applied by some manufacturers	• For DW and WM, the array of components that fail more often is broad • A time provision guarantee bears the risk of oversupply of spare parts that become WEEE at a later point in time • Detailed research on costs and effects of this option needed • Verification may require a future protocol, so surveillance takes part some months or years after the appliance has been on the market, and not when the product is placed on the market for the first time
4h	Provision of Repair and Maintenance Information Repair manuals shall be available for free or at reasonable fees at least to independent repairers, including clear disassembly and repair instructions to enable non-destructive disassembly of product for the purpose of replacing key components or parts for upgrades or repairs. Information shall be publicly available or by entering the product serial number on a webpage to facilitate access for recognized / independent repair centres. Wiring and connection diagrams showing the location of the components shall be available online for at least 5 years (ideally for the length of availability of the spare parts)	• Seen as very important and prerequisite for reparability by some stakeholders • Repair manuals and wiring and connection diagrams are already in place for approved service providers which undergo specific in-house training / qualification programmes, and pay fees to manufacturers	• Having access to electronic repair software is becoming even more relevant to repairers as appliances become electronically more complex • Public availability of repair manuals bears the risk of abuse by non-professional repairers, potentially causing damage to manufacturers brand image • Making repair manuals available publicly is straightforward. Making restricted access would require a multi-brand tailored system of access to repairers, similar to the system in place for automotive repair. • Reparability and after-sales services are currently seen as market differentiation / competition issues, however the restriction of market competition is not in the benefit of consumers
4i	Manufacturers shall mandatorily offer to the customer a commercial guarantee, that extends	• This requirement would have the advantage that the manufacturer guarantees the proper functioning of the product e.g.	• The actors involved (manufacturer or seller) shall be defined, not to confuse the customer. • The Guarantee Directive would

Op-tion	Policy option	Pros	Cons/Challenges / drawbacks
	the 2-year warranty (legal guarantee) currently applicable, and ensure that the goods are in conformity with the contract of sale, without passing the burden of proof to the consumer. It includes service agreement with a pick-up and return option. A commercial guarantee would rule in addition to the current legal obligation relating to the guarantee of conformity. The duration of the commercial guarantee, however, would be defined by the manufacturer.	for a certain number of cycles or years (whichever occurs first), i.e. that the manufacturer has to prove misuse by the consumer, and not the other way around that the consumer has to prove that the failure was due to a manufacturing fault). This approach might facilitate reducing early failures. An extension of the guarantee would also mean that manufacturers will pay attention to the availability of spare parts. • The guarantee should include a take back requirement by the manufacturer, so that it can be properly recycled or components be reused if the product cannot be repaired.	prescribe the minimum conditions to be met by the commercial guarantee. • Ideally, commercial guarantee yearly primes could better reflect the expected durability of the appliances, but it may take long before the market is transparent enough to reflect this. • This initiative shall better be addressed horizontally, and not only to dishwashers or washing machines.

Regarding the options 4 on reparability, some stakeholders have proposed to combine some of the options outlined, which are initially conceived as ecodesign criteria (i.e. mandatory minimum criteria), into a more flexible 'scoring system' that could be communicated to the consumer by means of the product fiche, or even the energy label.

Two proposals have been tabled by stakeholders:

(1) a simplified scoring of three categories (green-yellow-red) or 'basic reparability grades':

- RED: No repair service by the manufacturer or authorized repair companies and no availability of spare parts for at least 10 years or no repair manual publicly available. The product information sheet and the information on the website of the manufacturer shall contain a warning on that.
- YELLOW: Repair service by the manufacturer or authorized repair companies for at least 10 years (could be variable per product, e.g. differ for WM/WD) after production.
- GREEN: Availability of spare parts for at least 10 years (variable) and repair manuals made publicly available by the manufacturer.

(2) a more elaborated, 5-star system, where the 5-stars are awarded to services (e.g. provision of the dishwashing service or clothes washing service per year/per month, including any necessary repair or appliance replacement), and no stars are awarded where no repair, spare parts or instructions are available.

This system is more flexible than mandatory ecodesign requirements, as the manufacturer shall communicate the choice to the consumer, but at the same time manufacturer has a choice to:

a) do nothing (when the product is too cheap to afford this),

b) keep the repair service in its own hands (repair manual need not be available publicly) or to the restricted circle to registered and authorised repair services.

c) have spare parts available and make the repair manual public, including private customers and/or independent repairers.

While this idea is very attractive and could have potentially a high impact, its practical implementation needs to be carefully designed. Two important aspects to consider are

(1) that it shall not only be suited to dishwashers and washing machines, currently under revision, but ideally be suited for all appliances, in a horizontal manner, and

(2) that a central element of its success is that consumers understand the message of the 'reparability scoring'. To this aim, an intuitive, well-designed pictogram and symbols shall be used, including equally clear distinction between the different grades or classes of reparability.

In addition to the feedback above, an important source of information for the development of a scoring system is the comprehensive scoring and labelling system of the Austrian standard ONR 192102 mentioned in the sections above

On the drawback side, it is easy to see that no matter how simple the system is designed with additional colours or icons (e.g. red/yellow/green, smileys or pluses/minuses), it will work for well-established manufacturers (which normally keep an eye on each other's declarations), but will not be on the way for deliberate wrong declarations and illegal commercialisation or import of products. A key point of these proposals is the extent to which swift market surveillance can hinder that e.g. smaller parties of DWs declared as very repairable have no actual system for spare part provision, repair, etc.

Underlying this discussion, and the requirements listed in Table 7-6, is the purpose of ensuring a transparent market for repair, the best conditions for access to that market for independent repairers and the interested consumers, as well as transparent communication to consumers of reparability characteristics of appliances, ideally before an appliance is purchased.

Given the arguments above, within the scope of this preparatory study it has not been discussed in-depth with the stakeholders how the reparability scoring could look like. The European Commission is likely encouraged to undertake a horizontal analysis of this option, including all appliances potentially included, and ensuring a thorough user behaviour survey that ensures that consumers understand clearly the scoring.

7.1.8.2. Recyclability

Similarly to durability and reparability, policy options on recyclability have been discussed with stakeholders. Specific requirements in the product design could be put forward that would enhance the effectiveness of end of life efforts by facilitating

- **Proper collection**, sorting and treatment of appliances after use; or
- **More efficient de-pollution of hazardous components,** enabling recyclers to comply with the WEEE Directive
- **More efficient recycling of the materials** that have a positive market value (i.e. with prices based on international trade and markets, and not subject to subsidies or tariffs.

Some stakeholders brought forward general comments to this approach, indicating that the proposed action is interesting from a theoretical point of view, but is superfluous to recyclers that currently use recycling practices or technologies where the proposals are inapplicable, and therefore of no real benefit. They also indicate that some of the proposals are very dependent on time and are only financially feasible under certain market conditions (e.g. certain price ranges for metals) that are not always met, due to the volatility of metal prices in the international market.

Table 7.7 below includes the proposals that have been generally supported. Other non-supported measures are discussed further below.

Table 7.7: Recycling policy options for follow-up

Proposed options	Rationale
Mandatory marking of Annex VII WEEE (2012/19/EU) **components** that are not always present, and are **not visible from the outside**: (1) F-gas – Back panel marking following an agreed pictogram (2) Electrolytic capacitor containing substances of concern - marking of component (3) Printed circuits >10cm2	WEEE contains in Annex VII a list of components in EEE that may contain hazardous substances. If so, those components need to be treated separately. The identification and removal of these components can be difficult if they are dispersed throughout the inside of the appliance, and furthermore if they are permanently fixed by e.g. soldering or gluing. Simple and cost-effective marking requirements in the frame of ecodesign could significantly facilitate compliance with WEEE. For the appliances of concern, three components have been identified (1) F-gases in heat pumps, (2) certain electrolytic capacitors, and (3) large printed circuits. A marking in the back plate indicating the presence and location of these components would be sufficient. Standardisation bodies are to define the adequate material characteristics, size, shape, etc. for the purpose described. For illustration, the marking shall be readable for recycling plant operators in the direct visual inspection of the appliances, as well as in control for surveillance purposes. The back panel F-gas marking shall be identifiable from any distance and readable from a distance of approx. 2m, while the capacitor marking shall be identifiable from approx. 1m. The marking must be indelible and durable for at least the technical lifetime of the appliance. For the back panel marking, tentatively a minimum size of 300cm^2, letter fonts (if present) of minimum 40mm tall, and contrasting colours (Black-white, black-yellow) could be appropriate. Pictograms are also possible and recommendable to avoid language translation issues.
Dismantlability for depollution in recycling operations: **Access to and extraction of the components of concern** (WEEE Annex VII, 2012/19/EU) **must not encounter fixings that require proprietary or not commonly available tools.**	Even if the majority of recycling currently takes place mechanically, there are still niche recyclers that operate business models based on quality of the recovered components. These recyclers need to comply with WEEE too, and therefore it is essential for them that the components in appliances that contain hazardous substances are easy to remove. This criterion addresses the concern above. The criterion reflects current practice in most manufacturers, and therefore should not imply any significant burden. In addition, it aligns objectives related to easier access and removal for the purpose of repair, which is also for the benefit of manufacturers that wish to project an image of repair-friendliness.

The marking of the F-gas (marked (1) on Table 7.7) has been widely supported by stakeholders, and will enable operators to detect when a heat pump is present in the appliance (normally not visible from the outside), and therefore requires special treatment for removal of the refrigerant gas and compressor oil, much in the same manner that is currently undertaken for refrigeration appliances.

Currently, standard IEC 60335-2-89:2012 describes the marking of flammable insulation blowing agent used in appliances, in particular:

- The marking shall declare the chemical name of the principal component of the insulation blowing agent

- The height of the letter used for the marking of the flammable insulation blowing agent shall be at least 40 mm

The marking shall include the symbol ISO 7010 W021:"Warning; Risk of fire/ flammable materials"

- the height of the triangle in the symbol "Warning; Risk of fire" shall be at least 15 mm

The other two markings discussed have less clear benefits. The marking of the electrolytic capacitor (marked (2) on Table 7.7) would allow to distinguish if it contains or not substances of concern, and therefore if it needs separate collection for hazardous waste treatment.

Electrolytic capacitors are used to accumulate charge and kick-start mechanical components such as motors. They have a liquid (electrolyte) sandwiched in an aluminium spiralled plate and have two poles, and two pins, positive and negative. The negative/positive pin is indicated like in batteries, with a "-" [minus] or "+" [plus] marking, and/or a coloured strip. Big capacitors are usually electrolytic, with no indication of the presence of substances of concern. There are other types of capacitors (non-electrolytic) which are also polarised and thus have pole markings.

Stakeholders interviewed for this purpose[1] indicate that currently, all large electrolytic capacitors in dishwashers, washing machines and washer dryers do all contain substances of very high concern, and therefore there is no current system for identification of electrolytic capacitors NOT containing substances of concern. Additionally, the producers of these components stated for the time being that they do not see chances for substitution. Therefore, there is potential for the development of non-hazardous capacitors, but these are not yet on the market.

Regarding printed circuit boards (marked (3) on Table 7.7), these have traditionally been placed behind the controls of the appliance, in the top frame (for free standard appliances) or in the door top (for integrated appliances). However, some appliances can have printed circuit boards elsewhere, making it less intuitive for recyclers to find and remove (especially if manual removal is used). In case of mechanical treatment (the vast majority of treatment in the EU), there is little difference to the placement, as the shredding process will tear the appliance into pieces from the outset and then the pieces of EEE will be separated. According to stakeholders, marking is not as important as a non-permanent fixing, so they loosen more easily during mechanical processing, or are easier to access and remove for the purpose of repair (see section above). Stakeholders have also indicated that the motivations for recycling of printed circuit boards for the purpose of material recovery e.g. of valuable metals (i.e. not for depollution of hazardous substance) are weaker for dishwashers and washing machines compared to the boards of information and communication technologies (ICT) products, as the concentration of these substances is much lower. This makes measures in this field less effective than some studies may suggest.

Recycled content

Stakeholders reject in general requirements on the use of recycled material. They argue that most metals are indeed stemming from a mix of virgin and recycled origin. For plastics, it is difficult to use recycled technical plastics, as it is not certain that they will meet specific performance requirements. Quality standards for those recycled materials do not exist at the moment. For example, in some cases the use of plastics with recycled content would increase the dimensions and weight of components to deliver the

[1] Including appliance manufacturers, and capacitor producers including Europe Chemi Con,Frolyt,FTCAP,Kemet and TDK

same mechanical properties, and this is not always possible for space reasons. In other cases, the recycled material is not available in a given colour (e.g. white) that is needed for aesthetic reasons.

The requirements above refer usually to the composition of appliances currently on the market and will appear in the end of life stage in approx. 12.5 years from now. They refer to the present recycling techniques, which are mainly based on mechanical treatment, starting with shredding and followed by mechanical and manual separation. It is argued that the technology of recycling is very slow moving. Given that dishwashers have an average real lifetime of 12.5 years, it is difficult to judge how the future recycling techniques will have evolved when e.g. more appliances with displays come to the end of their lives. Recycling business models vary: some recyclers work on high flows, and generate large volumes of not very pure fractions of e.g. copper, steel, aluminium, or plastics, while others treating specific appliances individually, e.g. manually, and obtain higher quality material yields from which they obtain a compensatory profit. One-fits-all recipes have to be considered cautiously, as recyclers with business models based on high flows would probably not benefit from the requirements of manual dismantling of specific components of the machine. Thus the effect on the real-life recycling praxis is still not clear.

In conclusion, in order to be widely accepted and implemented the proposals, measurement and verification standards will be needed, and incorporate profound knowledge of the market mechanisms that drive recycling.

7.2. Scenario analysis

7.2.1. Introduction

The objective of this section is to set up a stock model (2015-2030) and calculate the impact of different policy scenarios regarding resource use (energy and water), emissions (CO_2eq), consumer expenditure and employment depending on the market evolution of dishwashers. The different policy options are identified in the previous section 7.1. Policy options taken into account for assessing their impacts are further described in section 7.2.3.1. Note that the calculated impacts for the different scenarios are indicative. A full impact assessment will be developed later in the policy process where the findings from this study can be refined. Parameters that could be taken into account in the full impact assessment, but are not taken into account in this study are e.g. a comparison with hand dishwashing, a sensitivity analysis of some parameters and assumptions, price elasticity, differentiation between slim-line and standard dishwashers, differentiation between parts of Europe where there is a high vs. low penetration rate.

7.2.2. Model description

In order to assess the effects of possible ecodesign requirements and changes in the energy label a model has been developed. For the assessment of the different scenarios the following common points have been considered.

7.2.2.1. Machine specific parameters

Machine specific parameters (e.g. average capacity, water and energy consumption, number of cycles, etc.) are based on the base cases presented in Task 5 and the improvement options presented in Task 6.

7.2.2.2. Correction factors for real-life conditions

The model determines the average annual energy and water consumption of dishwashers by multiplying the per-cycle energy and water consumption of the Eco programme by the number of cycles per year (280 cycles per year) which is then multiplied by a correction factor to achieve the estimated energy and water consumption under real-life conditions.

The correction factors equal the ratio of the annual energy consumption under real-life conditions and the annual energy consumption of the Eco programme. For the base cases the calculation of the correction factors can be found in Table 5.3 and Table 5.5. Depending on the implemented design option and the frequency of use of certain programmes the correction factors change. This is illustrated in Annex 8.2.9 in

Table 8.23 and Table 8.25.

To define the correction factors between 2015 and 2030 it is assumed that in the future the Eco programme and the automatic programme will be used more often. The fact that the Eco programme is clearly indicated on the machine and that it is set as default program, leads to the assumption that the use of this programme increases (+15% in use) at the expense of other programmes such as the 'normal programme 45-55°C' (-10% use) and the 'normal programme 60-65°C' (-10% use). The use of the automatic programme is estimated to increase with 5%. This is illustrated in Annex 8.2.9 in Table 8.22 and

Table 8.24. This assumption applies for all scenarios except for scenario 3 where the effects of measuring the Eco programme along with the automatic programme will be studied. Further information of the assumptions considered for scenario 3 can be found in section 7.2.3.5.

7.2.2.3. Real lifetime

This section describes how possible impacts on the lifetime regarding durability and reparability requirements could be taken into account. The reference point is the average technical lifetime of a dishwasher which is considered to be 12.5 years (taken as average lifetime of the first useful service life of dishwashers replaced due to a defect in accordance with Prakash et al. (2016)). However, the real lifetime of a machine can be shorter or longer than its average technical lifetime due to different reasons such as differences in quality of different models, re-use after first useful life, repair in case of a defect, etc. This section aims at modelling the different pathways for the end of life of the dishwashers and studying the possibilities for extending its real lifetime beyond its average technical lifetime.

The model assumes that for the real lifetime of a dishwasher two parts or paths can be considered. The first path lasts until the end of the useful service life for the first owner. At that point, two possibilities are considered:

a) the machine could be replaced without having a failure, e.g. if the consumer wants to buy a new machine for aesthetic reasons or for having lower operational costs due to the higher energy efficiency of the new machines. This machine can go straight to a waste stream or can be re-used or sold in the second hand market (in this last case, the second part of the lifetime starts and the machine is supposed to be kept in the stock until it breaks)
b) a failure occurs. If a failure occurs the machine can be replaced or the machine can be repaired. If the machine is repaired, the lifetime can be extended (probably when repaired close to its end of life) or will be the same as the original technical lifetime (probably when repaired in an early stage).

Machines that are replaced in the stock are assumed to follow a Weibull distribution with its characteristic parameters α = 1.64 and β = 13.72 for the BAU scenario according to Prakash et al. (2016) having an average lifetime on the market close to 12.3 years. The model aggregates the discarded machines into three classes, i.e. less than 5 years old, between 6-11 years and more than 11 years old. An overview is given in Figure 8.4 in Annex 8.2.11.

The real lifetime calculated in this way is the lifetime that is assumed for 2015 in the stock and sales model. The literature reports that the real and technical lifetime of the appliances have not been kept constant along the years. A reduction of the lifetime of the machines has been observed by several authors and modelled by changing the characteristic parameters of the Weibull distribution along the years. For the years 1981-2014 the values considered are in accordance with Balde et al. (2015). For years before 1981, the same parameters are assumed as in 1981. For years after 2014 the parameters are set according to the assumptions which can be found in section 8.2.10.2. For scenarios not related to end of life the parameters are equal to those in year 2015. If the real lifetime is extended or shortened this would have an effect on the total sales, the turnover of the machines, the annual energy and water consumption and the consumer expenditure among other aspects. Further information of the assumptions considered for scenario 4 can be found in section 7.2.3.6.

7.2.2.4. Stock and sales of the products

The overall stock of dishwashers on the European market is estimated by the number of households (Eurostat 2016d) and the estimated penetration rate (CLASP 2013). The stock values can be found in Annex 8.2.10.1 in Table 8.26 and in Figure 7.6.

The total sales in year *j* are defined as

Total sales (j) = New sales (j) + Replacement sales (j)

Where the *total sales (j)* are the overall sales of dishwashers in the EU28 in year *(j)*, the *new sales (j)* are the number of new installations in year *(j)* and the *replacement sales (j)* are the units of dishwashers retired and replaced in that year *(j).*

The *new sales* in year *(j)* are calculated as the difference between the overall stock of dishwashers in year *(j)* and year *(j-1)*. This difference represents the number of households that own a dishwasher for the first time, i.e. the penetration rate increases.

The *replacement sales* are estimated based on assumptions about the lifetime of the dishwashers and are estimated by calculating the number of machines that "*survive*" in a certain year. This survival rate is based on a Weibull cumulative function with specific parameters per year defined in Annex 8.2.10.2 in Table 8.27. The replacement sales in year *j* are thus estimated as

Replacement sales (j) = Stock (j) – New Sales (j) – Survivals (j)

This sales accounting provides an estimate of the age distribution of the dishwasher stock for all years. The age distribution of in-service dishwashers serves as an input to both the consumption and cost calculations, because the costs and resource consumption for a certain year depend on the age distribution of the stock. The sales figures can be found in Annex 8.2.10.3 in Table 8.28 and in Figure 7.5.

The results of these calculations show that the EU28 total sales increase from around 10 million units in 2015 to about 14 million in 2030 (Figure 7.5). The forecast of the total sales in 2030 consists of approximately 30% of new sales and 70% of replacement sales. In the same period the EU28 dishwasher stock increases from 100 million units in 2015 to 164 million in 2030 (Figure 7.6). The expected increase in stock is due to the assumed increase of the number of European households and an assumed increase in the penetration rate from 45% in 2015 to 64% in 2030 (Table 8.26 in Annex 8.2.10.1).

The modelled and forecasted total sales were compared to the available sales data and forecasted sales found in the literature. VHK (2014 / status 2013) and CLASP (2013) predict 8.1 and 8.8 millions of units respectively to be sold in 2015 and 11.5 and 11.9 millions of units respectively to be sold in 2030. Stakeholders estimated that the number of sales in 2015 reached 8.6 million of units. With the model applied in this study a sales figure of 10.4 million units is estimated for 2015 and 14.2 million units for 2030 (see Figure 7.1).

Even though the sales figures obtained in this study are higher than the ones predicted in the previously mentioned studies, the sales figure of around 14 million units in 2030 will be further used. It is in any case difficult to judge the accuracy of the different models.

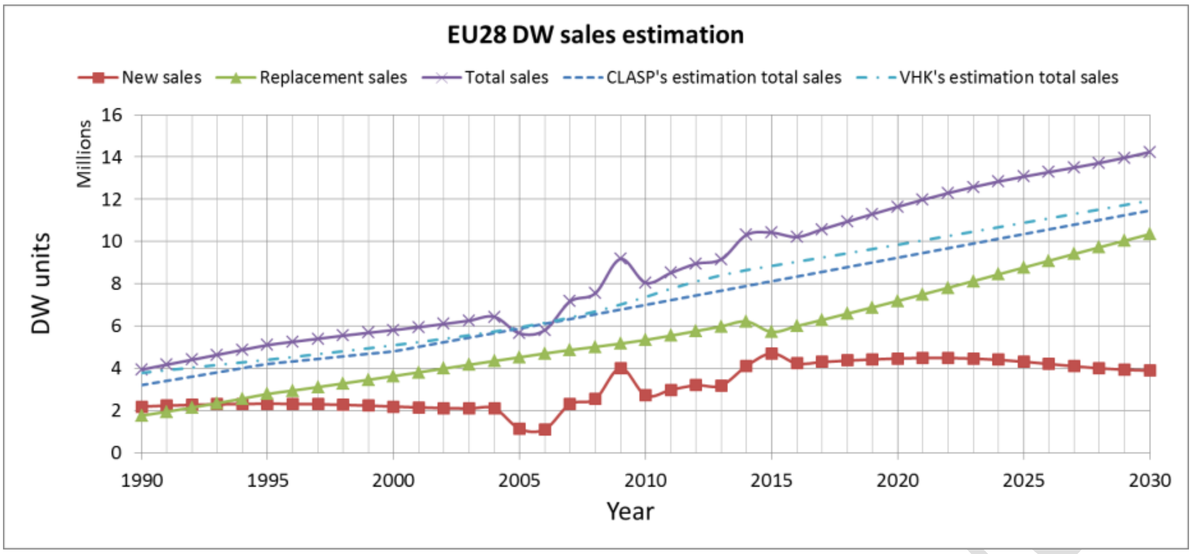


Figure 7.5: **Forecast of the sales of dishwashers in million units in the EU28 market together with the forecasts of VHK (2014 / status 2013) and CLASP (2013)**

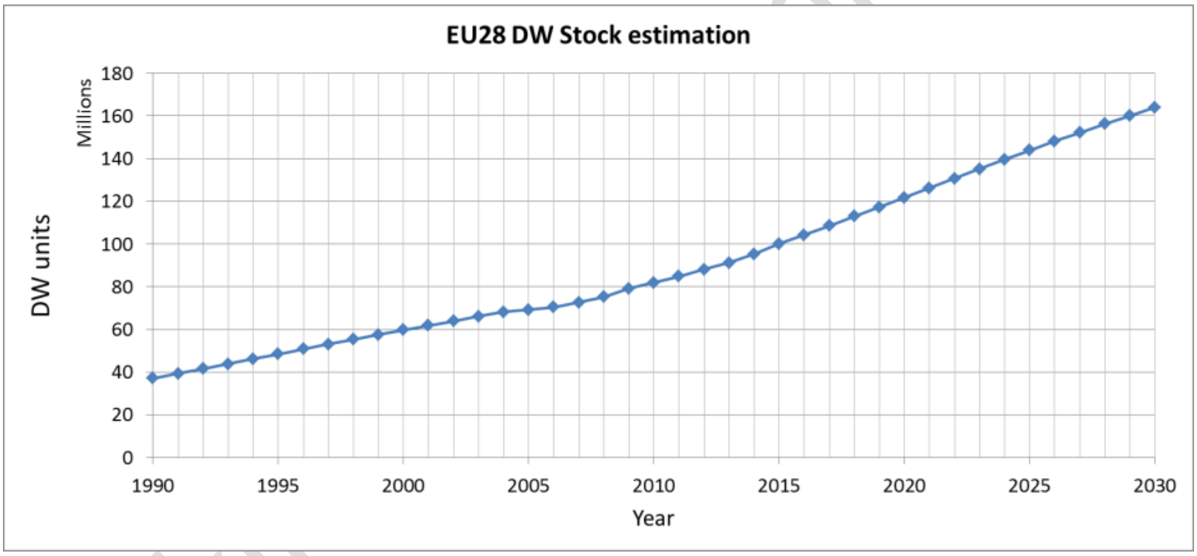


Figure 7.6: **Forecast of the stock of dishwashers in the EU28 market**

7.2.2.5. Consumer expenditure

The impacts of possible policy measures on the consumer expenditure are analysed. These impacts include a change in the operating expenses (which are usually decreased because of more energy efficient machines) and a change in the purchase price (which is usually increased). The consumer expenditure is calculated as the life cycle cost (LCC), i.e. including purchase costs and operating costs (energy and water costs, auxiliaries' costs and repair and maintenance costs).

Purchase price

The *purchase price* is estimated based on the information included in Table 5.10 regarding manufacturing costs, mark-ups for the manufacturers and retailers and the VAT. The manufacturing costs include, when appropriate, the additional manufacturing costs of the improvement options which are added to the base case to achieve better energy performance (see Table 6.14).

The real cost of a product usually decreases over time because of the manufacturer's experience in producing that product (see also section 6.1.2.2). In the case of dishwashers a part of the downward trend in purchase price might also be attributed to a change in sales channels, i.e. from specialised electronics retailers to big supermarket chains and internet sales.

To arrive at the purchase prices beyond 2015 the manufacturing cost in 2015 was corrected by the experience curve and the mark-ups. Prices beyond 2015 are reported in Euro_{2015} to avoid uncertainties due to future inflation.

An experience curve connects the real cost of the production with the manufacturer's cumulative production and could be described as $Y(j) = a\, X(j)^{-b}$ where a is the initial purchase price (which in this case is set to the price in 2015), b is a positive constant known as the experience rate parameter, $X(j)$ are the units of cumulative production and $Y(j)$ is the purchase price in year j. The constant b was estimated by fitting the experience function, corrected by the harmonized consumer price index (HCPI), to the harmonized index of consumer prices for household appliances ($\text{HCPI}_{\text{appliances}}$) provided by Eurostat (2016a). The fitting results in a value of b = 0.3. This factor was applied to all technologies.

The state of development of the heat pump technologies for dishwashers was considered to be not as mature as other technologies. This means that technologies that are considered already mature and widely applied will have a softer effect of gaining experience than heat pumps that are considered to have a higher improvement potential. The difference was modelled by considering a different level of cumulative production of dishwashers equipped with heat pumps compared to dishwashers without this technology. The cumulative production is derived in each of the scenarios modelled from the penetration of certain technologies which in turn comes from the assumptions of sales distribution of the different energy classes (see Figure 7.12 in section 7.2.3.4).

Operating costs

The operating costs consist of the electricity and water cost, maintenance and repair costs, and auxiliaries' costs. The auxiliaries consist of detergent, regeneration salt and rinsing agent.

The energy consumption of the overall stock at EU28 level per year is calculated as follows

$$AEC_{EU\,28}\,(j) = \sum_{i=1}^{j} Survival_{(j-i)}\; UEC_{(j-i)}$$

Where $AEC_{EU28}\,(j)$ is the EU28 annual energy consumption in year j, $survival_{(j-i)}$ is the number of units surviving in year j which have entered the market in year j-i and $UEC_{(j-i)}$ is the average energy consumption of a machine in year j-i in which the product was purchased as a new unit. The average energy consumption of a new machine is calculated from the distribution of the sales over the label classes when it is purchased.

The energy and water consumption of each dishwasher in a certain label class is calculated at the maximum value of EEI of that energy class. For example, for the current A++ class the energy consumption of the machine is taken at EEI = 56 even though the class is spread from EEI = 56 to EEI = 50. This stems from observing the CECED database where most models in a certain class are declared at the maximum EEI of that class (see Figure 2.18).

To calculate the EU28 cost for electricity use from dishwashers, $AEC_{EU28}\,(j)$ is multiplied with the corresponding cost for electricity per kWh in year j. The same approach is applied for calculating the water cost at EU28 level. The energy price trends are estimated considering the projections in the EU Reference scenario 2016 (European Commission 2016) and the water trend prices are estimated by an escalation factor of 2.5%. Table 8.29 in Annex 8.2.12 show the price values per year that were used in the calculation.

The repair and maintenance costs include costs associated with repairing or replacing components that have failed and costs associated with maintaining the operation of the dishwasher. As already outlined in section 6.1.2.2 it is assumed that small incremental changes in product energy efficiency produce no changes in repair and maintenance costs over the base case costs. However, dishwashers having significantly higher energy efficiencies (such as those equipped with heat pumps) are more likely to incur higher repair and maintenance costs, because their increased complexity and higher part count typically increases the cumulative probability of failure. This difference was not considered in the model. The repair and maintenance costs in the reference year are shown in Table 5.1. This value was reported for the years to come and kept constant (in $Euro_{2015}$).

For the auxiliaries cost, the cost per year per machine (Table 5.11) is multiplied by the stock on the EU28 market in that year. The annual average price is assumed constant, the same as for the repair and maintenance costs.

7.2.2.6. Annual emissions of CO_2eq and annual primary energy consumption

The *annual emissions of CO_2eq* related to the use of dishwashers are estimated based on the annual electricity consumption. Yearly emission factors (g of CO_2 eq/$kWh_{electricity}$) were considered to convert electricity consumption into greenhouse gas (GHG) emissions. The value of the emission factor depends on the electricity mix at EU-level. Historical data series show that this value has been changing along the years due to among other reasons the higher proportion of renewable energy sources and the European targets to reduce the GHG emissions. The forecast for future emission factors was calculated from the EU Reference scenario 2016 (European Commission 2016) and is tabled in Annex 8.2.13.

The *annual demand of primary energy* associated to the use of electricity of dishwashers at the EU level was modelled based on the current primary energy factor (PEF) included in the Directive 2012/27/EU (European Parliament 2012b) on energy efficiency and its expected trend in accordance with the EU Reference Scenario 2016. Directive 2012/27/EU establishes in Annex IV a default coefficient of 2.5 which may be applied by Member States when transforming electricity savings into primary energy savings. As the real electricity generation in the EU-28 is comprised of a variety of different power plants and generation installations using different technologies, fuel types and qualities the conversion factors are not a constant value. The estimated values of PEF in the future assume an increase in the efficiency in generating electricity from fuels as well as a higher integration of more renewable and carbon-neutral technologies. The forecast for the future primary energy factors is tabled in Annex 8.2.13.

7.2.2.7. Impacts on jobs of manufacturers and retailers

The total turnover per year is calculated from the average purchase price of that year multiplied by the total sales of that year. This turnover is then partitioned over the manufacturers and retailers according to the mark-ups of each sector (see section 5.1.2). Even though it is a rough estimation, it provides an initial insight. Local levies and recycling contributions are not taken into account.

Employment impacts were calculated based on data reported in the Impact Assessment of 2008 (European Commission 2012a) on the basis of the average turnover per employee in each sector (manufacturing industry: 188 000 € / employee and white good retailers: 60 000 € / employee).

7.2.3. Policy scenarios

7.2.3.1. Description of the assessed scenarios

Table 7.8 shows the policy options that have been assessed more in detail in this study. The business-as-usual scenario (BAU) is used as a reference. This scenario implies no changes whatsoever in the legal requirements for dishwashers, i.e. no changes in ecodesign or other requirements and no changes in the energy label. However, given that the revision of the energy labelling directive (European Commission 2015c) is on-going some changes will most likely be implemented in the future. The BAU scenario is therefore a rather virtual option.

Possible changes of those regulations are reflected in the assessed policy scenarios (Scenario 1 and Scenario 2a, 2b and 2c). In these scenarios the calculation of the energy efficiency index EEI is based on the same formula as today however without counting the energy consumption of the different low power modes' energy consumption (see also section 1.2.1.2). This brings back the calculation of the EEI to the same formula as used when the energy label for dishwashers was introduced in 1997. Policy options related to low power modes are described in section 7.1.3.5. An energy consumption limit on these low power modes is not expected to save much energy at the moment, but would prevent these modes from becoming more important in terms of energy consumption.

Table 7.8. Policy scenarios under consideration

Scenario	Sub-scenario	Comments
0. Business as usual		No change in the current situation for dishwashers, no further policy tools implemented. This is a virtual option given the upcoming revision of the energy label directive, but it serves as a reference scenario.
1. Stricter minimum energy performance requirements and removal of the energy label		Increase in the minimum threshold for energy efficiency and removal of the energy label. From 2020, EEI < 56.
2. Energy label class revision	2a. and 2b	The energy classes are revised to an A-G scale. Scenario 2a is a bit more challenging than scenario 2b. The minimum energy performance requirements are not updated as they are judged to be already at a high level.
	2c.	A strict energy label revision where probably only appliances with a dedicated technology (e.g. heat pump) will fall in the best label classes. This could cause the market to split by technology to reach a specific label distribution, e.g. only heat pump equipped machines in the highest label classes. Also in this case the minimum energy performance requirements are not updated as they are judged to be already at a high level
3. Additional measurement of the automatic programme		Applied to scenario BAU and 2a with an optimized and more efficient automatic programme, i.e. as efficient as the Eco programme to estimate the most optimistic scenario.
4. Durability / Reparability	4a. Increasing the robustness/durability of the machines	Applied to BAU and to scenario 2a with an additional 2.5 years of technical lifetime
	4b. Decreasing the number of machines	Applied to BAU and to scenario 2a with an increase in the re-use of machines that are discarded for

Scenario	Sub-scenario	Comments
	without failure that are discarded	reasons other than a failure.
	4c. Increasing the reparability of the machines	Applied to BAU and to scenario 2a, increase the repair of machines that are under technically and/or economically feasible repair conditions.

7.2.3.2. Business as usual scenario

The definition of the Business as Usual (BAU) scenario for dishwashers is based on the assumption that no additional regulation is implemented. The BAU scenario is only used for reference as it is highly unlikely that nothing will change in the energy label given the current revision of the energy labelling directive.

The BAU scenario does not mean that without further regulation the sector will not improve the energy efficiency of its products. However, given the development of the energy consumption of the dishwashers over time (see Figure 2.10), it could be assumed that a "plateau" is going to be reached and, as improving energy efficiency might come at a high cost, it would not be implemented as quickly as in the other scenarios.

In this scenario it is assumed that there are little additional energy efficiency improvements. As the energy label would lose its potential for making a differentiation among the dishwashers, manufacturers will have little incentive to go beyond the current energy label class A+++, except for advertising claims such as 20% more efficient than the A+++ class. These claims would be difficult to verify as they are not bound to legal rules. Note that currently there is still differentiation on the market even though only three label classes are significantly populated. Sales figures for the A+++ class reached at the end of 2015 around 8% of the total sales. This top class could thus be further populated in the coming years even if no additional policy measures would be implemented. A gradual shift to populate only the A++ and A+++ classes could be expected. The estimated evolution of the sales distribution over the different classes in the BAU scenario is shown in Figure 7.7.

7.2.3.3. Scenario 1: Stricter minimum energy performance requirements and removal of the energy label

In this scenario the option is explored to remove the energy label and implement stricter minimum requirements allowing only machines with EEI < 56 (which means appliances with energy efficiency class A+ and worse would not be allowed anymore) from 2020.

The manufacturers would not be encouraged to improve the DW beyond the mandatory requirements since there would be no differentiation based on energy efficiency. They could focus on decreasing the costs or focus on other non-energy parameters such as basket design, durability, internet connections, etc. Some manufacturers, however, will keep improving their products and communicate their improved energy efficiency to the consumers.

One aspect to consider in this context is that currently the label displays also other information like water consumption, drying efficiency, noise and the number of place settings. It is not defined where and how this information should be transmitted to the consumer if the energy label was removed.

The estimated evolution of the sales distribution over different EEI values in this scenario is shown in Figure 7.8.

7.2.3.4. Scenario 2a, 2b and 2c: Revised labelling classes

Energy labelling is a mechanism to help consumers making an informed decision regarding energy consumption of the machine. It serves to differentiate products and identify the best energy performing machines. This scenario considers the policy options discussed in section 7.1.3 regarding the implementation of new energy label classes.

In these scenarios, a new label class differentiation is created with a full scale of seven energy classes ranging from A to G. No additional ecodesign requirements are put forward as the dishwashers have already reached a high level of efficiency since the introduction of the energy label in 1997 (see Figure 2.10). The three sub-scenarios differ mainly regarding the strictness of the requirements for the label classes.

The label class thresholds for the three sub-scenarios are shown in Table 7.9. These label class thresholds are also illustrated in Figure 7.9, Figure 7.10 and Figure 7.11 which also show the estimated dishwasher sales evolution.

Table 7.9: Current energy label class distribution and for scenarios 2a, 2b and 2c.

Since 2011*			Revision							
				Scenario 2a		Scenario 2b		Scenario 2c	
Label class	EEI min	EEI max	Label class	EEI min	EEI max	EEI min	EEI max	EEI min	EEI max
A+++		50	A		38		39		27
A++	50	56	B	38	43	39	44	27	31
A+	56	63	C	43	48	44	49	31	36
A	63	71	D	48	54	49	55	36	43
B	71	80	E	54	60	55	62	43	49
C	80	90	F	60	67	62	69	49	57
D	90		G	67		69		57	

* The classes marked in red are not allowed because of ecodesign requirements which are already implemented. The last tier enters into force at 1 December 2016. Note that table-top machines are still allowed with EEI < 71.

To better understand the implications of the different thresholds it is important to know the EEI of the best available appliances currently on the market which are shown in Table 7.10.

Table 7.10: Annual energy consumption and EEI of best available dishwashers on the market mid 2016

	No. of place setting	Annual energy consumption	EEI
A+++ -40% (heat pump dishwasher)	13 ps	137 kWh/a	29
A+++ -20% (best DW without heat pump)	14 ps	189 kWh/a	40
A+++ -10%	13 ps	211 kWh/a	45

Both scenario 2a and scenario 2b would allow heat pump equipped appliances (i.e. EEI = 29) in energy class A from the start of the revision. This might be in conflict to a proposal made in the revision of the energy label directive revision that "*no products are expected to fall in energy class A at the moment of the introduction of the label*" (European Parliament 2016). It could be debated however if heat pump equipped appliances would fulfil the requirement of being "*a product on the market*"; the sales figures for heat pump equipped appliances are currently very low (estimated to be around 0.01% of the total sales).

At the moment of writing (September 2016) no machines without heat pump have been identified with an EEI < 40. This means that class A would initially be almost completely empty for both scenarios (with exception of the heat pump appliances). In both scenarios (2a and 2b) the manufacturers could be motivated however to develop machines that can achieve higher energy label classes (i.e. classes A to C) as there are already dishwashers on the market that achieve the proposed class C (currently A+++ -10%) or even the proposed class B (currently A+++ -20%). The current best dishwasher on the market without heat pump is almost reaching the proposed class A. The proposed classes A and B are seen to be positioned to allow for innovation and exploit possible improvement potentials. Dishwashers that currently reach A+++ would be classified in the proposed class D, current A++ dishwashers would be classified class E, current A+ dishwashers class F. Table-top dishwashers could fall in label class G. It has to be noted that currently only 8% of all dishwashers are classified with A+++ (or claimed to be even better). The majority of dishwashers would therefore still be classified between E and F, leaving much room for improvement.

The main difference of the two sub-scenarios is that sub-scenario 2a is slightly stricter than sub-scenario 2b.

Scenario 2c shows an energy label class revision where the current heat pump equipped dishwasher falls in class B, leaving class A completely empty at the moment of writing. Given that this is the second revision of the energy label for dishwashers, it can be assumed that further energy improvement would imply a slow technological progress for dishwashers. Hence, it could be justified to only keep label class A empty instead of keeping label class A and label class B empty from the beginning. Moreover, keeping energy class B empty at the start of this revision would mean very little differentiation among the products. Such a distribution of the different classes over the range of EEI taking into account the current ecodesign measures would leave the best model without heat pump on the market now (A+++ -20%, EEI = 40) in class D. Dishwashers that currently reach A+++ would be classified in class E, current A++ dishwashers would be classified class F. All other dishwashers would fall in class G. It is supposed that under such circumstances it is possible that the market splits into heat pump equipped machines, which are more complex and expensive, and (cheaper) dishwashers without this technology. The producers of dishwashers without the heat pump technology would have little incentive to improve their products regarding energy efficiency.

Given the current knowledge, it would be very difficult to nearly impossible in this scenario 2c to reach a good label class without an expensive heat pump. Due to the high purchase price there might be a lower uptake of heat pump equipped machines than expected. Furthermore, as all dishwashers without heat pump would be in the low energy efficiency classes (D to G), this might result in the perception that non-heat pump machines do not perform well. This could decrease the penetration rate of dishwashers in favour of hand dishwashing and could therefore lead to the adverse effect that overall more energy and water would be consumed by the revision of an energy label (see also section 3.3 for a comparison of manual vs. automatic dishwashing). A switch to hand washing or a lower penetration rate is not included in the model, but would reduce the potential overall energy and water savings. Additionally, other environmental impacts could become more important when massively switching to heat pump equipped dishwashers (see Figure 6.1).

Note that a similar market change has happened with tumble driers, i.e. a switch to heat pump equipped appliances. It should be mentioned however that the energy savings attributed to a heat pump in tumble driers are much more significant than for dishwashers. Also introducing a heat pump in tumble driers is less complex than for dishwashers where more space restrictions are encountered.

It might also be possible that another technology is developed that could compete with the heat pump in terms of energy efficiency, but no indications of this have been identified so far. Moreover, for the time being most manufacturers are hesitant to implement the heat pump technology and see the heat pump equipped dishwasher more as a lighthouse technology without much sales arguments.

Evolution of the sales distribution for the scenarios 1, 2a, 2b and 2c

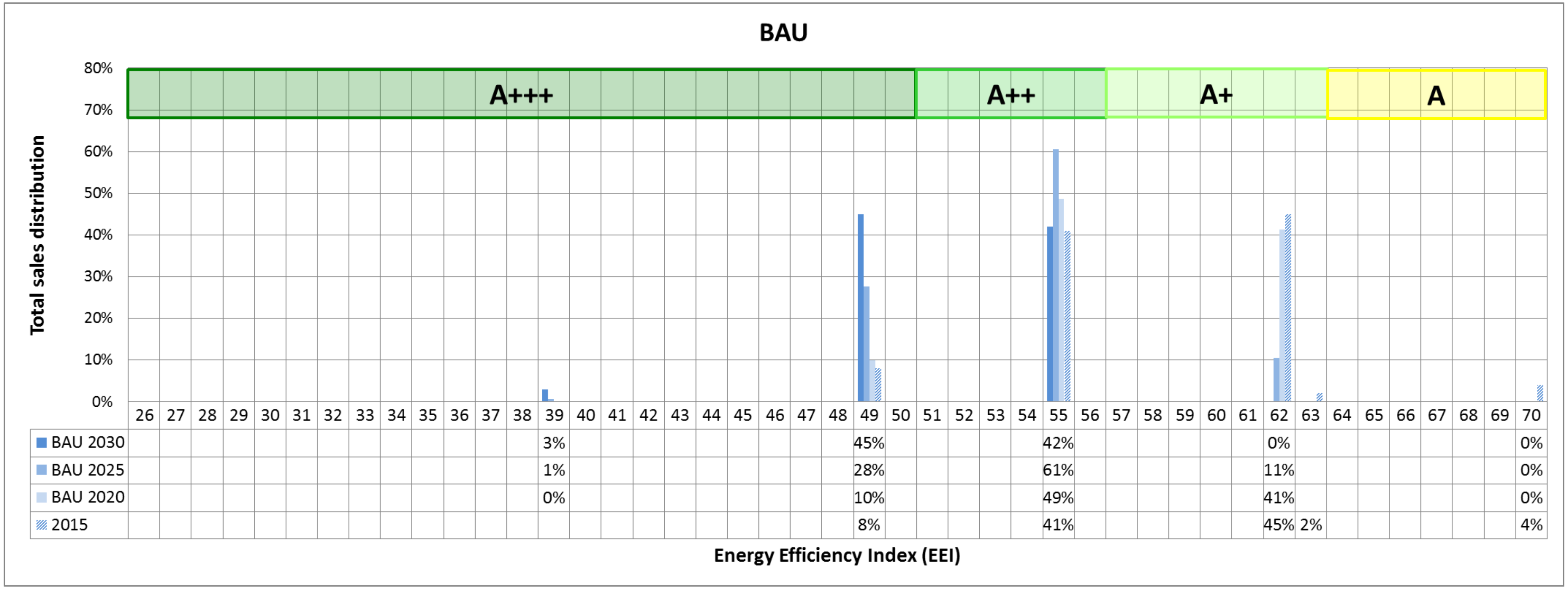
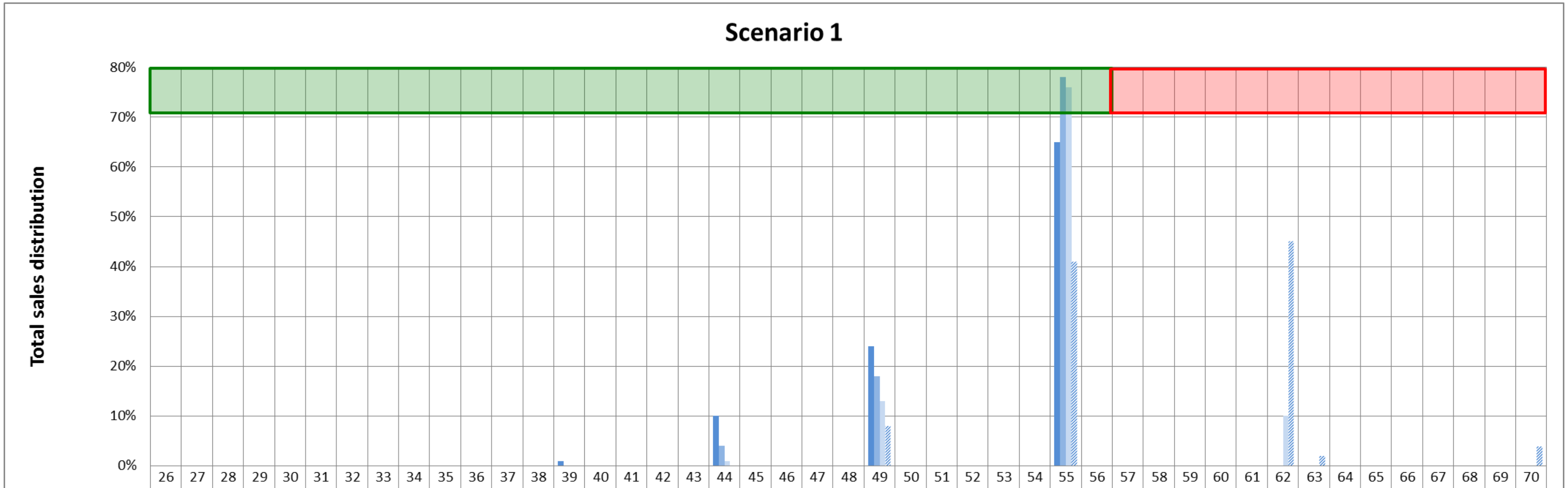
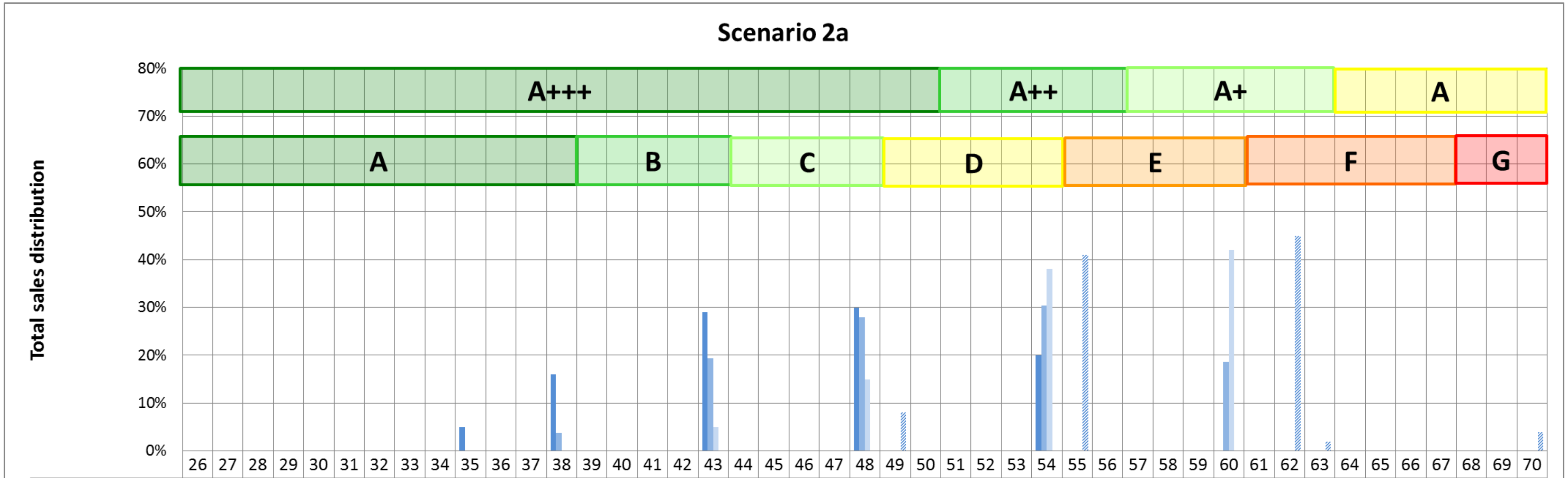


Figure 7.7: **Estimated sales distribution for the BAU scenario according to declared EEI values. The current label classes are indicated.**



	30	35	39	44	49	55	62	63	70
Scenario 1 2030	0%	0%	1%	10%	24%	65%	0%		0%
Scenario 1 2025	0%	0%	0%	4%	18%	78%	0%		0%
Scenario 1 2020	0%	0%	0%	1%	13%	76%	10%		0%
2015					8%	41%	45%	2%	4%

Figure 7.8: **Estimated sales distribution for scenario 1 according to declared EEI values. The ecodesign requirement at EEI = 56 is indicated.**



	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70
Scenario 2a 2030					0%					5%			16%					29%					30%						20%						0%							0%			0%
Scenario 2a 2025					0%					0%			4%					19%					28%						30%						19%							0%			0%
Scenario 2a 2020					0%					0%			0%					5%					15%						38%						42%							0%			0%
2015																								8%						41%							45%	2%							4%

Figure 7.9: **Estimated sales distribution for scenario 2a according to declared EEI values. The current energy label classes are indicated together with the proposed label class distribution for scenario 2a.**

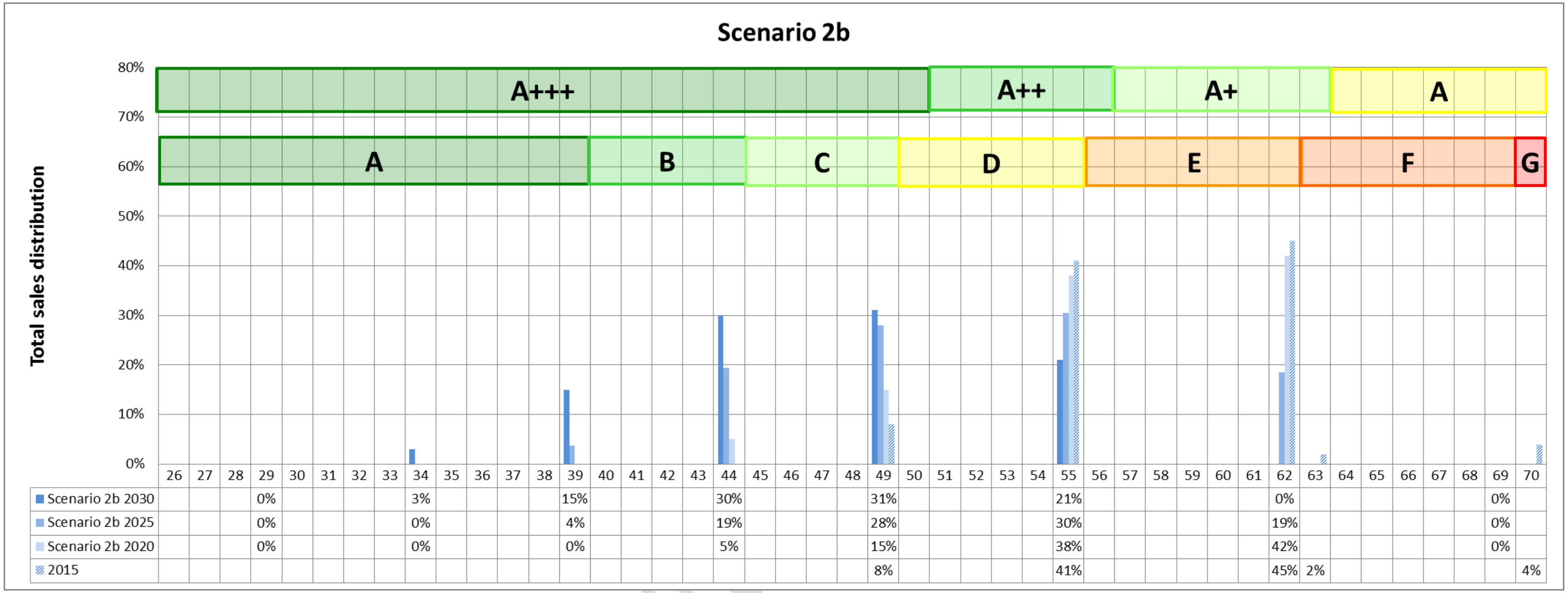


Figure 7.10: **Estimated sales distribution for scenario 2b according to declared EEI values. The current energy label classes are indicated together with the proposed label class distribution for scenario 2b.**

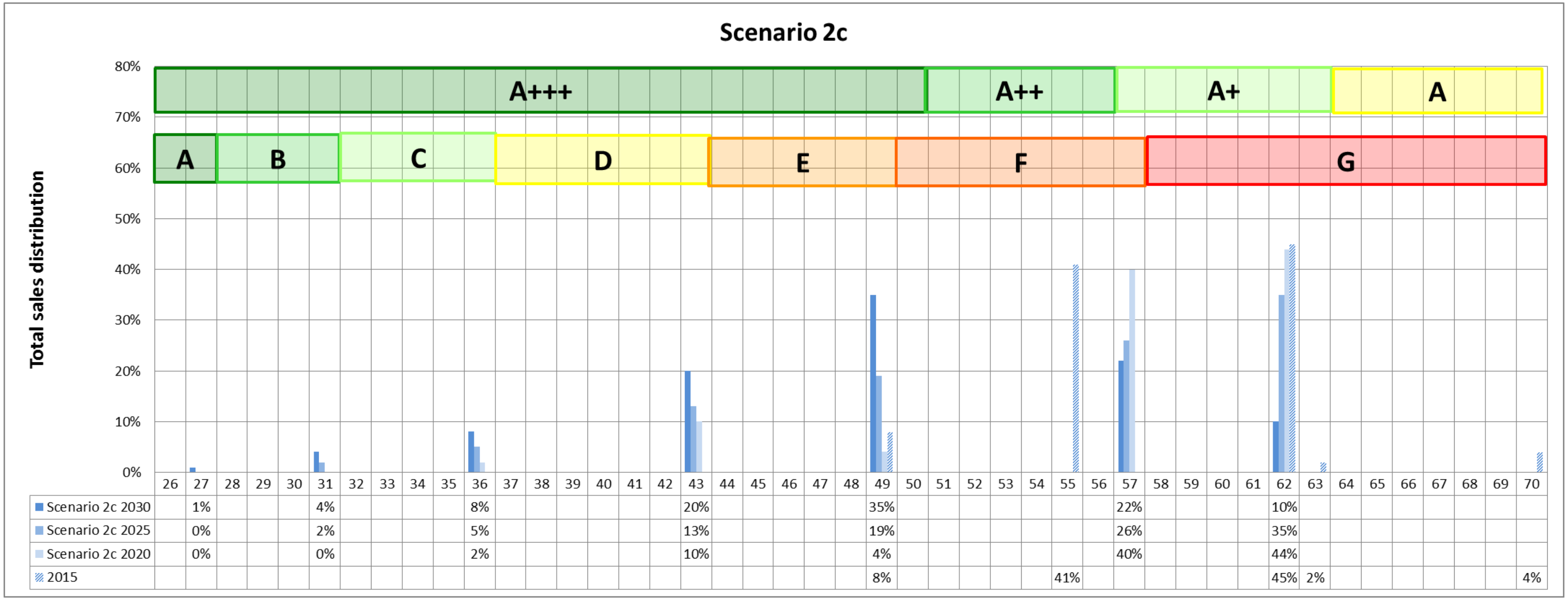
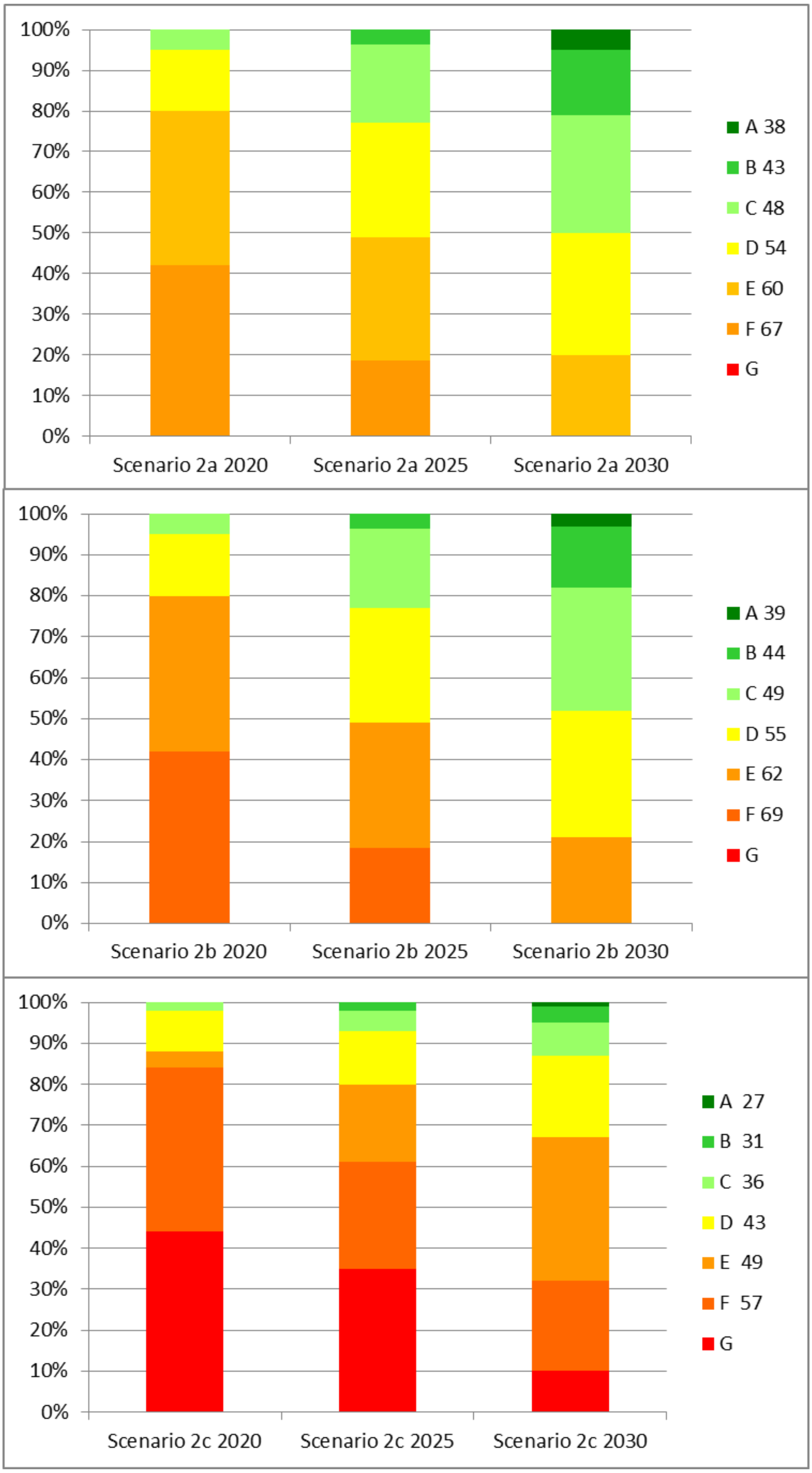


Figure 7.11: **Estimated sales distribution for scenario 2c according to declared EEI values. The current energy label classes are indicated together with the proposed label class distribution for scenario 2c.**



In the legend, the label classes are accompanied by their maximum EEI value.

Figure 7.12: Estimated sales distribution for scenarios 2a, 2b and 2c

Impacts on resources for the scenarios 1, 2a, 2b and 2c

The different scenarios act differently on the evolution of resource consumption (energy and water) in the EU28. The effects of the different scenarios on energy and water consumption for the EU28 in the period 2015-2030 are shown Figure 7.13 and Figure 7.14. Figure 7.15 and Figure 7.16 show the average individual machine consumption of energy and water over the period 2015-2030, respectively. Note that scenario 2c is not the most efficient one, even though intuitively this would be expected as it poses the strictest requirements. This counter-intuitive observation is due to the assumptions made in the distribution of the appliances split into two big groups over the different label classes (highly efficient machines and machines falling in the lower energy efficiency classes).

For all scenarios the overall energy and water consumption of dishwashers in the EU28 increase between 2015 and 2030, even though the individual machine consumption decreases over time. This is due to the expected increase of DW stock on the European EU28 market because of the combined effect of growth in number of households and the increase of ownership rate as outlined in section 7.2.2.4.

The expected energy and water savings are displayed in Figure 7.17 and Figure 7.18, respectively. From Figure 7.17 it can be seen that the maximum energy saving is expected for scenario 2a with an energy saving of 2.1 TWh/year in 2030. This is a saving of about 5% of the DW energy consumption in the BAU scenario estimated in 2030. As a comparison, 2.1 TWh is 0.3% of the total electricity consumption of private households in EU28 in 2014 (67 511 tons of oil equivalent which equals 785 GWh, cf. Eurostat (2016c)). A maximum water saving of 4.5 million m³ per year is expected in 2030 for scenarios 2a and 2b (Figure 7.18). This is around 1% of the water consumption expected in 2030 in the BAU scenario for DW in EU28.

The values for electricity and water consumption are provided in table form in Table 8.32 and Table 8.33 in Annex 8.2.15.

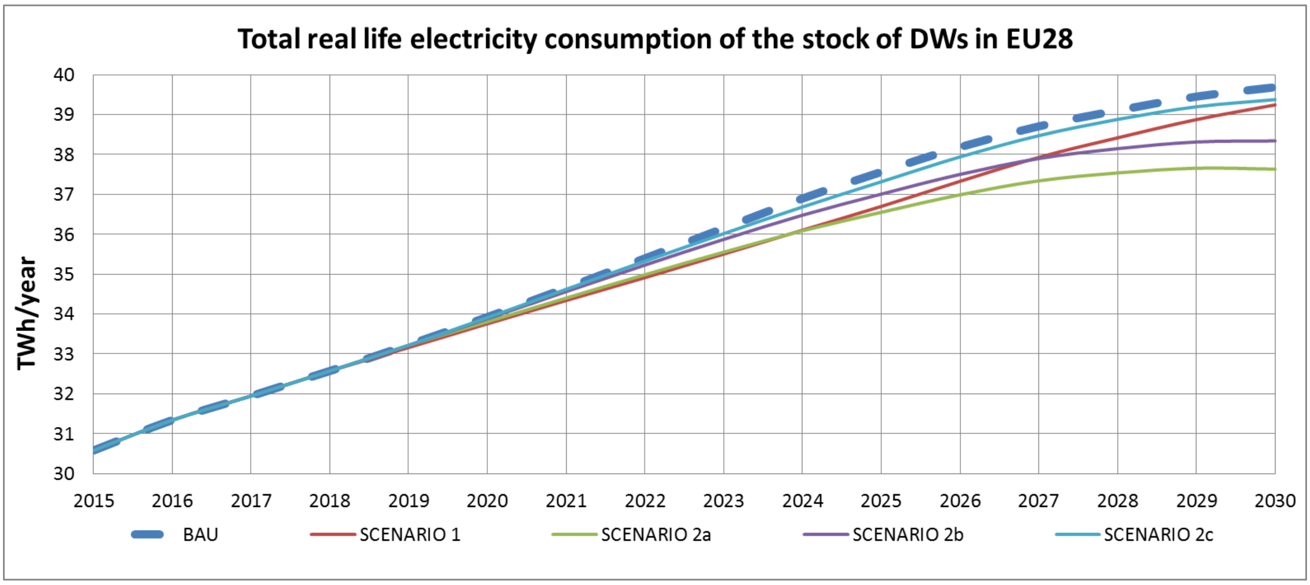
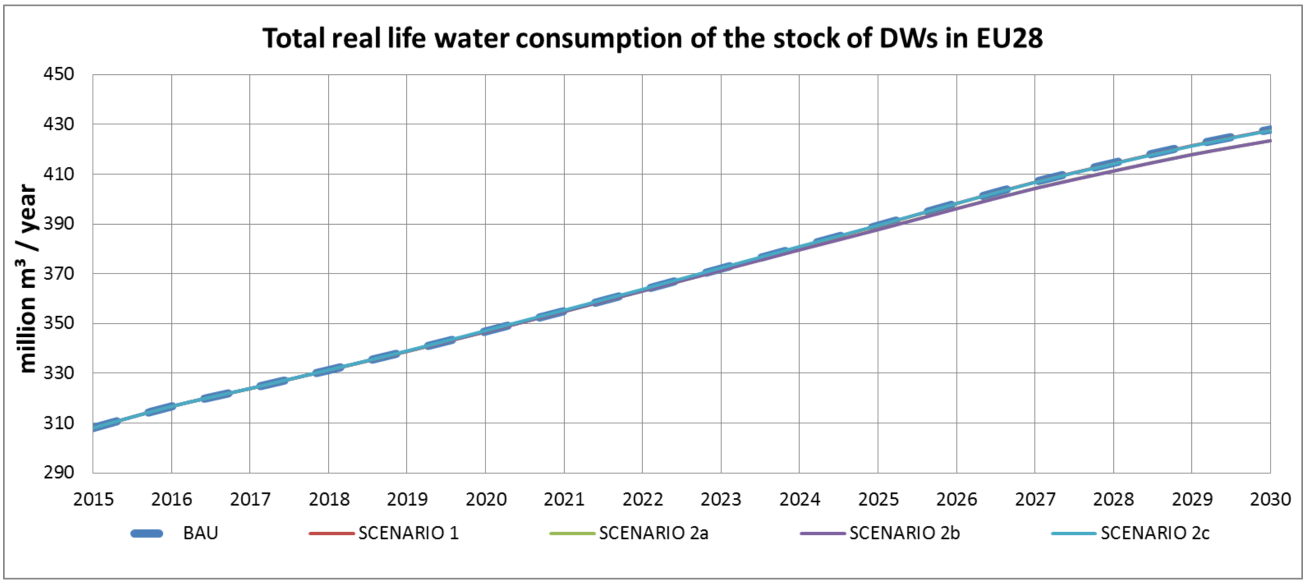


Figure 7.13: Estimated annual real life electricity consumption of the stock of dishwashers in the EU28 for the scenarios BAU, 1 and 2



Note that scenario 1 and 2c are almost overlapping, and scenario 2a and 2b as well.

Figure 7.14: **Estimated annual real life water consumption of the stock of dishwashers in the EU28 for the scenarios BAU, 1 and 2**

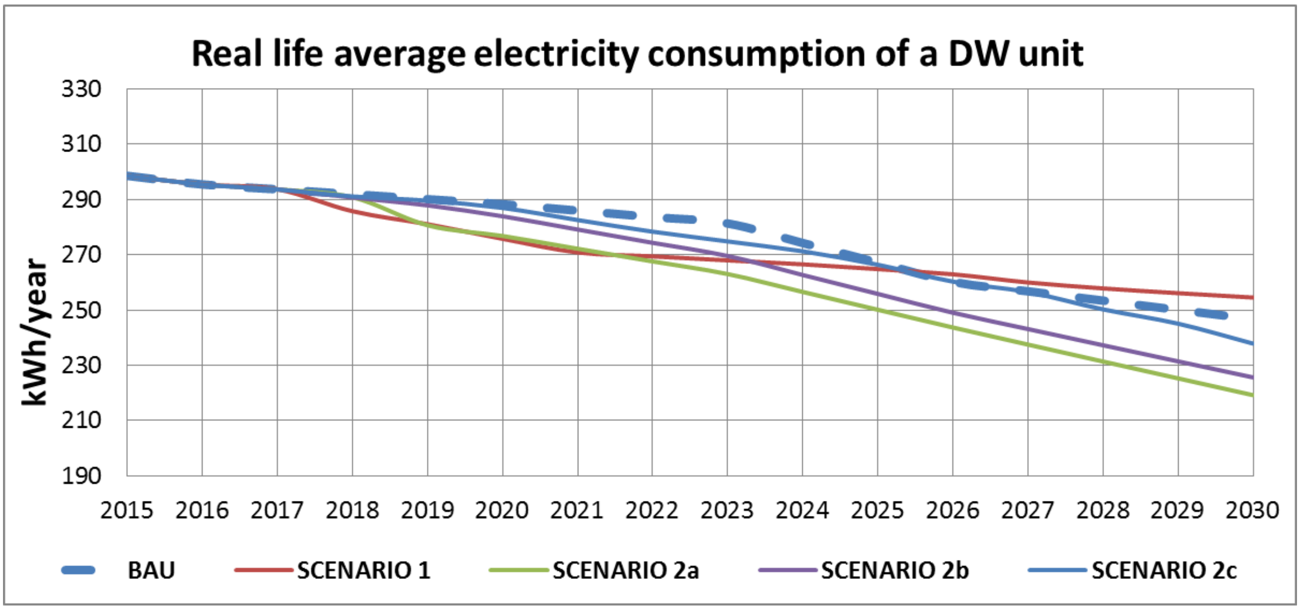
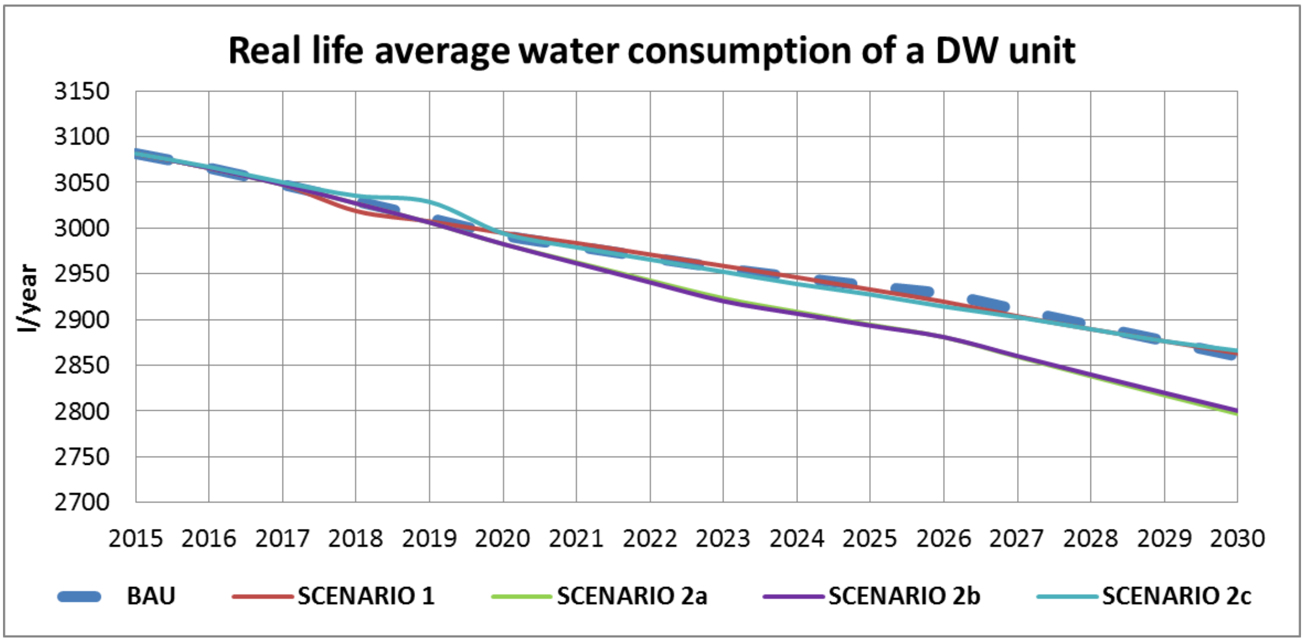


Figure 7.15: **Estimated annual real life average electricity consumption of a dishwasher unit for scenarios BAU, 1 and 2**



Note that scenario 1 and 2c have almost the same impact on water consumption, and scenario 2a and 2b as well.

Figure 7.16: **Estimated annual real life average water consumption of a dishwasher unit for scenarios BAU, 1 and 2**

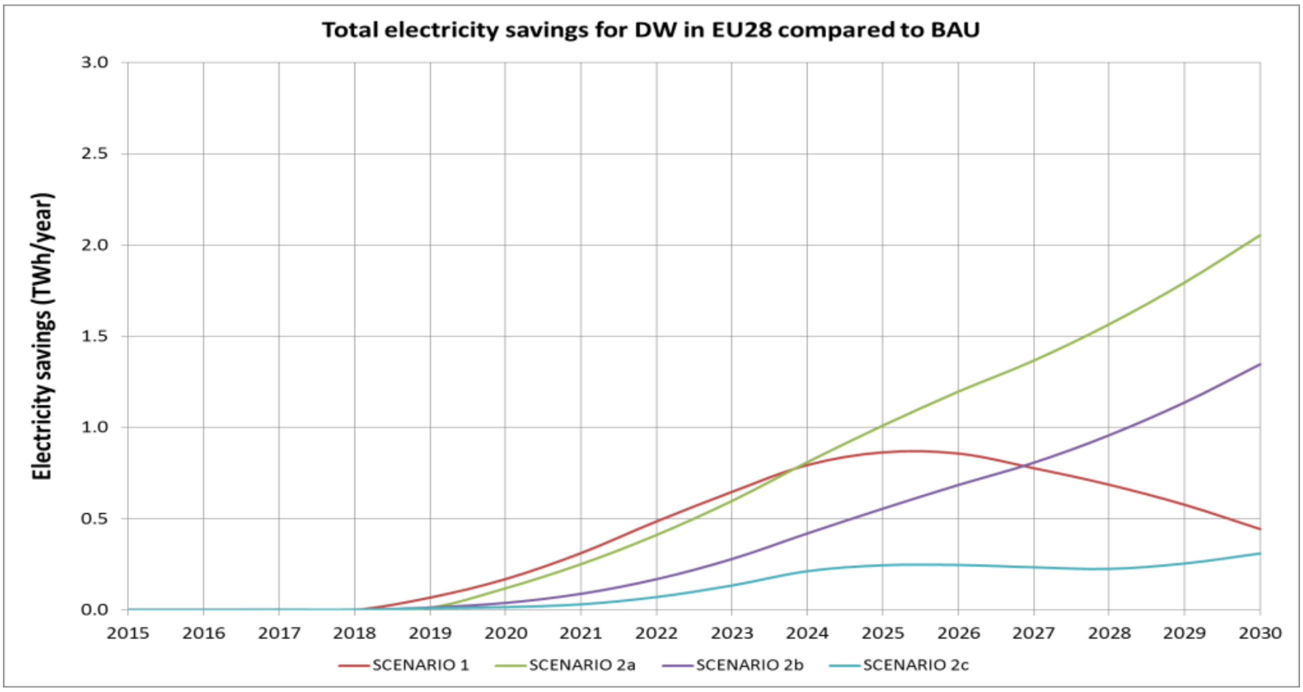


Figure 7.17: **Estimated annual total electricity savings for the stock of dishwasher in EU28 under the assumptions of scenarios 1 and 2 compared to BAU scenario**

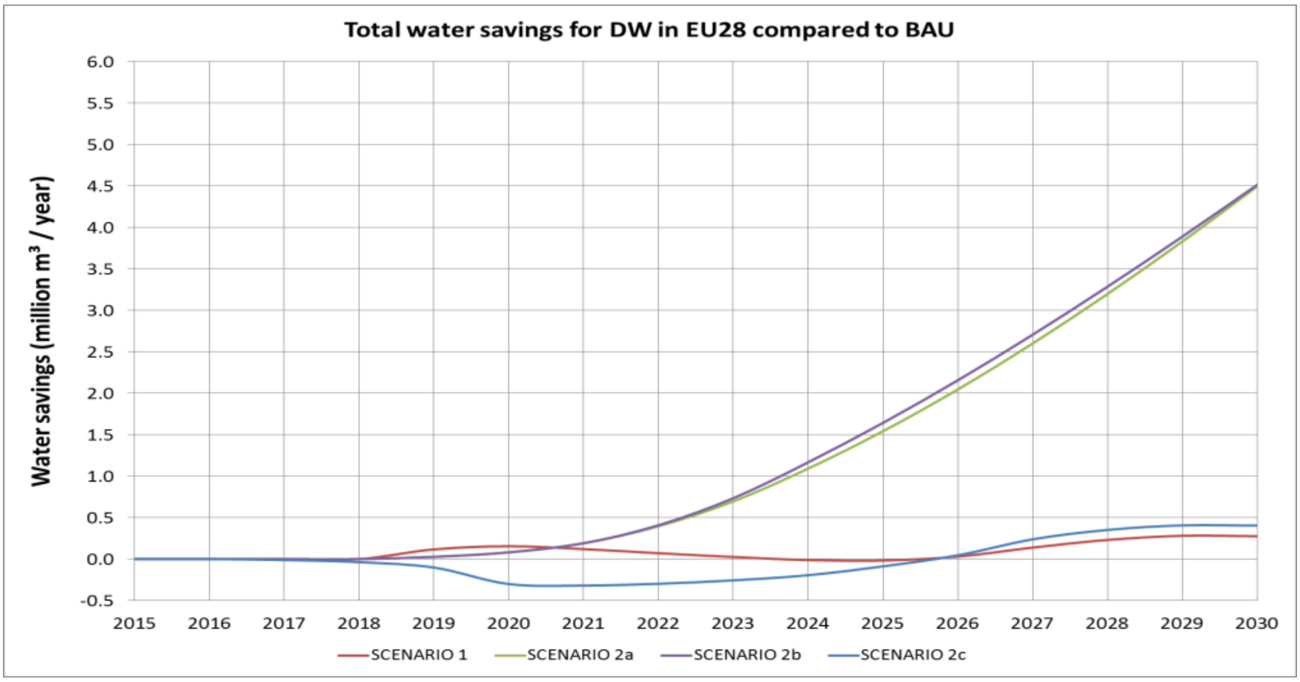


Figure 7.18: **Estimated annual total water savings for the stock of dishwasher in EU28 under the assumptions of scenarios 1 and 2 compared to BAU**

Impacts on GHG emissions and primary energy for the scenarios 1, 2a, 2b and 2c

The GHG emissions and the consumption of primary energy are directly linked to the electricity consumption. The environmental impact in terms of GHG emissions is illustrated in Figure 7.19. The reduction of carbon emissions attributed to the electricity in the coming years is considered to exceed the higher electricity demand of the European dishwashers shown in Figure 7.13.

Figure 7.19 shows in a decrease of CO_{2eq} emissions in all scenarios and especially in scenarios 2a and 2b as they reach a saving of around 0.6 and 0.4 Mt CO_{2eq} with respect to the BAU scenario in 2030, respectively (about 6% and 4% saving respectively). The calculated values are provided in table form in Table 8.34 in Annex 8.2.16.

Regarding the consumption of primary energy related to the electricity use of the dishwashers at EU-28 level, it can be observed from Figure 7.20 that the total primary energy is expected to increase in the coming years even if the primary energy factor is forecasted to decrease. This is due to an expected higher penetration rate of this appliance and the higher number of machines that will be part of the EU stock. The calculated values can be found in Table 8.35 in Annex 8.2.17.

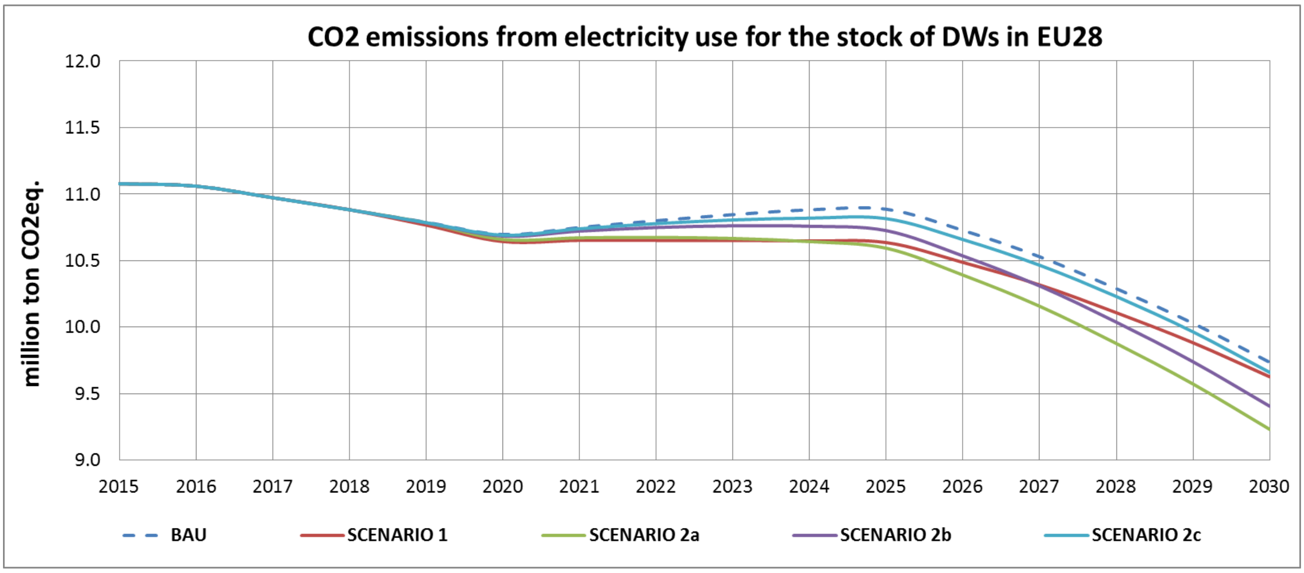


Figure 7.19: **Estimated annual CO_2eq emissions from electricity use from the stock of dishwashers in the EU28 for the scenarios BAU, 1 and 2**

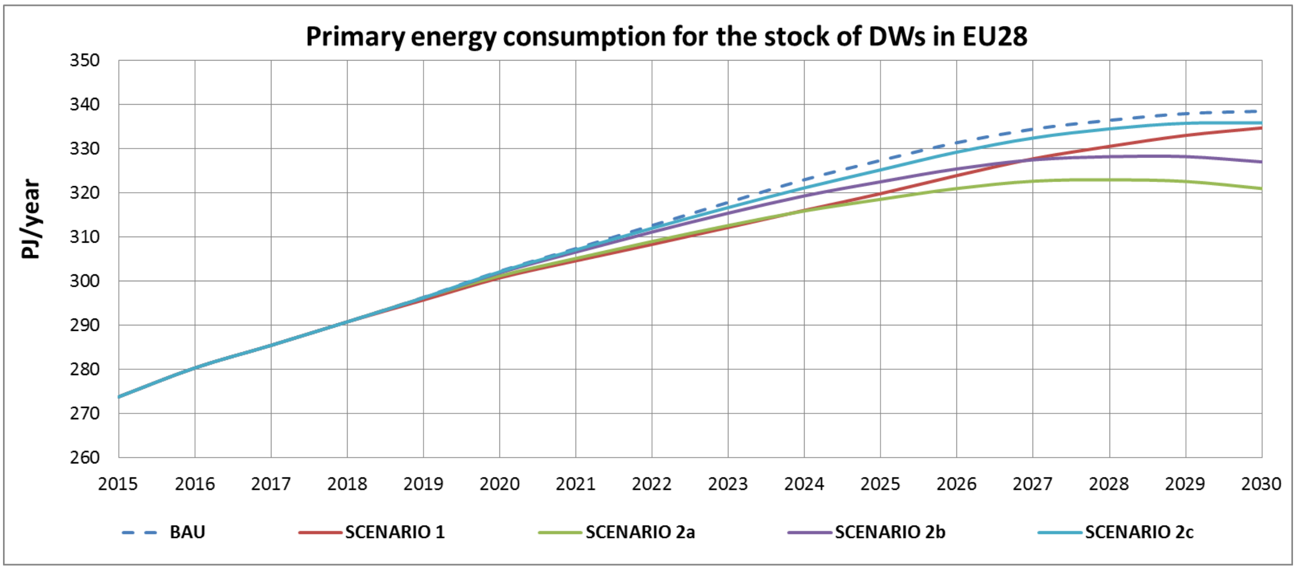


Figure 7.20: **Estimated primary energy consumption from electricity use from the stock of dishwashers in the EU28 for the scenarios BAU, 1 and 2**

Impacts on consumer expenditure and jobs for the scenarios 1, 2a, 2b and 2c

The impact of the different scenarios on the consumer expenditure is shown in Figure 7.22. The average unitary price (observed retail price) is shown in Figure 7.21.

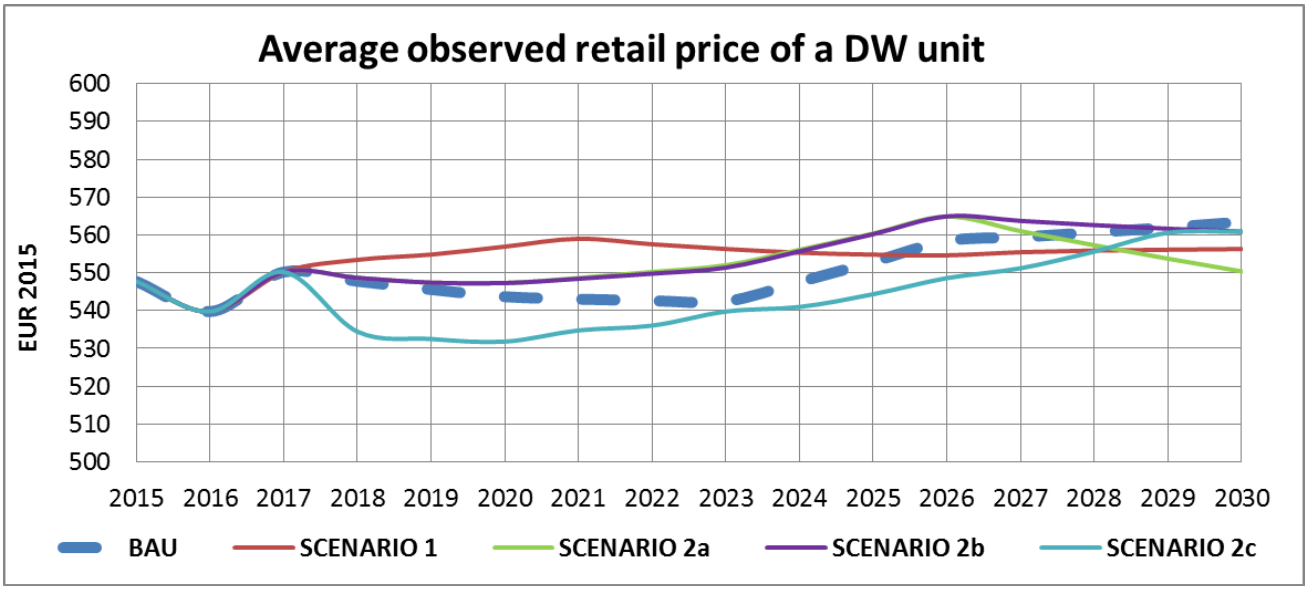


Figure 7.21: **Estimated average observed retail price of an average dishwasher for the scenarios BAU, 1 and 2**

Compared to the observed retail price in Figure 7.21, the total consumer expenditure in Figure 7.22shows a different trend. This is because for consumer expenditure also energy, water, repair and maintenance and auxiliaries costs are taken into account. Repair and maintenance, and auxiliaries costs are the same for all scenarios, but purchase price, energy and water costs change. This results in a decrease of the total EU28 consumer expenditure for the scenarios 1 and 2 in comparison to the BAU scenario, as shown in Figure 7.23. A maximum saving of around 0.54 billion euro$_{2015}$ per year is estimated for 2030 in scenario 2a as shown in Figure 7.23. This is about 2.06% of the total expenditure for DW in 2030.

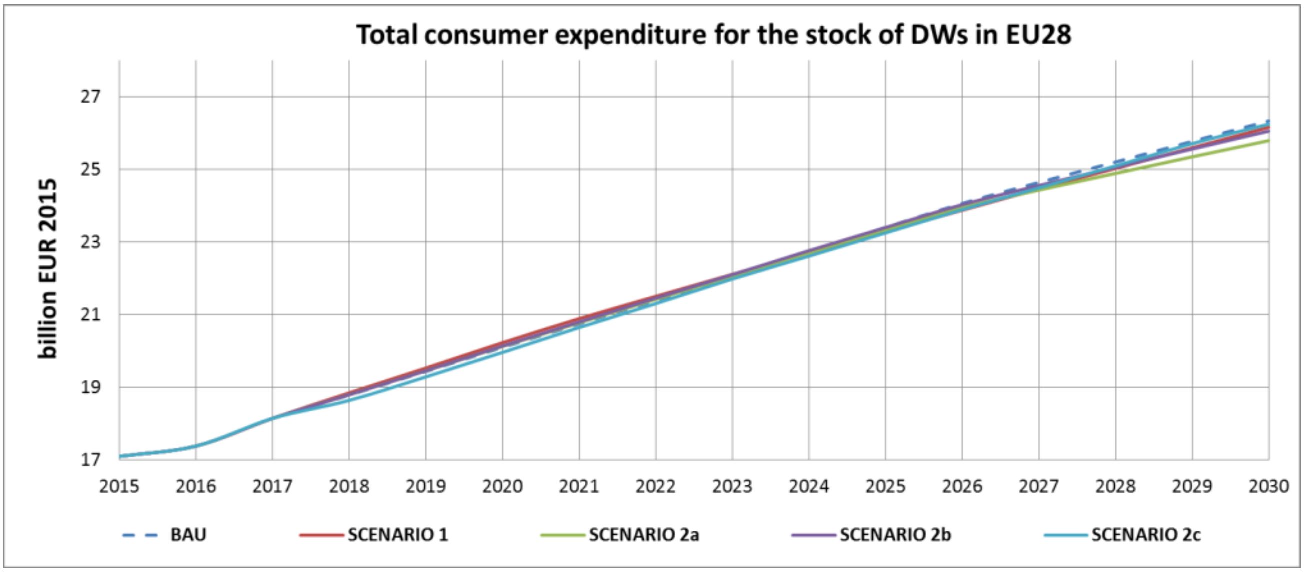


Figure 7.22: **Estimated consumer expenditure for the dishwasher stock in the EU28 (including costs for purchase, electricity, water, maintenance, detergent, rinsing agent and re-generation salt)**

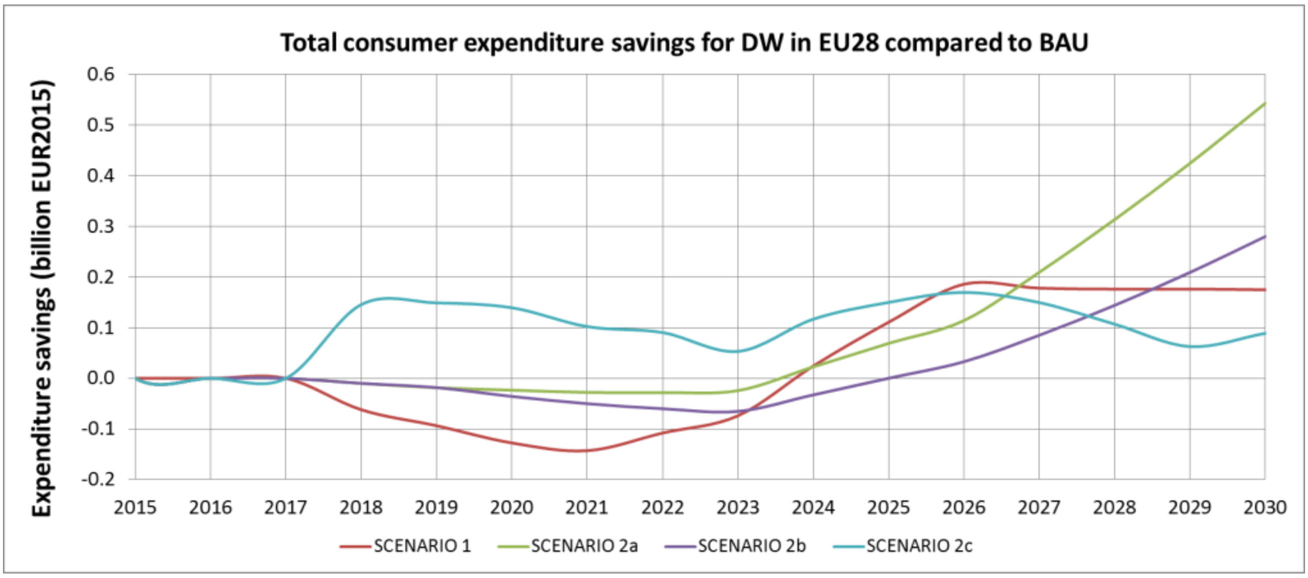


Figure 7.23: **Estimated consumer expenditure savings for the dishwasher stock in EU28 compared to the BAU scenario**

Finally, the impact in terms of expected job is considered. As explained in section 7.2.2.7 the job creation is estimated by the turnover and a ratio of 188 000 € / employee for the manufacturing industry and 60 000 € / employee for white good retailers. The turnover of the manufacturers and the white good retailers is calculated as the number of sold machines by the price at the manufacturer's door and the selling price, respectively (excluding VAT).

Figure 7.24 shows that the amount of jobs in the EU28 in 2030 is stable for all scenarios.

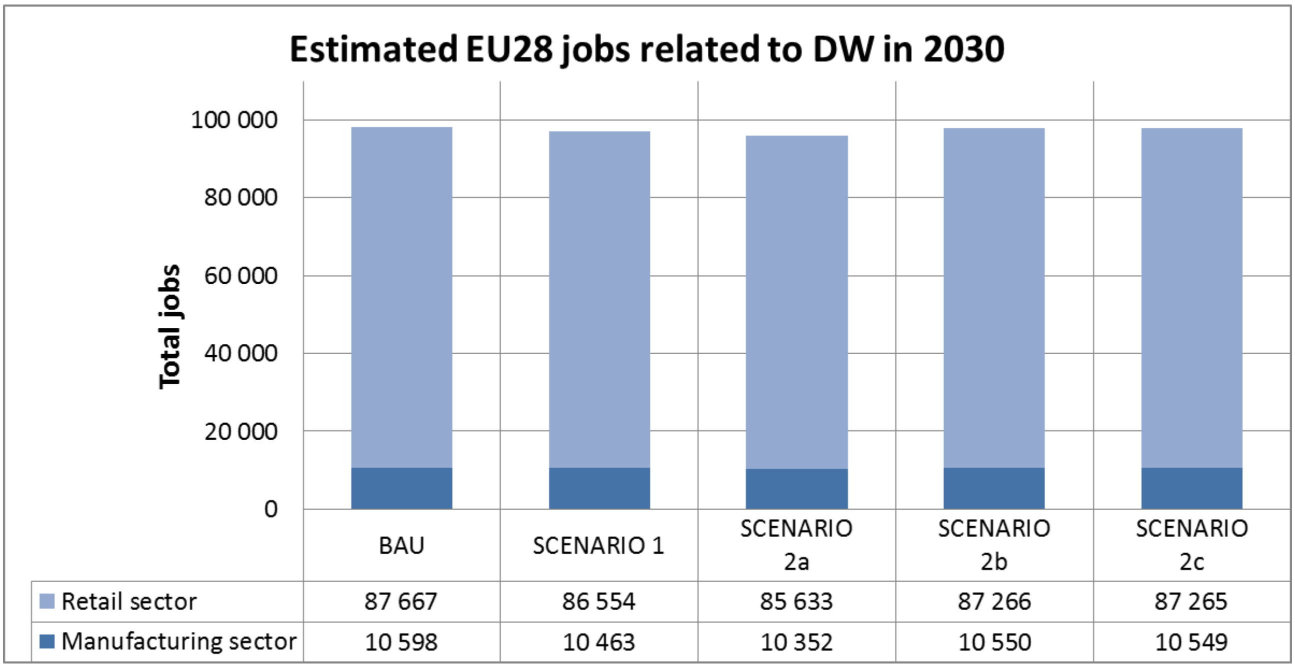


Figure 7.24: **Estimated number of new jobs by 2030 in the dishwasher sector**

7.2.3.5. Scenario 3: Measurement of Eco and automatic programme, 2 measurement conditions

This scenario assumes that besides the Eco programme also the automatic programme would be measured to show compliance within the energy label and eco-design requirements. The automatic programme would be measured under 2 usage conditions (e.g. full load and soil and full load and half soil).

As already discussed in section 7.1.3.1 under such conditions it is assumed that the automatic programme will be optimised with regard to the two defined usage conditions. This means, the energy consumption of the future automatic programmes would be lower than in current automatic programmes whereas the programme duration would be longer as today. All in all, the automatic programme would be more similar to the current Eco programme.

One of the consequences of this assumption is that the automatic programme would become more unattractive to consumers because of its longer programme duration or that manufacturers might introduce further programmes to offer more attractive (i.e. shorter) programmes to the consumers. A possible shift from the automatic to other programmes is not considered in the model.

The energy savings of scenario 3 have been roughly estimated considering also the assumption done for scenario 2a. This means that given the same assumptions as described before for scenario 2a with the only difference that in 2030 the automatic programme consumes the same amount of electricity and water as the Eco programme. This fact means in the model, that the correction factors that convert the Eco programme energy consumption (on which the energy label is based) to the real life energy consumption would change. Note that this would be the most optimistic scenario since the effect that this measure could have on the user behaviour and the programme preferences is not considered. Under these assumptions, an additional 0.5 TWh/year could be saved in 2030. The costs of additional test burden have not been estimated.

7.2.3.6. Scenario 4: Durability/reparability

As shown in section 7.1 the complex question of whether or not it is better to replace more quickly an older dishwasher with a more energy efficient dishwasher needs to be addressed. This question can also be read as if an extension of the product lifetime will bring benefits. In this study, preliminary estimations are made which could be further refined in the actual impact assessment. The preliminary estimations are mainly based on the model explained in Figure 8.4 in Annex 8.2.11.

The repair of performance failures in the dishwashers will have an impact on the average time of a product on the European stock. The BAU scenario estimated that old in-service dishwashers will be replaced by new ones after, on average, 12.3 years on the market (in-service time, see Figure 8.4 in Annex 8.2.11) and that the amount of machines that will display a failure along their lifetime will be approximately 75%. This scenario considers that 37.5% of the dishwashers are repaired once in their lifetime and that 8% of the machines that were discarded without a failure are foreseen to be reused.

The scenarios on durability/reparability will model possible extensions of the time an average product remains in the stock (in-service) either by manufacturing more robust machines (i.e. increasing the technical product lifetime, scenario 4a) or by increasing the number of machines that are repaired (scenario 4b) or reused (scenario 4c). The increase of the machines that can be repaired can be either due to measures that increase the technical feasibility of a repair and/or decreasing the cost of a repair. The extension of the in-service time of a dishwasher will have an impact on the forecasted sales (especially replacement sales), the consumer expenditures, the energy and water savings and all other related parameters. Only the impact on electricity consumption, total sales and direct effects of manufacturer and retail jobs are shown in this document. The influence of these scenarios on the use of resources has not been studied here. Intuitively, one could think that more durable products would save resources, but this has not been studied in detail in this study, and may possibly be addressed in the IA. Examples of studies elaborating on this issue are Cases i Sampere (2015); Bobba et al. (2015) and Hur et al. (2005).

The three following sub-scenarios were used to estimate the impacts of extending the time a machine remains in-service. For clarity, the durability/reparability scenarios are applied only on top of the energy labelling scenario 2a.

Scenario 4a: Increasing the robustness of the machines

This scenario is modelled by assuming an increase in the technical lifetime of the machines with 2.5 years, i.e. from 12.5 years to 15 years. This would shift the in-service time of an average dishwasher from 12.3 years to 14.9 years. No other parameters, e.g. the purchase cost, are changed due to this assumption. The percentages of machines repaired (37.5%) or reused (8%) are kept the same as well.

Scenario 4b: Increasing the rate of machines repaired

This scenario is modelled by assuming an increase in the rate of machines with a failure that are repaired, i.e. from 38% to 58%. This scenario represents either a higher number of dishwashers that are sent to be repaired by the consumers or an increase in the ratio of those that are technically and economic successfully repaired. The original technical lifetime of 12.5 years and ratio of 8% of machines reused is kept in the model, together with all the other parameters. This would shift the in-service time from 12.3 years to 13.4 years.

Scenario 4c: Increasing the rate of machines reused

This scenario is modelled by assuming an increase in the rate of machines that are reused when discarded without failure, i.e. from 8% to 18%. The original technical lifetime of 12.5 years and the rate of 38% of machines repaired are kept constant, together with all the other parameters. As the machines that are considered to be reused are only a part of those machines that would be discarded without any failure and replaced by new machines the overall effect of the increase in the rate of machines that are reused is very diluted. In this sense, the time in-service of the dishwashers hardly changes and an average dishwasher will stay around 12.3 years in the European dishwasher stock.

Table 7.11: Parameters changed in comparison to the BAU / 2a scenario for each of the scenarios 4a, 4b and 4c

Scenario	Measure	Technical lifetime (years)	% of repairs	% reused machines without failure	Average in-service time (years)
BAU/2a	-	12.5	38%	8%	12.28
4a. Durability	Increase in the technical lifetime	15	38%	8%	14.89
4b. Reparability	Increase % of repairs	12.5	58%	8%	13.43
4c. Reuse	Increase % of reused machines without failure	12.5	38%	18%	12.31

Impacts on electricity consumption

The total electricity consumption for the different scenarios is shown in Figure 7.25. It shows that none of the scenarios (4a, 4b or 4c) significantly affect the total real life electricity consumption under the assumptions proposed in scenario 2a. Therefore none of the scenarios 4 have a relevant additional potential for electricity savings in addition to those shown by scenario 2a, neither affect the energy savings in a negative way.

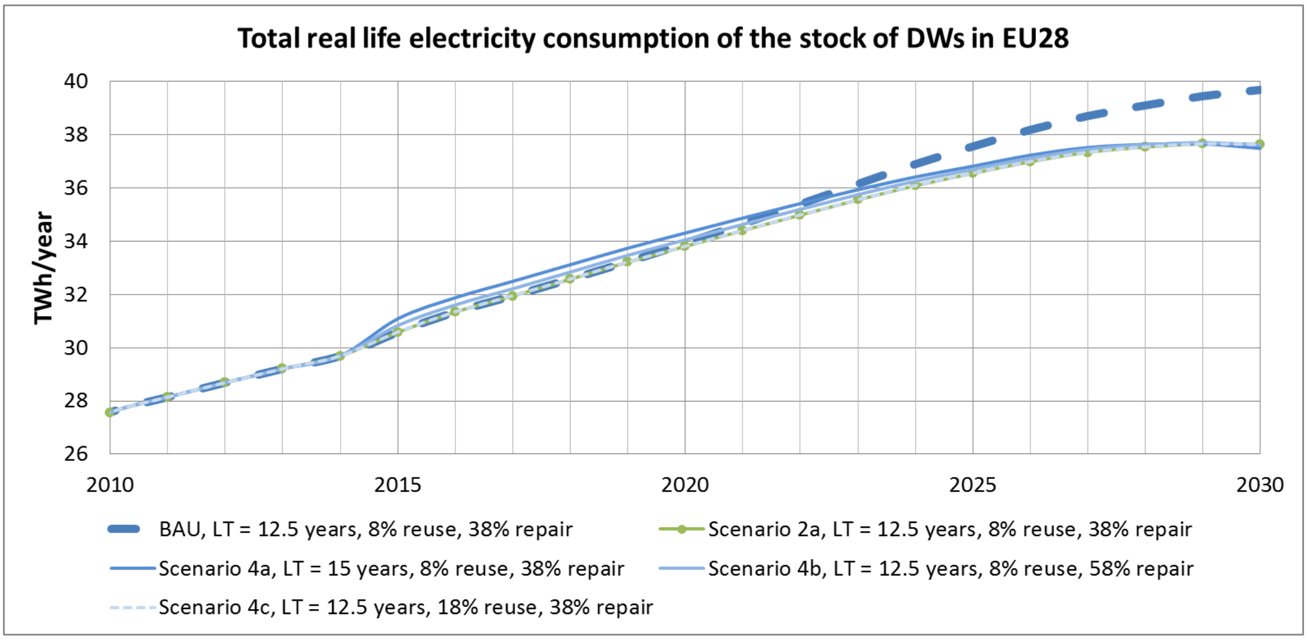


Figure 7.25: **Estimated annual total real life electricity consumption of the stock of dishwashers in EU 28 under the conditions of the BAU scenario, scenario 2a and a combination of scenario 2a with scenarios 4a, 4b and 4c**

Impacts on total sales

The total sales figures for the BAU scenario and the scenarios 4a, 4b and 4c in combination with scenario 2a are shown in Figure 7.26. The scenarios 4a and 4b lead to a decrease in the total annual sales figures which has an impact on the turnover of both the manufacturers and the retailers and therefore on the jobs in both sectors (Figure 7.27).

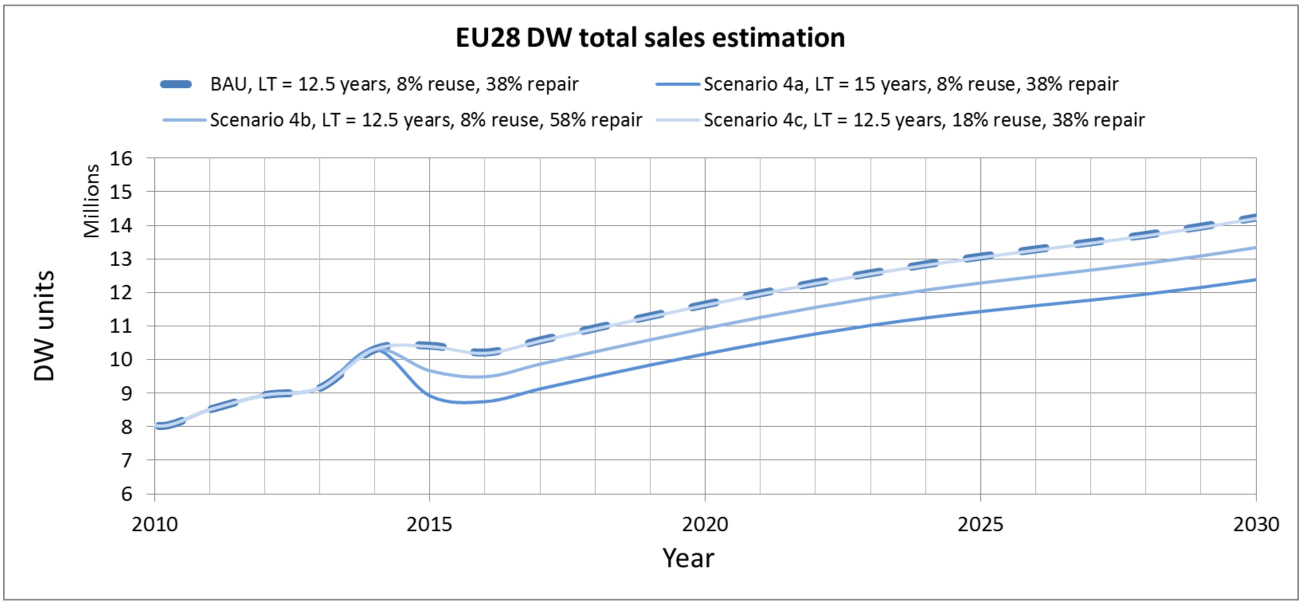
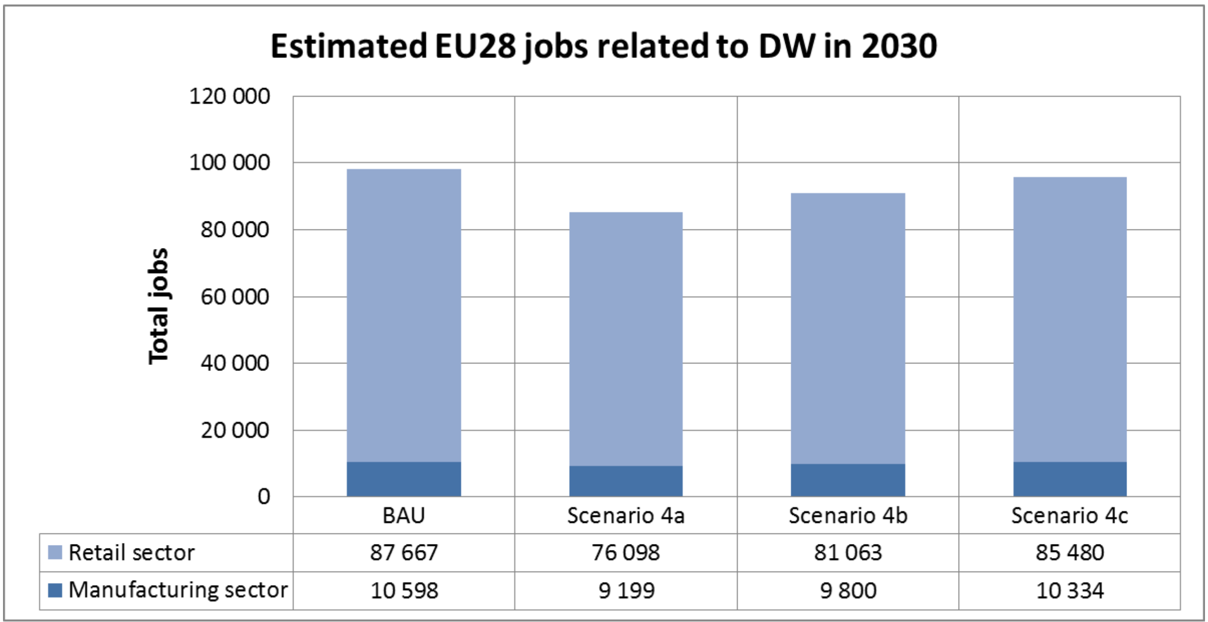


Figure 7.26: **Estimated annual total sales of dishwashers in EU 28 under the conditions of scenarios BAU, and a combination of scenario 2a with scenarios 4a, 4b and 4c**



Note that these figures do not account for a possible job increase in the repair sector.

Figure 7.27: Estimated number of jobs in the dishwasher sector (manufacturing and retail) in 2030 in EU 28 under the conditions of the BAU scenario and a combination of scenario 2a with scenario 4a, 4b and 4c

The decrease in the total sales is observed for both scenarios where policy measures promoting a higher technical lifetime (scenario 4a) or an increase in the number of machine sent for repairing or successful repairs (scenario 4b) are considered. This is due to the longer in-service time and consequently the lower need of the consumers to buy new dishwashers for replacing the old ones.

The lower sales figures will automatically result in lower turnover for the manufacturers and retailers (as long as the mark-ups for both agents remain constant) which will lead to a decrease in the number of jobs in these sectors as illustrated in Figure 7.27. The job market for reparability will however increase if more machines are repaired. Such an increase in the repair sector is not estimated in this study.

7.3. Summary

The main outcomes of the ecodesign and energy label scenarios are summarized in Table 7.12. The scenarios 3 and 4 are not included in this table as the impacts of these measures are not as thoroughly developed as scenario 1 and 2. Moreover, scenarios 3 and 4 take into account assumptions considered in scenario 2a. Direct comparison between scenarios 3 and 4 and the BAU scenario (or even scenarios 1 and 2) should be done carefully to avoid possible confusion, e.g. by comparing directly scenario 3 or 4 with scenario 1, 2b or 2c.

Table 7.12: Summary of the outcomes of the scenarios BAU, 1 and 2 for 2030

MAIN IMPACTS 2030			Ecodesign and energy label scenario's 2030				
			1	2	3	4	5
			BAU	Scenario 1	Scenario 2a	Scenario 2b	Scenario 2c
ENVIRONMENT							
	ELECTRICITY	TWh/a	39.7	39.2	37.6	38.3	39.4

MAIN IMPACTS 2030			Ecodesign and energy label scenario's 2030				
			1	2	3	4	5
			BAU	Scenario 1	Scenario 2a	Scenario 2b	Scenario 2c
	ENERGY	PJ/a	357	353	339	345	354
	GHG	Mt CO_2 eq./a	13.5	13.3	12.8	13.0	13.4
	WATER (use phase)	million m^3/a	428	428	423	423	428
CONSUMER							
EU totals	expenditure	€ bln./a*	26.3	26.2	25.8	26.1	26.3
	purchase costs	€ bln./a	8.0	7.9	7.8	8.0	8.0
	electricity costs	€ bln./a	6.4	6.3	6.1	6.2	6.3
	water costs (use phase)	€ bln./a	2.5	2.5	2.5	2.5	2.5
	consumables (detergent, etc.)	€ bln./a	8.6	8.6	8.6	8.6	8.6
	maintenance cost	€ bln./a	0.8	0.8	0.8	0.8	0.8
per product	product price	€	556	556	550	561	561
	installation cost	€	0	0	0	0	0
	energy costs	€ /a	81	84	72	74	78
BUSINESS							
EU turnover	manufacturers	€ bln./a	4.0	3.9	3.9	4.0	4.0
	retailers	€ bln./a	6.6	6.5	6.4	6.5	6.5
EMPLOYMENT							
employ-ment (jobs)	industry EU (incl. OEM)	'000	10.6	10.5	10.4	10.5	10.5
	retailers	'000	87.7	86.6	85.6	87.3	87.3
	TOTAL	'000	98.3	97.0	96.0	97.8	97.8
*=economic terms are expressed in Euros 2015							

8. Annex

8.1. Tasks 1-4

8.1.1. 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).

8.1.1.1. 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 2012b):

- 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.

8.1.1.2. 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 2013a):

- 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 2013a):

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.

8.1.1.3. Draft EU ecodesign requirements on electronic displays

The European Commission provided draft proposals for the ecodesign and energy label regulations on electronic displays including some new end-of-life requirements. According to the explanatory notes of the possible ecodesign and energy label 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, and (3) 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."*

Examples of end-of-life requirements that were proposed for electronic displays (European Commission 2014a) are:

Design for recovery of electronic displays

Manufacturers shall ensure that electronic displays are designed so that at least the following 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;

The compliance to this requirement 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.

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 and y= brominated fire retardant coding, according to EN 1043.

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.

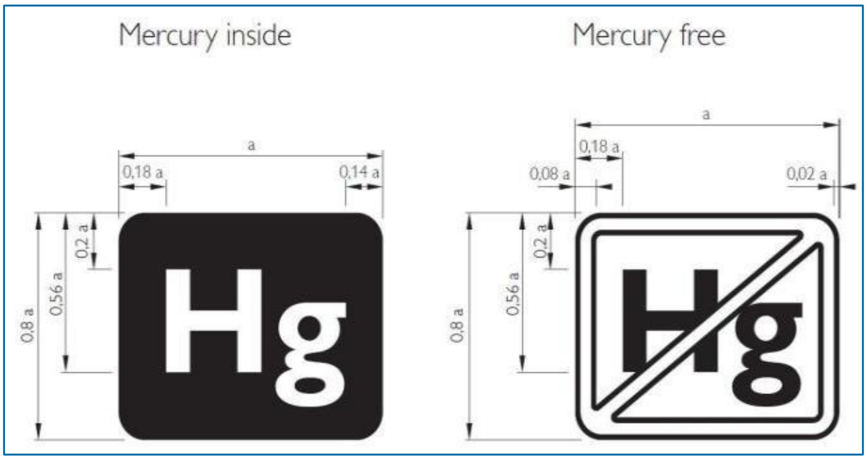


Figure 8.1: Mercury free logo as proposed in the draft ecodesign regulation for displays; source: European Commission (2014a)

Documentation for recycling at end of life of displays

Manufacturers, and/or importers in the European Union shall provide an ‘end-of-life report’ containing information relevant for disassembly, recycling and/or recovery at end-of-life. The report shall include among other:

- 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 rationale for each exemption, if some plastic parts are not marked as set out.

8.1.1.4. 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.

8.1.1.5. National legislation: France

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)

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 Euros 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”.

8.1.1.6. 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 reparability). 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
    - Accidental 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 reparability: 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

8.1.2. CECED Calculation of the saving potential through increased dishwasher penetration rate

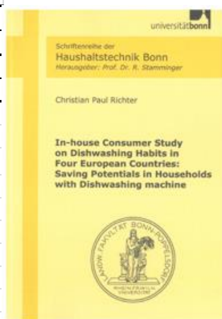
Facts for calculation the energy saving potential by increasing the penetration rate:

Data used from Task 5

page 11	0,96 kWh	energy consumption Base case 1	268 kWh/a
	9,8 l	water consumption Base case 1	2731 l/a
	13	number of place settings Base case 1	151 parts
page 15	1,08 kWh	"real life" usage base case 1	303 kWh/a
	10,9 l	"real life" usage base case 1	3057 l/a
page 11	0,87 kWh	energy consumption Base case 2	245 kWh/a
	10,9 l	water consumption Base case 2	2877 l/a
	10	number of place settings Base case 2	118 parts
page 16	0,97 kWh	"real life" usage base case 2	272 kWh/a
	12,1 l	"real life" usage base case 2	3401 l/a
page 17	86%	large appliances relative market share 86%	
	14%	small appliances relative market share 14%	
page 20	213 mio	households in EU-28 in 2011 (Eurostat 2011)	
	40%	average penetration rate for dishwasher in 2012	
	~85 mio	households owing a dishwasher	
	280	number of cycles per year	

Data used from the study: "In-house Consumer Study on Dishwashing habits…"

	per part	
	Household without dishwasher	Household with dishwasher
energy consumption	0,0344 kWh	0,0248 kWh
water consumption	1,5 l	0,7 l



Dishwashing behaviour of European consumers 2015

2.4. Manual treatment of dishware in households with dishwashers

Although there is an automatic dishwasher in the household, certain items are washed by hand. After summing up all items per day on average over all households (with a dishwasher) 37.1 items are used per day per average household and have to be cleaned afterwards: of these items, 5.0 are cleaned manually. Generally more than 40 % of all pots and pans and 21 % of all bowls are washed in average by hand. Even plates, cups, glasses and items of cutlery are washed by hand in households owning a dishwasher (Figure 2-5).

Calculations:

a) 13 place settings → number of parts

13	place settings
11	parts per place setting
8	parts serving pieces
151	**overall number of parts**

b) 10 place settings → number of parts

10	place settings
11	parts per place setting
8	parts serving pieces
118	**overall number of parts**

c) Used energy consumption doing handwash of 13 PS per year

151	overall number of parts
0,0344	Energy consumption [kWh] per part
5,1944	Energy consumption [kWh] doing handwash of 13 place settings

d) Used energy consumption doing handwash of 10 PS per year

118	overall number of parts
0,0344	Energy consumption [kWh] per part
4,0592	Energy consumption [kWh] doing handwash of 13 place settings

e) Calculation of increased number of household in case of theoretical increase of penetration rate to 60%

213000000	households in EU-28 in 2011 (Eurostat 2011)
40%	average penetration rate for dishwasher in 2012
85200000	households owing a dishwasher (Stakeholder report Task 5)
60%	Hypothetical increased penetration rate
127800000	Hypothetical households owing a dishwasher
42600000	Hypothetical increased number of households owing a dishwasher

f) Calculation of the difference handwash - automatic wash for increased penetration 60% vs 40% considering the ratio large and small dishwasher

42600000	Hypothetical increased number of households owing a dishwasher
86%	Large appliances relative market share 86%
14%	Small appliances relative market share 14%
36636000	Hypothetical households owing a **large** dishwasher
5964000	Hypothetical households owing a **small** dishwasher
Base case 1	
268	energy consumption Base case 1 [kWh/a] for Eco
303	energy consumption Base case 1 [kWh/a] for "real life"
5,1944	Energy consumption [kWh] doing handwash of 13 place settings
1454,43	Energy consumption [kWh/a] doing handwash of 13 place settings
1186,43	Difference energy consumption [kwh/a] Handwash - BC for Eco
1151,43	Difference energy consumption [kwh/a] Handwash - BC for "Real life"
43,47	**Energy saving [TWh/a] by increased penetration "Eco"**
42,18	**Energy saving [TWh/a] by increased penetration "Real life"**
Base case 2	
245	energy consumption Base case 2 [kWh/a] for Eco
272	energy consumption Base case 2 [kWh/a] for "real life"
4,0592	Energy consumption [kWh] doing handwash of 13 place settings
1136,58	Energy consumption [kWh/a] doing handwash of 13 place settings
891,58	Difference energy consumption [kwh/a] Handwash - BC for Eco
864,58	Difference energy consumption [kwh/a] Handwash - BC for "Real life"
5,32	**Energy saving [TWh/a] "Eco"**
5,16	**Energy saving [TWh/a] "Real life"**
OVERALL Energy consumption saving [TWh/a]	
48,78	**Overall Energy saving [TWh/a] "Eco"**
47,34	**Overall Energy saving [TWh/a] "Real life"**

g) Theoretical additional use of energy for prewashing items which may be substracted from f)		
37,1	Items pretreated for Dishwashing	
0,0248	Energy consumption [kWh] per part in households using a dishwasher	
0,92008	Energy consumption [kWh] for pretreated items	
257,62	Energy consumption [kWh/a] for pretreated items in a household	nearly as much as energy consumption for dishwashing
21,95	Overall energy consumption [TWh/a] for pretreatment in households (penetration rate 40%)	
32,92	Overall energy consumption [TWh/a] for pretreatment in household (theoretical penetration rate 60%)	
10,97	**Difference of overall energy consumption [TWh/a] for pretreatment in household with theoretical increased penetration rate 40%→60%)**	
OVERALL Energy consumption saving [TWh/a] taking into account pretreatment		
37,81	**Overall Energy saving [TWh/a] "Eco"**	
36,37	**Overall Energy saving [TWh/a] "Real life"**	

8.1.3. 2015 consumer survey

8.1.3.1. Identification and exclusion of outliers

The validity of each dataset was controlled before starting the analysis with the aid of three questions, two of which assessed essentially the same information. These two questions were included in different parts of the questionnaire and asked simply about “the number of runs of the dishwasher per week”, while the other question asked about “the frequency of using different cleaning programmes per week”. The latter information was recoded into numbers and summed up revealing the number of cleaning cycles per week. Comparing both figures showed a tendency towards higher figures of cleaning cycles for the data calculated from individual cleaning programmes. The difference between both measurements was used as one of two indicators for an inconsistent answering of the questionnaire. The second exclusion criterion was based on the question, “Please indicate all the types of information you are able to identify on the label presented”. Among the nine features given, three are not listed on the energy label, and participants who chose two or all three of them were excluded from the following evaluation in case they also gave inconsistent answers to the question about the number of cleaning cycles per week. After excluding the outlier data, the size of the panel diminished from 5450 to 5277.

8.1.3.2. Coding

The following coding () was defined for the question about the frequency of using different dishwashing programmes. The frequencies indicated by the participants for each dataset were summed up and then used to identify outliers.

Table 8.1: Coding of frequencies of dishwashing per week

Frequency of using different cleaning programmes	Coded values
Not at all	0
Once every 4 weeks	0.25
Once every 2 weeks	0.5
1 to 2 times per week	1.5
3 to 4 times per week	3.5
5 to 6 times per week	5.5
More than 6 times per week	7

Table 8.2 Household size coding

Household size	Coded size
1	1
2	2
3	3
4	4
More than 4 people	5

8.1.3.3. Important features of a dishwasher

The participants of the survey were asked for the main features that are taken into consideration when buying a new dishwasher. Nineteen features were given; firstly, six of them should be chosen as the most important ones and, secondly, they should be arranged according to the priorities of the participant. Features that were not chosen, i.e. 13 out of 19 features, received 0 points while the others got 1 to 6 points.

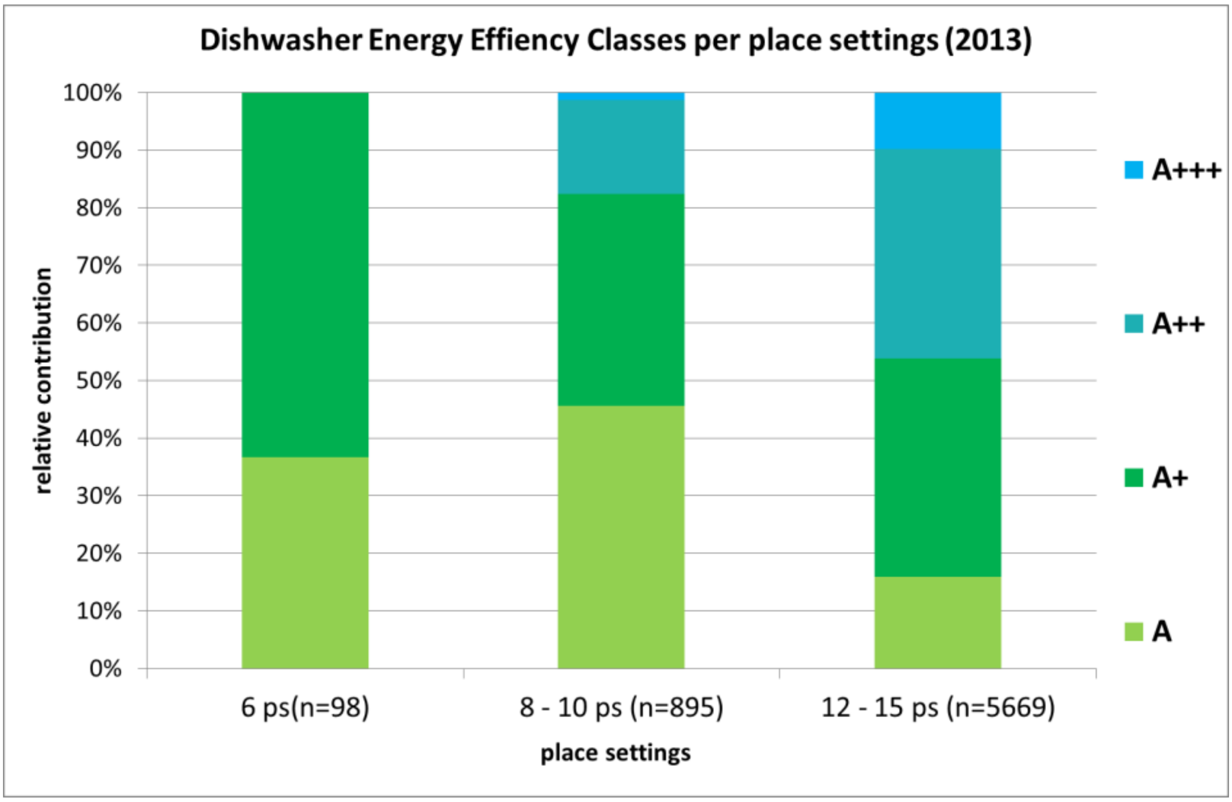
Correlations:

- Significant relationship between the household size and the possession of a dishwasher: Chi-square test, $\chi 2$ (4) = 179.376, Cramér's V'= 0.184; $p < 0.001$
- Significant relationship between the number of dishwashing cycles per week and the number of people in the household: Spearman Rho correlation test leads to rs= 0.454; $p < 0.001$
- Significant relationship of the use of the Eco programme and the age of the dishwasher: Spearman Rho correlation test leads to rs=-0.189, $p<0.001$.
- Slight association between maximum time participants would accept for a cleaning cycle during day and night and accepting longer programme cycles or not: Chi-square test $\chi 2$ (6) = 422.615; $p < 0.001$.

8.1.4. Market data

Table 8.3: Energy and water consumption of different dishwasher capacities in 2013 (data from CECED, personal communication)

	Energy consumption			Water consumption		
Ps	Annual (kWh/year)	per cycle (kWh/cycle)	per standard ps (kWh/cycle/ps)	Annual (l/year)	per cycle (l/cycle)	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
7	n.a	n.a	n.a	n.a	n.a	n.a
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



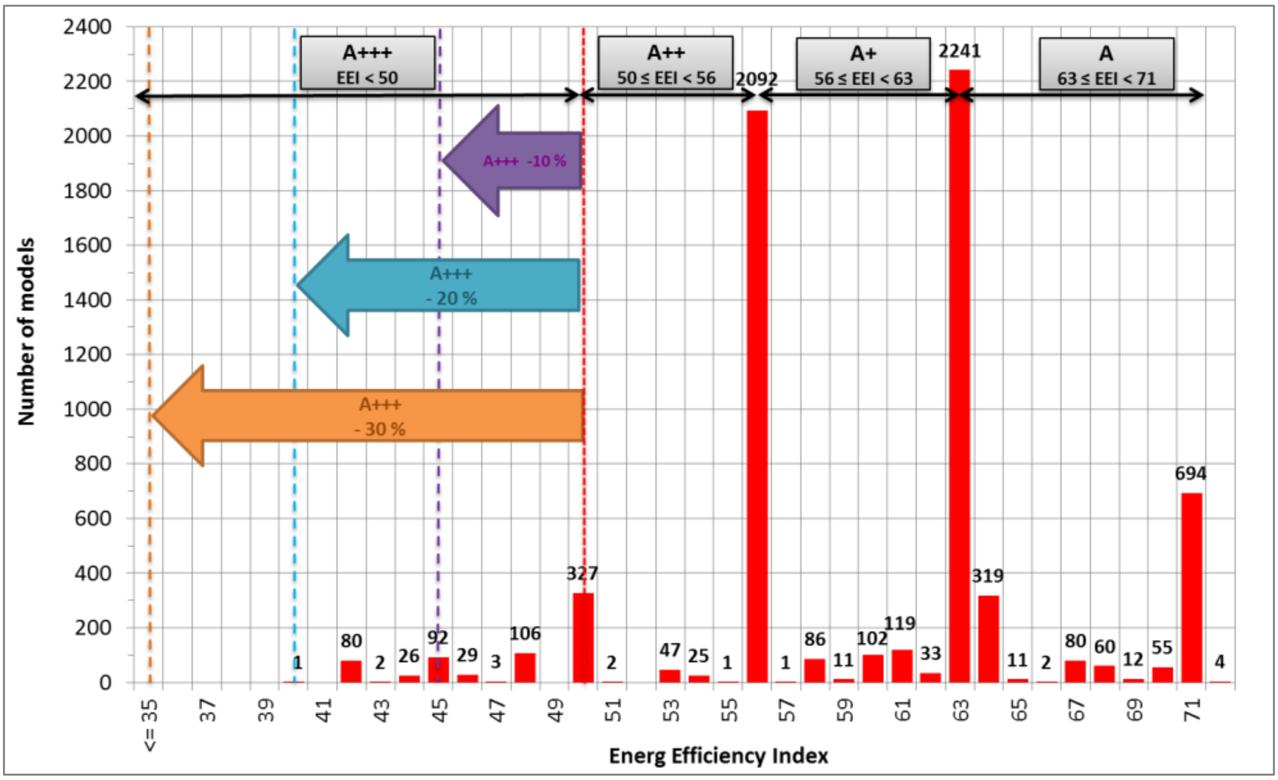


Figure 8.2: **Distribution of dishwasher models of a certain energy efficiency index on the European market in 2013 (data from CECED, personal communication)**

8.1.4.1. CECED database of dishwasher models 2014

After release of the draft Task 1-4 report in May 2015 additional data from the CECED database on dishwasher models was received. Comparing these data with the 2013 database these data show a continuation of the trend observed earlier (see Table 8.4).

Table 8.4: Average values of CECED databases for dishwashers for 2013 and 2014 and relative difference

CECED database	2013		2014		2014 vs. 2013
	average	valid data	average	valid data	
Standard place settings	12.2	6 663	12.6	5 849	3.21%
Annual energy consumption in (kWh/year)	269.70	6 663	263.86	5 849	-2.17%
Annual water consumption (in L)	3 001	6 663	2 896	5 849	-3.48%
Noise (in dB(A))	46.33	6 663	45.85	5 849	-1.04%
With (in cm)	57.6	6 663	59.2	5 843	2.75%
Weight (in kg)	41.7	5 666	42.8	5 693	2.65%
Energy consumption per cycle (in kWh)*	0.963	6 663	0.942	5 849	-2.17%
Energy consumption per standard place setting (in kWh)	0.0802	6 663	0.0761	5 849	-5.14%
Water consumption per cycle (in L)*	10.72	6 663	10.34	5 849	-3.48%
Water consumption per place setting (in L)	0.900	6.663	0.840	5.849	-6.75%

*calculated from annual consumption values by dividing annual value by 280 cycles.

The rated capacity of dishwashers increased by 3.2% resulting in an average capacity in 2014 of 12.6 ps. At the same time the average annual energy consumption was reduced by 2.2%, whereas the specific consumption per place setting was reduced by even 5.1%. Also the water consumption was reduced by 3.5% absolute and 6.75% on the specific values per place setting.

8.2. Tasks 5-7

8.2.1. CECED aggregated estimations on the energy saving potential of improvement options

Table 8.5: CECED aggregated estimations on the energy saving potential of improvement options (Eco = Eco programme, RL = real-life)

Improvement options BAT		Average
D1: Heat exchanger for pre-warming incoming water and fostering the condensation in the drying phase	Eco	5%
	RL	4%
D2: improved drying through automatic door opening system	Eco	9%
	RL	8%
D3: improved drying through adsorption technology	Eco	12%
	RL	11%

Improvement options BAT		Average
D4: Fan for better air circulation	Eco	9%
	RL	8%
D5: moderate increase of programme duration	Eco	/
	RL	/
D6: Heat pump with common refrigerant (R134a)	Eco	28%
	RL	10%
D7: advanced sensor technology	Eco	/
	RL	/
D8: consumer feedback mechanisms	Eco	/
	RL	/
Combinations of single design options		Average
C1= D4 + D2 (fan + door opener)	Eco	13%
	RL	13%
C2 = D5 + D4 + D7 + D2 (in-creased programme duration + fan+ + advanced sensor technology + door opener)	Eco	17%
	RL	16%
C3 = D4 + D2 + D1 (fan + door opener + heat exchanger)	Eco	16%
	RL	15%
C4 = D5 + D4 + D7 + D2 + D1 (increased programme duration + fan+ advanced sensor technology + door opener + heat exchanger)	Eco	18%
	RL	19%
C5 = D5 + D4 + D7 + D2 + D1 + D8 (increased programme duration + fan+ ad-vanced sensor technology + door opener + heat exchanger + consumer feedback mechanisms)	Eco	18%
	RL	19%
C6a = D5 + D4 + D7 + D8 + D3 (increased programme duration + fan + advanced sensor technology + consumer information mechanisms + adsorption drying technology)	Eco	20%
	RL	22%
C6b = D4 + D7 + D2 + D1 + D8 + D6 (fan+ advanced sensor technology + door opener + heat exchanger + consumer feedback mechanisms +heat pump)	Eco	32%
	RL	26%

8.2.2. Input data ErP-Ecoreport tool – Base Case 1 (13 ps)

Table 8.6: DW BC1 Inputs 'Materials extraction and production'

Pos	MATERIALS Extraction & Production	Weight	Category	Material or Process	Recyclable?
nr	Description of component	in g	Click &select	select Category first !	
1	Bitumen	5400,4	7-Misc.	56 -Bitumen	No
2	ABS	884,2	1-BlkPlastics	11 -ABS	Yes
3	CC-sheet / coloured	3712,0	3-Ferro	22 -St sheet galv.	Yes
4	chipboard /	2240,0	7-Misc.	57 -Cardboard	No
5	corrugated cardboard / Q. 1.4	0,0	7-Misc.	57 -Cardboard	Yes
6	Cr / Coil 1.4016	3166,4	3-Ferro	26 -Stainless 18/8 coil	Yes
7	crepe tape /	0,9	7-Misc.		No
8	CrNi / Coil 1.4301	6464,8	3-Ferro	26 -Stainless 18/8 coil	Yes

Pos	MATERIALS Extraction & Production	Weight	Category	Material or Process	Recyclable?
nr	Description of component	in g	Click &select	select Category first !	
9	CrNi / stainless steel screw 0- 3g	18,8	3-Ferro	26 -Stainless 18/8 coil	Yes
10	Cu / tube	67,7	4-Non-ferro	30 -Cu wire	Yes
11	CuZn /	8,8	4-Non-ferro	32 -CuZn38 cast	Yes
12	double-sided adhesive tape /	0,1	7-Misc.		No
13	EPDM / for PDC	395,6	1-BlkPlastics	1 -LDPE	Yes
14	EPS / white	4,3	1-BlkPlastics	6 -EPS	Yes
15	Fe / Coil	129,1	3-Ferro	22 -St sheet galv.	Yes
16	Fe / Coil zinced	2933,9	3-Ferro	22 -St sheet galv.	Yes
17	Fe	4921,3	3-Ferro	22 -St sheet galv.	Yes
18	LDPE / shrinking foil	0,0	1-BlkPlastics	1 -LDPE	Yes
19	PA 6	131,7	2-TecPlastics	12 -PA 6	Yes
20	PC / transparent	14,0	2-TecPlastics	13 -PC	Yes
21	PC + ABS	216,5	2-TecPlastics	13 -PC	Yes
22	PE	136,4	1-BlkPlastics	2 -HDPE	Yes
23	PMMA / transparent	69,0	2-TecPlastics	14 -PMMA	Yes
24	POM	366,7	1-BlkPlastics	2 -HDPE	Yes
25	PP	6523,0	1-BlkPlastics	4 -PP	Yes
26	PP G20	15,3	1-BlkPlastics	4 -PP	Yes
27	PP G20 / 20% glasfiber added	3,8	2-TecPlastics	19 -E-glass fibre	Yes
28	PP G30	104,4	1-BlkPlastics	4 -PP	Yes
29	PP G30 / 30% glasfiber added	44,8	2-TecPlastics	19 -E-glass fibre	Yes
30	PUR / flexible foam	370	2-TecPlastics	17 -Flex PUR	Yes
31	PUR / Moltopren	6,8	2-TecPlastics	16 -Rigid PUR	Yes
32	PVC	389,5	1-BlkPlastics	8 -PVC	Yes
33	rating plate / self-adhesive A4	498,8	7-Misc.	58 -Office paper	No
34	Silicon / liquid silicon	10,9	1-BlkPlastics		No
35	spring steel / Ø	207,3	3-Ferro	23 -St tube/profile	Yes
36	TPE / high quality	24,0	2-TecPlastics	13 -PC	Yes
37	Vlies /	1162,4	1-BlkPlastics	10 -PET	Yes
38	zinc diecast / Z410	5180,0	4-Non-ferro	32 -CuZn38 cast	Yes
39	electronics	1381,5	6-Electronics	98 -controller board	Yes
40	cable	574,7	4-Non-ferro	30 -Cu wire	Yes
41	packaging				
42	corrugated cardboard / Q. 1.4	407	7-Misc.	57 -Cardboard	Yes
43	EPS / white	787,92	1-BlkPlastics	6 -EPS	Yes
44	LDPE / shrinking foil	138	1-BlkPlastics	1 -LDPE	Yes
	TOTAL	49113			

Table 8.7: DW BC1 Inputs 'Manufacturing and distribution'

Pos nr	MANUFACTURING Description	Weight in g	Percentage Adjust	Category index (fixed)
201	OEM Plastics Manufacturing (fixed)	11799		21
202	Foundries Fe/Cu/Zn (fixed)	5189		35
203	Foundries Al/Mg (fixed)	0		36
204	Sheetmetal Manufacturing (fixed)	21346		37
205	PWB Manufacturing (fixed)	0		54
206	Other materials (Manufacturing already included)	10778		
207	Sheetmetal Scrap (Please adjust percentage only)	1067	5%	38

Pos nr	DISTRIBUTION (incl. Final Assembly) Description		Answer	Category index (fixed)
208	Is it an ICT or Consumer Electronics product <15 kg ?		NO	60
209	Is it an installed appliance (e.g. boiler)?	0	NO	61
				63
210	Volume of packaged final product in m^3	in m3	0,4	64
				65

Table 8.8: DW BC1 Inputs 'Use phase'

Pos nr	USE PHASE direct ErP impact Description		unit	Subtotals
226	**ErP Product (service) Life in years**	12,5	years	
	Electricity			
227	On-mode: Consumption per hour, cycle, setting, etc.	303,3	kWh	303,3
228	On-mode: No. of hours, cycles, settings, etc. / year	1	#	
229	Standby-mode: Consumption per hour	0	kWh	0
230	Standby-mode: No. of hours / year	0	#	
231	Off-mode: Consumption per hour	0	kWh	0
232	Off-mode: No. of hours / year	0	#	
	TOTAL over ErP Product Life	3,79	MWh (=000 kWh)	66
	Heat			
233	Avg. Heat Power Output	0	kW	
234	No. of hours / year	0	hrs.	
235	Type and efficiency (Click & select)		8	86-not applicable
	TOTAL over ErP Product Life	0,00	GJ	
	Consumables (excl, spare parts)			**material**
236	Water	3,057	m^3/year	**84-Water per m3**
237	Auxiliary material 1 (Click & select)	5,6	kg/ year	**81 -Detergent dishw.**
238	Auxiliary material 2 (Click & select)	0,84	kg/ year	**82 -Rinsing agent dish**
239	Auxiliary material 3 (Click & select)	5,32	kg/ year	**83 -Regen. Salt dishw**

Pos nr	USE PHASE direct ErP impact Description		unit	Subtotals
240	Refrigerant refill (Click & select type, even if there is no refill)	0	kg/ year	**1 -none; 0000**
	Maintenance, Repairs, Service			
241	No. of km over Product-Life	160	km / Product Life	87
242	Spare parts (fixed, 1% of product materials & manuf.)	491	g	1%

Table 8.9: DW BC1 Inputs 'Disposal and recycling'

Pos nr	DISPOSAL & RECYCLING Description				
253	product (stock) life L, in years	12,5		Please edit values with red font	
		current	L years ago	period growth PG in %	CAGR in %/a
254	unit sales in million units/year	7,000	**5,504**	27,2%	1,9%
255	product & aux. mass over service life, in g/unit	196604	196604	0,0%	0,0%
256	total mass sold, in t (1000 kg)	1376,226223	1082,107019	27,2%	1,9%

Pos nr	Per fraction (post-consumer)	1	2	3	4	5	6	7a	7b	7c	8	9	
		Bulk Plastics	TecPlastics	Ferro	Non-ferro	Coating	Electronics	Misc. , excluding refrigerant & Hg	refrigerant	Hg (mercury), **in mg/unit**	Extra	Auxiliaries	TOTAL (CARG avg.)
263	EoL mass fraction to re-use, in %						**1%**			1%		**0%**	*0,2%*
264	EoL mass fraction to (materials) recycling, in %	29%	**29%**	94%	94%	94%	**50%**	**64%**	**30%**	**39%**	**60%**	**0%**	*14,9%*
265	EoL mass fraction to (heat) recovery, in %	15%	**15%**	0%	0%	0%	**0%**	**1%**	**0%**	**0%**	**0%**	**0%**	*0,6%*
266	EoL mass fraction to non-recov. incineration, in %	22%	**22%**	0%	0%	0%	**30%**	**5%**	**5%**	**5%**	**10%**	**0%**	*1,1%*
267	EoL mass fraction to landfill/missing/fugitive, in %	33%	**33%**	5%	5%	5%	**19%**	**29%**	**64%**	**55%**	**29%**	**100%**	*83,2%*
268	TOTAL	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100,0%*
269	EoL recyclability****, (click& select: 'best', '>avg', 'avg' (base case); '< avg'.; 'worst')	avg	avg	avg	avg	avg	avg	avg	avg	avg	avg	avg	avg
		0%	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	

Table 8.10: DW BC1 Inputs for EU-Totals and LCC

nr	INPUTS FOR EU-Totals & economic Life Cycle Costs Description		unit
A	Product Life	12,5	years
B	Annual sales	7,0	mln. Units/year
C	EU Stock	84,6	mln. Units
D	Product price	€ 526,00	Euro/unit
E	Installation/acquisition costs (if any)	€ 0,00	Euro/ unit
F	Fuel rate (gas, oil, wood)		Euro/GJ
G	Electricity rate	€ 0,208	Euro/kWh
H	Water rate	€ 3,98	Euro/m3
I	Aux. 1: None	€ 8,00	Euro/kg
J	Aux. 2 :None	€ 3,00	Euro/kg
K	Aux. 3: None	€ 1,00	Euro/kg
L	Repair & maintenance costs	€ 15,00	Euro/ unit
M	Discount rate (interest minus inflation)	4%	%
N	Escalation rate (project annual growth of running costs)	4%	%
O	Present Worth Factor (PWF) (calculated automatically)	12,50	(years)
P	Ratio efficiency STOCK: efficiency NEW, in Use Phase	0,925	

8.2.3. Input data ErP-Ecoreport tool – Base Case 2 (10 ps)

Table 8.11: DW BC2 Inputs 'Materials extraction and production'

Pos nr	MATERIALS Extraction & Production Description of component	Weight in g	Category Click &select	Material or Process select Category first !	Recyclable?
1	Bitumen	4954,3	7-Misc.	56 -Bitumen	No
2	ABS	699,2	1-BlkPlastics	11 -ABS	Yes
3	CC-sheet / coloured	3712,0	3-Ferro	22 -St sheet galv.	Yes
4	chipboard /	1680,0	7-Misc.	57 -Cardboard	No
5	corrugated cardboard / Q. 1.4	0,0	7-Misc.	57 -Cardboard	Yes
6	Cr / Coil 1.4016	2541,0	3-Ferro	26 -Stainless 18/8 coil	Yes
7	crepe tape /	0,7	7-Misc.		No
8	CrNi / Coil 1.4301	5456,2	3-Ferro	26 -Stainless 18/8 coil	Yes
9	CrNi / stainless steel screw 0- 3g	18,8	3-Ferro	26 -Stainless 18/8 coil	Yes
10	Cu / tube	66,4	4-Non-ferro	30 -Cu wire	Yes
11	CuZn /	8,8	4-Non-ferro	32 -CuZn38 cast	Yes

Pos	MATERIALS Extraction & Production	Weight	Category	Material or Process	Recyclable?
nr	Description of component	in g	Click &select	select Category first !	
12	double-sided adhesive tape /	0,1	7-Misc.		No
13	EPDM / for PDC	362,1	1-BlkPlastics	1 -LDPE	Yes
14	EPS / white	4,3	1-BlkPlastics	6 -EPS	Yes
15	Fe / Coil	129,1	3-Ferro	22 -St sheet galv.	Yes
16	Fe / Coil zinced	3342,9	3-Ferro	22 -St sheet galv.	Yes
17	Fe	3518,4	3-Ferro	22 -St sheet galv.	Yes
18	LDPE / shrinking foil	0,0	1-BlkPlastics	1 -LDPE	Yes
19	PA 6	131,6	2-TecPlastics	12 -PA 6	Yes
20	PC / transparent	9,9	2-TecPlastics	13 -PC	Yes
21	PC + ABS	216,5	2-TecPlastics	13 -PC	Yes
22	PE	128,5	1-BlkPlastics	2 -HDPE	Yes
23	PMMA / transparent	69,0	2-TecPlastics	14 -PMMA	Yes
24	POM	351,9	1-BlkPlastics	2 -HDPE	Yes
25	PP	4860,55	1-BlkPlastics	4 -PP	Yes
26	PP G20	15,32	1-BlkPlastics	4 -PP	Yes
27	PP G20 / 20% glasfiber added	3,83	2-TecPlastics	19 -E-glass fibre	Yes
28	PP G30	104,44	1-BlkPlastics	4 -PP	Yes
29	PP G30 / 30% glasfiber added	44,8	2-TecPlastics	19 -E-glass fibre	Yes
30	PUR / flexible foam	277,5	2-TecPlastics	17 -Flex PUR	Yes
31	PUR / Moltopren	0,0	2-TecPlastics	16 -Rigid PUR	Yes
32	PVC	352,4	1-BlkPlastics	8 -PVC	Yes
33	rating plate / self-adhesive A4	498,8	7-Misc.	58 -Office paper	No
34	Silicon / liquid silico	12,4	1-BlkPlastics		No
35	spring steel / Ø	203,4	3-Ferro	23 -St tube/profile	Yes
36	TPE / high quality	24,0	2-TecPlastics	13 -PC	Yes
37	Vlies /	776,0	1-BlkPlastics	10 -PET	Yes
38	zinc diecast / Z410	5180,0	4-Non-ferro	32 -CuZn38 cast	Yes
39	electronics	1205,7	6-Electronics	98 -controller board	Yes
40	cable	574,7	4-Non-ferro	30 -Cu wire	Yes
41	packaging				
42	corrugated cardboard / Q. 1.4	305,3	7-Misc.	57 -Cardboard	Yes
43	EPS / white	665	1-BlkPlastics	6 -EPS	Yes
44	LDPE / shrinking foil	103,5	1-BlkPlastics	1 -LDPE	Yes
	TOTAL	42609			

Table 8.12: DW BC2 Inputs 'Manufacturing and distribution'

Pos nr	MANUFACTURING Description	Weight in g	Percentage Adjust	Category index (fixed)
201	OEM Plastics Manufacturing (fixed)	9213		21
202	Foundries Fe/Cu/Zn (fixed)	5189		35
203	Foundries Al/Mg (fixed)	0		36
204	Sheetmetal Manufacturing (fixed)	18718		37
205	PWB Manufacturing (fixed)	0		54
206	Other materials (Manufacturing already included)	9489		
207	Sheetmetal Scrap (Please adjust percentage only)	936	5%	38

Pos nr	DISTRIBUTION (incl. Final Assembly) Description		Answer	Category index (fixed)
208	Is it an ICT or Consumer Electronics product <15 kg ?		NO	60
209	Is it an installed appliance (e.g. boiler)?	0	NO	61
				63
210	Volume of packaged final product in m^3	in m3	0,303	64
				65

Table 8.13: DW BC2 Inputs 'Use phase'

Pos nr	USE PHASE direct ErP impact Description		unit	Subtotals	
226	**ErP Product (service) Life in years**	**12,5**	years		
	Electricity				
227	On-mode: Consumption per hour, cycle, setting, etc.	271,55	kWh	271,55	
228	On-mode: No. of hours, cycles, settings, etc. / year	1	#		
229	Standby-mode: Consumption per hour	0	kWh	0	
230	Standby-mode: No. of hours / year	0	#		
231	Off-mode: Consumption per hour	0	kWh	0	
232	Off-mode: No. of hours / year	0	#		
	TOTAL over ErP Product Life	**3,39**	**MWh (=000 kWh)**		**66**
	Heat				
233	Avg. Heat Power Output	0	kW		
234	No. of hours / year	0	hrs.		
235	Type and efficiency (Click & select)		8	86-not applicable	
	TOTAL over ErP Product Life	**0,00**	**GJ**		
	Consumables (excl. spare parts)			material	
236	Water	3,401	m^3/year	84-Water per m3	
237	Auxiliary material 1 (Click & select)	5,6	kg/ year	81 -Detergent dishw.	
238	Auxiliary material 2 (Click & select)	0,84	kg/ year	82 -Rinsing agent dish	
239	Auxiliary material 3 (Click & select)	5,32	kg/ year	83 -Regen. Salt dishw	

Pos nr	USE PHASE direct ErP impact Description		unit	Subtotals
240	Refrigerant refill (Click & select type, even if there is no refill)	0	kg/ year	3-R404a; HFC blend; 3920
	Maintenance, Repairs, Service			
241	No. of km over Product-Life	160	km/Product Life	87
242	Spare parts (fixed, 1% of product materials & manuf.)	426	g	1%

Table 8.14: DW BC2 Inputs 'Disposal and recycling'

Pos nr	DISPOSAL & RECYCLING Description												
253	product (stock) life L, in years	**12,5**			Please edit values with red font								

Pos nr	Description	current	L years ago	period growth PG in %	CAGR in %/a
254	unit sales in million units/year	1,100	**0,896**	22,8%	1,7%
255	product & aux. mass over service life, in g/unit	190035	190035	0,0%	0,0%
256	total mass sold, in t (1000 kg)	209,0390101	170,2717755	22,8%	1,7%

Pos nr	Per fraction (post-consumer)	1 Bulk Plastics	2 TecPlastics	3 Ferro	4 Non-ferro	5 Coating	6 Electronics	7a Misc., excluding refrigerant & Hg	7b refrigerant	7c Hg (mercury), **in mg/unit**	8 Extra	9 Auxiliaries	TOTAL (CARG avg.)
263	EoL mass fraction to re-use, in %						1%			1%		0%	*0,2%*
264	EoL mass fraction to (materials) recycling, in %		29%		94%		50%	64%	30%	39%	60%	0%	*12,3%*
265	EoL mass fraction to (heat) recovery, in %		15%		0%		0%	1%	0%	0%	0%	0%	*0,6%*
266	EoL mass fraction to non-recov. incineration, in %		22%		0%		30%	5%	5%	5%	10%	0%	*1,1%*
267	EoL mass fraction to landfill/missing/fugitive, in %		33%		5%		19%	29%	64%	55%	29%	100%	*85,9%*
268	TOTAL	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100,0%*
269	EoL recyclability****, (click& select: 'best', '>avg', 'avg' (base case); '< avg'.; 'worst')	**avg**	**avg**	**avg**	**avg**	**avg**	**avg**	**avg**	**avg**	**avg**	**avg**	**avg**	**avg**
		0%	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	

Table 8.15: DW BC2 Inputs for EU-Totals and LCC

nr	INPUTS FOR EU-Totals & economic Life Cycle Costs Description		unit
A	Product Life	**12,5**	years
B	Annual sales	1,1	mln. Units/year
C	EU Stock	13,7	mln. Units
D	Product price	€ 516,00	Euro/unit
E	Installation/acquisition costs (if any)		Euro/ unit
F	Fuel rate (gas, oil, wood)		Euro/GJ
G	Electricity rate	€ 0,208	Euro/kWh
H	Water rate	€ 3,98	Euro/m3
I	Aux. 1: None	€ 8,00	Euro/kg
J	Aux. 2 :None	€ 3,00	Euro/kg
K	Aux. 3: None	€ 1,00	Euro/kg
L	Repair & maintenance costs	€ 15,00	Euro/ unit
M	Discount rate (interest minus inflation)	4%	%
N	Escalation rate (project annual growth of running costs)	4%	%
O	Present Worth Factor (PWF) (calculated automatically)	12,50	(years)
P	Ratio efficiency STOCK: efficiency NEW, in Use Phase	0,925	

8.2.4. Selected EcoReport results

Table 8.16: Environmental impacts of a standard household dishwasher with 13 place settings (use of Eco programme)

Life Cycle phases -->		Production			Distribution	Use phase	End-of-Life			Total
	Unit	Material	Manufacturing	Total			Disposal	Recycl.	Total	
Resources & Waste										
Total Energy (GER)	MJ	5 641	829	6 470	590	32 943	163	-439	-277	39 727
of which, electricity (in primary MJ)	MJ	2 740	497	3 236	1	30 364	0	-114	-114	33 488
Water (process)	ltr	1 442	7	1 449	0	47 458	0	-199	-199	48 709
Water (cooling)	ltr	971	232	1 202	0	1 358	0	-51	-51	2 510
Waste, non-haz./ landfill	g	34 005	2 750	36 755	346	18 930	716	-7 140	-6 424	49 607
Waste, hazardous/ incinerated	g	204	0	204	7	539	0	-7	-7	743
Emissions (Air)										
Greenhouse Gases in GWP100	kg CO2 eq.	314	46	360	39	1 409	1	-30	-29	1 779
Acidification, emissions	g SO2 eq.	2 543	199	2 743	118	6 412	6	-216	-210	9 063
Volatile Organic Compounds (VOC)	g	54	0	55	8	679	0	-9	-9	733
Persistent Organic Pollutants (POP)	ng i-Teq	531	11	542	2	93	0	-95	-95	542
Heavy Metals	mg Ni eq.	2 445	27	2 472	18	331	2	-385	-383	2 437
PAHs	mg Ni eq.	156	0	156	20	77	0	-6	-6	248
Particulate Matter (PM, dust)	g	2 674	31	2 704	1 368	162	38	-322	-284	3 951
Emissions (Water)										
Heavy Metals	mg Hg/20	1 166	1	1 166	1	159	0	-218	-218	1 108
Eutrophication	g PO4	36	0	36	0	3 758	813	-7	807	4 601

The following table shows the environmental impacts of a household dishwasher with 10 place settings over the whole lifecycle of 12.5 years, when only the Eco programme is used.

Table 8.17: Environmental impacts of a household dishwasher with 10 place settings (use of Eco programme)

Life Cycle phases -->		Production			Distribution	Use phase	End-of-Life			Total
	Unit	**Material**	**Manu-facturing**	**Total**			**Disposal**	**Recycl.**	**Total**	
Resources & Waste										
Total Energy (GER)	MJ	4 873	682	5 555	474	30 350	170	-422	-252	36 128
of which, electricity (in primary MJ)	MJ	2 379	409	2 787	1	27 776	0	-151	-151	30 413
Water (process)	ltr	1 221	6	1 227	0	49 989	0	-161	-161	51 055
Water (cooling)	ltr	782	191	973	0	1 241	0	-41	-41	2 173
Waste, non-haz./ landfill	g	30 091	2 271	32 362	288	17 559	677	-5 602	-4 925	45 283
Waste, hazardous/ incinerated	g	173	0	173	6	498	0	-9	-9	668
Emissions (Air)										
Greenhouse Gases in GWP100	kg CO2 eq.	272	38	310	32	1 299	1	-27	-27	1 614
Acidification, emissions	g SO2 eq.	2 235	164	2 398	96	5 921	7	-197	-191	8 224
Volatile Organic Compounds (VOC)	g	49	0	49	6	621	0	-8	-8	669
Persistent Organic Pollutants (POP)	ng i-Teq	491	10	501	2	86	0	-75	-75	514
Heavy Metals	mg Ni eq.	2 119	23	2 143	15	302	2	-298	-296	2 163
PAHs	mg Ni eq.	136	0	136	16	71	0	-6	-6	217
Particulate Matter (PM, dust)	g	2 393	25	2 418	1 036	149	39	-304	-266	3 338
Emissions (Water)										
Heavy Metals	mg Hg/20	999	1	1 000	0	146	0	-164	-163	983
Eutrophication	g PO4	30	0	31	0	3 758	817	-5	812	4 600

Table 8.18: Life Cycle Costs for the base cases both using the Eco programme and under real-life conditions over the whole product life cycle (in Euro) (RRP)

	Unit	Base Case 1 (13 ps)			Base Case 2 (10 ps)		
		Real-life usage	Use of Eco programme	Change	Real-life usage	Use of Eco programme	Change
Product price	€	800	800	0%	750	750	0%
Electricity	€	758	696	-8%	706	636	-10%
Water	€	152	136	-11%	169	143	-15%
Dishwashing detergent	€	560	560	0%	560	560	0%
Rinsing agent	€	32	32	0%	32	32	0%
Regeneration salt	€	67	67	0%	67	67	0%
Repair & maintenance costs	€	57	57	0%	57	57	0%
Total	€	2 425	2 347	-3%	2 340	2 244	-4%

8.2.5. Full list of policy options for household dishwashers regarding energy and water consumption

The following Table 8.19 provides a full list of policy options for household dishwashers. The policy instruments addressed are the energy label (EL), generic and/or specific ecodesign-measures (ED), standards and measurement methods (SM), as well as consumer information (CI) measures.

Table 8.19: Full list of policy options for household dishwashers regarding energy and water consumption

No.	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
1a	The consumer survey reveals that the **ECO programme is not used so much in real-life**, there are other "most used" programmes (mainly automatic and short programmes). Currently, the basis / target of ecodesign "ECO" programmes is not clear (most used <=> most efficient programme?)	Define the **"most used" programme for 'normally soiled tableware' as standard programme** (not the "most efficient" one as today); e.g. by an open formulation "The programme to be used is the one recommended by the manufacturer for everyday use for normally soiled dishes, and which is the one that is most easily accessible on the appliance"; the standard would have to be ready for all programmes, including an automatic programme	ED / EL / SM / CI	Better alignment to real-life conditions	The "most used" programme is different for each consumer. The survey shows the use of dishwashing machines currently IN STOCK, which is presumably different to how people would use a NEW machine (e.g. DW machines in stock do not necessarily indicate it "ECO", also a default set-up of the ECO programme only became mandatory a short time ago). Consumer choice of most used programmes might further change in future
				Additional stakeholders' input: - an open formulation would improve the policies' relevance for real-life, the test programme would be the most use programme for a higher share of real-life cycles. - It seems reasonable to define the ''most used'' programme as standard programme. It is possible that the consumer behaviour will change in the future but it is currently not predictable	**Additional stakeholders 'input:** - more potential disadvantages than benefits - better leave it at the ECO programme - It would complicate the test, and in some cases it might not be clear which programme would have to be tested. It is key that no longer the Eco programme, but a 'normal' programme (automatic or normal) is tested in the future - The last data of the consumer behaviour study clearly showed that the Eco programme is used with new DWs much more than with older ones. This is a clear indication that the ecodesign requirement "ECO as default" is working well and should not be ''disturbed' by controversial requirements
1b	cf. 1a	**Include further cleaning programmes** (e.g. automatic and/or short programme) into the test procedure and calculation formulae for energy and water consumption. The consumption value could be a (weighted?) average value	ED / EL / SM	Better alignment to real-life conditions, realizing further improvement potentials of ecodesign/energy label measures (e.g. incentive to improve the other programmes as well)	Increasing testing effort for manufacturers and also market surveillance authorities. Currently, automatic programmes in the test procedure cannot deliver repeatable and reproducible results. The declared energy consumption becomes less transparent because it is a calculated average value based on different programmes.
				Additional stakeholders' input:	**Additional stakeholders 'input:**

No.	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
		from the different standard programmes		- Best option to increase the declaration's relevance for real-life energy consumption. Partly because it could be linked to a max. programme duration requirement for one of the test programmes. This would guarantee that users who do not like long programmes have a programme at hand that is both not too long and optimised regarding energy efficiency. - This would probably lead to more exact values for energy and water consumption.	- Based on the outcome of the consumer survey, there is little scope for adding these cycles which have scored low usage percentages: - 12% short cycle - 10% automatic cycle -Such policy option would also increase the complexity of market surveillance and would deter them from performing physical tests. - Standards for testing other programmes are not available yet. - too costly - due to the fact that the energy and water consumption is in any case different for each consumer, it does not seem reasonable to complicate the test procedure. Leaving it as it is today seems sufficient for a good estimation of energy and water consumption - each programme is defined to deal with specific load and soil, but each manufacturer is doing that on their own. Additionally, the term "automatic' is not defined. There are a lot of sensors in the market and automatic should not be restricted only to load and soil. Otherwise future developments can be prevented.
1c	cf. 1a; consumers might not be aware of the performance values (energy & water consumption, cycle time etc.) of other programmes compared to the ECO programme	Standardized format of the consumer information on the programme time, energy and water consumption for the main cleaning programmes. Definition of "main programmes".	CI	Programme values should become comparable between different machines / manufacturers	There are too many possible combinations of programmes and options to be able to reference them in a cost effective manner. If more data (consumption values of other programmes) is provided, they may need to be verified which requires more testing effort by manufacturers and market surveillance authorities. However, results of ATLETE II (for washing machines) reveal bad compliance regarding implementation of information requirements on programme values. Thus, a way is needed to ask for declaration without verification of the values.
				Additional stakeholders' input: - interesting proposal - as voluntary agreement by manufacturers - information is necessary and an identical	**Additional stakeholders 'input:** - Mandatory information in the display is not acceptable as not all models have a display. Besides, all display technology (e.g. entry level) does not allow for comprehensive/complex information to be displayed.

No.	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
				way of providing those information may be beneficial - very important for consumers to do informed choices - according to Regulation (EC) No 1016/2010, information of the consumption values for the main programmes should be available in the material delivered with the appliance (user manual, short manual, CD, etc). - the programme time is often already shown on the display, so it seems to be possible to show also energy and water consumption on the display, at least for the standard and Eco programmes	- better indicate in ranges to avoid misleading information - overload of information should be avoided - a rather simple measure, with however limited impact - not sure how consumers would react - there would be a super-efficient Eco programme - due to the fact that the programmes are defined to serve for specific load and/or soil it might not be possible to compare programmes form one manufacturer to another manufacturer. Therefore even a standardized format will not help for comparison.
1d	cf. 1a	Ways of information: - on the display a programme choice (in case of a display available), - in the manual and/or - the label fiche; - also a QR code might be possible.	ED	Avoids the washing machine situation where the main programmes are duplicated to reach better energy label classes	Prevents product innovation / market variety / consumer choices
				Additional stakeholders' input: - the requirement might be necessary to avoid having "hidden" standard programs and other programs, which have nothing to do with the declaration - similar programmes that have a clearly different purpose could be allowed (e.g. normal/ normal cool) this would not mean any innovation prevention	**Additional stakeholders 'input:** - the legitimacy of such provision under the Ecodesing regulation is dubious. Smarter ways of reaching the same goal are needed (e.g. communicate programme duration) - some programmes are suitable for various applications (e.g. short programmes for light vs normal for heavy soil) - this prescription would probably be too restrictive for the manufacturers - according to the user behaviour study, the QR-code is the least efficient information channel, but maybe relevant tool in the future. - this kind of requirement will only improve the creativity to rename programmes not to name it short or automatic and will not solve the problem which does not exist on DWs
2a	Consumers might not use the ECO programme (most effi-	Cap for maximum **programme duration** of the ECO programme, for example 2 - 4	ED	Unrealistic cycle times will be avoided. Consumers might use the ECO programme more often if the cap is rather short and	Energy consumption in the ECO programme would increase. Consumers which would generally accept longer programme times would not find programmes which are really saving a lot

No.	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
	cient for normally soiled tableware) as it is often optimised by **increased programme duration** which is not convenient for consumers (cf. survey results). Also, consumers might believe that short programmes consume less energy compared to the ECO programme.	hours. During the stakeholder meeting and as result of the 2015 consumer survey (60-70%) rather 2 hours were favoured. The 2015 consumer survey reveals that only few consumers (around 5% during daytime, around 20% during night-time) are willing to accept programmes of 4 hours or more.		convenient (e.g. 2 hours). On the other hand, a more flexible cap (e.g. 3.5 hours) would leave enough freedom for manufacturers for differentiation. The increase of energy consumption, if the programme duration is shortened (see drawbacks), however, should not have an effect under real-life conditions as at the moment the (very efficient) standard programme is only used in 22% of the cases. It can also be an incentive for manufacturers to find other possibilities to reduce the energy consumption than just increasing the duration of the cycle. Despite a cap, manufacturers still can offer longer and thus more energy saving programmes (as an extra/competitive feature). However this should not be the "standard programme" as people are not willing to use it as "standard" if it is too long.	of energy. If the cap of the programme duration is too strict, machines might not differ any more in their energy consumption. Within the Sinner Circle, the following factors are directly or indirectly limited by current regulations: - temperature: limited due to energy efficiency targets, certain temperature level needed to maintain performance (particular drying); - mechanics: indirectly limited by consumer expectations in regard to noise emission (also depicted on energy label) - chemistry: EN50242 limits the amount of detergent to a certain maximum amount per place setting Thus, time is the only truly flexible factor left in the development of high performing, energy and water efficient Eco programmes. Other shorter programmes can still be offered and selected. New innovation / developments are possibly prevented (e.g. efficient heat pumps need longer programme durations). The accuracy of measuring the rinsing performance has to be increased to avoid workarounds circumvention (the effect could be a reduction of rinsing cycles to reach shorter cycle times, i.e. worse rinsing performance or higher water consumption).
				Additional stakeholders' input: - maximum 2.5 h (it would be good if it was clear for the consumer when the dishing cycle is ready and the machine is only drying) - It should rather serve to avoid excesses (> 5h). If there are 2 standard programme (e.g. 'normal' and ECO) the cap could be applied to only one of these, then an a bit a tighter cap might be thinkable. On the other hand it might be an option to inform consumers about the advantages of long programme duration. - agreement with a cap for the maximum programme duration of the standard programme (even if it is not the Eco	**Additional stakeholders 'input:** - The outcome of the consumer survey study does not justify this requirement. Informing consumers on the energy saving potential by using long programmes is a better option. - more potential disadvantages than advantages - If the 'Eco' programme remains the only standard programme and the only one with a time cap, this would create a strange situation: all other programmes would have the potential to use less energy (because they can last longer). If the Eco programm must be the most energy saving programme, this would prohibit longer duration completely as energy efficiency option. We think it would be better to link a max. duration requirement to a different (standard) programme, but not to the ECO programme. If linked to a 'normal' standard programme this is an option for us.

No.	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
				programme) of 2hours	- Better not too strict time cap, as it would prevent higher efficiency.
2b	cf. 2a	Information about the maximum (average) programme duration of the ECO programme and/or the most used programm(s) on the energy Label	EL / CI	Consumers might use the ECO programme more often; better consumer information before a purchase decision; consumers might choose DW with shorter cycle times which might lead to an overall market shift / competition towards machines with shorter cycle times (even more than a cap) and thus stimulating manufacturers to reduce the time, driven by competition, i.e. with other innovations to reach better Energy efficiency classes	Overload of label information; with this explicit information, consumers might choose machines with shorter programme durations resulting in higher energy consumption. The accuracy of measuring the rinsing performance has to be increased to avoid workarounds circumvention (the effect could be a reduction of rinsing cycles to reach shorter cycle times, i.e. worse rinsing performance or higher water consumption).
				Additional stakeholders' input: - Programme time of the Eco programme shall be already communicated in the product fiche, and also for other main programmes in the user manual. If available, it is also depicted via the display. - reasonable way to reduce programme times. Indication of the ECO programme duration on the label could be a compromise. Requesting only the duration of the ECO programme on the label would be a possibility to stimulate innovation and competition without confusing the consumer. - Not necessary on the label. But important to show the consumer the duration of the programmes in the booklet or on the display/machine.	**Additional stakeholders 'input:** - "Maximum (average) programme duration" needs further clarification. - risk of performance reduction due to the competition on time - Should be combined with developing a standard for measuring rinsing performance, and put requirement on good enough rinsing. - indicating the duration of several programmes on the label is likely to distract the attention from the energy efficiency. Consumer might buy less efficient but quicker DWs.. - even if you would be able to find a technology (e.g. hypothetically nuclear fusion) with which you are able to clean and dry quicker and with less energy, these appliances would be much more expensive and the payback point is never reachable for the customer within the product life time. - giving a max programme duration would unjustly favour appliances with a higher amount of programmes.
2c	cf. 2a	Adjust the measurement standard so that long programme times do not longer	SM	Would reduce programme time for ECO programme of today	Still the ECO programme might not be used sufficiently in real-life. But risk of circumvention, as this point of the time cap in the

No.	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
		add benefit to the drying performance as the drying phase is usually responsible for the longer cycle times This could be done by introducing a time cap into the measurement standard when the programme has to end and the evaluation start (e.g. 1 hour after the last water intake or the highest temperature).			measurement is not well defined or can easily be circumvented. Better would be to give the cycle/programme time a high visibility to the consumer at the purchasing state, so those appliances taking long times will not be bought (cf. option 2b)
				Additional stakeholders' input: - Better to assure it is clear when the drying starts so consumers could choose to open then	**Additional stakeholders 'input:** - Any type of measurement procedure should be objective and not subjective; it should also not affect performance. - Any "time cap" or adjustment would be counterproductive in regard to energy or performance. - In theory the legislation could set a malus to long lasting programmes, but this would entail a degree of subjective evaluation, while objective consumer information is preferable. - According to consumers survey there are more than 30% of consumers for whom longer duration is not a problem. - It might lead to higher temperature (and higher energy use) in the last rinse, in order to reach A in drying performance on a shorter time. - better drying efficiency by longer drying time should not be prohibited. To get rid off moisture in shorter time you have to increase the temperature so that the remaining water can evaporate faster. temperature can only be increased by heating up the DWs, that means higher energy consumption
2d	cf. Option No 2a; also, people do not understand that long programmes can save energy (they assume that longer programmes automatically consumer more energy).	Better / mandatory consumer information about the environmental benefits of a longer programme duration in terms of energy savings (e.g. leaflets, stickers, educational campaigns, …) which also result in economic benefits for consumers when using primarily the ECO programme. Furthermore, more information is needed about using the dishwasher during the night: consumers are aware that	ED / CI	Consumers might use the ECO programme more often (i.e. overcome the misperception of consumers that longer programmes consume more energy	Consumer information is difficult to be regulated by ecodesign measurements (cf. ATLETE II results for washing machines with regard to (non-) compliance of consumer information measurements)
				Additional stakeholders' input: - support the development of better information to the consumer in conjunction with NGOs. - Better information on energy saving programmes is necessary but not only the manufactures are responsible for this. Also other stakeholders should increase their efforts to inform consumer on a sustaina-	**Additional stakeholders 'input:** - Mandatory requirement should be avoided as it creates unnecessary burden, also for market surveillances authorities. - rather easy option, but unclear impact.

No.	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
		electricity may be cheaper, but according to the 2015 user survey, there seems to be some reluctance in using the appliance at night, most probably by fear of accidents. The consumer should be more informed that appliances are safe and that many appliances are equipped with water safety functions (e.g. Aquastop)		ble way to use their household appliances. - it could be additional to other measures	
3a	Trend to increasing number of place settings vs. non-increasing households sizes/ loads: The overall trend to higher capacities might compensate (at least partly) the efficiency gains due to their better efficiency classes as the absolute energy consumption of larger machines might be similar compared to that of smaller ones. In addition, the situation could be worse under real-life conditions as the real-life loading is expected to be rather lower than the declared rated capacity.	Cap for absolute energy consumption independent of the number of place settings (maybe differentiation between table-top, compact and standard machines might be necessary)	ED	Smaller machines with less absolute consumption in real-life; no thrive for bigger machines just to reach a better energy label class. Avoid the increase of ps within a category as it is mainly a marketing argument which consumers are happy to take ('I get one more ps for the same price of the machine'	No clear evidence if this measure is able to affect the market trend to increasing capacities at all.
				Additional stakeholders' input: - Consumption caps are generally welcome to us, as it is a very clear signal and measure.	**Additional stakeholders 'input:** - The data from consumer survey study shows that, on average, users tend to fill their dishwasher "at full capacity without overloading it". Therefore, cap for absolute energy consumption does not make sense as it would constitute an incentive for consumers to buy smaller appliances, which would lead to an increase of the number of cycle and, in fine, an increase of the total energy consumption. - there cannot be a cap for all programmes but only for the ECO programme, otherwise all programmes would immediately have the same conditions as the Eco programme and there would be no diversification between the programmes any more. - There is no gain in energy efficiency evaluation by adding an extra place setting. Differentiation is already included in calculation of energy consumption for big and small size dishwashers. Today, ecodesign requirements and energy label classes are calculated on the basis of energy efficiency, intended as the energy consumption to carry out a specific task or provide a particular service. This represents a balanced approach and

No.	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
					should be maintained. - No justification in setting caps for the absolute energy consumption or to introduce malus in the calculation of energy efficiency – to prevent larger appliances from qualifying for the top classes. The choice should be left to the consumer, who buys an appliance due to its performances and features. The legislator should refrain from "over-advising" consumers in this respect. - Ideas like an artificial malus for larger appliances could be even detrimental to the effort of reducing the overall energy consumption. In some circumstances, consumers could be driven to purchase two smaller appliances rather than a larger but more efficient one – which would be badly ranked due to an artificial malus – leading to an increase in total consumption. - It is a rather 'harsh' measure with unclear effect, especially if the real-life-relevance of the declared energy consumption remains unclear. - increasing size / energy consumption is not a big issue in DWs.
3b	cf. 3a	Cap for absolute water consumption independent of the number of place settings	ED	More smaller machines with less absolute consumption in real-life	cf. 3a
				Additional stakeholders 'input: - Since water consumption is not (or only indirectly) considered in the Label's main message, the efficiency class, a cap might indeed be an option to avoid excessive water use. A cap should be introduced at a high enough level to guarantee a good rinsing performance.	**Additional stakeholders 'input:** - The water consumption obtained with current dishwasher technology is already extremely low (e.g. 6-7 litres per cycle), this becomes particularly obvious when comparing to manual dishwashing. - Any reduction/ limitations would be difficult to obtain and could be counterproductive in terms of performances. Consumer will very likely start to prewash there heavily soiled items again and therefore will waste water and energy - Water consumption is decreasing together with the energy consumption and a cap might worsen the rinsing performance if this step is omitted. - Better to develop a standard for measuring rinsing performance, and put requirement on good enough rinsing.
3c	cf. 3a	Different calculation formulae	ED / EL	The different levels for small and large	No clear evidence if this measure is able to affect the market

No.	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
		for smaller and larger machines, being stricter for larger machines		machines might promote that small households buy more likely small DW (otherwise they might buy large DW based on their better Energy efficiency class not knowing that the absolute consumption might be the same or even higher compared to small ones; and in the end the large DW is not appropriate for small households when it cannot be full-loaded).	trend to increasing capacities at all; the definition of "small" and "large" dishwashers might be reconsidered - today it is based on a combination of width and number of place settings
				Additional stakeholders 'input: - already done but with bending curves for the largest ones. It's easiest to keep it this way (even if unclear impact). - The SAEc for large DWs is pretty flat, also a horizontal line is thinkable. - support to options 3c and 3d because this could promote that consumers buy devices with lower absolute energy consumption	**Additional stakeholders 'input:** - There is no logical justification to such policy option. Users tend to fill their DWs "at full capacity without overloading it". Therefore, promoting small appliances would be counter-productive in terms of energy efficiency. - Strictly linear efficiency definitions always make it easier for larger models to reach better efficiency classes - this should certainly be avoided for DWs. - this requirement does not help to change the situation. 60cm is the most common width for DWs because it is a standard size for kitchens. 45cm DWs are more common in countries where flats are smaller. Both dimensions are standardised by the kitchen furniture industry.
3d	cf. 3a	Progressive (bended) curves / calculation of EEI, i.e. stricter for larger machines	ED / EL	cf. 3c	cf. 3c
				Additional stakeholders 'input: - sticking to the current formulas would be easier, as increasing size is less of a problem for DWs than for other products. - To keep the current approach of a flatter SAEc for larger DWs should be sufficient.	**Additional stakeholders 'input:**
4a	The standard load is difficult to reach under real-life conditions; also the standard includes heavy soiling. Under standard test	Take the automatic programme as "standard" programme which adapts the energy and water consumption by sensors to real-life loading and soiling. Allow sensors to	ED / SM	Real-life has normally less soil / less dishes. Machines equipped with intelligent sensors should be able to adapt the programme accordingly and realize savings.	Sensors are not measured in the standard programme performance test so far, i.e. no effect on EEI; sensor use is difficult to measure (reproducibility) - the mandate M481 asks to develop a measurement method that makes sure that the cycle tested is always the same in order to deliver reproducible and repeatable results;

No.	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
	conditions, sensors (adapting energy & water consumption better to the real-life conditions) have to be switched off.	be switched on during standard measurements.			In case of heavily soiled dishes the consumption could even increase with sensor use. Price of low cost machines might increase if sensors become mandatory.
				Additional stakeholders 'input: - interesting option, but better for the future	**Additional stakeholders 'input:** - consumers should be and are encouraged to always fill the available space completely, coupled with the ECO cycle as this remains the best energy efficiency option. -today's Auto programmes in the EU market, has a good adaptation to soil levels and load size (amount of dishes loaded), resulting in a clear differentiation regarding energy and water consumption for different response levels. This could no longer be the case if the automatic programme were to be standardised. Automatic programmes might have up to 90 programmes cycles. - The latest RRT showed that repeatability and reproducibility of the cleaning and drying results is rather low even with a fixed programme structure; it is assumed that this would worsen for measurements of a sensing programme. - no test standard available - doubts about how much DWs can adapt water and energy consumption to the load and especially to the soiling - this would complicate the test procedure very much
4b	cf. 4a	Sensor use in the measured standard programme(s): Measurement of dishwashers in the standard programme(s) not only with full load and full soil, but also with half load and half soil. Proposal: 3 x full load/soil + 4 x half load/soil	ED / EL / SM	Sensor will be active also in half load cases; better alignment to real-life conditions (according to the 2015 consumer survey, consumers fill their dishwashers at the full volumetric fill, which is assumed to be less than the standard full load). Stiftung Warentest and University of Bonn already conduct automatic programme tests (sensor driven programme) with "half load" as well as less or more soil than in the standard programme.	Increased testing effort (Fall back option could be e.g. 3x full + 2x half). Currently, to use automatic programmes / sensors in the test procedure, cannot deliver repeatable and reproducible results. Consumer studies show that half load cycles are not often used. The IEC 60436 4th edition already better reflects real-life user behaviour, e.g. including plastic items, pots & pans. Further, measurements show that for high efficient appliances, the effect of reducing the energy consumption is significantly lower than for less efficient appliances; therefore, half load testing for the declaration would be counterproductive. Having partial loads included in the test procedure might also give a

No.	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
					wrong signal to consumers as it may encourage them to use their appliances half loaded.
				Additional stakeholders 'input: - Indeed the use of sensors in the test makes much more sense if also half load is tested. - it is more important to include additional programmes to the test than half load.	**Additional stakeholders 'input:** - This proposal would increase test burden and be costly for market surveillance authorities. - It should not be recommended to use half-load, as half load Eco or half-load normal programme does not consume half of the energy necessary for Eco or normal programme. - the use of half load would clearly favour less efficient DWs because in these DWS the heating phases are longer than in the high efficient DWs and therefore the effect of lower load is higher. It will get more and more difficult to sell high efficient DWs.
5	The current EN standard test method does not reflect real-life consumer behaviour e.g. with regards to combined cleaning and drying and plastic items	Align EN test procedure to new IEC performance standard	SM	Is a must! The new IEC standard aligns testing conditions better to real-life (e.g. more plastic items etc.)	None
				Additional stakeholders 'input: - total agreement	**Additional stakeholders 'input:**
6	The new IEC standard includes a measurement method for the rinsing performance, however, without testing experiences so far with regard to repeatability	Introduce minimum requirements for measuring the rinsing performance within the next few years (issuing a mandate for a standard on rinsing performance for DW)	SM / ED	Consumers get a guarantee of a certain minimum rinsing performance in the standard programme, i.e. energy efficiency gains are not realized at the expense of rinsing performance	Additional testing effort for manufacturers and also market surveillance authorities
				Additional stakeholders 'input: - Working on a rinsing performance method should be intensified, before setting requirements. - Very important! - Rinsing is one of the primary functions of a DW, so a sufficient rinsing performance should be guaranteed.	**Additional stakeholders 'input:** - There is no sufficiently reliable test procedure to measure rinsing performance, nor a proper definition of the term. - A clear definition is needed of what is meant by "rinsing performances": a) getting rid of detergent affect the main wash b) Spots and stains remaining on dishes. Rinsing performance cannot be sufficiently/reliably assessed using the standard water for testing, as artificial hardening of water is done with calcium

No.	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
					hydrogen carbonate, which causes water stains. Any other setup/ water for testing would increase test burden. - The link between reducing water consumption and detergent residue on the dishes should not be forgotten. This is not part of the procedures available. - Much more work is needed and as long as there is no consolidated experience on the topic, a min requirement for measuring the rinsing performance is absolutely no possible.
7	Consumers often do not know that a certain minimum cleaning performance of the standard programme is mandatory and might mistrust the performance especially when getting knowledge about longer times in this programme	Information about the cleaning performance provided on the label	CI / EL	Confirmation of good cleaning performance in standard programme might lead to consumers choosing this programme more often despite knowledge about longer duration	Does only make sense if performance level of machines differs (but there seems no need to differentiate the todays A-class cleaning performance of all machines even more); overload of label information
				Additional stakeholders 'input: - Clear information to the consumers about cleaning performance is supported. - important to show the consumer cleaning information in the booklet, on the display or on the label	**Additional stakeholders 'input:** - It should be considered whether such information should be on the label or only on the fiche. - not needed on the label - The evaluation of the cleaning performance has a high standard deviation according the RRT 2014. Therefore a differentiation of today A-class seems not feasible because otherwise the standard deviation is bigger than the width of the cleaning efficiency class. Therefore the cleaning performance should remain as a min requirement in the ED
8a	Standby consumption is covered by Ecodesign Regulations 1275/2008 and 801/2013 on standby/networked standby anyway; low contribution to total energy consumption	Leave standby-values totally out of the calculation formulae	ED / EL	Simplifies the measurement which saves costs for manufacturers and market surveillance authorities	The energy consumption of the standby modes might be enough - at the annual level - to pass from one energy efficiency class to another (if not taken into account any more)
				Additional stakeholders 'input: - due to the requirements of Regulation (EC) No 1275/2008 the contribution of the low power modes are already limited (<4kWh/year) so the risk that appliances are just shifted to the next efficiency class is reduced. Most of the DWs are defined just to reach the class but not to just miss it by 4 kWh/year.	**Additional stakeholders 'input:** - Appliances' consumption levels for the low power modes should be below the threshold specified in the relevant regulation, without claiming for exceptions. -This should be addressed within the framework of the new standby regulation. - Standby energy consumption has only a minimal effect on the displayed energy consumption and makes the calculation much

No.	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
					more difficult to understand for the consumer and to assess for the manufacturer. Should be left out. - It should be aligned with the regulation of washing machines - the formula can be simplified, and it allows to go to a per cycle basis for energy declaration
8b	Delay start is not covered by Standby-regulation as it is not an "unlimited" mode; delay start might become relevant in context of smart appliances / smart-grid-ready appliances	Include delay start mode into standby measurement / calculation of machine's total energy consumption	ED / EL / SM	Might avoid delay start modes with high wattages. Assuming 8 hours delay for each cycle with 5 or 10 W could contribute between 10 to 20% to the total annual energy consumption.	This mode only is assumed to have only minor contribution to the overall energy consumption of the machine. May lead to a less acceptance of delay start-mode. Higher test burden (for manufacturers and market surveillance authorities) if measurement in an extra test cycle would be needed.
				Additional stakeholders 'input: - It need not go into the EEI / consumption calculation formula, but should be covered by an ecodesign power cap.	**Additional stakeholders 'input:**
8c	cf. 8b	Set MEPS / power cap for delay start mode as it is the case for standby mode	ED	Avoids delay start modes with high wattages. Assuming 8 hours delay for each cycle with 5 or 10 W could contribute between 10 to 20% to the total annual energy consumption.	This mode only is assumed to have only minor contribution to the overall energy consumption of the machine. May lead to a less acceptance of delay start-mode. Higher test burden if measurement in an extra test cycle would be needed. Ideally, this mode would also be covered by the horizontal Ecodesign Regulation(s) on standby (Regulation (EC) no 1275/2010 and 801/2013)
				Additional stakeholders 'input: - Horizontal regulation would be an option. Networked standby could be included here. From other products (e.g. settop boxes, UHD TVs) we know that if the power of standby modes is neither declared nor capped or anything it can reach very high values (e.g. 20 or 30W), because nobody cares. Therefore, precautions should be taken.	**Additional stakeholders 'input:** - in the delay start mode the consumer wants to stay informed about the remaining waiting time so some indication has to be provided. A little bit higher consumption value should be allowed to provide the information to the consumer. This timely small increase in energy consumption will be largely compensated by the cost saving of using energy at a lower tariff or green electricity during the programme run
8d	cf. 8b	Provide "allowances" on delay start consumption for DW with	ED	Smart-grid ready appliances are an important instrument within the total	No standards / no real smart grids available yet. Demand-response ability does not make the appliance more

No.	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
		smart-grid functionality (at least for a certain time of market introduction)		energy transition system and thus should be favoured; too strict limit values might hinder product innovations	efficient. Allowances for certain functions should be avoided as far as possible within ecodesign; also, using the EU energy label for promoting these functions of smart appliances would not be compatible with the primarily role of the label (information tool for consumers on energy efficiency and selected other aspects which have a direct impact on operating costs such as water consumption, or which are relevant because of convenience issues, such as noise level). Networked standby should ideally be covered by the horizontal ecodesign regulation on standby/networked standby; new product innovations should comply ideally with existing energy efficiency targets.
				Additional stakeholders 'input: **-** Important not to give allowances in order not to increase energy consumption.	**Additional stakeholders 'input:** - It would be better to tackle this in the framework of the standby/network standby regulations. - strange: 2h are max. accepted for the programme duration, but for delayed start many hours are accepted. Better to allow 5h programme time - this would enable real energy savings!
8e	cf. 8a/8b	Set MEPS / power cap (e.g. max. 2 W) for any other standby-modes of dishwashers in case they are not covered by existing Ecodesign regulations 1275/2008 and 801/2013 so far, e.g. in the context of smart-grid functionality	ED	The introduction of smart-grid appliances (or other functionalities) should not lead to an overall increase of the energy consumption only due to the supply of this functionality	Smart-grid ready appliances are an important instrument within the total energy transition system and thus should be favoured; too strict limit values might hinder product innovations. Ideally, these modes would also be covered by the horizontal Ecodesign Regulation(s) on standby (1275/2010 and 801/2013)
				Additional stakeholders 'input:	**Additional stakeholders 'input:** - double regulation should be avoided - maybe problematic because the modes are not well defined.
9	A large part of the dishwashing impact is due to consumers' **pre-rinsing** of a lot of items (see results of consumer survey)	Mandatory consumer information on ecological drawbacks of **pre-rinsing**	ED / CI / (EL)	Consumers might less pre-rinse	Overload of (label) information might lead to no effect in the end
				Additional stakeholders 'input: - Most manufacturers already inform consumer that pre-rinsing is not necessary and should be avoided. - Link to CECED specific page on good use	**Additional stakeholders 'input:** - overloading of the label

No.	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
				of DW: http://www.ceced.eu/site-ceced/media-resources/Consumer-Tips/Dishwashers.html. - include to the best practice list mentioned below - this could be a standard formulation for the manual, no need to be on the label	
10	Nearly all DW do have a possibility to connect the machine directly to the hot water tap; in practice, this option is rather seldom used	Mandatory consumer information on **hot fill option** (e.g. symbol on EL for hot fill connection; further consumer information under which conditions hot fill is beneficiary)	CI / EL	For DWs, a direct connection to the hot water tap could be beneficiary if certain framework conditions are met. The saving potential for GWP and primary energy consumption depends on the type of electricity generation, the type of warm water generation, the dishwasher technology and the length and insulation of the water stub line. With better consumer information, this option might be used more often as consumers might not be aware of this electricity saving option.	Overload of (label) information might lead to no effect in the end; might still be difficult to understand and implemented by consumers. Benefits will only be realized if the framework conditions are beneficial. If this is not the case the overall energy consumption and the respective environmental impacts might even increase.. For those consumers explicitly looking for those types of appliances, the information of hot water supply is already available in the manual at the point of sale.
				Additional stakeholders 'input: - Other option could be to indicate this information in the fiche. - Mandatory information in the booklet, not on the label. - An icon would be easier, renewables are on the rise, so this could inform consumers about this option. - Perhaps a small mandatory symbol on the label and detailed information in the manual could be a solution.	**Additional stakeholders 'input:** - This policy is not appropriate as benefits depend on the heating and plumbing system. - Such information is not relevant for all consumers. - Having it on the label would overload the energy label while this information is already available in the user manual. - Also you might not get full benefit of the detergents, as some work best at lower temperatures. - Too complicated to be completely displayed on the label. - recommendation of the Australian government suggests not to use hot water in DWs if the water feed is too long and the water is heated up with other means than renewable energy.
11a	Current consumer survey reveals that the	Keep number of annual cleaning cycles (280) as they	ED / EL	continuity; better understandable in terms of annual	For smaller or larger households these average numbers do not represent their individual behaviour (cf. Consumer survey

No.	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
	EU average number of use cycles is still near to 280 cycles/year; these are average and theoretical numbers for relative comparison of machines	are		savings **Additional stakeholders' input:** - agreement	results) **Additional stakeholders' input:**
11b	cf. 11a	Indication of total energy consumption per cycle, not annual average consumption. Alternative: to keep some differences visible, it could be declared per 100 cycles	ED / EL	Better understandable and scalable for consumers. The choice of the Latin expression "kilo-watt hours per annum" alleviates the burden of expressing "yearly" in all the languages of the single market. In a survey 2012/2013 of 1 006 German consumers, more than 70% did not understand correctly (or did not under-stand at all) the meaning of "per annum" on the energy label. In the 2015 consumer survey, the option of providing the con-sumption value "per cycle" was reached an importance of around 60%, whereas the option "per annum" reached an importance of around 40%. "Per cycle" communicates more clearly that the energy consumed depends on usage. **Additional stakeholders' input:** - Both! information about both annual average consumption and total energy consumption per cycle would be beneficial on the label (or otherwise in the booklet). - It is not the Label's purpose to allow for a cross-product category comparison. We favour a per cycle declaration, and this would also facilitate the declaration of semi-pro DWs. - Better per cycle, differences are still	The consumption values (kWh and litres) are already at a very low level; differences between machines (decimal places) might become insignificant for consumers whereas yearly consumption values deliver greater numbers, where differences between appliances become more obvious and easier to quantify by users (in favour of energy efficient appliances). Coherence with the energy labels of other products would be omitted as for all other products the consumption is indicated per year. **Additional stakeholders' input:** - indicating the saving potential per year is also clearer than per cycle.

No.	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
				visible, per 100 is already less clear.	
12a	Consumers do not use the appliance in its best way (programme choice, loading, detergent dosage, pre-rinsing,...)	Develop an agreed list of Best Practice Tipps and include them as 'Beipackzettel' (= product insert, instruction leaflet) to each machine. Proposals include: - Advice to full load whenever possible - Advice that programmes at lower temperatures save energy; - Advice to use the pre-wash programme only when needed - Advice on the best use of rinse and hold options if applicable; - Advice to adjust salt dosing with regard to the local water hardness; - Advice on the correct installation in order to minimise the noise emitted; - Advice on correct maintenance of the dishwasher such as cleaning of the filter; - Advice on whether the machine can be operated with hot-fill water or not;	CI	If branded by EU it will give some confidence in the best way of using the machine; improved consumer behaviour, thus realising further efficiency potentials	Additional costs, also for compliance checks; overload of information might lead to no effect in the end
				Additional stakeholders' input: - Interesting proposal, industry is ready to cooperate with NGOs - Even though this is written already in many consumer manuals this information should be provided in many different ways. - It does not mean high additional costs because these should be general advices which are almost equal for each dishwasher.	**Additional stakeholders' input:** - Additional effort is very small - CECED has already created a list of Best Practice Tips and is available at CECED webpage. It is a summary of all user manual advices of all manufacturers. This request is already fulfilled since years
13a	In general, consumer information requirements are difficult to be regulated by ecodesign measurements (cf. ATLETE II results for washing machines with regard to (non-) compliance of consumer infor-	Introduce a template for the most relevant information requirements of the main programmes (e.g. consumption per cycle, programme duration, ...)	ED/CI	Easier to fill out, easier to check compliance; facilitates better comparability between programmes and/or appliances for consumers	Not all the consumers would consider the same pieces of information as relevant. If more performance data of additional programmes are provided, they may need to be verified, thus more testing would be necessary. A way is needed to ask for declaration without verification of the values.
				Additional stakeholders 'input: - The layout could be standardized - If a way for declaration without verifica-	**Additional stakeholders' input:** - Manufacturers should be free to maintain different names and amount of information.

No.	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
	mation measurements)			tion can be found the additional information might be helpful. - a simple standardised table in the beginning of the booklet giving the most important facts of the machines and some programmes (duration, temperature, energy use etc)	- The way the communication is provided should not lead to additional burdens. - Today's situation is that a manufacturer can provide the data either in the user manual, the short manual, a CD/DVD or anything delivered with the appliance. If the template has to be copied exactly like prescribed the information might be part of the user manual and not on the short manual anymore which could have been used in a faster way
13b	cf. 13a	Use of a QR code to provide consumer information	ED/CI	Modern form of consumer information, more flexible; might address younger consumers better	Not all consumers have access to this kind of information tool (QR-code reader necessary)
				Additional stakeholders 'input: - Manufacturers are open to consider this policy option.	**Additional stakeholders' input:** - Should be decided by the manufacturer or seller and not be obligatory. - QR code should be for standardised information for all products, not for random information. Not enough evaluated. Source of least importance to today's consumers. - other alternative technologies should be considered
13c	cf. 13a	Compulsory information via the display of the appliance when the programme is chosen	ED/CI	Modern form of consumer information, direct feedback and influence possibilities	Not all appliances are equipped with a display so far; communication such information can only be done with special displays (TFT e.g.). Such indications would be subject to certain tolerances which would make to only rough estimations; the more accurate it is required to measure, the more costly would be the technology to measure. Significant raise of the appliance prices expected, especially on low range models; would not help improving resource efficiency (more materials needed for display); impact is not clear (if consumers are really changing their behaviour).
				Additional stakeholders 'input: - Compulsory on display or on the machine: information about duration and possible when drying cycle starts - More information on the display when a certain programme is chosen seems to be the most effective way of consumer	**Additional stakeholders' input:** - This is not feasible for most displays. Besides, many models do not have a display. - Disadvantages prevail. - difficult to implement

No.	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
				information..	

8.2.6. Full list of policy options for household dishwashers regarding material resource efficiency

Table 8.20 provides a full list of policy options for household dishwashers. The policy instruments addressed are the energy label (EL), generic and/or specific ecodesign-measures (ED), standards and measurement methods (SM), as well as consumer information (CI) measures.

Table 8.20: Full list of policy options for household dishwashers regarding material resource efficiency

No	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
Component level					
1 a	**Unsatisfactory mechanical robustness / durability** of certain components and/or the whole appliance which lead to early failure rates There are standards on safety that could be used as starting point to handle such aspects.	Requirement on **performing durability tests of certain components** which are known to be prone for early failures	ED / SM	Decreased failure rate of appliance components	No clear evidence of certain components which usually fail more often (might be different from appliance to appliance); high effort / costs for testing; quality of just performing tests might be variable from manufacturer to manufacturer; testing alone would not lead automatically to higher durability **Additional stakeholders' input:** - Measurement standards need to be available and the feasibility (costs and time) for manufacturer and market surveillance need to be considered, application of EN 60335-1 in general and EN 60335-2-7 for washing machines might be a first step. - security tests are not suitable for endurance testing due to their different testing purpose (conditions for safety testing mostly do not reflect normal use) Compared to a whole device, testing of components may be easier but does not secure prolonged life time of the whole product .- is a fall-back option if testing of the whole product (2a) turns out to be not reliable or too costly - durability of product is highly influenced by usage patterns of consumers (place of installation, frequency of utilisation, maintenance etc.). - manufacturers should be free to make strategic choices according to the brand image they have or they wish to develop. This allows for a large offer of brands and price levels on the EU market from which the consumer, according to his wishes, expectations and purchasing power, can make the most appropriate choice. - there is no proof of early failures of certain components (cf UBA Study on Obsolescence - Intermediary report).

No	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
					- an assessment of what have been done for vacuum cleaners should be done before to impose it for new products. - safety standards are not the right tools to measure durability and lifetime. - high effort / costs for testing, not only for manufacturers but also for market surveillances. - supporting the activity of CEN/CENELEC's ecodesign Coordination Group TF 4: all requirements which are mandated under the draft standardisation request on material efficiency aspects to CEN/CENELEC and lead to a harmonised standard, will be accepted.
1b	cf. 1a	Requirements on a **minimum operational lifetime** of certain components which are known to be prone to early failures	ED / SM	Decreased failure rate of appliance components	Measurement standard needed; high effort for market surveillance authorities Additional stakeholders 'input - does not hinder breakdown of a device due to other failure parts. Harmonised testing standards are needed. - should be favoured over option 1a - there is no definition of "operational lifetime" available.
1c	cf. 1a	Consumer information on the operational lifetime of certain components (e.g. motor)	ED / SM / CI	Transparency to consumers; they might choose higher quality products; manufacturers can actively use this as a competitive argument	Claims on operational lifetime must be backed with verifiable durability tests (not only marketing instrument); does not ensure that other components / the whole appliance are defective due to other reasons Additional stakeholders' input - risk of market distortion and consumer misinformation if not massively controlled by market surveillance authorities. - such detailed information might not influence consumers when making their purchase decision but is a fall-back option if 2c turns out to be not reliable - this type of requirements is dependent on the availability of standardised methods and definitions

No	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
Whole product level					
2 a	cf. 1a	Requirement on **performing durability tests of the whole product** (e.g. endurance tests; and/or tests for extraordinary constraints like shocks, vibration, accidental drop, high tempera-tures, water, …)	ED / SM	Decreased failure rate of appliances	Specification of typical extreme stresses for those appliances needed; measurement stand-ards needed; high effort / costs for testing; quality of just performing tests might be variable from manufacturer to manufacturer; testing alone may not lead automatically to higher durability Additional stakeholders 'input - does only make sense in conjunction with requirements on minimum lifetime of the whole product. Testing conditions should reflect standard conditions. - the time required to test lifetime can be prohibitively expensive for manufacturers and market surveillance - should be favoured over option 1a - by no means, it can be compared to durability tests. Indeed, durability tests cannot be performed under extreme conditions, but should be close to the average usage patterns of consumers. - there are currently no available standards to test whole devices
2 b	cf. 1a	Requirements on a **minimum operational lifetime** of the whole appliance (e.g. machines to run a minimum number of cycles)	ED/SM	Decreased failure rate of appliances	cf. 1b; further: market intervention which might hinder/prevent innovations; few incentives for manufacturers to design the appliance beyond this mandatory minimum lifetime; disad-vantage for those manufacturers providing already better quality (as market surveillance might not be effective enough to override bad quality products to a large extent); must be combined with legal rights for consumers to claim if the minimum lifetime is in practice not reached Additional stakeholders' input - Testing conditions need to reflect normal use patterns which means that testing procedures are lengthy and expensive. This bears significant risk of market distortions as market surveil-lance authorities cannot manage this task, let alone in a timely manner. Infringers would not have to fear prosecution. - even if it would be set at 50% of the Average Expected Product Lifetime (AEPL), it is more crucial that it can be repaired if it fails after the minimum operational lifetime has expired.
2 c	cf. 1a	Consumer infor-mation about the **expected opera-tional lifetime**	ED / SM / CI / EL	Transparency to consumers; they might choose higher quality products; manu-	cf. 1c Additional stakeholders' input - this would probably not lead to an additional benefit for the consumer because also manu-facturers of rather low priced appliances would probably not indicate a shorter expected

No	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
		of the whole product (e.g. label, manual)		facturers can actively use this information as a competitive argument	operational lifetime, and until standards are available to test this, it cannot be enforced. Poor quality device manufacturers could say depends on usage: e.g. lifetime 10 years …when used once a week. - must be easily understood and not misleading, based on a solid measurement standard corresponding to the one for energy consumption? Could include information on certain components (1c)
General information of consumers					
3 a	**Wrong user behaviour leading to defects** of appliances (e.g. incorrect use, insuffi-cient mainte-mainte-nance)	General consumer information about correct use and maintenance of appliances	ED / CI	Decreased mis-use, decreased defects of appli-ances	Those consumer information is already mostly available in the manuals; is does not generally prevent consumers from misuse (precondition is that they read the information at all and act accordingly) Additional stakeholders' input - In general manufacturers provide information about the correct use and maintenance of appliances in the user's manual. Also trouble shooting information is included. - a standard format could help enforcement of such requirements
3 b	cf. 3a	Compulsory **direct feedback** on necessary maintenance intervals via the machine's **dis-play**	ED / CI	Possibly more regular mainte-nance done by consumers	Not all appliances are equipped with a display so far; communication of such information requires special displays (TFT; text to be displayed) and a sensoric which measures the next maintenance interval to be necessary (e.g. counting number of cycles); significant raise of appliances prices expected especially in the low-price segment; impact is not clear (if con-sumers would really change their behaviour) Additional stakeholders' input - compulsory feedback will not ensure consumer maintenance actions. - there is no proof that consumers will implement the feedback of the machine, as, often, maintenance implies extra-costs which can be high compared to the initial price of the product. - such messages risk to disturb consumers and would increase resource usage. Maintenance by a technician is not necessary. - Not all appliances have displays; making such feature compulsory would imply extra costs. There would also be additional extra costs due to the technology necessary to monitor the user behaviour. - this service is a competitive feature

No	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
3c	Early replacement of appliances due to **changes in consumer preferences and needs** (e.g. larger / newer products, design, ...)	Consumer information about the environmental (and economic) benefits of prolonged product use (e.g. campaign, sign on the appliance etc.)	ED / CI	Might reduce early replacements by consumers	No clear evidence of the impact; consumers might have still other predominant arguments / reasons for exchanging products Additional stakeholders' input - this is rather a general issue for which general information campaigns could be appropriate. - educational effects might be limited. - 30-40% of large appliances are replaced by consumers while they are still functioning. Therefore, proper information on disposal and more efficient WEEE collection/recycling should be the priority.
Reparability					
4a	In case of a defect, appliances are increasingly discarded although a **repair** might have increased the lifetime; reasons might be e.g. a certain product design impeding repairs, missing and/or no access to	**Design for upgrades and repairs**: components being prone to early failures should **not be designed in a manner prohibiting repairs** (e.g. high integration of different components)	ED	Modular design facilitates repairs in a cost-effective manner: otherwise whole component groups might have to be exchanged in case of a defect of only a single component which is more costly	Modular design might be more expensive. No clear evidence of certain components which usually fail more often (might be different from appliance to appliance); market intervention possibly hindering innovations; highly integrated components might have advantages themselves (e.g. better quality of the whole component group due to integration) Additional stakeholders' input - manufacturers offer after-sales service and thus are familiar with requirements of repair, which are part of the design considerations. Reasons for not repairing are different and cannot be addressed by ecodesign in their entirety. Evaluation of design options with regard to enabling / prohibiting repairs would be challenging. - This requirement would need to be specifically aimed at certain components to be effective. - there is no clear evidence which components usually fail more often. - accessibility for repairing is an aspects that can be verified. This can be verified via the provision of a disassembly report (similarly to the dismantling report used for the recyclability), or limiting non-reversible fastening for some key components

No	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
	spare parts, high costs for repairs compared to purchase of a new product etc.				
4 b	cf. 4a	**Design for upgrades and repairs**: compo-nents being prone to early failures should be **easily accessible and exchangeable** by the use of univer-sal tools	ED	Facilitates repairs in a cost-effective manner	No clear evidence of certain components which usually fail more often (might be different from appliance to appliance); high effort / costs for testing / market surveillance; "easily accessible" should be well defined Additional stakeholders' input - this is already the case. However, early failures of products are covered by the warranty and defects liability regulation.
4 c	cf. 4a	**Appliance internal failure diagnosis sys-tems** to report error specific messages to the user	ED	Digital pre-diagnosis of the specific failure would reduce duration and costs of repairs	Not all appliances are equipped with such a system and display so far; communication of such information requires special displays (TFT; text to be displayed) and a system which recognizes the kind of failure; significant raise of appliances prices expected especially in the low-price segment; impact is not clear) Additional stakeholders' input - this is particularly relevant for electronic control systems, which may make finding defects difficult for repairers. - seems to be more important to us that external diagnostic tools are available also to independent repair operators who can also understand the error codes - Relevant information is already given for most of the appliances. This information should target the after-sale services.
4 d	cf. 4a	**Information requirements on reparability** (e.g. repair label), e.g. 1) indicating if the	ED / CI / (EL)	Transparency for consumers; they might choose products being better reparable	1) Manufacturers would always claim reparability; difficult to define / measure, i.e. difficult to prove non-compliance (standard needed) 2) Difficult to define; in general, most components will be reparable or exchangeable - cost factor Additional stakeholders' input

No	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
		machine can be repaired or not; 2) indicating which components are not reparable		or which contain e.g. modular components	- this kind of self-declared claims is prone to creating market distortion - first a respective methodology for assessing the reparability would need to be established at the European Level. A first step should be 4e and 4f providing most benefit for the consumer. Even if an old product is repairable, if the costs of repair are 150 euros, purchasing a new product may be more desirable for the consumer. - requires a comprehensive standard such as ONR 192102. It does not say if repair is cost-effective measure. Maybe it should refer only to non-destructive dis- and re-assembly so that key components can be replaced (see 4b)
4e	cf. 4a	**Consumer information about access to professional repairs** (e.g. information in user instruction / manufacturer's website / on the appliance itself to let the user know where to go to obtain professional repairs and servicing of the product, including contact details)	ED / CI	Facilitates the possibilities for repairs	Those consumer information is already mostly available in the manuals; (precondition is that they read the information at all and act accordingly); it does not generally prevent consumers from not repairing the devices as other reasons might play a role (e.g. costs of repairs, inconvenience of long waiting times); often only authorized repair shops listed which might be more expensive than independent ones Additional stakeholders' input - it seems questionable if such requirements should be set on a product by product case or if an overarching respectively horizontal regulation would be more advantageous - a standard format could help enforcement of such requirements - such information is already provided by manufacturers. Repairs should always be undertaken by properly qualified repair service personnel. - manufacturers provide repair documentation/software to recognised repair services that are qualified to undertake repairs safely. For safety and liability reasons, it is crucial that no obligation is set to make repair and disassembly information available to end-consumers. - the repair of products needs appropriate technical skills that most consumers do not have.
4f	cf. 4a	Information about the availability (and price) of spare parts (current practice: from 0 to 10-15 years after production)	ED / CI	Transparency to consumers; they might choose higher quality products; manufacturers can actively use this information as a competitive	Price indications are variable and dependent on several factors; costs for spare parts is only one factor of the total costs of repair (labour costs, travel costs); indication of prices in advance might even discourage consumers from doing repairs Additional stakeholders' input - detailed documentation of spare parts availability should be reserved to professionals. A general information, in principle, would be feasible. However, it would be difficult to verify the claims and false claim would endanger producers with a strong performance (and high costs) in this field.

No	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
				argument	- is a key prerequisite for reparability and should be favoured over e.g. 4d and 4e -Prices of spare parts do not only depend on manufacturers but also on independent repairs centres. - several pieces of legislation, in particular REACH, can also negatively affect the possibilities to repair products. As contrary to RoHS Directive, where the principle "repair as produced" is foreseen as a legal provision, within REACH this principle is not implemented. It is essential to provide equivalent items to ensure the repair is safely done. However, due to the frequent addition of substances to the Authorisation and Restriction lists of REACH, the production of spare parts could be limited. - the issue becomes even more complex when are considered the current discussions on the review of ecodesign requirements for fans and other products integrated into products. In this case, exemptions have been proposed for a limited period of time for spare parts - it is not easy to check the claims of availability (and price) of spare parts. This could be helped by on-going standardisation works.
4g	cf. 4a	**Guarantee of public availability of spare parts** for a certain period following the end of the production of the model; ensure original and backwardly compatible spare parts	ED, EL, CI	Facilitates that products can be repaired for a long period and by repair centres which are not manufacturer-bound	Costly for manufacturers to hold a stock of spare parts for a long time; for long-lasting large household appliances, this period might be at least 5 years to cover early breaks, but up to 10-15 years; environmental benefits not clear (if spare parts are not needed in this period, the might be destroyed without being used); Additional stakeholders' input - a guarantee bears the risk of 1) changes in the policy framework (see above) and 2) an oversupply of spare parts that become WEEE at a later point in time. - need for a detailed investigation of costs and effects of this option - should be favoured over mere information requirements such as in 4f

No	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
4h	cf. 4a	**Repair manual: clear disassembly and repair instructions** to enable non-destructive disassembly of product for the purpose of replacing key components or parts for upgrades or repairs. **Information publicly available** or by entering the products unique serial number on a webpage **to facilitate access for recognized / independent repair centres**. A diagram of the inside of the housing showing the location of the components available online for at least 5 years	ED	Might decrease of repair costs for consumers if independent repair organisations and approved re-use centres have information access and are able to perform repairs	Accountability (e.g. safety, lifetime, guarantee) and confidentiality of manufacturers might not be ensured if information is public available / non-authorized repair centres can do the repairs Additional stakeholders' input - repair manuals are available for approved service providers. Those undergo specific in-house training programmes in order to secure the consumer satisfaction after a repair, which implicitly is part of maintaining the brand value. Public availability bears the risk of abuse causing liability issues or damage to consumers - the repair manual should be available for repair centres. Having access to electronic repair software may be more relevant to repairers as dishwashers become more electronically complex.

No	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
4j	cf. 4a	**Commercial guarantee** providing a minimum of 3 years guarantee effective from the purchase of the product during which manufacturers shall ensure the goods are in conformity with the contract of sale (without passing the burden of proof to the consumer). It includes **service agreement** with a pick-up and return option.	ED	Manufacturers might improve the quality of their products to prevent claims	Costly for manufacturers; risk that costs are transferred to the total product purchase price; risk that appliances (especially low-cost) would be replaced by a new model instead of being repaired; for the long-lasting large household appliances, 3 years are quite a short time. Additional stakeholders' input - two types of guarantees are existing : the legal guarantee (2 years of conformity set by the 1999 Directive) and the commercial guarantee which is a service offered by manufacturers/retailers to their customers on competitive markets. Guarantees should not be tackled under ecodesign and should remain under the solely responsibility of DG Justice. Existing rules on commercial guarantees have proven their efficiency in ensuring a high-level for protection of consumers.
4h	cf. 4a	**Mandatory consumer information about commercial guarantees**, i.e. the number of years the producer guarantees the full functioning of the appliance for free and without passing the burden of proof to	ED / CI	Transparency to consumers; they might choose higher quality products; manufacturers can actively use this information as a competitive argument	Additional stakeholders' input - those information are already available in the contract signed by a consumer buying the appliance. The 1999 Directive sets minimum requirements at EU level, with the possibility for Member States to increase the protection at national level : 2 years of period of conformity and 6 months of the reversal of the period of the burden of the proof - any commercial guarantee applied by a manufacturer is part of its commercial strategy and thereby de facto a competitive issue. We take for granted that any manufacturer offering additional commercial guarantees will highlight this in its communication towards the consumer as it differentiates him from competition.

No	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
		the consumer			
5a	**The design of appliances can influence the practicability of recycling facilities at the EoL** according to WEEE requirements (dismantling of certain PCBs, displays, refrigerant containing components like heat pumps etc.) or to recover valuable resources (e.g. rare earth elements in permanent magnets of motors)	**Design for recovery and recycling** which allows better / easier access to dismantle / separate WEEE relevant components or components containing valuable resources	ED	These requirements are devised to help recyclers to better comply with the WEEE directive by providing information relevant for depollution, disassembly and or shredding operations	Measurement standard needed otherwise it would be too generic; high effort for manufacturers and market surveillance authorities Additional stakeholders' input - current technologies involve only a minimum of manual labour in dismantling, mainly for depollution. Thus design has a limited influence on this stage of the life cycle. Further, future technologies in WEEE treatment cannot properly be anticipated in the design phase - this is a very general formulation. As in the case of the TV revision, specific components should be named, e.g. printed circuit boards etc. Components with particular environmental relevance (and reusability?) should be easy to separate from the machine: e.g. heat pumps, permanent magnet motors. - setting a dismantling description would be meaningful only if products were actually dismantled in the prescribed way at the end of life - PCB of domestic appliances is not comparable to those of ICT, having a lower content of copper and precious metals. This makes measures in this field less effective than some studies suggest - recycling is following price signals in the up taking markets and the level of material recovery (in a broad sense) depends more on the profitability of the recycling activity than on parameters the producers of products can influence by design.

No	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
5b	cf 5a	Clear **marking of** special components and/or identification of **appliances with heat pumps** (recyclers of category 1 waste (large household appliances") are not always certified to also treat appliances with refrigerants)	ED	Better transparency for recycling facilities to treat separately refrigerant-containing appliances	New WEEE categories will be introduced from August 2018 which restructures large household appliances with refrigerants into another category (temperature exchange equipment) Additional stakeholders' input - with the new F-Gas Regulation 517/2014, new labelling requirements on gas contained in appliances (including heat pump) have been put in place (cf. Article 12). Those new labelling requirements are sufficient for recyclers to identify appliances relying on gases to allow temperature exchanges, like heat pump tumble dryers
5c	cf 5a	Clear **marking of appliances** with permanent magnet motors containing **rare earth elements**	ED	A clear marking would facilitate the motors being manually removed before a subsequent shredding process and separately treated to improve the recycling potential of the rare earths which would otherwise be lost	Might have no relevance if not or nearly not applied to a large extent to motors of WM/WD/DW; only effective if such motors are treated separately in the recycling facility Additional stakeholders' input - should be aligned with the proposals on the same issues for the motors and fans regulation
5d	cf 5a	**Marking of plastic parts containing hazardous substances** (e.g. halogenated	ED	Might improve to get recyclates without hazardous substances (avoid contamination)	Effective only if it is possible to separate the recycled plastic streams (those free from hazardous substances) Additional stakeholders' input - this faces a number of issues as in the televisions lot. A minimum threshold must be set and all components must be checked for compliance by market surveillance. Br-free logo implies no retardants in device, however small fittings or cables may still contain these.

No	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
		flame retardants); example: brominated fire retardants logo as proposed in the ED draft for electronic displays			Testing is difficult for market surveillance to carry out. Large parts with markings may be useful, but it depends on recycling regimes (shredding or manual separation). Is the future more likely to be automated separation by shredding? - should be aligned with the proposals on the same issues for electronic displays regulation
5e	cf 5a	**"End-of-life report"** for recyclers containing information relevant for disassembly, recycling and recovery at end-of-life at least on exploded diagram of the product labelling the targeted components defined together with a documentation of the sequence of dismantling operations needed to access to the components	ED	These requirements might help recyclers to better comply with the WEEE directive by providing information relevant for depollution, disassembly and or shredding operations	In the daily recycling practice such documents might not be used at all. Additional stakeholders' input - feedback from recyclers signals that any written documentation had little value for the recycling process. Our experience with this kind of information is that it has not been asked for since years, though specific diagrams were available.
5f	cf 5a	Declaration of the **recyclability index** for products indicating the share of recyclable materials, as for example	ED	Transparency, market differentiation of machines	Well developed and widely accepted procedures needed; so far only a theoretical number as the real treatment of the specific appliances and thus their recyclability depends of further factors; does not help to improve the real recycling process Additional stakeholders' input - there is no consensus about the recyclability of single materials; this currently is item to research and should be subsequently item to standardisation. The declaration would not be

No	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
		proposed in the ED draft for electronic displays			relevant for consumers, but invite free riders for providing unrealistic values that cannot be verified - recyclers should be asked if this is useful; for consumers it is not likely to be major selling point, whilst the recycling rates for washing machines are already fairly high - added value of this information needs to be verified as it does not guarantee recycling of certain materials in real-life. As an aggregated index it might be too simplistic compared to targeted measures to promote recovery of key materials - this type of requirements was discussed within the first draft of electronic displays. However, it is still affected by problems for verification. For this reason it was not included in the last version of the draft regulation for electronic displays.
6a	**Effectiveness of EoL efforts only if proper collection and treatment of appliances after use is ensured.** Ongoing standardization activity within CENELEC in collaboration with recyclers that covers collection, transport, storage, separation and recycling	Require the **mandatory application of the standard** that CENELEC is developing	ED	Activity supported by industry	A standard is not yet available Additional stakeholders' input - not clear if this standard refers only to collection and treatment of waste products or if it addresses product design. Only in the latter case it could be interesting to derive specific information or design requirements.

No	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
	of the product				
6b	cf 6a	Require the mandatory presence of a code / chip to track the appli-ance	ED	Possible track of the appliance	Availability of tools and infrastructures; does not solve the issue alone Additional stakeholders' input - could be useful to promote enforcement of WEEE obligations or to transfer information to recyclers, but the practicability needs to be tested in real-life - due to the long life of white goods, it cannot be guaranteed that the tags will still be on appliances and that it will be useful. In the daily recycling practice such code/chip might not be used at all.

Added stakeholder proposal:

7. Specific requirements focusing on **reuse** could be beneficial. Some of the previous requirements (e.g. 3a, 3c, 4a, 4d, 4f, 6b) could be tailored to promote reuse (as design for disassembly, access to repair information for non-authorised repairers, availability of diagnosis software (for free or under fee), tracking of appliances to avoid illegal ship-ments). Also the option of adopting reduced thresholds (on e.g. energy requirements) for devices reusing some components could be explored (see example on enterprise servers).

8.2.7. Calculation on the energy increase due to the use of delay start

8.2.7.1. Calculation 1 (rather worst case on a per appliance basis)

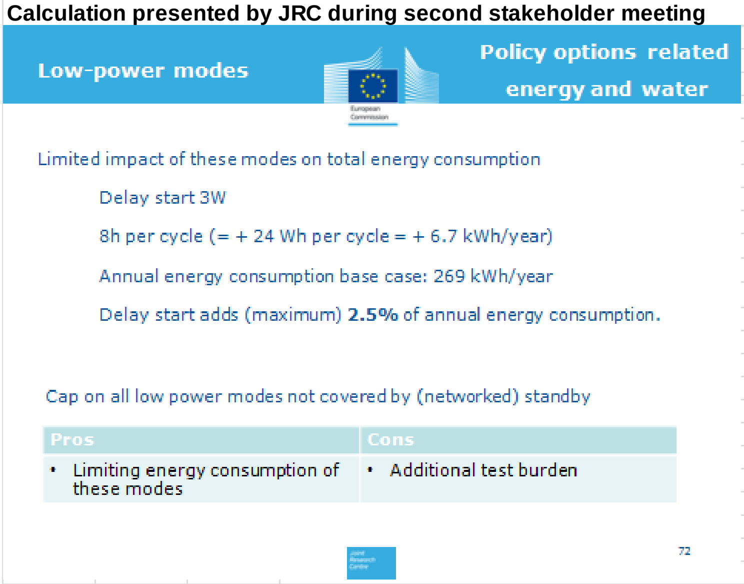
Table 8.21: Annual energy consumption of delay start mode (example: BC1, 13 ps)

	Option a: half of all cycles	Option b: all cycles
Annual energy consumption (according to energy label)	268 kWh p.a.	
Power consumption in delay start mode (currently worst case)	3 W	
Duration of delay start	8 h	
Number of cycles with delay start	140	280
Annual consumption of delay start mode	3.4 kWh p.a.	6.7 kWh p.a.
Relative Contribution to overall annual energy consumption (including energy consumption according to energy label plus delay start mode)	1,2%	2,4%

8.2.7.2. CECED Calculations

Facts for calculation the energy increase used by delay start:

Calculation presented by JRC during second stakeholder meeting



7,95	**Decreasing factor to JRC assumption**
0,31	**% of annual energy consumption**

Facts from Dishwashing behaviour of European consumers 2015

Question (q18) "Does your dishwasher have a “delay start” function? This function allows you to set the programme to automatically start later."

Answers:	9%	Yes, and I often use it
	13%	Yes, and I sometimes use it

Question (q19) "If you use a “delay start” function, how long does your machine usually remain this position before a programme starts?"

Answers:	43%	Less than 3 hours
	40%	Between 3 and 6 hours
	7%	more than 6 hours
	10%	it varies a lot

Calculations:

General conditions

3	Delay start [W]
280	Number of cycles / year
9	% of people use the delay start "often"
13	% of people use the delay start "sometimes"
78	% of people do not use the delay start
43	% use delay start less than 3 hours
40	% use delay start between 3 and 6 hours
7	% use delay start more than 6 hours
10	% use delay start with varying duration

Assumptions

		Possible parameter sets	
		Worst case	Mean value
100	Delay start usage for "often" [%]	100	66
50	Delay start usage for "sometimes" [%]	50	33
0	Delay start usage for "do not use the delay start" [%]	0	0
3	Delay start "less than 3 hours" [h]	3,0	1,5
6	Delay start "between 3 and 6 hours " [h]	6,0	4,5
24	Delay start "more than 6 hours " [h]*	24,0	15,0
11	Delay start "it varies a lot " is weighted ∅ of others [h]	11,0	7,0

a) Calculation of additional energy consumption per delay start time if used 100%

9,00	[Wh/cycle] 100% usage "less than 3 hours"
2,52	[kWh/year] 100% usage "less than 3 hours"
18,00	[Wh/cycle] 100% usage "between 3 and 6 hours"
5,04	[kWh/year] 100% usage "between 3 and 6 hours"
72,00	[Wh/cycle] 100% usage "more than 6 hours"
20,16	[kWh/year] 100% usage "more than 6 hours"
33,00	[Wh/cycle] 100% usage "it varies a lot"
9,24	[kWh/year] 100% usage "it varies a lot"

b) Calculation of additional energy consumption for 100% usage using the delay start time share of consumer behavior study

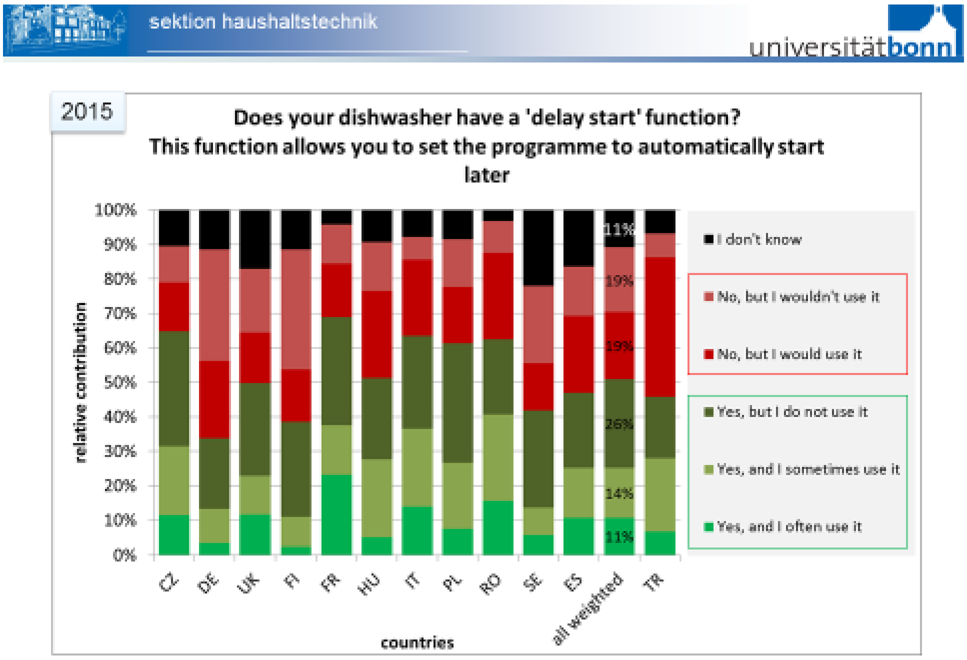
43	% use delay start less than 3 hours
40	% use delay start between 3 and 6 hours
7	% use delay start more than 6 hours
10	% use delay start with varying duration
19,41	[Wh/cycle] weighted
5,43	[kWh/year] weighted

c) Calculation of additional energy consumption using the usage share of delay start time of consumer behavior study

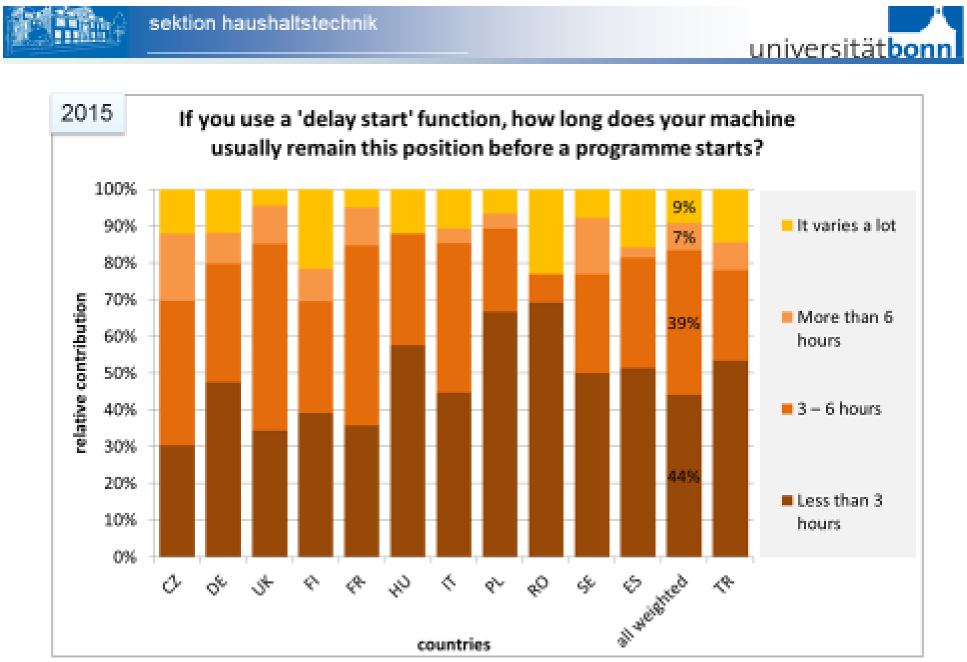
280	Number of cycles / year
9	% of people use the delay start "often"
13	% of people use the delay start "sometimes"
78	% of people do not use the delay start
100	Delay start usage for "often" [%]
50	Delay start usage for "sometimes" [%]
0	Delay start usage for "do not use the delay start" [%]
280	Number of cycles for "often"
140	Number of cycles for "sometimes"
0	Number of cycles for "do not use delay start"
3,01	[Wh/cycle] added energy consumption acc real usage
0,84	**[kWh/year] added energy consumption acc real usage**

8.2.8. Results of the 2015 consumer survey with regard to delay start

The following figures show the results of the consumer survey with regard to the existence and use of a ‘delay start’ function in dishwashers, to which the CECED calculation on the energy consumption in this mode refer to (cf. section 7.1.3.5 and Annex 8.2.7)



Q18 - Does your dishwasher have a 'delay start' function? This



Q19 - If you use a 'delay start' function, how long does your machine

8.2.9. Correction factors

This Annex shows the correction factors that were applied in the modelling to convert from the energy consumption in the Eco programme to the energy consumption under real-life conditions. This was calculated with the assumptions for 2015 and 2030. The values for the years in between were fitted linearly.

Table 8.22: Assumptions for the calculation of the energy consumption under real-life conditions in 2015

2015	Eco programme	Normal programme 45-55°C	Normal programme 60-65°C	Intensive programme 70-75 °C	Automatic (avg)	Glass Gentle/Soft/ Delicate/Light programme	Short	Rinse/ Rinse and Hold	
Consumer behaviour, use of programme	20.5%	19.9%	15.6%	9.1%	9.9%	5.9%	12.0%	7.1%	100.0%
Change of consumer behaviour (D9)	10%	5%	5%						
Changed consumer behaviour (D9: consumer feedback mechanisms)	30.5%	15%	11%	9%	10%	6%	12%	7%	100.0%
Energy consumption base case 13ps (kWh/cycle)	Eco programme	Normal programme 45-55°C	Normal programme 60-65°C	Intensive programme 70-75 °C	Automatic (avg)	Glass/gentle	Short	Rinse and hold	Total (real-life)
Base case	0.96	1.15	1.34	1.53	1.18	0.92	0.76	0.06	1.042
C1: D2+D3 (door opener + fan)	0.85	1.02	1.19	1.36	1.05	0.81	0.68	0.06	0.92
C2 (before: C3): D2+D3+D1 (door opener+fan+HE)	0.80	0.97	1.13	1.29	1.00	0.77	0.64	0.06	0.88
C3 (before C2): D5+D2+D7+D3 (duration, door opener, sensors, fan)	0.76	0.92	1.07	1.22	0.94	0.73	0.61	0.06	0.83
C4: D5+D2+D7+D3+D1 (= C3+D1)	0.68	0.81	0.95	1.08	0.84	0.65	0.54	0.06	0.74
C5: D5+D2+D7+D3+D1+D8 (= C4+D8)	0.68	0.81	0.95	1.08	0.84	0.65	0.54	0.06	0.72
C6: D5+D7+D1+D8+D4	0.75	0.91	1.06	1.21	0.93	0.72	0.60	0.06	0.80
C7: D5+D2+D7+D3+D8+D6	0.46	0.94	1.01	1.07	0.83	0.69	0.64	0.06	0.69

Table 8.23: Conversion factors for converting the Eco programme energy consumption to the energy consumption under real-life conditions for different EEI values in 2015

Conversion factor Eco program to real-life conditions 2015							
Current energy label class	A+	A++	A+++	A+++-10%	A+++-20%	A+++-30%	A+++-40%
EEI	63-56	56-50	50-45	45-40	40-35	35-30	<30
Conversion factor	1.09	1.09	1.09	1.06	1.06	1.06	1.49

Table 8.24: Assumptions for the calculation of the energy consumption under real-life conditions in 2030

2030	Eco programme	Normal programme 45-55°C	Normal programme 60-65°C	Intensive programme 70-75 °C	Automatic (avg)	Glass/ Gentle/ Soft/ Delicate/ Light programme	Short	Rinse/ Rinse and Hold	
Consumer behaviour	35.5%	9.9%	5.6%	9.1%	14.9%	5.9%	12.0%	7.1%	100.0%
Change of consumer behaviour (D9)	10%	5%	5%						
Changed consumer behaviour (D9: consumer feedback mechanisms)	45.5%	4.9%	0.6%	9.1%	14.9%	5.9%	12.0%	7.1%	100.0%
Energy consumption base case 13ps (kWh/cycle)	Eco programme	Normal programme 45-55°C	Normal programme 60-65°C	Intensive programme 70-75 °C	Automatic (avg)	Glass/gentle	Short	Rinse and hold	Total (real-life)
Base case	0.96	1.15	1.34	1.53	1.18	0.92	0.76	0.06	0.994
C1: D2+D3 (door opener + fan)	0.85	1.02	1.19	1.36	1.05	0.81	0.68	0.06	0.88
C2 (before: C3): D2+D3+D1 (door opener + fan + HE)	0.80	0.97	1.13	1.29	1.00	0.77	0.64	0.06	0.84
C3 (before C2): D5+D2+D7+D3 (duration, door opener, sensors, fan)	0.76	0.92	1.07	1.22	0.94	0.73	0.61	0.06	0.79
C4: D5+D2+D7+D3+D1 (= C3+D1)	0.68	0.81	0.95	1.08	0.84	0.65	0.54	0.06	0.70
C5: D5+D2+D7+D3+D1+D8 (= C4+D8)	0.68	0.81	0.95	1.08	0.84	0.65	0.54	0.06	0.68

C6: D5+D7+D1+D8+D4	0.75	0.91	1.06	1.21	0.93	0.72	0.60	0.06	0.76
C7: D5+D2+D7+D3+D8+D6	0.46	0.94	1.01	1.07	0.83	0.69	0.64	0.06	0.60

Table 8.25: Conversion factors for converting the Eco programme energy consumption to the energy consumption under real-life conditions for different EEI values in 2030.

Conversion factor Eco program to real-life conditions 2030							
Current energy label class	A+	A++	A+++	A+++-10%	A+++-20%	A+++-30%	A+++-40%
EEI	63-56	56-50	50-45	45-40	40-35	35-30	<30
Conversion factor	1.04	1.04	1.04	1.01	1.01	1.01	1.31

8.2.10. Stock and sales

8.2.10.1. Stock

The stock figures are based on the penetration rate and the number of households. The penetration rate is taken from (CLASP 2013) and the number of households comes from Eurostat, extracted on 22/4/2016, last update 8/2/2016. The stock values for 1990-2004 are taken from (CLASP 2013).

Table 8.26: Dishwasher stock figures derived from penetration rate and number of households.

year	EU28 Dishwasher household penetration rate (CLASP 2013)	EU28 Number of households (million) (Eurostat 2016)	DW units in EU28 stock (million)
1990	27%		37.0
1991	28%		39.3
1992	29%		41.5
1993	30%		43.8
1994	31%		46.1
1995	33%		48.4
1996	35%		50.8
1997	36%		53.0
1998	38%		55.3
1999	39%		57.5
2000	39%		59.7
2001	38%		61.9
2002	36%		64.0
2003	34%		66.0
2004	34%		68.1
2005	35%	195.1	67.4
2006	35%	199.0	70.4
2007	36%	201.0	72.7
2008	37%	203.1	75.2
2009	38%	208.9	79.2
2010	39%	210.5	81.9
2011	40%	212.0	84.9
2012	41%	213.3	88.1
2013	43%	214.1	91.3
2014	44%	216.8	95.4
2015	45%	220.4	100.1
2016	47%	222.7	104.3
2017	48%	225.1	108.6
2018	50%	227.5	112.9
2019	51%	229.8	117.4
2020	52%	232.2	121.8
2021	54%	234.6	126.3

year	EU28 Dishwasher household penetration rate (CLASP 2013)	EU28 Number of households (million) (Eurostat 2016)	DW units in EU28 stock (million)
2022	55%	236.9	130.8
2023	57%	239.3	135.2
2024	58%	241.7	139.6
2025	59%	244.0	143.9
2026	60%	246.4	148.1
2027	61%	248.8	152.2
2028	62%	251.1	156.2
2029	63%	253.5	160.1
2030	64%	255.9	164.0

8.2.10.2. Weibull parameters

The idea of working with a Weibull distribution to estimate the dishwasher sales is taken from US EERE (2014a). The Weibull distribution is a probability distribution commonly used to measure failure rates. Its form is similar to an exponential distribution, which models a fixed failure rate, except that a Weibull distribution allows for a failure rate that changes over time in a particular fashion.

The equation for the Weibull cumulative distribution function takes the form:

$$P(j) = e^{-\left(\frac{j-\theta}{\alpha}\right)^{\beta}}$$

Where:

P(j) is the probability that the appliance is still in use at age j

j is the appliance age

α is the scale parameter, which would be the decay length in an exponential distribution

β is the shape parameter, which determines the way in which the failure rate changes through time, and

θ is the delay parameter, which allows for a delay before any failures occur.

When β=1, the failure rate is constant over time giving the distribution form of cumulative exponential distribution. In the case of appliances, β commonly is greater than 1, reflecting an increasing failure rate as appliances are getting old.

The Weibull function is a memoryless function. This means that the probability of survival for the next year depends on the probability of survival for this year.

$$P\ (next\ year) = \frac{P(j+1)}{P(j)}$$

The lifetime (LT) of the machine is calculated as

$$LT = exp^{GammaLn\left(\frac{\alpha+1}{\alpha}\right)}\ \beta + \theta$$

The parameters α and β and the corresponding lifetime are given in Table 8.27 for the years 1990-2015 and correspond with parameters found in Baldé et al. (2015) for the years 1981-2014. For years before 1981 the same parameters are assumed as in 1981. For years after 2014 the parameters are set according to the assumptions in the scenario which can be found in sections 7.2.3.2 (and for scenarios not related to end of life) and 7.2.3.6..

Using the Weibull parameters shown in Table 8.27 result in an estimation of the total sales different from the values estimated by VHK (2014 / status 2013) and CLASP (2013). It should be noted that in CLASP (2013) a standard distribution has been used rather than a Weibull distribution to estimate the fall out of machines.

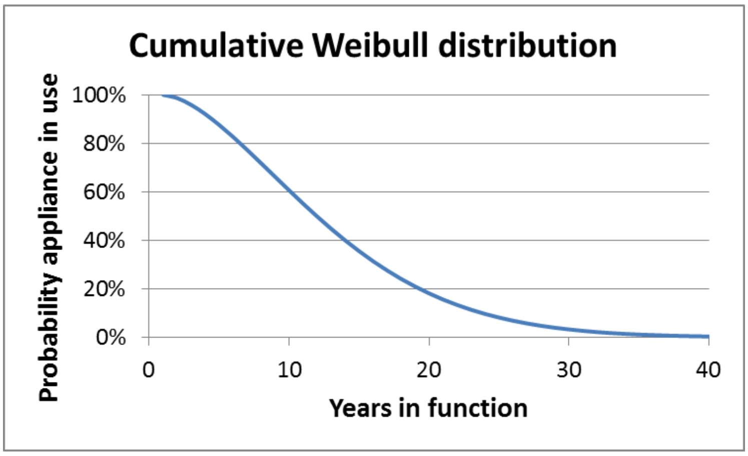


Figure 8.3: **Weibull cumulative distribution function for α = 13.72, β = 1.64 and θ = 1.**

Table 8.27: **Weibull parameters used for estimating the replacement sales according to Baldé et al. (2015) for 1981-2014, for the years 2015-2030 based on Figure 8.4.**

Year	α	β	Average lifetime (years)	Year	α	β	Average lifetime (years)
1981	1.64	14.00	12.53	2006	1.64	13.10	11.72
1982	1.64	16.78	15.01	2007	1.64	13.06	11.68
1983	1.64	16.52	14.78	2008	1.64	13.02	11.65
1984	1.64	16.27	14.56	2009	1.64	12.98	11.61
1985	1.64	16.02	14.33	2010	1.64	12.94	11.58
1986	1.64	15.77	14.11	2011	1.64	12.90	11.54
1987	1.64	15.52	13.88	2012	1.64	12.86	11.51
1988	1.64	15.26	13.66	2013	1.64	12.82	11.47
1989	1.64	15.01	13.43	2014	1.64	12.78	11.43
1991	1.64	14.76	13.21	2015	1.64	13.72	12.28
1992	1.64	14.51	12.98	2016	1.64	13.72	12.28
1993	1.64	14.26	12.75	2017	1.64	13.72	12.28
1994	1.64	14.00	12.53	2018	1.64	13.72	12.28
1995	1.64	13.75	12.30	2019	1.64	13.72	12.28
1996	1.64	13.50	12.08	2020	1.64	13.72	12.28
1997	1.64	13.46	12.04	2021	1.64	13.72	12.28
1998	1.64	13.42	12.01	2022	1.64	13.72	12.28
1999	1.64	13.38	11.97	2023	1.64	13.72	12.28
2000	1.64	13.34	11.93	2024	1.64	13.72	12.28
2001	1.64	13.30	11.90	2025	1.64	13.72	12.28
2002	1.64	13.26	11.86	2026	1.64	13.72	12.28
2003	1.64	13.22	11.83	2027	1.64	13.72	12.28

Year	α	β	Average lifetime (years)	Year	α	β	Average lifetime (years)
2004	1.64	13.18	11.79	2028	1.64	13.72	12.28
2005	1.64	13.14	11.76	2029	1.64	13.72	12.28
				2030	1.64	13.72	12.28

8.2.10.3. Sales

Table 8.28: Calculated sales figures including new sales (leading to an increase in penetration rate), replacement sales and total sales for scenarios BAU, 1 and 2.

Year	Stock (million units)	New sales (million units)	Replacement sales (million units)	Total sales (million units)
1990	37.0	2.2	1.8	3.9
1991	39.3	2.2	1.9	4.2
1992	41.5	2.3	2.1	4.4
1993	43.8	2.3	2.3	4.6
1994	46.1	2.3	2.6	4.9
1995	48.4	2.3	2.8	5.1
1996	50.8	2.3	2.9	5.2
1997	53.0	2.3	3.1	5.4
1998	55.3	2.3	3.3	5.5
1999	57.5	2.2	3.4	5.7
2000	59.7	2.2	3.6	5.8
2001	61.9	2.1	3.8	5.9
2002	64.0	2.1	4.0	6.1
2003	66.0	2.1	4.2	6.3
2004	68.4	2.4	4.3	6.7
2005	70.4	2.0	4.5	6.5
2006	72.7	2.3	4.7	7.0
2007	75.2	2.5	4.9	7.4
2008	77.2	2.0	5.1	7.0
2009	79.2	2.0	5.3	7.3
2010	81.9	2.7	5.4	8.1
2011	84.9	3.0	5.6	8.6
2012	88.1	3.2	5.8	9.0
2013	91.3	3.2	6.0	9.2
2014	95.4	4.1	6.2	10.4
2015	100.1	4.7	5.7	10.4
2016	104.3	4.2	6.0	10.2
2017	108.6	4.3	6.3	10.6
2018	112.9	4.4	6.6	11.0
2019	117.4	4.4	6.9	11.3

Year	Stock (million units)	New sales (million units)	Replacement sales (million units)	Total sales (million units)
2020	121.8	4.5	7.2	11.7
2021	126.3	4.5	7.5	12.0
2022	130.8	4.5	7.8	12.3
2023	135.2	4.5	8.1	12.6
2024	139.6	4.4	8.4	12.8
2025	143.9	4.3	8.8	13.1
2026	148.1	4.2	9.1	13.3
2027	152.2	4.1	9.4	13.5
2028	156.2	4.0	9.7	13.7
2029	160.1	3.9	10.0	14.0
2030	164.0	3.9	10.3	14.2

8.2.11. Real lifetime of DW

					years	Lifetime	Contribution of different pathways
			Lifetime extension	87%	5.35	17.85	4.5
		Repaired			WRAP, 2011 (1500 cycles, 280 cycles/year)		
	Failure	38%					
	77%	BIOIS, 2016	No lifetime extension	13%		12.5	0.5
				Prakesh, 2016 (repaired under warranty)			
	75%		Lifetime				
	Obsolesenz, Stiwa	not repaired	< 5 years	22%		3.0	0.3
		63%	6-11 years	35%		9.5	1.6
			> 11 years	42%		14.0	2.8
Retirements				Weibull distribution			
100%							
(about 8% of stock per year)							
Technical product lifetime			Lifetime				
12.5			< 5 years	13%		3.0	0.1
Preparatory study DW		to waste	6-11 years	31%		9.5	0.7
	Replacement without failure	92%	> 11years	56%		14.0	1.8
	25%			Obsolesenz			
		to re-use					
		8%					
		Italy 2012, Magalani et al.					
							Average lifetime of machine
							12.28

Figure 8.4: Representation of the model that has been used to define the average lifetime of a dishwasher on the market.

8.2.12. Prices for electricity and water

The EU28 household electricity price is taken from the Reference Scenario 2016 (European Commission 2016) (i.e. average price of electricity in final demand sectors scaled to $Euro_{2015}$). For the water price, 2011 is used as reference year with an escalation rate of 2.5% in accordance with COWI and VHK (2011b) (see section 5.1.2).

Table 8.29: Household electricity and water prices.

Year	Household electricity price (EUR_{2015}/kWh)	Household water price (EUR_{2015}/m^3)
1998	0.089	2.68
1999	0.093	2.75
2000	0.097	2.82
2001	0.101	2.89
2002	0.105	2.96
2003	0.109	3.04
2004	0.114	3.11
2005	0.118	3.19
2006	0.121	3.27
2007	0.125	3.35
2008	0.129	3.44
2009	0.133	3.52
2010	0.137	3.61
2011	0.138	3.70
2012	0.140	3.79
2013	0.141	3.89
2014	0.143	3.98
2015	0.145	4.08
2016	0.146	4.19
2017	0.148	4.29
2018	0.150	4.40
2019	0.152	4.51
2020	0.154	4.62
2021	0.154	4.74
2022	0.155	4.85
2023	0.156	4.98
2024	0.157	5.10
2025	0.158	5.23
2026	0.159	5.36
2027	0.159	5.49
2028	0.160	5.63
2029	0.161	5.77
2030	0.162	5.92

8.2.13. Carbon intensity indicators

European related carbon dioxide emissions have decline in the recent past. This trend has been led by emissions reductions in the electric power sector. The power sector has become less carbon intensive (measured as CO_2 emitted per kWh of generation).

The power sector has become less carbon intensive for two reasons: the substitution of less-carbon-intensive natural-gas-fired generation, displacing coal and petroleum generation and the growth in non-carbon generation, especially from renewable sources.

The trends of electric power generation for the coming years are very different depending on the assumption under consideration. Even though there is a common agreement that the electricity and steam generation sector will undergo a decarbonisation process, some authors consider that it will be faster than others. This means that the forecast of the future carbon intensity of the electricity for the coming years is quite different depending on the sources.

For this study electricity emission factors are taken from the Reference scenario 2016 (European Commission 2016) and calculated as the division between the total CO_{2eq} emissions of the power sector divided by the gross electricity generation. The reference scenario 2016 provides data or estimations every five years. The interpolated figures are shown in Table 8.30.

Table 8.30: Electricity emission factors

year	g CO_2/kWh	year	g CO_2/kWh
1990	558.9	2010	403.3
1991	551.1	2011	395.1
1992	543.3	2012	386.9
1993	535.4	2013	378.7
1994	527.6	2014	370.5
1995	519.8	2015	362.3
1996	511.9	2016	352.9
1997	504.1	2017	343.5
1998	496.3	2018	334.1
1999	488.4	2019	324.7
2000	467.9	2020	315.3
2001	464.7	2021	310.2
2002	461.5	2022	305.1
2003	458.3	2023	300.0
2004	455.1	2024	294.9
2005	451.9	2025	289.8
2006	442.2	2026	280.9
2007	432.5	2027	272.0
2008	422.7	2028	263.1
2009	413.0	2029	254.2
		2030	245.3

8.2.14. Primary energy factors

The primary energy is defined as the energy that has not been subjected to any conversion or transformation process (i.e. fossil fuels). The secondary energy originates from the primary energy, through conversion or transformation processes (i.e. electricity). The purpose of the primary energy factors (PEF) is to weigh the different energy carriers, comparing them to the corresponding energy sources. The PEF are numerical coefficients determined as the inverse of the ratio between one unit of energy delivered and n units of primary energy expected to deliver it. Therefore the PEF takes into account the energy expenditure per energy carrier's distribution and transmission, and also takes into account the efficiency of conversion or transformation processes form primary to secondary energy.

An average European reference value of the electricity PEF is given in the Directive 2006/32/EC and equals 2.5. In the recent past, a decrease in the PEF values has been observed. This fact is due to mainly two reasons: the replacement of coal and petroleum by natural gas fired combustion plants and the increasing penetration of the renewable sources in the generation of electricity. The forecast of the PEF values are influenced by technical progress and political decisions, as well as the methodology followed for its calculation, therefore different authors report different values.

Based on a technical methodology, the Reference Scenario 2016 (European Commission 2016) reports an increase in the efficiency of the power generation, this aspect has been considered as forecast for the PEF values at EU level. To estimate the future values of the PEF at EU level, the inverse of the power generation efficiency. This calculation reports a value of 2.49 in the year 2015, which is in line with the value of 2.5 for 2015 as suggested by Directive 2006/32/EC. The reference scenario reports value every 5 years. The interpolated figures are shown in Table 8.31.

Table 8.31: Primary energy factors (PEF)

year	PEF	year	PEF
1990	2.84	2010	2.59
1991	2.83	2011	2.57
1992	2.82	2012	2.55
1993	2.81	2013	2.53
1994	2.80	2014	2.51
1995	2.79	2015	2.49
1996	2.78	2016	2.49
1997	2.77	2017	2.48
1998	2.76	2018	2.48
1999	2.75	2019	2.48
2000	2.69	2020	2.48
2001	2.68	2021	2.46
2002	2.66	2022	2.45
2003	2.65	2023	2.44
2004	2.64	2024	2.43
2005	2.62	2025	2.42
2006	2.62	2026	2.41
2007	2.61	2027	2.40
2008	2.60	2028	2.39
2009	2.60	2029	2.38
		2030	2.37

8.2.15. Energy and water consumption of DW stock

Table 8.32: Estimated total EU28 electricity consumption of DW stock 2015-2030

Year	EU28 total electricity consumption DW stock (TWh/year)				
	BAU	SCENARIO 1	SCENARIO 2a	SCENARIO 2b	SCENARIO 2c
2015	30.58	30.58	30.58	30.58	30.58
2016	31.34	31.34	31.34	31.34	31.34
2017	31.95	31.95	31.95	31.95	31.94
2018	32.57	32.57	32.57	32.57	32.57
2019	33.23	33.16	33.22	33.21	33.22
2020	33.92	33.76	33.81	33.89	33.91
2021	34.65	34.34	34.40	34.56	34.62
2022	35.40	34.91	34.99	35.23	35.33
2023	36.15	35.50	35.55	35.87	36.02
2024	36.90	36.10	36.09	36.48	36.69
2025	37.56	36.70	36.55	37.01	37.32
2026	38.19	37.33	36.99	37.50	37.94
2027	38.71	37.93	37.34	37.90	38.47
2028	39.11	38.42	37.54	38.15	38.88
2029	39.45	38.87	37.66	38.31	39.20
2030	39.69	39.24	37.63	38.34	39.38

Table 8.33: Estimated total EU28 water consumption of DW stock 2015-2030

Year	EU28 total water consumption DW stock (million m^3/year)				
	BAU	SCENARIO 1	SCENARIO 2a	SCENARIO 2b	SCENARIO 2c
2015	308.1	308.1	308.1	308.1	308.1
2016	316.7	316.7	316.7	316.7	316.7
2017	323.9	323.9	323.9	323.9	323.9
2018	331.3	331.3	331.3	331.3	331.3
2019	338.9	338.8	338.9	338.9	339.0
2020	346.8	346.7	346.8	346.8	347.1
2021	355.0	354.9	354.8	354.8	355.3
2022	363.5	363.4	363.1	363.0	363.7
2023	372.1	372.0	371.4	371.3	372.3
2024	380.7	380.7	379.6	379.6	380.9
2025	389.3	389.3	387.8	387.7	389.4
2026	397.9	397.9	395.9	395.8	397.9
2027	407.0	406.8	404.4	404.3	406.7
2028	414.6	414.3	411.4	411.3	414.2
2029	421.8	421.5	417.9	417.9	421.4
2030	428.0	427.7	423.5	423.5	427.6

8.2.16. Total GHG emissions from electricity use of DW stock

Table 8.34: Estimated GHG emissions from electricity use of DW stock 2015-2030

Year	EU28 GHG emissions from electricity use of DW stock (million ton $CO_{2eq.}$/year)				
	BAU	SCENARIO 1	SCENARIO 2a	SCENARIO 2b	SCENARIO 2c
2015	11.1	11.1	11.1	11.1	11.1
2016	11.1	11.1	11.1	11.1	11.1
2017	11.0	11.0	11.0	11.0	11.0
2018	10.9	10.9	10.9	10.9	10.9
2019	10.8	10.8	10.8	10.8	10.8
2020	10.7	10.6	10.7	10.7	10.7
2021	10.7	10.7	10.7	10.7	10.7
2022	10.8	10.7	10.7	10.7	10.8
2023	10.8	10.7	10.7	10.8	10.8
2024	10.9	10.6	10.6	10.8	10.8
2025	10.9	10.6	10.6	10.7	10.8
2026	10.7	10.5	10.4	10.5	10.7
2027	10.5	10.3	10.2	10.3	10.5
2028	10.3	10.1	9.9	10.0	10.2
2029	10.0	9.9	9.6	9.7	10.0
2030	9.7	9.6	9.2	9.4	9.7

8.2.17. Primary energy from electricity use of DW stock

Table 8.35: Estimated primary energy use from electricity use of DW stock 2015-2030

Year	EU28 primary energy from electricity use of DW stock (PJ/year)				
	BAU	SCENARIO 1	SCENARIO 2a	SCENARIO 2b	SCENARIO 2c
2015	274	274	274	274	274
2016	280	280	280	280	280
2017	286	286	286	286	286
2018	291	291	291	291	291
2019	296	296	296	296	296
2020	302	301	301	302	302
2021	307	305	305	307	307
2022	313	308	309	311	312
2023	318	312	313	315	317
2024	323	316	316	319	321
2025	327	320	319	323	325
2026	331	324	321	325	329
2027	335	328	323	328	332
2028	337	331	323	328	335

Year	EU28 primary energy from electricity use of DW stock (PJ/year)				
	BAU	SCENARIO 1	SCENARIO 2a	SCENARIO 2b	SCENARIO 2c
2029	338	333	323	328	336
2030	339	335	321	327	336

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