Preparatory Studies for Eco-design Requirements of Energy-using Products

Lot 24: Professional Washing Machines, Dryers and Dishwashers

Tender No. TREN/D3/91-2007

February 2011

Final Report, Part: Dishwashers

Task 1: Definition

Öko-Institut e.V.
Institute for Applied Ecology, Germany
Ina Rüdenauer
Markus Blepp
Eva Brommer
Carl-Otto Gensch
Kathrin Graulich

BIO Intelligence Service, France
Shailendra Mudgal
Raul Cervantes
Thibault Faninger
Lorcan Lyons

Büro Ö-Quadrat, Germany
Dieter Seifried

Öko-Institut e.V.
Freiburg Head Office
P.O. Box 17 71
79017 Freiburg, Germany
Street Address
Merzhauser Str. 173
79100 Freiburg, Germany
Tel. +49 (0) 761 – 4 52 95-0
Fax +49 (0) 761 – 4 52 95-88

Darmstadt Office
Rheinstr. 95
64295 Darmstadt, Germany
Tel. +49 (0) 6151 – 81 91-0
Fax +49 (0) 6151 – 81 91-33

Berlin Office
Schicklerstr. 5-7
10179 Berlin, Germany
Tel. +49 (0) 30 – 40 50 85-0
Fax +49 (0) 30 – 40 50 85-388

www.oeko.de

For reasons of better readability, two Task 1 reports were prepared.

The report at hand covers ***professional dishwashers***.

The Task 1 report on *professional washing machines and dryers* is published separately.

For the benefit of the environment, this document has been optimised for **double-sided printing**.

Part: Professional Dishwashers

Table of Contents – Task 1: Definition

List of tables VI

List of figures VI

1 Introduction 1

1.1 General objective of the preparatory study 1

1.2 Objective of Task 1 2

2 Product category and performance assessment 3

2.1 Scope of Task 1 report, part 'Professional Dishwashers' 3

2.2 The professional dishwashing process 4

2.3 Detergents and rinse agents for professional dishwashers 5

2.4 Delimitation and definition of professional dishwashers 5

2.4.1 Eco-design regulation on household dishwashers 6

2.4.2 Distinction according to Machinery Directive 6

2.4.3 Definition of professional dishwashers within Lot 24 8

2.4.4 Distinction according to functional performance and technological differences 8

2.5 Classification of professional dishwashers 12

2.5.1 The European PRODCOM classification 12

2.5.2 The European customs classification 12

2.5.3 The International Patent Classification 13

2.5.4 Categories according to EN- or ISO-standard(s) 15

2.5.5 Functional performance classification 17

2.5.5.1 Primary and secondary functions of professional dishwashers 17

2.5.5.2 Main properties of professional dishwashers 18

2.5.5.3 Categories of professional dishwashers used in Lot 24 20

3 Test standards on professional dishwashers 25

3.1 Performance 25

3.1.1 ASTM International Standards (USA / International) 25

3.1.1.1 ASTM F857–07 26

3.1.1.2 ASTM F858–07 26

3.1.1.3 ASTM F859–09 27

3.1.1.4 ASTM F860–07 27

3.1.1.5 ASTM F953–08 27

3.1.1.6 ASTM F1021–95(2007) 28

3.1.1.7	ASTM F1022–06	28
3.1.1.8	ASTM F1114–06	29
3.1.1.9	ASTM F1202–06	29
3.1.1.10	ASTM F1203–06	29
3.1.1.11	ASTM F1237–09	30
3.1.1.12	ASTM F1696–07	30
3.1.1.13	ASTM F1920–07	31
3.1.1.14	ASTM F2687–07	32
3.1.1.15	ASTM WK24910	33
3.1.1.16	ASTM – summarizing conclusions	33
3.1.2	IEC and European harmonised standards EN 50242 / 60436	35
3.1.3	Work on development of new performance standards for professional dishwashers	38
3.1.3.1	By EFCEM (Europe)	38
3.1.3.2	By DIN (Germany)	38
3.1.4	Further used or adapted performance testing methods	39
3.1.4.1	By DTI (Denmark)	39
3.1.4.2	By ENAK (Switzerland)	40
3.2	**Hygiene**	**41**
3.2.1	ISO 15883 (International)	41
3.2.2	NSF/ANSI 3–2009 (International / USA / Canada)	42
3.2.3	NSF/ANSI 29–2009 (International / USA / Canada)	43
3.2.4	DIN 10510 / 10511 / 10512 / 10522 (Germany)	44
3.3	**Safety**	**47**
3.3.1	IEC 60335 (International)	47
3.3.2	EN 50416 (Europe)	47
3.3.3	UL 921 (USA / Canada)	48
3.4	**Noise**	**49**
3.4.1	IEC 60704 (International)	49
3.4.2	ISO 3744 (International)	49
3.4.3	ISO 3746 (International)	50
3.4.4	ISO 4871 (International)	51
3.4.5	ISO 9614 (International)	51
3.4.6	ISO 11204 (International)	51
3.5	**Electromagnetic fields / Electromagnetic compatibility (EMC)**	**52**
3.5.1	IEC 62233 (International)	52
3.5.2	IEC 61000 (International)	53
3.5.3	EN 50366 (Europe)	53
3.5.4	EN 55014 (Europe)	53
3.6	**Gas**	**54**
3.6.1	UL 921 (USA / Canada)	54

3.7 Standardisation needs for the EU 55

4 Existing legislation and environmental labelling 56

4.1 European legislation 56

4.1.1 Machinery Directive (MD) 2006/42/EC (replacing 98/37/EC) 56

4.1.2 Low Voltage Directive (LVD) 2006/95/EC 57

4.1.3 Electromagnetic Compatibility Directive (EMC) 2004/108/EC 57

4.1.4 Restriction of Hazardous Substances Directive (RoHS) 2002/95/EC 58

4.1.5 Waste Electrical and Electronic Equipment Directive (WEEE) 2002/96/EC 60

4.1.6 Biocide Directive 98/8/EC 61

4.1.7 Gas Appliances Directive (GAD) Directive 2009/142/EC 63

4.1.8 Water Framework Directive (WFD) 2000/60/EC 63

4.1.9 Commission Regulation (EC) No. 648/2004 – Detergents 64

4.1.10 Commission Regulation (EC) No. 842/2006 – Fluorinated GHG 65

4.1.11 Commission Regulation (EC) No. 1275/2008 – Standby 66

4.1.12 European labelling 66

4.2 Legislation at member state level 66

4.3 Third country legislation 66

4.3.1 USA 66

4.3.2 Canada 69

4.3.3 Australia 69

4.3.4 China 69

4.3.5 Russia 70

5 Conclusions: Scope of the study 71

6 Sources 72

7 Annex 73

7.1 Questionnaire “Task 1” for stakeholders 73

7.2 Stakeholder feedback to draft versions of Task 1 73

7.3 Method used by DTI for performance measurement of hood-type dishwashers 77

List of tables

Table 1	Main product groups of dishwashers according to customer segment	10
Table 2	Extract from PRODCOM list 2009 (Source: Eurostat)	12
Table 3	Classifications of dishwashers according to the HS-Classification (Source: World Customs Organisation)	13
Table 4	Classification of dishwashers according to International Patent Classification (IPC)	14
Table 5	Overview of dishwasher categories according to functional and performance parameters	24
Table 6	Corresponding Lot 24 dishwasher categories of ASTM standards	34
Table 7	Process temperatures for professional multi-tank conveyor-type dishwashers depending on the use of detergents with or without disinfection or oxidising component	45
Table 8	Process temperatures for professional one-tank dishwashers depending on the use of detergents with or without disinfection or oxidising component	45
Table 9	Energy Star Efficiency Requirements for Professional Dishwashers	68
Table 10	Manufacturers' and industry associations' web pages screened within EuP Lot 24	72
Table 11	Mean value of the results of 10 washes according to method used by DTI for performance measurement of hood-type dish-washers	78

List of figures

Figure 1	Different steps of a professional dishwashing process	4

1 Introduction

1.1 General objective of the preparatory study

Many aspects of energy-using products (EuPs) have a negative impact on the environment (emissions to air including greenhouse gases, to soil, recycling, water consumption…). In line with the Integrated Product Policy (which promotes the principle that requirements on the environmental performance of products should address all environmental aspects during the complete lifecycle of the product), the Commission decided in August 2003 to propose an integrated framework for setting "eco-design" requirements for EuPs (including energy efficiency requirements) while avoiding fragmentation of the market.

By adopting Directive 2009/125/EC[1], the European Parliament and the Council have granted a mandate to the Commission, assisted by a committee and after consultation of the stakeholders forum, to regulate the environmental characteristics of energy-using products (except vehicles) through adopting implementing measures (e.g. decisions, regulations or directives) laying down eco-design requirements for particular EuPs.

First step in considering whether and which eco-design requirements should be set for a particular product is a preparatory study identifying and recommending ways to improve at the design phase the environmental performance of the product throughout its lifecycle.

Preparatory studies should provide the necessary information to prepare for the next phases (carried out by the Commission) and in particular the impact assessment, the consultation of the Forum and the possible draft implementing measure.

Each product specific preparatory study follows a defined methodology especially developed for the European Commission (Methodology Study for the Eco-design of Energy-using Products (MEEuP)[2]). The MEEuP approach covers the following tasks:

- Task 1: Definition,
- Task 2: Economic and market data,
- Task 3: Consumer behaviour and local infrastructure,
- Task 4: Technical analysis of existing products,
- Task 5: Definition of base case,
- Task 6: Technical analysis of best available technology (BAT),
- Task 7: Improvement potential,
- Task 8: Scenario-, policy-, impact- and sensitivity analysis.

---

1 http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:285:0010:0035:EN:PDF

2 http://ec.europa.eu/energy/efficiency/studies/doc/ecodesign/2005_11_28_methodoly_report.pdf

1.2 Objective of Task 1

Within Task 1, the product category and system boundaries of the 'playing field' for eco-design shall be defined. It is important for a realistic definition of design options and improvement potential and it is also relevant in the context of technically defining any implementing legislation or voluntary measures (if any).

Subtask 1.1 – Product category and performance assessment

The following classification schemes and documents shall be analysed to define the product categories for Lot 24:

- Prodcom category or categories (Eurostat);
- Categories according to EN- or ISO-standard(s);
- Labelling categories (EU Energy Label or Eco-label), if not defined by the above.

Categorisation will often be linked to the assessment of the primary product performance parameters (the "functional unit"). If needed, on the basis of functional performance characteristics and not on the basis of technology, a further segmentation can be applied on the basis of secondary product performance parameters.

Subtask 1.2 – Test Standards

Subtask 1.2 will identify and shortly describe the harmonised test standards and additional sector-specific directions for product-testing regarding the test procedures for:

- the primary and secondary functional performance parameters mentioned above;
- resources use (energy, water, detergent, etc.) and emissions (NOx, CO, particulate matter) during product-life;
- safety (gas, oil, electricity, EMC, stability of the product, etc.);
- noise and vibrations (if applicable);
- other product specific test procedures.

Apart from mentioning these standards, including a short description, it should also be reported which new standards are being developed, which problems (e.g. regarding tolerances, etc.) exist and what alternatives are being developed. Furthermore, the (ongoing) work on an eco-design standard, mandated by the European Commission to standardisation bodies, shall be considered.

Subtask 1.3 – Existing legislation

Task 1.3 should identify the relevant legislation for the product. This task can be subdivided in three parts:

Subtask 1.3.1 – Legislation and Agreements at European Community level

Apart from the obvious environmental directives (RoHS, WEEE, Packaging directive), this could be building regulations (e.g. developed under the Performance of Buildings Directive), regulations on health and labour conditions (e.g. for air conditioners, copiers), minimum efficiency directives (boilers, refrigerators, ballasts, etc.), product liability, safety, electro-magnetic compatibility (EMC) etc. Also EU Voluntary Agreements and already existing eco-design standards (e.g. ECMA, EIA) of the sector or related sectors need to be identified. And finally, especially in a Business-to-business context it needs to be described which quality requirements (e.g. “proven design”, maximum failure rate) are customary.

Subtask 1.3.2 – Legislation at Member State level

This section deals with the subjects as above, focussing on legislation that has been indicated as being relevant by the Member States.

Subtask 1.3.3 – Third Country Legislation

This section again deals with the subjects as above, focussing on legislation and measures in Third Countries (extra-EU) that have been indicated by stakeholders (NGOs, industry, consumers) as being relevant for the product group.

2 Product category and performance assessment

2.1 Scope of Task 1 report, part ‘Professional Dishwashers’

Objective of this task is to present and discuss the definition and scope of the product family “Lot 24: Professional washing machines, dryers and dishwashers”.

In previous preparatory studies on household appliances, washing machines and dish-washers have been jointly discussed as “wet appliances” within Lot 14, whereas laundry dryers have been dealt with in a different study (Lot 16). In Lot 24, we consider dryers as one module of the whole laundry process and therefore integrate the discussion on washing machines and dryers, whereas the research on professional dishwashers will be presented separately.

For reasons of better readability two Lot 24 reports are prepared. The report at hand covers professional dishwashers. The report on professional washing machines and dryers is published separately.

2.2 The professional dishwashing process

The entire dishwashing process, e.g. in a large canteen, consists of several steps which are depicted in the following figure.[3]

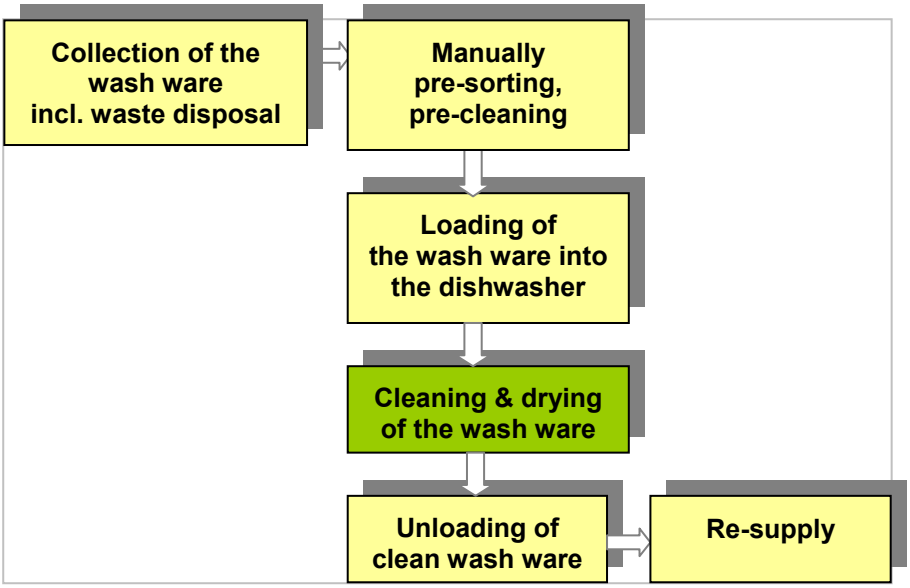


Figure 1 Different steps of a professional dishwashing process

Only the technical cleaning and drying process and the machines used for this are in the focus of the preparatory study at hand (green box), although from customers' and costs' perspective the manual parts of the dishwashing process might be also of interest.[4]

The study also concentrates on the dishwashing machine itself and does not consider the different water quality which has an influence on the result of the dishwashing process. Most of the machines are supplied with a separate water treatment system or this can be delivered on demand[5]. Finally, the analysis ignores external accessories kits not being components of the dishwashing machines, but usually supplied together with the machines (e.g. clearing station, admission table, and external baskets).

---

3 Own figure according to VGG-brochure "Gewerbliches Geschirrspülen und Hygiene" (professional dish-washing and hygiene), March 2006 http://www.vgg-online.de/download/merkblaetter/Gewerbliches_Geschirrspuelen_und_Hygiene.pdf

4 In a dishwashing process, 60% to 80% of the total costs are caused by labour costs. Source: aid Infodienst: Küche und Technik – Handbuch für gewerbliche Küchen. [Kitchen and Technology – Guide for commercial kitchens]; Bonn 2005.

5 Regarding dishwasher categories 1 and 2 (cf. Section 2.5.5.3), the water treatment system can be part of the machine itself or equipped separately. For the other categories, water treatment systems are usually separate.

According to the VGG glossary[6] "dishes" is a collective term for containers and vessels which are used for preparing, cooking, arranging and serving food. It includes plates, cups, saucers and bowls made of various materials. Next to "dishes" dishwashers are also used to clean, rinse and dry glasses, cutlery, black cookware, and other cooking utensils. The more general term of all these items that may be cleaned by a dishwasher is "wash ware". According to the VGG glossary, "wash ware" constitutes all components which are cleaned in the warewasher. Their shape and material must be suitable for cleaning by machine.

In our study, we will use "wash ware" as superordinated term for the different kinds of items to be cleaned.

2.3 Detergents and rinse agents for professional dishwashers

Treatment agents like detergents and rinse aids serve to clean, disinfect, rinse and descale wash ware of large-scale catering establishments.

Detergents come as powder mixtures, as solid blocks and in paste and liquid form. Their purpose is to remove food particles from wash ware completely and to counteract any re-soiling from the detergent solution. General decontamination performance might be enhanced by the use of a disinfecting component like for example active chlorine[7].

The function of the rinse aid is to reduce the surface tension of the water in the final fresh water rinse cycle and, by lowering the interfacial tension, to achieve a uniform wetting of the cleaned wash ware. This, together with the heat stored up in the wash ware itself (from the hot detergent solution or a separate feed of hot drying air) means that rapid drying of the wash ware is achieved. This results in spotless, gleaming and dry surfaces on the washware (VGG 2010).[8]

2.4 Delimitation and definition of professional dishwashers

Dishwashers have already been object of research in a previous preparatory study,[9] although focussing on domestic appliances (Lot 14: Domestic Washing Machines and

---

6 see "Commercial dishwashing: glossary of terms (technical information sheet No. 1)" published by Commercial Dishwashing Association, January 2008 http://www.vgg-online.de/download/information_sheets/01Commercial_dishwashing-glossary_of_terms.pdf

7 The possible usage and environmental impacts are described in Task 6 (effects of lower washing temperatures on composition of detergents)

8 Arbeitsgemeinschaft Gewerbliches Geschirrspülen [Commercial Dishwashing Association]: Commercial dishwashing & cleaning agents (Technical information sheet No. 05); Status: 20. April 2010. http://www.vgg-online.de/download/information_sheets/05cleaning_agents.pdf

9 Further information: www.ecowet-domestic.org

Dishwashers). Nevertheless, the following general definition for dishwashers of Lot 14 can also be applied to professional dishwashers:

> *Dishwashers are defined as machines which clean, rinse, and dry dishware, glassware, cutlery and 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 programs.*

Lot 24 focuses on professional appliances. Professional dishwashers are used to clean, rinse, and dry wash ware that is connected to the preparation, cooking, arrangement or serving of food (including drinks) in commercial and industrial market segments.

Professional dishwashers are always connected to the mains (electricity used for motor and electronics), although the heating of the water can also be realised by other energy sources like steam or gas. Professional dishwashers may or may not have a specific drying operation at the end of the programmes: in large conveyor machines (cf. Section 2.5.5.3), the drying process is generally carried out in a separate drying zone within the dishwashing machine whereas in manually loaded batch dishwashers, drying takes place mainly outside the machine by virtue of the heat from the wash ware itself[10].

In the following the basic differences between professional and household dishwashers are described to properly define the scope of this preparatory study.

2.4.1 Eco-design regulation on household dishwashers

The Commission Regulation[11] with regard to eco-design requirements for household dishwashers provides the following definition: “household dishwasher means a machine […] which is designed to be used principally for non-professional purposes”. This distinction, on basis of the intended use of a machine, equates the Machinery Directive (cf. next section).

2.4.2 Distinction according to Machinery Directive

A possible general differentiation gives the amended version of the Machinery Directive 2006/42/EC,[12] in force since 29th December 2009. It, clarifies the borderline between machinery for household and for professional use in order to provide greater legal certainty. Whereas for the latter machinery the scope of the Machinery Directive applies, in

---

[10] see “Commercial dishwashing: glossary of terms (technical information sheet No. 1)” published by Commercial Dishwashing Association, January 2008 http://www.vgg-online.de/download/information_sheets/01Commercial_dishwashing-glossary_of_terms.pdf

[11] COMMISSION REGULATION (EU) No 1016/2010 of 10 November 2010 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for household dishwashers. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:293:0031:0040:EN:PDF

[12] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:2006L0042:20091215:EN:PDF

Article 1 (2) k 'household appliances intended for domestic use' are explicitly excluded therefrom. They belong to low voltage electrical and electronic machinery with an electrical supply within the voltage limits of the Low Voltage Directive (between 50 and 1000 V for alternating current or between 75 and 1500 V for direct current) and therefore must fulfil the safety objectives of the Low Voltage Directive 2006/95/EC20.

Concerning the exclusion of household appliances intended for domestic use from the scope, the following clarifications are given in the '*Guide to application of the Machinery Directive 2006/42/EC*'.[13]

- The expression 'household appliances' designates equipment intended for house-keeping functions such as washing, cleaning, heating, cooling, cooking, etc. Examples of household appliances include washing machines, dishwashers, vacuum cleaners and machinery for food preparation and cooking.
- The exclusion concerns appliances 'intended for domestic use', in other words, intended for use by private persons (consumers) in the home environment. Thus appliances for the housekeeping functions mentioned above that are intended for commercial or industrial use are not excluded from the scope of the Machinery Directive.

While it is possible for a private consumer to acquire an appliance intended for commercial use or for a commerce to acquire an appliance intended for domestic use, the criterion to be taken into account for determining the 'intended use' is the use intended and stated by the manufacturer of the appliance in his product information or his Declaration of Conformity (DoC). Evidently, this statement must accurately reflect the foreseeable use of the product.[14]

In general, the design and construction of machinery must take account of the intended use. Recital 15 of the Machinery Directive stresses that the machinery manufacturer must consider whether the machinery is intended to be used by a professional or a non-professional operator or is intended to provide a service to consumers. Annex I of the directive describes essential health and safety requirements relating to the design and construction of machinery, i.e. of appliances for commercial or industrial use.

In summary, the machinery directive provides a legal principle to distinguish between devices for usage in households on the one side and professional use on the other side.

---

[13] Ian Fraser (General Editor): Guide to application of the Machinery Directive 2006/42/EC. Brussels, 1st Edition December 2009; revised by 2nd edition from June 2010 http://ec.europa.eu/enterprise/sectors/mechanical/files/machinery/guide_application_directive_2006-42-ec-2nd_edit_6-2010_en.pdf sighted at 15.02.2011

[14] l.c., page 54/337

2.4.3 Definition of professional dishwashers within Lot 24

To date, there is no official or standardised definition or delimitation between the terms professional, commercial, and industrial. CENELEC TC59X[15] proposed that the term "commercial" shall be used in connection with *market and market segments*. The term "professional", however, shall be used in connection with *equipment* designed for use in commercial segments.

In our study, we will follow this distinction and apply the term "professional" as super-ordinated term for dishwashing appliances used in commercial and / or industrial market segments. However, please note that for example in existing standards, the term commercial or industrial might be used based on another approach (cf. Section 3). Therefore, an accurate delimitation and standardised definition of industrial equipment or market segments in comparison to other professional appliances would still be necessary.

On the basis of the Eco-design Regulation on household dishwashers and the Machinery Directive, within Lot 24 we define professional dishwashers as follows:

> '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).

2.4.4 Distinction according to functional performance and technological differences

With regard to functional performance and technological differences, the boundary between household and professional use is fluent. There is a semi-professional context, where some requirements of the household and some of the professional context apply.

In *private households,* a dishwasher usually runs on average 280 cycles per year, i.e. more than 5 times per week.[16] Household dishwashers run with fresh water for each programme cycle meaning that for each cycle, the whole process water has to be heated. Further, in

[15] CENELEC TC59X decided to clarify their understanding of the terms commercial, professional, industrial and to decide which of them are inside the scope of TC59X on one of their next meetings (cf. also Section 3.1.3)

[16] Total number of standard cleaning cycles per year as used in the "Method for calculating the Energy Efficiency Index, Cleaning Efficiency Index, and the Drying Efficiency Index" in the COMMISSION REGULATION (EU) No 1016/2010 of 10 November 2010 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for household dishwashers. Official Journal of the European Union L 293/31 from 11.11.2010

household dishwashers, the wash ware often is not cleaned directly after the meals so that the soil is rather dried; thus, dishwashers for household usually have a longer soaking time; for these reasons, standard programmes of household dishwashers usually have longer cycle times of up to 3 hours. However, the duration of the programme is of less importance to private users as the device runs e.g. over night or between two meals. Household dishwashers are designed to clean various kinds of wash ware (dishes, cutlery, glasses, pots and pans) at the same time, i.e. they usually have rather unspecific programmes for general use (even though some have special programmes for glasses or "intense" programmes for highly soiled pots and pans).

In the *professional context*, the specific requirements according to space or type of wash ware differ considerably compared to household use, leading to a variety of different types of professional dishwashers varying in e.g. size and capacity (number of wash ware or baskets to be cleaned per hour). Compared to household use, usually a higher number of items have to be cleaned in professional dishwashers. Thus, they are operated more often (in case of program automats[17]) or for longer times (in case of conveyor-type dishwashers[18]). Moreover, in the professional context the programmes are required to be much faster than in private households.

The time requirement leads to the use of a tank system, where the detergent solution, i.e. the process water including the detergent in the required concentration, for the cleaning step is stored in a wash tank at high temperatures. The tank system saves the time used otherwise to heat up the water before each cleaning cycle. During operation the detergent solution is circulated through the dishwasher by means of a pump; to reuse the detergent solution for the next cleaning cycles, intensive water filtration takes place. The detergent solution is not changed between the cycles of the programme, but only partly replaced by hot fresh water from the final rinse zone (so called regeneration of detergent solution). The water in the tank is usually changed once a day or after each working shift.

Using a water-change system instead of a tank system makes sense in applications which are very similar to household use, the so called *semi-professional applications*, like Kindergartens or pre-schools, where the number of items to be cleaned per day is rather small (compared to other professional applications). Tank machines would not make sense due to this small amount of wash ware. As the time requirements in the semi-professional context are higher than in households, the programme cycles are shorter than in household

[17] Program automats are dishwashers where the different steps of the dishwashing process are conducted consecutively in time. The basket(s) with the wash ware stay(s) in the same position during the whole dishwashing programme. See also Section 2.5.5.2

[18] Conveyor-type dishwashers are dishwashers where the different steps of the dishwashing process are allocated to several individual treatment zones, i.e. the wash ware is transported through these zones, which are constructed as chambers, with openings in the transport direction. They are operated continuously within a certain period of time. See also Section 2.5.5.2

dishwashers (from approximately 5 to less than 30 minutes). The faster programmes compared to household appliances usually lead to a higher energy consumption of these semi-professional appliances.

Sometimes only one specific type of wash ware has to be cleaned or there is enough space and needed capacity to use several dishwashers in parallel, resulting in much more specialised dishwashers compared to household use. In bars or taverns, for example, mainly glasses have to be cleaned. Therefore, special glass washers are used. In canteens a large number of wash ware have to be cleaned. For this purpose, often several dishwashers are used, with each dishwasher being specialised for a certain kind of wash ware. In large-scale catering establishments the pots and pans used are usually much bigger compared to those used in private households and thus require more spacious dishwashers.

Further differences between appliances for household and professional use are:

- The connected load (professional dishwashers are available with higher load and three phases connectivity (400 V));
- The detergent dosage (manual dosing of cleaning agent in case of household dishwashers, use of tabs possible, vs. automatic detergent dosage in case of professional dishwashers);
- The distribution channels (professional appliances are sold directly by the manufacturers or via specialized gastronomy trade);
- The price (production costs of professional appliances are usually higher than household dishwashers).

Table 1 gives an overview of a possible delimitation between household, semi-professional and professional dishwashers.

Table 1 Main product groups of dishwashers according to customer segment

Group	Domestic Dishwashers	Semi-professional Dishwashers	Professional Dishwashers
Target group / Applications	Private households	Offices, small pensions, hospitals, hotels, nursing homes, restaurants, community kitchens, bed & breakfasts, institutional kitchens, kindergartens & pre-schools, schools, supermarkets	E.g. bakeries, bars, bistros, bread & bakery industry, butcheries, cafeterias, canteens, care homes, caterers, community centres, food processing industry, food retailing; hospitals, hotels, institutional kitchens, kindergartens & pre-school, marine, meat processing industry, restaurants, schools, supermarkets, etc.
Wash ware	Dishes, glasses, cutlery and further kitchen utensils	Dishes, glasses, cutlery and further kitchen utensils	Dishes, glasses, cutlery, crockery, black cookware, further kitchen utensils of large-scale catering establishments

Group	Domestic Dishwashers	Semi-professional Dishwashers	Professional Dishwashers
Temporal requirements	No special requirements regarding running times (cycle times up to 3 hours)	Short running times per cycle (5 to 30 min) through higher thermal, mechanical or chemical action	Very short running times per cycle (from below 1 minute per cycle) / high dishwashing capacity per hour
Water intake	Freshwater intake for each step in the programme.	Freshwater intake for each step in the programme.	Freshwater intake only for final rinse (smaller volume than for freshwater system dishwasher)
Water treatment	None (freshwater intake)	None (freshwater intake)	Intensive filtration of the detergent solution for re-use in several cycles (tank operation)
Operating principle	Discontinuous operation in cycles	Discontinuous operation in cycles	Discontinuous operation in cycles or continuous operation
Cleaning and hygienic requirements	Good cleaning efficiency important	Good cleaning efficiency important and hygienic requirements to be met	Good cleaning efficiency important and hygienic requirements to be met
Number of baskets to be cleaned at once	Dishwashing on two or three levels possible (loading of two or three baskets possible)	Dishwashing on two or three levels possible (loading of two or three baskets possible)	Dishwashing usually on one level (in front loaders loading of only one basket possible, in conveyor-type dishwashers continuous cleaning of baskets possible)
Type of programmes	Rather unspecific programmes for various items to be cleaned in one cycle	Rather unspecific programmes for various items to be cleaned in one cycle	Specific programmes or specific appliances for different kinds of items to be cleaned.
Detergent dosage	Manual detergent dosing	Manual or automatic detergent dosing	Automatic detergent dosing
Effort for maintenance	Low effort for cleaning of dishwasher	Low effort for cleaning of dishwasher	At least daily cleaning of machine necessary[19]
Power supply, heating system	Normal load connection	Normal or high load connection	Usually high load and three phases (400 V) connection; partly additionally alternative energy sources (steam, gas, warm water connection)
Product categories	Typical dimension: height x width x depth 850 x 600 x 600 mm	Typical dimension: height x width x depth 850 x 600 x 600 mm	Variable dimensions depending on amount and type of items to be cleaned and spatial possibilities.

The table shows that there are only minor differences between household and semi-professional dishwashers (main differences are the shorter running times of the programmes and the possibility to connect to higher load in case of semi-professional dishwashers). However, there are significant differences between household and semi-professional appliances on the one hand and professional ones on the other hand.

[19] According to VGG "Professional dishwashing & hygiene (2006)" machines have to be cleaned carefully after each end of operations (i.e. emptying of the tanks, cleaning of the interiors, the filter systems, the water intake and outlet, the partition curtains and the spraying systems). The reason is to avoid depositions in the machine and on the washware as these might accelerate the settling and breeding of microorganisms. (see http://www.vgg-online.de/download/merkblaetter/Gewerbliches_Geschirrspuelen_und_Hygiene.pdf)

After this general delimitation of professional dishwashers, the following sections describe the individual professional products in more details.

2.5 Classification of professional dishwashers

2.5.1 The European PRODCOM classification

PRODCOM is a system for the collection and dissemination of statistics on the production of manufactured goods. It is based on a product classification called the Prodcom List of the European Community[20] which consists of about 4 500 headings relating to manufactured products. The products are detailed on an 8-digit level; digits 1 to 4 refer to the NACE classification in which the producing enterprise is normally classified. Further to the 2008 review of the NACE codes, the following table lists the code classifications PRODCOM List 2009.

Table 2 Extract from PRODCOM list 2009 (Source: Eurostat)

Code	Description
28.29	Manufacture of other general-purpose machinery n.e.c.
28.29.50	Dish washing machines, of the industrial type
28.29.50.00	Non-domestic dish-washing machines
28.29.85	Parts of dish washing machines and machines for cleaning, filling, packing or wrapping
28.29.85.10	Parts of dish washing machines

From a practical point of view and against the overall aim of the preparatory study, the table shows that PRODCOM categorisations will be too rough to provide a basis for defining a clear scope of professional dishwashers. For example, among the dishwashers there is no further differentiation with regard to capacity or other functional performance parameters.

2.5.2 The European customs classification

The *Harmonized Commodity Description and Coding System (HS)* of tariff nomenclature is an internationally standardized system of names and numbers for classifying traded products developed and maintained by the World Customs Organization (WCO). The HS Nomenclature comprises about 5 000 commodity groups. The HS is a six-digit nomenclature. The first four digits are referred to as the heading. The first six digits are known as a subheading. Individual countries may extend a HS number to eight or ten digits for customs or export purposes. On the basis of the Harmonized System nomenclature, there is further comprised

[20] http://epp.eurostat.ec.europa.eu/portal/page/portal/prodcom/introduction

the *Combined nomenclature (CN)*[21] which is used to classify goods when being declared to customs in the Community. Each CN subdivision has an eight digit code number, the CN code, followed by a description. The CN also include preliminary provisions, additional section or chapter notes and footnotes relating to CN subdivisions.

According to the European customs classification, the following product categories for dishwashers are distinguished. As for the PRODCOM list, this classification is not detailed enough for the purposes of EuP Lot 24.

Table 3 Classifications of dishwashers according to the HS-Classification (Source: World Customs Organisation[22])

Code	Description
84.22	Dishwashing machines; machinery for cleaning or drying bottles or other containers; machinery for filling, closing, sealing or labelling bottles, cans, boxes, bags or other containers; machinery for capsuling bottles, jars, tubes and similar containers; other packing or wrapping machinery (including heat-shrink wrapping machinery); machinery for aerating beverages
	Dishwashing machines
84.22.11.00	Of the household type
84.22.19.00	Other
84.22.20.00	Machinery for cleaning or drying bottles or other containers

The European Customs Classification will be too rough to provide a basis for defining a clear scope of professional dishwashers. For example, there is no further differentiation with regard to capacity or other functional performance parameters.

2.5.3 The International Patent Classification

The International Patent Classification (IPC) is a hierarchical patent classification system created under the Strasbourg Agreement (1971) and updated on a regular basis by a Committee of Experts, consisting of representatives of the Contracting States of that Agreement and observers from other organisations, such as the European Patent Office. The Strasbourg Agreement is one of a number of treaties administered by the World Intellectual Property Organization (WIPO). Patent publications from all of the Contracting States (and also most others) are each assigned at least one classification term, indicating the subject to which the invention relates, and may also be assigned further classification and indexing terms to give further details of the contents.

Each classification term consists of a symbol, such as A01B 1/00. The first letter is the "section symbol" consisting of a letter from A to H[23]. This is followed by a two digit number to

[21] http://ec.europa.eu/taxation_customs/customs/customs_duties/tariff_aspects/combined_nomenclature/index_en.htm

[22] http://www.wcoomd.org/files/1.%20Public%20files/PDFandDocuments/HarmonizedSystem/2007/1684_2007E.pdf

give a "class symbol". The second letter indicates the "subclass" which is then followed by a 1 to 3 digit "group number", an oblique stroke and a number of at least two digits representing a "main group" or "subgroup".[24]

Table 4 Classification of dishwashers according to International Patent Classification (IPC)

A47L 15/00	**Washing or rinsing machines for crockery or table-ware**
A47L 15/02	. with circulation and agitation of the cleaning liquid in the cleaning chamber containing a stationary basket
A47L 15/04	. . by reciprocating movement of the cleaning chamber
A47L 15/06	. . by means of an impeller in the chamber
A47L 15/08	. . by application of a pressure effect produced by pumps
A47L 15/10	. . by introducing compressed air or other gas into the liquid
A47L 15/12	. . by a boiling effect
A47L 15/13	. . using sonic or ultrasonic waves
A47L 15/14	. with stationary crockery baskets and spraying devices within the cleaning chamber
A47L 15/16	. . with rigidly-mounted spraying devices
A47L 15/18	. . with movably-mounted spraying devices
A47L 15/20	. . . Swingable spraying devices
A47L 15/22	. . . Rotary spraying devices
A47L 15/23	. . . . moved by means of the sprays
A47L 15/24	. with movement of the crockery baskets by conveyers
A47L 15/26	. with movement of the crockery baskets by other means
A47L 15/28	. . by lowering and lifting only
A47L 15/30	. . by rotating only
A47L 15/32	. . . rotated by means of spraying water
A47L 15/33	. . . with moving baskets submerged in the cleaning fluid
A47L 15/34	. . by lowering and lifting combined with a rotating movement
A47L 15/36	. . by a sideways motion
A47L 15/37	. with crockery cleaned by brushes
A47L 15/39	. . with brushes on movable supports
A47L 15/42	. Details
A47L 15/44	. . Devices for adding cleaning agents
A47L 15/46	. . Devices for the automatic control of the different phases of cleaning
A47L 15/48	. . Drying arrangements
A47L 15/50	. . Racks

[23] A: Human Necessities; B: Performing Operations, Transporting; C: Chemistry, Metallurgy; D: Textiles, Paper; E: Fixed Constructions; F: Mechanical Engineering, Lighting, Heating, Weapons; G: Physics; H: Electricity

[24] Sources: http://www.wipo.int/export/sites/www/classifications/ipc/en/guide/guide_ipc_2009.pdf, http://en.wikipedia.org/wiki/International_Patent_Classification

The comparison with the former statistical product classification schemes European PRODCOM and Customs classification clearly shows that the IPC scheme offers the most detailed graduation by product design and applications; for example, items A47L 15/42 to A47L 15/50 being parts of professional dishwashers are supplementary parts even not supplied by manufacturers of dishwashers but by different suppliers (e.g. devices for adding cleaning agents are produced by special manufacturers of dosing equipment). The IPC classification provides an overview of the diversity of professional dishwashing appliances. It distinguishes e.g. between machines with stationary and moving baskets (e.g. conveyor-type machines), and provides further details on working techniques of dishwashers (e.g. with or without brushes; different kinds of spraying devices or circulation techniques of the cleaning liquid). .

2.5.4 Categories according to EN- or ISO-standard(s)

There are no EN- or ISO-standards covering professional dishwashers.

The U.S. Energy Star (cf. Section 4.3.1)[25] distinguishes the following four categorisations of professional dishwashers:

- Under Counter Dishwasher: A machine with an overall height 38 inches or less, in which a rack of dishes remains stationary within the machine while being subjected to sequential wash and rinse sprays, and is designed to be installed under food preparation workspaces. Under counter dishwashers can be either chemical or hot water sanitizing, with an internal booster heater for the latter. For purposes of this specification, only those machines designed for wash cycles of 10 minutes or less can qualify for ENERGY STAR.
- Stationary rack, single tank, door type dishwasher: A machine in which a rack of dishes remains stationary within the machine while subjected to sequential wash and rinse sprays. This definition also applies to machines in which the rack revolves on an axis during the wash and rinse cycles. Subcategories of stationary door type machines include: single and multiple wash tank, double rack, pot, pan and utensil washers, chemical dump type and hooded wash compartment (“hood type”). Stationary rack, single tank, door type models are covered by this specification and can be either chemical or hot water sanitizing, with an internal or external booster heater for the latter.
- Single tank conveyor dishwasher: A ware washing machine that employs a conveyor or similar mechanism to carry dishes through a series of wash and rinse sprays within the machine. Specifically, a single tank conveyor machine has a tank for wash water followed by a final sanitizing rinse and does not have a pumped rinse tank. This type of machine may include a pre-washing section before the washing section. Single tank

[25] http://www.energystar.gov/index.cfm?c=comm_dishwashers.pr_crit_comm_dishwashers

conveyor dishwashers can be either chemical or hot water sanitizing, with an internal or external booster heater for the latter.

- Multiple tank conveyor dishwasher: A conveyor type machine that has one or more tanks for wash water and one or more tanks for pumped rinse water, followed by a final sanitizing rinse. This type of machine may include one or more pre-washing sections before the washing section. Multiple tank conveyor dishwashers can be either chemical or hot water sanitizing, with an internal or external booster heater for the latter.

The German standards DIN 10510, DIN 10511, DIN 10512 and DIN 10522 provide another categorisation of professional dishwashing machines (see also Section 3). DIN 10510 and DIN 10512 classify dishwashers according to their construction and working techniques as "multi-tank conveyor-type dishwasher" or "one-tank dishwasher":

- DIN 10510 defines minimum hygiene requirements for multi-tank conveyor-type dishwashers. In these dishwashers, the wash ware is continuously transported through individual treatment zones. Those are usually constructed as chambers, with openings in the transport direction. Multi-tank dishwashers generally comprise at least one pre-cleaning zone using a reservoir tank, one cleaning zone using another reservoir tank and a final rinse zone using fresh water. With regard to the transportation of the wash ware, two construction types are distinguished:
  - Belt conveyor-type dishwasher: The wash ware is automatically transported on a conveyor belt through the machine. (further definition see below, Section 2.5.5.3)
  - Basket conveyor-type dishwasher: The wash ware is put into baskets which are then automatically transported through the machine. (further definition see below, Section 2.5.5.3)
- DIN 10512 defines minimum hygiene requirements for one-tank dishwashers: These dishwashers are professional dishwashers with one cleaning zone using a reservoir tank and a final rinse zone using fresh water. The following sub-categories are differentiated:
  - Manually loaded programme automats: The pre-cleaning of the soiled wash ware takes place manually outside of the dishwasher. The basket(s) are manually loaded and placed into the appliance. The front door or hood is shut and the cleaning cycle is started. Two construction types are distinguished:
    - Front door dishwashers (loaded and unloaded through the front door, further definition see below, Section 2.5.5.3)
    - Pass through dishwashers (loaded and unloaded from two different sides, further definition see below, Section 2.5.5.3)
  - Belt conveyor-type dishwashers
  - Basket (rack) conveyor-type dishwasher.

– Mobile dishwashers for cleaning wash ware on trailers, at festivals etc.

DIN 10511 and DIN 10522 classify the dishwashers according to the type of wash ware and hygienic needs.

- DIN 10511 defines minimum hygiene requirements for glass washing machines: These dishwashers are defined as machines commercially used for washing glasses, having a spray mechanism, a reservoir tank in which detergent solution is collected and a final hot fresh-water rinsing system.
- DIN 10522 defines minimum hygiene requirements with regard to the commercial cleaning of reusable boxes and reusable containers for unpackaged foodstuffs and describes the test procedures for the hygienic operation of dishwashers used for these purposes.

2.5.5 Functional performance classification

Building on the categorisation in the IPC and German DIN standards professional dishwashers are classified in this section according to functional performance parameters. To better understand the differences between the described categories, first of all an overview of the primary and secondary functions and important framework requirements of professional dishwashers is given (Section 2.5.5.1). Then the main properties to distinguish between different professional dishwashers are described (Section 2.5.5.2). Some of these aspects were already shortly described in Section 2.4 on the differences between household and professional dishwashers. Finally, in Section 2.5.5.3, six product categories were identified as a result of this analysis of functions and the respective properties of professional dishwashers.

2.5.5.1 Primary and secondary functions of professional dishwashers

In general, the *primary function* of a dishwasher is to clean, rinse, and dry a certain amount of dishware, glassware, cutlery, and / or cooking utensils by chemical, mechanical, thermal and electric means within a given time and with respect to the spatial possibilities (see definition of dishwashers in Section 2.4). Primary performance parameters are the cleaning and hygienic performance.

Important *secondary functions* that have to be met by professional dishwashers are related to the costs in use, they include:

- short programme duration,
- energy efficiency,
- water efficiency, and
- low detergent consumption.

In contrast to household dishwashers there are some *framework requirements* that have to be taken into account and that vary to a great extent for different customer groups of professional dishwashers. These framework requirements are:

- amount of items to be cleaned,
- types of items to be cleaned, and
- spatial requirements.

While short running cycles are an important requirement for almost each professional application, the other requirements might be very different depending on the application. These variations in the framework requirements that have to be met by professional dishwashers are the main reason for a range of different product categories on the market, compared to e.g. dishwashers for household use which are quite similar regarding the design (i.e. mainly undercounter dishwashers using fresh water for each dishwashing cycle, with a capacity of 12-14 place settings).

2.5.5.2 Main properties of professional dishwashers

The following properties of professional dishwashing can be used to facilitate the classification of professional dishwashers into different categories (see Section 2.5.5.3):

- **Water supply**: water-change operation vs. tank systems (one-tank or multi-tank):

  Devices with *water-change operation* use fresh water for each step of the programme (prewash (optional), cleaning, and final rinsing). They are used in the semi-professional area, where comparatively few wash ware has to be cleaned and time is not as relevant as in the professional areas. In the professional customer segment, the fresh water system is rather seldom. Usually, professional dishwashers are run with tank systems to reduce programme duration.

  Devices with *tank systems* are either one-tank or multi-tank machines. In *one-tank dishwashers* the detergent solution for the cleaning step is stored in a reservoir tank at high temperatures; the final rinsing is conducted with hot fresh water. During operation the detergent solution is circulated through the dishwasher by means of a pump and intensive water filtration takes place. The detergent solution is not changed between two programme cycles, but only partly replaced by hot fresh water from the final rinsing step (so called regeneration of detergent solution). The water in the tank is usually changed once a day or after each working shift. The pre-cleaning is usually conducted manually, e.g. with rinsing hoses before the wash ware is put into the dishwasher. *Multi-tank dishwashers* comprise at least one prewash zone using a reservoir tank, one cleaning zone using a reservoir tank, and a final rinse zone using hot fresh water. Before the items are put into the machine, only loose waste and leftovers are manually removed. Tank dishwashers do not make sense if only a small amount of items has to

be cleaned, as time requirements are usually not as high and tank dishwashers need more effort for the cleaning of the appliance itself.

- **Operating principle of machine dishwashing**: program automats vs. conveyor-type dishwashers

  In case of *program automats* the different steps of the dishwashing process are conducted consecutively. The baskets with the wash ware stay in the same position during the whole dishwashing programme. In case of *conveyor-type dishwashers* the different steps of the dishwashing process are allocated to several individual treatment zones, i.e. the wash ware is transported through these zones, which are constructed as chambers, with openings in the transport direction. Program automats need much less space than the spacious conveyor-type dishwashers. However, the latter allow for continuous dishwashing of large amounts of wash ware in a short time.

- **Type of loading** (with regard to program automats): front loading vs. pass through

  In case of program automats two types can be distinguished: either the basket(s) is/are put into and taken out of the dishwasher from the front (*front loading dishwasher*) or the basket(s) is/are put into the dishwasher from one side and is/are taken out of the dishwasher from the other side (*pass through or 'hood type' dishwasher*). Depending on the spatial requirements, available space and organisation of the dishwashing process (number of personnel, storing capacity of soiled wash ware, hygienic requirements and total amount of wash ware to be cleaned in a certain timeframe), these differences might impact the choice of machine categories by customers: The front loading automats need less space than pass through dishwashers; the latter are ergonomically easier to operate. Further, a separation of a dirty and a clean area is possible when using the pass through type.

- **Type of wash ware**: dishes, glasses, cutlery, pots and pans, utensils, etc.

  Some customers have to clean a certain type of items or use several dishwashers at once (e.g. bars usually mainly have to clean glasses, in large kitchens several dishwashers for different types of wash ware may be used in parallel). This means professional dishwashers are usually more specialised with regard to the wash ware compared to dishwashers for household use. Pot dishwashers for instance operate with extremely high scavenging pressure in order to dissolve incrustations. They can therefore not be loaded with glass or ordinary crockery.

In addition to these distinguishing criteria between different categories of professional dishwashers, dishwashers also vary according to the following criteria. These criteria, however, do not justify further product categories (too little technological difference or these differences inherently come along with one of the above mentioned properties):

- **Means of transport** (relevant for conveyor-type dishwashers): basket vs. conveyor belt

  In case of *basket transport* the items to be cleaned are put into baskets which are transported through the dishwasher. The items can be sorted in advance of dishwashing. In case of *belt conveyor dishwashers*, the items to be cleaned are put directly on a conveyor belt which continuously moves through the dishwasher. The items can either be sorted after dishwashing, when unloading the machine or, if there are several belt conveyor dishwashers for a different kind of items, in advance of the dishwashing process.

- **Number of baskets** that can be cleaned at the same time (relevant for program automats):

  In case of semi-professional program automats with water-change operation (see above), it is possible to put two or three baskets at the same time into the appliance (like in case of dishwashers for household use). In program automats with tank system (front loaders or pass through) usually only one basket can be cleaned as the tank also needs space and only one level for the basket is possible. However, there are also pass through appliances, where two baskets can be cleaned next to each other at the same time. These appliances are like two pass through appliances connected next to each other.

- **Size / format**: undercounter, cupboard size or large conveyor-type dishwashers

  Obviously, the different construction types come along with different sizes and formats of the different dishwashers. Pass through dishwashers are usually cupboard size, whereas front loading devices might be undercounter or also cupboard size.

- **Way of utilisation**: stationary or mobile

  Most professional dishwashers are used stationary in kitchens, bistros or similar locations. There are, however, also dishwashers that can be used on mobile devices (like in vehicles, tents or similar locations). These devices are usually one-tank undercounter front loaders or one-tank pass through dishwashers. There are only minor technological differences to those for stationary use, e.g. they can be operated at lower surrounding temperatures or the water can be removed completely. Therefore dishwashers for mobile use are subsumed under the respective category of dishwashers for stationary use.

2.5.5.3 Categories of professional dishwashers used in Lot 24

The following categories are derived by the authors from the analysis of functions and framework requirements and the respective properties of professional dishwashers in the previous sections (Sections 2.5.5.1 and 2.5.5.2). Also other information (e.g. from the official product categories or from standards) were considered for this categorisation.

These categories form the concluding categorisation that is used for the forthcoming tasks in this preparatory study.

1. Undercounter water-change dishwashers (semi-professional)

These manually, front loaded program automats use fresh water for each step of the programme (prewash (optional), cleaning, final rinsing). They are used in the semi-professional area, where usually only a small amount of wash ware has to be cleaned and time is not as relevant as in the professional context. These dishwashers are very similar to those for household use, whereas main differences namely are shorter programme duration and the possibility to connect them to higher loads (400 V).

The different steps of the dishwashing process are conducted consecutively in time, the baskets with the items to be cleaned staying in the same position during the whole dishwashing programme. Usually two baskets can be put into the dishwasher from the front side.

As for dishwashers for household use, these devices are designed to clean various kinds of items (dishes, cutlery, and glasses) at the same time, i.e. they usually have rather unspecific programmes for general use. They are undercounter dishwashers, with only small differences in size and capacity, which can be sub-categorised in free standing, integrated, fully-integrated and build-in models as in case of dishwashers for household use. Typical dimensions are (height/width/depth): 850 mm (without lit 820 mm)/600 mm/600 mm.

2. Undercounter one-tank dishwashers

These manually front loaded program automats use one reservoir tank with detergent solution for cleaning, and fresh water for the final rinsing. The detergent solution is constantly filtrated / regenerated. The pre-cleaning is usually conducted manually before the items are put into the dishwasher.

The different steps of the dishwashing process are conducted consecutively in time, the baskets with the items to be cleaned stay in the same position during the whole dishwashing programme. Usually only one basket can be placed into the dishwasher (loading and unloading from the front side), as the tank needs space as well. The appliances are undercounter dishwashers that can be constructed as “generalists” for different items (dishes, glasses, and cutlery) or in specialised versions, i.e. only for dishes, for glasses or for cutlery respectively.

3. Hood-type dishwashers

These one-tank pass through dishwashers use one reservoir tank with detergent solution for cleaning, and fresh water for the final rinsing. The detergent solution is constantly filtrated / regenerated. Pre-cleaning is conducted manually, e.g. with rinsing hoses before the items are put into the dishwasher. The different steps of the dishwashing process are conducted

consecutively in time, the baskets with the items to be cleaned stay in the same position during the whole dishwashing programme. The basket(s) is/are put into the dishwasher from one side and is/are taken out of the dishwasher from the other side. Only *one basket* can be cleaned on one level, as the tank also needs space. There are appliances, where *two baskets* can be cleaned next to each other at the same time. The appliances are usually constructed to clean different items: dishes, glasses, cutlery, pots and pans, utensils, etc.

4. Utensil / pot dishwashers

These dishwashers are especially constructed for the cleaning of other items than dishes, glasses and cutlery, i.e. black cookware, pots, pans, containers, trays or other mostly large utensils. The cleaning performance is usually higher, e.g. by means of higher scavenging pressure or other stronger mechanical and chemical treatment.

Two construction types can be distinguished:

- Front loading dishwashers;
- Pass through dishwashers.

Both types are one-tank dishwashers (i.e. they use one reservoir tank with detergent solution for cleaning, and fresh water for the final rinsing, if necessary manual pre-cleaning). The pass-through dishwashers are usually loaded manually, however, some manufacturers offer special roll containers that can be filled outside the machine and then pushed into the dishwasher. The dimensions are often bigger than those of undercounter front loaders or pass through dishwashers for dishes, glasses and cutlery as the items to be cleaned are bulkier, too.

A special type of these dishwashers is the so-called **granulate dishwasher**. In these dishwashers (both front loaders and pass through) the mechanical cleaning is intensified through scouring of the wash ware (mainly black cookware) with plastic granules of different size. A granule collector catches the plastic pellets during the granule washing program. The granules can be subsequently cleaned out in a sink with a pipe-mounted sprayer.

5. One-tank conveyor-type dishwashers

The different steps of the dishwashing process are allocated to several individual treatment zones, i.e. the items to be cleaned are transported through these zones, which are constructed as chambers, with openings in the transport direction. These dishwashers use one reservoir tank for cleaning and fresh water for the final rinsing. Pre-cleaning may be conducted manually. The dishwashers can be used for different wash ware: dishes, glasses, cutlery, black cookware (pots and pans), utensils, etc. Two different transport systems are available:

- In case of the *basket transport system* the wash ware is put into baskets which are transported through the dishwasher. The items can be sorted in advance of

dishwashing. The pre-cleaning is usually conducted manually with rinsing hoses before the items are put into the dishwasher.

- In case of *belt conveyor (also: flight type) dishwashers*, the wash ware is put directly on a conveyor belt which continuously moves through the dishwasher. The items can either be sorted after dishwashing, when unloading the machine or, if there are several belt conveyor dishwashers for a different kind of items, in advance of the dishwashing process. Before the items are put into the machine, usually only loose waste and leftovers are manually removed.

6. Multi-tank conveyor-type dishwashers

The different steps of the dishwashing process are allocated to several individual treatment zones, i.e. the items to be cleaned are transported through these zones, which are constructed as chambers, with openings in the transport direction. These dishwashers comprise at least one prewash zone using a reservoir tank, one cleaning zone using a reservoir tank and a final rinse zone using fresh water. The dishwashers can be used for different wash ware: dishes, glasses, cutlery, black cookware (pots and pans), utensils, etc. As with one-tank conveyor-type dishwashers, two different transport systems are available:

- *Basket transport system* (see above at one-tank conveyor-type dishwashers).
- *Belt conveyor dishwashers* (see above at one-tank conveyor-type dishwashers).

A special type of multi-tank conveyor-type dishwashers are **dishwashers for the commercial cleaning of reusable boxes and containers**. Serially produced dishwashers for standard packaging boxes and container dishwashers can be assigned to the professional dishwashers.

Table 5 Overview of dishwasher categories according to functional and performance parameters

	No 1 Undercounter water-change dishwasher	**No 2** Undercounter one-tank dishwasher	**No 3** Hood-type dishwasher	**No 4** Utensil / Pot dishwasher	**No 5** One-tank conveyor-type dishwasher	**No 6** Multi-tank conveyor-type dishwasher
Main properties						
Water supply	water-change operation	tank system / one-tank	tank system / one-tank	tank system / one-tank	tank system / one-tank	tank system / multi-tank
Operating principle of dishwashing machine	program automat	program automat	program automat	program automat	conveyor-type dishwasher	conveyor-type dishwasher
Type of loading	front loading	front loading	pass through	front loading or pass through	n.a.	n.a.
Type of wash ware to be cleaned	dishes, glasses, cutlery, pots and pans, utensils	mainly plates, glasses, cups, cutlery	mainly plates, glasses, cups, cutlery	black cookware, large utensils	mainly plates, glasses, cups, cutlery, trays	mainly plates, glasses, cups, cutlery, trays
Further properties						
Means of transport	n.a.	n.a.	n.a.	n.a.	basket transport or conveyor belt	basket transport or conveyor belt
Number of baskets to be cleaned at the same time	two or three (on two or three levels)	one (on one level)	one or two (on one level)	one (on one level)	n.a.	n.a.
Size / format	undercounter	undercounter	cupboard size	undercounter or cupboard size	large conveyor-type dishwashers	large conveyor-type dishwashers
Way of utilisation	stationary	stationary or mobile	stationary or mobile	stationary	stationary	stationary
Heat sources	electricity	electricity	electricity	electricity, low pressure steam or hot water	electricity, low pressure steam or hot water, (natural gas)	electricity, low pressure steam or hot water, (natural gas)
Variants	freestanding, built-under, integrated and fully integrated models	freestanding and built-under models		granulate dishwasher for black cookware		dishwashers for cleaning of reusable boxes and containers

n.a. = not applicable

3 Test standards on professional dishwashers

This subtask aims to specify the relevant test standards for professional dishwashers concerning test procedures for functional performance parameters, resource use, safety and hygiene as well as noise and vibrations and (if any) other specific test procedures. A short overview on existing test standards is given, including household standards whose scope has currently been modified to 'household and similar electrical appliances' thus including standardisation work on professional machines.

3.1 Performance

3.1.1 ASTM International Standards (USA / International)

ASTM International (ASTM), originally known as the American Society for Testing and Materials, is an international standards organization that develops and publishes voluntary consensus technical standards for a wide range of materials, products, systems, and services. In 2001, ASTM changed its name to ASTM International to reflect global participation in ASTM and worldwide use of its standards. As of 2007, ASTM has more than 30 000 members, including over 1 100 organizational members from more than 120 countries, including 120 members in China as of 2005. The application of ASTM standards is voluntarily expect for publicly funded areas in the USA [26].

ASTM International has no role in requiring or enforcing compliance with its standards. The standards, however, may become mandatory when referenced by an external contract, corporation, or government. For example, ASTM Standards F1696 and F1920 are referenced in the U.S. ENERGY STAR criteria and used by manufacturers to obtain an ENERGY STAR qualification or rating (cf. Sections 3.1.1.12, 3.1.1.13, and 4.3.1).

The following ASTM International standards refer to professional dishwashers, sorted in ascending order.[27] They have been developed by Technical Committee F26 on Food Service Equipment[28] and belong to the work of the following subcommittees:

---

[26] ASTM standards are voluntary in the sense that their use is not mandated by ASTM. However, government regulators often give voluntary standards the force of law by citing them in laws, regulations and codes. In the United States, the relationship between private-sector standards developers and the public sector has been strengthened with the 1995 passage of the National Technology Transfer and Advancement Act (Public Law 104-113). The law requires government agencies to use privately developed standards whenever it is at all possible. Source: www.astm.org

[27] Source: www.astm.org

[28] "Food service equipment is apparatus intended for use in commercial and institutional establishments for handling, storage, preparation, cooking, holding, display, dispensing, and/or the serving of food which, at the time of serving, is ready for direct consumption on or off the premises. Also included are cleaning, sanitation

- F26.01: Cleaning and Sanitation Equipment (Sections 3.1.1.1 to 3.1.1.11)
- F26.06: Productivity and Energy Protocol (Sections 3.1.1.12 and 3.1.1.13)
- F26.05: Life Cycle Cost and Sustainability (Sections 3.1.1.14 and 3.1.1.15). These two standards generally apply to all product categories subsumed under 'Food Service Equipment' and only refer to the respective product specific standards.

Finally, Section 3.1.1.16 provides an overview to which Lot 24 product categories the ASTM standards correspond and conclusions with regard to the applicability of the standards in the EU.

3.1.1.1 ASTM F857–07

ASTM F857–07: Standard specification for hot water sanitizing commercial dishwashing machines, stationary rack type

This specification covers the material, design, and performance requirements pertinent to the construction of spray-type, stationary rack commercial dishwashing machines that are manually loaded yet automatically controlled to uniformly wash, rinse, and sanitize eating and drinking utensils. Representative production models of the washers shall pass performance, operation, leakage, and energy and productivity tests, and should function satisfactorily as specified. Certification, product marking, and packaging are also considered.

3.1.1.2 ASTM F858–07

ASTM F858–07: Standard specification for hot water sanitizing commercial dishwashing machines, single tank, conveyor rack type

This specification covers single tank, automatic rack type, hot water sanitizing professional dishwashing machines. Covered by this specification are dishwashing machines of various types (types I and II based on feed direction, from right or left, respectively), styles (styles 1 to 3 based on method of heating: steam, electric, or gas), classes (classes A-D based on heat source: injector, heat exchange coil, natural gas, or LP gas), sizes, and capacities. Components comprising the dishwashing machine shall be manufactured from corrosion-resistant steel (tank, scrap trays or strainers, overflow drain, access door/s, and legs), corrosion-resisting materials (conveyor, piping and fittings, valves, and spray assemblies), nickel-copper alloys, and plastics. Pump casings shall be of cast iron or corrosion-resisting material. When specified, the dishwashing machine assembly may include a final rinse booster, detergent feeder, and rinse agent feeder. The dishwashing machine shall be tested for performance standards compliance and noise level as well as for operational, leakage, and performance profile requirements. All tests shall comply with the requirements specified.

---

and ancillary items associated with food preparation and service." Source: http://www.astm.org/COMMIT/SCOPES/F26.htm

3.1.1.3 ASTM F859–09

ASTM F859–09: Standard specification for heat-sanitizing commercial dishwashing machines, multiple tank, conveyor rack type

This specification covers multiple tank automatic rack-type commercial dishwashing machines. Dishwashing machines shall be of various types (types I and II based on feed direction, from right or left, respectively), styles (styles 1 to 4 based on method of heating: steam, electric, or gas; style 4: pre-wash unit), and classes (classes A-D based on heat source: injector, heat exchange coil, natural gas, or LP gas). The standard includes requirements with regard to construction; electrical, steam and gas equipment; lubrication; treatment and painting; and performance.

3.1.1.4 ASTM F860–07

ASTM F860–07: Standard specification for hot water sanitizing commercial dishwashing machines, multiple tank, rackless conveyor-type

This specification covers multiple-tank, automatic rackless conveyor-type, commercial dishwashing machines. These machines can be classified into various types (types I and II based on feed direction, from right or left, respectively), styles (styles 1 to 4 based on method of heating: steam, electric, or gas), and classes (classes A-D based on heat source: injector, heat exchange coil, natural gas, or LP gas). In addition, these dishwashing machines can be classified into three groups A to C according to size and capacity. The standard includes several requirements: Materials used in the manufacture of these machines shall consist of corrosion-resistant steel, corrosion resisting material, nickel-copper alloy and plastics. The dishwashing machine shall be complete so that when connected to the specified source of power, water supply, heating means (steam, electric, or gas), drainage, detergent, and rinse agent feeder as applicable, the unit can be used for its intended function. Dishwashers shall be rigid, quiet in operation, free from objectionable vibration, and so constructed as to prevent objectionable splashing of water to the outside of the machine. Operational test, leakage test, and performance profiles shall be done in order to determine the overall efficiency of the dishwashing machine.

3.1.1.5 ASTM F953–08

ASTM F953–08: Standard Specification for Commercial Dishwashing Machines (Stationary Rack, Dump Type) Chemical Sanitizing

This specification covers manually fed, spray-type, stationary rack, automatically controlled, dump type, chemical sanitizing commercial dishwashing machines. Dishwashing machines shall be of the following types, styles, classes: Type I - straight-through model. This machine is used in line with table on each side; Type II - corner model. Type III - undercounter, front

load. Style A - single rack, and Style B - double rack. This standard includes several requirements: No leakage shall occur when tested at pressures up to 125% of the manufacturer's recommended supply line pressure. The dishwasher materials, construction, operation cycle, electrical equipment, lubrication, and coating shall meet the requirements prescribed.

3.1.1.6 ASTM F1021–95(2007)

ASTM F1021–95(2007): Standard specification for feeders, detergent, rinse agent, and sanitizing agent for commercial dishwashing and glasswashing machines

This specification covers detergent feeders, rinse additive feeders, and sanitizing agent feeders intended to automatically maintain the concentration of additives in the wash, recirculated rinse, or non-recirculated rinse water of commercial spray-type dish-washing and glasswashing machines. Detergents, rinse additives, and sanitizing agent feeders are classified according to different types and styles. Materials used shall be free from defects that would adversely affect the performance or maintainability of individual components or of the overall assembly. The feeder shall be complete so that when connected to the specified source of power (electrical or water, or both), the unit can be used for its intended function. Feeders shall be tested in accordance with specified requirements.

3.1.1.7 ASTM F1022–06

ASTM F1022–06: Standard specification for chemical sanitizing commercial dishwashing machines, recirculated wash, fresh water rinse type

This specification covers manually fed, spray-type, stationary rack, automatically controlled chemical sanitizing commercial dishwashing machines. These machines can be classified into two types: Type I is used in line with the table on each side and Type II is used in corner placement forming a 90° side. In terms of mode of heating, there are three styles of dishwashing machines: Style 1 is steam heated with two classes namely Class A which uses injector and Class B which uses heat exchange coil; Style 2 is electrically heated; and Style 3 is gas heated with two classes namely Class C which uses natural gas and Class D which uses LP gas. The standard includes several requirements: Materials used shall be free from defects that would adversely affect the performance or maintainability of individual components of the overall assembly. These materials shall consist of corrosion-resistant steel, corrosion-resisting material, and nickel-copper alloy. The dishwashing machine shall be complete so that when connected to the specified source of power, water supply, heating means (steam, electric, or gas), drainage, detergent, sanitizer and rinse agent feeder as applicable, the unit can be used for its intended function. Dishwashers shall be rigid, quiet in operation, free from objectionable vibration, and so constructed as to prevent objectionable splashing of water or overflow of water to the outside of the machine. Parts requiring adjustment or service, or both shall be readily accessible. Requirements of electrical

equipment, gas equipment, steam equipment, lubrication, and painting for the dishwashing machine are specified.

3.1.1.8 ASTM F1114–06

ASTM F1114–06: Standard Specification for Heat Sanitizing Commercial Pot, Pan, and Utensil Station Rack Type Water-Driven Rotary Spray

This specification covers material, design, and performance requirements pertinent to the construction of water-driven rotary spray type, stationary rack commercial pot, pan, and utensil washing machines that are manually loaded yet automatically controlled to uniformly wash, rinse, and heat-sanitize food preparation utensils. Representative production models of the washers shall pass performance, operation, leakage, and energy and productivity tests, and should function satisfactorily as specified. Certification, product marking, and packaging are also specified.

3.1.1.9 ASTM F1202–06

ASTM F1202–06: Standard Specification for Washing Machines, Heat Sanitizing, Commercial, Pot, Pan, and Utensil Vertically Oscillating Arm Type

This specification covers the requirements for manually fed, motor-driven vertically oscillating arm type, automatically controlled, commercial pot, pan, and utensil washing machine (also referred to as "the washer"). The washer is of one rack capacity (Type I) and is available in either Style A (one door/front loading) or Style B (three door/pass-through with front load door). Heat shall be provided to the washer through steam (Style 1) by injection (Class A) or heat exchange coil (Class B) or through electric means (Style 2). The standard includes several requirements: The washer and its components shall be manufactured free of defects. Piping and fittings shall be manufactured from corrosion-resisting material or heat-resisting plastic material. Valves, spray assemblies, and overflow drain shall be manufactured from corrosion-resisting materials. Tank and housing shall be constructed of corrosion-resistant steel. Scrap trays (strainers), access door/s, and legs shall be constructed of corrosion-resistant steel or other corrosion-resisting material. The pump motor shall be mounted on the tank or rigid steel base, with the pump casing being of cast iron or corrosion-resisting material. When specified, a final rinse booster heater and/or detergent feeder may be provided. The washer shall be operated at ambient room temperature. Tests for performance standards and operational compliance as well as for noise level, leakage, energy, and productivity requirements shall be performed and shall conform to the requirements specified.

3.1.1.10 ASTM F1203–06

ASTM F1203–06: Standard specification for washing machines-pot, pan, and utensil, heat sanitizing, commercial rotary conveyor-type

This specification covers manually loaded, motor-driven rotary conveyor-type, automatically controlled, commercial pot, pan, and utensil washing machines. The washer shall be of the following type, and class as specified. Motor-driven continuous rotary conveyor: Type I - one door (front loading); Type II - one or two door (pass-through corner operation); and Type III - one or two door (pass-through straight line operation). Style and class: Style 1 - steam heated; Style 2 - electric heat; Class A - injection; and Class B - heat exchange coil. The design, construction, and performance requirements of the washing machine are presented in details. The operational test; leakage test; and energy and productivity test shall be performed to meet the requirements prescribed.

3.1.1.11 ASTM F1237–09

ASTM F1237–09: Standard specification for commercial dishwashing machines, multiple-tank, continuous oval-conveyor-type, heat sanitizing

This specification covers commercial multiple-tank dishwashing machines of the continuous type, oval shaped, with horizontal table conveyor systems. According to direction of rotation, the dishwashing machines can be classified into two types: Type I-CW (clockwise) rotation is designed and supplied to accept the feeding of soiled wash ware from the right side, when viewed from above and Type II-CCW (counter clockwise) rotation is designed and supplied to accept the feeding of soiled wash ware from the left side.

These dishwashing machines can also be classified into three styles: Style 1 is a steam heated machine, with two classes (Class A using injectors, Class B heat exchange coils). Style 2 is an electrically heated dishwashing machine. Style 3 on the other hand is gas heated with two classes (Class C using natural gas, Class D LP gas).

The standard includes several requirements: Materials used in the manufacture of these machines shall consist of corrosion-resistant steel, corrosion resisting material, nickel-copper alloy and plastics. These materials used shall be free from defects that would affect the performance or maintainability of individual components of the overall assembly. The dishwashing machine shall be complete so that when connected to the specified source of power, water supply, heating means (steam or electric) and drainage, detergent and rinse agent feeder as applicable, the unit can be used for its intended function. Dishwashers shall be quiet in operation, free from objectionable splashing of water to the outside of the machine. Operational test, leakage test, and performance profiles shall be done.

3.1.1.12 ASTM F1696–07

ASTM International F1696–07: Energy performance of single-rack, door-type commercial dishwashing machines

This test method covers the evaluation of the energy and water consumption of single-rack, door-type commercial dishwashers (hereafter referred to as dishwashers). It is applicable to

both hot water sanitizing and chemical sanitizing stationary rack machines, which include undercounter single rack machines; upright door-type machines; pot, pan, and utensil machines; fresh water rinse machines; and fill-and-dump machines. Dishwashers may have a remote or self-contained booster heater[29]. Dishwasher tank heaters are evaluated separately from the booster heater. The following procedures are included in this test method:

- Procedures to confirm dishwasher is operating properly prior to performance testing:
  - Maximum energy input rate of the tank heaters.
  - Maximum energy input rate of the booster heater, if applicable.
  - Water consumption calibration.
  - Booster temperature calibration, if applicable.
  - Wash tank temperature calibration.
- Energy consumption (kWh/rack) and cycle rate (racks/h) performance tests:
  - Washing energy test.
  - Tank heater idle energy rate (door(s) open and door(s) closed).
  - Booster idle energy rate, if provided.

This test method does not address cleaning or sanitizing performance[30]. This standard does not address safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3.1.1.13 ASTM F1920–07

ASTM International F1920–07: Standard test method for performance of rack conveyor, commercial dishwashing machines

This standard is equivalent to ASTM International F 1696–07, i.e. it evaluates the energy and water consumption of rack conveyor, professional dishwashing machines, hereafter referred to as dishwashers. It is applicable to both hot water sanitizing and chemical sanitizing rack conveyor machines, which include both single tank and multiple tank machines. Dishwashers may have remote or self-contained booster heater[29]. Dishwasher tank heaters are evaluated separately from the booster heater. The following procedures are included in this test method:

- Procedures to confirm that the dishwasher is operating properly prior to performance testing:

[29] Booster heater: water heater for taking supply hot water (typically 140°F / 60°C) up to 180°F / 82°C for sanitizing rinse; the booster heater may be separate from dishwasher or integrated.

[30] I.e. the wash ware used for testing the energy consumption per rack is not soiled at all.

  - Maximum energy input rate of the tank heaters.
  - Maximum energy input rate of the booster heater, if applicable.
  - Final sanitizing rinse water consumption calibration.
  - Booster temperature calibration, if applicable.
  - Wash tank temperature calibration.
  - Wash tank pump and conveyor motor calibration.
- Energy consumption (kWh/rack) and cycle rate (racks/h) performance tests
  - Washing energy performance test.
  - Tank heater idle energy rate.
  - Booster idle energy rate, if provided.

This procedure does not address cleaning or sanitizing performance[30]. This standard does not address safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3.1.1.14 ASTM F2687–07

ASTM F2687–07: Standard practice for life cycle cost analysis of commercial food service equipment

This standard practice[31] for life cycle cost (LCC analysis of commercial food service equipment is designed for producers and end-users to utilize when forecasting and (or) evaluating the life cycle costs of equipment by accounting for tangible differences in operating and maintenance costs of commercial food service equipment[32]. Inter alia, the standards refer to “F1696 Test Method for Energy Performance of Single-Rack, Door-Type Commercial Dishwashing Machines” and “F1920 Test Method for Performance of Rack Conveyor, Commercial Dishwashing Machines”.

The standard practice provides a detailed list of terminology with regard to specific cost factors and other parameters like lifespan or consumption values being relevant for calculating life cycle costs. A procedure to calculate the LCC is proposed, a tabular sample of a spreadsheet-based tool provided by the North American Association of Food Equipment Manufacturers (NAFEM) is shown in the appendix.

Major categories included in this analysis include total purchase price, service and repair costs, preventative maintenance costs, utility operating costs and disposal costs. The results

[31] A standard practice by ASTM defines a sequence of operations that, unlike a standard test method, does not produce a result.

[32] A range of product groups, inter alia professional dishwashing machines as covered by ASTM standards F1696 and F1920 (single-rack door-type and rack conveyor commercial dishwashing machines).

may be quantified as a yearly running total and a net present value. Inputs for this life cycle analysis will need to come from a variety of sources, including manufacturers, service agents, utility companies, and end users.

Results of the analysis detailed in this standard practice are intended for budgetary purposes. The results may also be used to compare projected life cycle cost of different models from a single manufacturer, or models manufactured by multiple suppliers, or to establish when it is cost effective to replace specific equipment versus incurring continued maintenance expenses.

3.1.1.15 ASTM WK24910

ASTM WK24910 – New practice for determining the sustainability rating of commercial food service equipment (status: draft under development)

This standard practice[31] for determining the sustainability rating of commercial food service equipment[32] is designed for producers and end-users to identify the environmental impact of using the equipment in a green building project.

Major categories included in this analysis include total recycled content of materials, impact of materials used in the construction of the equipment, energy consumption of the equipment and water consumption of the equipment. The results may be combined with life cycle cost analysis to present a complete environmental impact of using a particular piece of commercial food service equipment in an operation. To calculate the life cycle analysis, inputs have to be gathered from a variety of sources, including manufacturers, service agents, utility companies, and end users. Not all proposed input variables need to be considered for effective analysis.

The commercial food service industry is continually being challenged to assess the total environmental impact of their equipment. The new ASTM practice intends to provide a consistent framework for developing a sustainability rating of the equipment that can be used to compare equipment models and vendors for green buildings.

3.1.1.16 ASTM – summarizing conclusions

ASTM standards correspond to the following professional dishwasher categories as defined in Lot 24:

Table 6 Corresponding Lot 24 dishwasher categories of ASTM standards

Lot 24 categories	Corresponding ASTM standards[33]	
Cat. 1: Undercounter water-change	F1696 Hot water sanitizing / chemical sanitizing; stationary single-rack door type: fresh water rinse machines	
Cat. 2: Undercounter one-tank	F1696 Hot water sanitizing / chemical sanitizing; stationary single-rack door type: undercounter single-rack machines	
Cat. 3: Hood-type dishwasher	F1696 Hot water sanitizing / chemical sanitizing; stationary single-rack door type: upright door-type machines	
Cat. 4: Utensil/pot dishwasher	F1114 Heat sanitizing, stationary rack; pot, pan and utensil washing machines; water driven rotary spray F1202 Heat sanitizing; pot, pan and utensil washing machines; motor-driven vertically oscillating arm type F1696 Hot water sanitizing / chemical sanitizing; stationary single-rack door type: pot, pan and utensil machines	
Cat. 5: conveyor-type, one-tank	F858 Hot water sanitizing, single tank, automatic conveyor rack type F1203 Heat sanitizing; pot, pan and utensil washing machines; motor-driven rotary conveyor type F1920 Hot water sanitizing / chemical sanitizing; rack conyeyor; single tank machines	
Cat. 6: conveyor-type, multi-tank	F859 Heat-sanitizing, multiple tank, automatic conveyor rack type F860 Hot water sanitizing, multiple tank, automatic rackless conveyor type F1237 Heat sanitizing; multiple tank, continuous - oval shaped - conveyor type F1920 Hot water sanitizing / chemical sanitizing; rack conyeyor; multiple tank machines	
Cat. 1-4	F857 Hot water sanitizing, stationary rack type	
Cat. 1-6	F2687 Standard practice for life cycle cost analysis of commercial food service equipment WK24910 New practice for determining the sustainability rating of commercial food service equipment	
-* -*	F953 F1022	Chemical sanitizing, stationary rack, dump type Chemical sanitizing, stationary rack, fresh water rinse type

** Note: Lot 24 does not take into account chemical sanitizing machinery*

Summarizing, ASTM standards cover material, design, and performance requirements for the different dishwasher categories addressed. The standards are typically used by end-use customers such as the federal government when purchasing products from manufacturers. They are a means to ensure the customers receive a consistent product each time they place an order. The standards include the following issues:

[33] Note: ASTM standards operate with hot water *sanitizing* processes in comparison to Lot 24 dishwashers being defined as machines operating with cleaning principle (cf. Task 6 for details)

- Description of the material, design and construction requirements such as metal types and thickness.
- Descriptions of the different styles such as straight thru and corner type.
- Various heat sources such as electric, steam or gas.
- Details that should be specified when ordering a dishwasher.
- Performance requirements stating the machines must conform to the requirements of Organisational Safety and Health Administration (OSHA), UL 921 (safety requirements, see Section 3.3.3), and NSF/ANSI 3 (hygienic performance, see Section 3.2.2).
- Maximum noise level of the dishwasher only, when operating, exclusive of loading, unloading, and servicing.
- Requirements for appropriate markings such as the operating times, temperatures, etc.

Finally, there is typically a reference to performance profiles such as operating energy consumption, water consumption, and productivity.

ASTM specifications apply to hot water and chemical *sanitizing* machines (for further details: see Task 6). These machines and processes, commonly used on the US market, generally require higher (sanitizing) temperatures compared to the (cleaning) temperatures of dishwashers in Europe[34]. This higher thermal minimum requirement results in higher energy consumption and lower efficiency, respectively. Therefore the ASTM standards are regarded to be not appropriate to cover European requirements and market trends and are not applied by European manufacturers.

3.1.2 IEC and European harmonised standards EN 50242 / 60436

EN 50242:2008-09, EN 60436:2008-09 Electric dishwashers for household use – Methods for measuring the performance (IEC 60436:2004, modified)

This standard is the main harmonised international standard regarding the performance measurement of household dishwashers. It is valid for electric mains-operated household dishwashers. The standard is used to measure the information required by Commission Directive 97/17/EC implementing Council Directive 92/75/EEC with regard to energy labelling of household dishwashers. In summary this standard defines the general test conditions and specific test methods for the following information:

- cleaning performance,

[34] Hot water sanitizing: according to NSF/ANSI minimum washing temperatures of 66 to 74°C required depending on the dishwashing machine category; cleaning: according to DIN 10512 washing temperatures of 60 to 65°C required, see Section 3.2.4.

- drying performance,
- energy consumption,
- water consumption,
- time, and
- airborne acoustical noise (reference to IEC 60704-3).

For measuring each of the information, the same programme has to be used.

Since adoption of IEC 60436 in 2004, the standard has repeatedly been amended and modified, currently IEC 60436 amendment 1 / edition 3.0 from 16.09.2009 being in effect. Following activities are ongoing:

a) In July 2012 IEC 60436 amendment 2 / edition 3.0 is expected to be first published[35]. By parallel voting, this amendment shall be adopted in EN 50242. It is expected that the corrected draft version (CDV) will be circulated in March 2011. If no comments will be done the phase for final draft for decision (FDIS) could be skipped and the publishing can be done already by the end of 2011. Changes to be discussed are for example the use of another dishwasher model as reference machine for the performance measurements, another load scheme for the oven for burning the soil of the washware and the replacement of some parts of the standard washware (cutlery, small bowl, as the former are not produced anymore).

b) Further, IEC currently works on a revision of the third into the IEC 60436 fourth edition; this would result in a completely revised measurement method, e.g. with regard to the load (new: including pots, pans and plastic materials). This revision will come into effect in a time period of 3 to 5 years. In this edition, the scope of the standard will be extended to 'electric dishwashers for household *and similar use",* i.e. covering household appliances being used in a commercial context, e.g. in offices.

c) The Technical Committee CENELEC TC 59X "Performance of household and similar electrical appliances" is the body responsible for providing harmonized standards in support of European legislation. CENELEC/TC59X dealing with the standards EN 50242 / 60436 on household dishwashers has been currently mandated (no. M481) by the European Commission to review the standards with regard to

   1. the adoption of Commission Regulations 1059/2010 and 1016/2010 on eco-design and energy labelling,
   2. the inclusion of low power modes and partial mode in the calculation of the energy efficiency index.

d) In 2009, TC59X settled two Sub Working Groups with the scope to develop performance standards for laundry machines for commercial use

[35] http://www.iec.ch/dyn/www/f?p=103:38:0::::FSP_ORG_ID,FSP_LANG_ID,FSP_PROJECT:1389,25,IEC 60436 am2 Ed. 3.0

(CLC/TC59X/SWG1.12) and for dishwashing machines for commercial use (CLC/TC59X/SWG2.1). The TC59X SWG2.1 kick off meeting held at 6 January 2011 aimed to present a project related to the energy consumption measurement of professional dishwashers. The next meeting will be on 24 February 2011. Points for discussion are

1. an analysis of the mandate M481 (in order to clarify that it is not related to professional dishwashers),
2. a comparison between ASTM (F1696) standard and the European household dishwasher standard EN 50242.
3. a discussion on how to consider a currently proposed document by EFCEM for a new performance measurement methodology for professional dishwashers (see Section 3.1.3.1 below).

The standard project is divided into two parallel parts: the first one is related to the measurement procedure of the energy consumption (appliance, environmental condition etc.), the second one is related to the performance test (hygienic test or similar which has to be developed). The time plan will be discussed in SWG 2.1. In a first step, the scope of the standard will only cover undercounter and hood type dishwashers.

To coordinate the norm activities of national and European standardisation bodies in parallel, in Germany, within the DKE[36] a national working group on professional dishwashers has been constituted as mirror committee to promote CENELEC/TC59X work on the performance of household and similar electrical appliances.

According to stakeholder information it is impractical to apply harmonised standards EN 50242 / 60436 to professional dishwashers as the defined soiling of the items is mainly related to the soiling in household use (the soiled wash ware undergoes an oven drying procedure for two hours to simulate stubborn soiling). In professional use, the dry-on time is usually very short (less than two hours at room temperature). Thus, the soil remains relatively soft and can be washed-off rapidly. The programs of professional dishwashers are adjusted to this kind of soiling. Measurement with EN 50242 / 60436 would therefore lead to rather poor cleaning performance of professional dishwashers which would not reflect real performances during use. Further, the kind of standard soiling (spinach) is for example not representative for specialized professional dishwashers like glasswashers. Finally, the standard measurement method includes a reference machine for household use being only

[36] DKE: Deutsche Kommission Elektrotechnik Elektronik Informationstechnik im DIN und VDE (German Commission for Electrical, Electronic & Information Technologies of DIN and VDE)

limited comparable to professional machines. Due to these inappropriate test procedures, up to now this test has not been applied to professional dishwashers.

An appropriate standard for measuring the performance of professional dishwashers does not exist at EU level. Manufacturers use internal test procedures which allow direct comparison between models of similar performance characteristics. However, these are not suitable for a performance classification of professional dishwashers because of insufficient reproducibility.

3.1.3 Work on development of new performance standards for professional dishwashers

3.1.3.1 By EFCEM (Europe)

Within the European Federation of Catering Equipment Manufacturers (EFCEM), a European Working Group is organised: „Energy Performance Standards Committee“. The goal is to develop a new standard on the cleaning performance and energy efficiency of professional dishwashers.[37] CECED Italia as member of EFCEM has proposed a draft standard for measuring the energy consumption (based on ASTM F1696-07), the washing performance (derived from EN 50242), and rinsing performance. The document proposed in EFCEM has been discussed at EFCEM meeting on 17 February 2011 and is intended to be published in order to consider and discuss it officially in TC 59X SWG 2.1 (see Section 3.1.2 above)

The German industry association HKI (Industrieverband Haus-, Heiz- und Küchentechnik e.V.), representing some manufacturers of professional dishwashers, has asked to exclude the category “utensil/pot dishwashers” from the scope of this standard as the proposed soiling of wash ware within the measurement method is not applicable for heavily soiled pots and utensils; due to this reason, a working group within HKI started to prepare a proposal for a separate performance standard on utensil/pot dishwashers (see next Section 3.1.3.2),

3.1.3.2 By DIN (Germany)

Based on the work of EFCEM on the development of a new standard on the cleaning performance and energy efficiency of professional dishwashers (see Section 3.1.3.1 above) the German industry association HKI (Industrieverband Haus-, Heiz- und Küchentechnik e.V.) asked to exclude the category “utensil/pot dishwashers” from the currently proposed measurement method. Due to the heavy soiling of pots and utensils compared to usual wash ware like dishes, cutlery or glasses, the defined soiling requirements of the proposed standard measurement method will not be applicable.

[37] Input by HKI Industrieverband e.V. as a member of EFCEM.

As customers nevertheless demand for independent tests for this product category, in Germany TÜV Süd tests utensil/pot dishwashers based on an own measurement method adapted to the conditions for those appliances. Based on this method, HKI has prepared a proposal for a separate standard measurement method specifically for utensil/pot dishwashers (for appliances both with and without granules). The standard shall comprise measurement of energy and water consumption and hygienic performance. The HKI working group working on the proposal is supported by several manufacturers (Miele, Ecolab, Granuldisk, Scandisk (German branch of Wexiödisk)), VDE and TÜV Süd[38]. According to HKI, the further proceedings of the proposed standard depend on the decision if this product category is being included in the scope for eco-design measures.

3.1.4 Further used or adapted performance testing methods

3.1.4.1 By DTI (Denmark)

The Danish Technological Institute (DTI)[39] has tested the energy and water consumption and cleaning performance of ten hood-type dishwashers using the following measurement method: „VGG Prüfverfahren zur Reinigungs-Index-Bestimmung von gewerblichen Geschirrspülmaschinen, Blatt 1 Kleinmaschinen; Entwurf 1970, ergänzt 1973“, with some modifications (for details, cf. Annex, Section 7.3).[40] These modifications follow as far as possible the European standard EN 50242 for household dishwashers.

Since three years, the laboratory has tested hood type dishwashers. The test started as a project for the Danish Energy Association (the association of Danish electric energy producing companies) in an energy saving programme for the Government. The idea was to have a list of a number of tested hood-type dishwashers with a data sheet for each machine showing consumption and performance parameters to help persons buying those appliances to select the machine appropriate for their needs and to make the manufacturers compete in delivering the most efficient dishwasher to the market. Meanwhile, manufacturers of dishwashers can at any time ask the laboratory to test (for their own cost) their new machines or programmes and after reviewing the test results they can ask the DTI to place the data sheet on the web site of the Danish Energy Association. They may also have older datasheets exchanged with new ones.

---

[38] TÜV Süd (TÜV = Technischer Überwachungsverein) is a testing and inspection organization providing consulting, testing, certification and training services to their clients.

[39] www.dti.dk

[40] The following information is based on personal communication with Danish Technological Institute

At the beginning, 10 machines have been tested. The mean values of the results are provided in the Annex, Section 7.3; some of the original datasheets and a number of datasheets for professional dishwashers tested later also can be found on the internet.[41]

At the interim and final EuP Lot 24 stakeholder meeting on professional dishwashers,[42] some stakeholders argued that the VGG methodology had not been updated in a long time and should be ignored (low repeatability), and that discussions should now take place within CENELEC. However, DTI argued that in their tests, the repeatability was sufficient for energy and water consumption and that the soiling method of VGG is today's only applicable soiling method for professional dishwashers.

3.1.4.2 By ENAK (Switzerland)

ENAK[43] (Energetischer Anforderungskatalog an Geräte für die Verpflegung und Beherbergung) is an association for the promotion of the energy efficiency of professional appliances in the business sectors hotels, catering and communal feeding. ENAK supports the provision of energy efficient exemplary appliances and their rational use. Members of ENAK are designers, users, engineers and manufacturers.

ENAK seeks to provide transparency with regard to comparable data for consumption[44] and standby values of professional dishwashers. Thus, ENAK has developed specific test definitions for the measurement of different professional dishwasher categories (undercounter, hood-type, pot/utensil, conveyor-type (basket / belt) dishwashers). To some extent, they are based on IEC 60436 "Methods for measuring the performance of electric dishwashers" (cf. Section 3.1.2).

At ENAK's homepage there is no public access to further information with regard to the detailed measurement method or data on tested appliances.

41 www.sparelisten.dk/spareopvaskemaskiner, select "Sparelisten"

42 http://www.ecowet-commercial.org/open_docs/Minutes_Final%20SH%20meeting%20dishwashers_09.12.2010.pdf

43 www.enak.ch

44 Regarding the cleaning performance, ENAK only carries out very few tests due to the high costs for this test.

3.2 Hygiene

3.2.1 ISO 15883 (International)

- ISO 15883-1 Washer-disinfectors – Part 1: General requirements, terms and definitions and tests:

  This norm specifies general performance requirements for washer-disinfectors and their accessories that are intended to be used for cleaning and disinfection of re-usable medical devices and other articles used in the context of medical, dental, pharmaceutical and veterinary practice. It specifies performance requirements for cleaning and disinfection as well as for the accessories which can be required to achieve the necessary performance. The methods and instrumentation required for validation, routine control and monitoring and re-validation, periodically and after essential repairs, are also specified. ISO 15883-1:2006 does not specify requirements intended for machines for general catering purposes.

- ISO 15883-2:2006 Washer-disinfectors – Part 2: Requirements and tests for washer-disinfectors employing thermal disinfection for surgical instruments, anaesthetic equipment, bowls, dishes, receivers, utensils, glassware, etc.:

  This norm specifies particular requirements for washer disinfectors that are intended for use for the cleaning and thermal disinfection, in a single operating cycle, of re-usable medical devices such as surgical instruments, anaesthetic equipment, bowls, dishes and receivers, utensils and glassware.

- ISO 15883-3:2006 Washer-disinfectors – Part 3: Requirements and tests for washer-disinfectors employing thermal disinfection for human waste containers:

  This norm specifies particular requirements for washer-disinfectors that are intended to be used for emptying, flushing, cleaning and thermal disinfection of containers used to hold human waste for disposal by one operating cycle.

- ISO 15883-4:2008 Washer-disinfectors – Part 4: Requirements and tests for washer-disinfectors employing chemical disinfection for thermo-labile endoscopes:

  This norm specifies the particular requirements, including performance, for washer-disinfectors that are intended to be used for cleaning and chemical disinfection of thermo-labile endoscopes. It also specifies the performance requirements for the cleaning and disinfection of the washer-disinfector and its components and accessories which may be required to achieve the necessary performance. The methods, instrumentation and instructions required for type testing, works testing, validation (installation, operational and performance qualification on first installation), routine control and monitoring and re-validation, periodically and after essential repairs, are also specified.

- ISO/TS 15883-5:2005 Washer-disinfectors – Part 5: Test soils and methods for demonstrating cleaning efficacy:

  This standard includes the test soils and methods that can be used to demonstrate the cleaning efficacy of washer-disinfectors. Acceptance criteria are included, based on visual inspection and/or a microbiological end-point as stated for each method. Where chemical detection of residual soiling is required / sought, methods can be complemented by the specific determination of a residual component of the applied test soil.

ISO 15883 is a special standard for washer-disinfectors. Washer disinfectors are used in medical as well as pharmaceutical applications (e.g. healthcare facilities or laboratories) to either prepare goods (e.g. surgery instruments, utensils, anaesthesia sets, and glassware) for later autoclaving (i.e. to remove residues like blood, protein) or to disinfect (semi sterilize) goods for later use. Temperatures range from 40 to 100°C.

According to the definition of professional dishwashers provided in Section 2.4, the scope of Lot 24 is on machines being used to clean, rinse, and dry wash ware like dishware, glassware, cutlery, and other utensils *that are connected to the preparation, cooking, arrangement or serving of food (including drinks)*. Thus, washer disinfectors do not fall under the scope of this preparatory study. The standard has been listed for completeness with regard to hygienic requirements.

3.2.2 NSF/ANSI 3–2009 (International / USA / Canada)

NSF/ANSI 3-2009: Commercial warewashing equipment

NSF/ANSI 3-2009 standard establishes minimum public health and sanitation requirements for the materials, design, construction, and performance of commercial spray-type dishwashing, glasswashing, and pot, pan, and utensil washing machines

It applies to commercial dishwashing, glasswashing, and pot, pan and utensil washing machines that wash their contents by applying sprays of detergent solutions and sanitize their contents by applying either hot water sprays or chemical sanitisation solutions. Covered by this standard are stationary rack and conveyor machines.

In particular this standard sets requirements regarding

- materials used in the manufacture of warewashing machines (e.g. corrosion resistance, smoothness and cleanability etc.),
- design and construction (e.g. general sanitation requirements, temperature indicating devices at the wash tanks, thermostatic control of the water temperature in the tanks, etc.),

- performance (soil removal[45], sanitization efficacy (hot water and chemical sanitizing), thermostat differential of dishwashing, glasswashing and pot, pan and utensil washing machines, including description of test method) and
- manufacturer's specifications (data to be stated on a data plate (e.g. minimum temperature of wash water in the tank, minimum and maximum pressure in the final sanitizing rinse line, etc.), equipment labelling (however, no information requirements on energy and water consumption but only regarding the intended use), and operating instructions.
- Both for hot water and chemical sanitizing machines requirements regarding the water temperature and pressure are set.

NSF/ANSI 3-2009 additionally contains requirements and exemptions for warewashing equipment provided with a security package (e.g. for use in prisons etc.) and for warewashing equipment for use in marine environments (under shipboard conditions).

This standard established and adopted by NSF as minimum voluntary consensus standard is used internationally as well as an American National Standard (ANS). The NSF/ANSI 3 standard is currently being under revision and should be finalized in 2011.

NSF/ANSI 3-2009 specifications apply to hot water and chemical *sanitizing* machines (for further details: see Task 6). These machines and processes, commonly used on the US market, generally require higher (sanitizing) temperatures compared to the (cleaning) temperatures of dishwashers in Europe[46].

This higher thermal minimum requirement results in higher energy consumption and lower efficiency, respectively. Therefore the NSF is regarded to be not appropriate to cover European requirements and market trends.

3.2.3 NSF/ANSI 29–2009 (International / USA / Canada)

NSF/ANSI 29–2009: Detergent and chemical feeders for commercial spray-type dishwashing machines

NSF/ANSI 29–2009 establishes minimum public health and sanitation requirements for chemical sanitizing feeders, detergent feeders, rinse agent feeders, and similar devices for commercial spray-type dishwashing machines that automatically maintain the concentration

[45] The soil removal efficacy of dishwashing machines shall be evaluated by observing the machine's ability to remove a dry coating of buttermilk from the surfaces of dinner plates and glasses; for pot, pan, and utensil washing machines: to remove a baked coating of pie filling from the surface of cookware respectively. For acceptance of the soil removal, the surfaces of the washware shall be visually inspected.

[46] Hot water sanitizing: according to NSF/ANSI minimum washing temperatures of 66 to 74°C required depending on the dishwashing machine category; cleaning: according to DIN 10512 washing temperatures of 60 to 65°C required, see Section 3.2.4.

of additives in the prewash, wash, pumped rinse, or final rinse of commercial spray-type dishwashing machines. In particular the requirements by this standard cover

- the materials used,
- the design and construction,
- the performance (e.g. hydrostatic test, maintenance of solution concentration, reliability, chemical resistance, etc.) and
- the installation, operation and maintenance instructions (manual, operating instructions).

This standard established and adopted by NSF as minimum voluntary consensus standard is used internationally as well as an American National Standard (ANS).

3.2.4 DIN 10510 / 10511 / 10512 / 10522 (Germany)

This family of standards covers hygienic requirements regarding the construction, operation and maintenance of different types of professional dishwashers. In the professional dishwasher context, hygienic requirements are an important performance parameter. However, the hygienic requirements are not mandatory by a legal regulation. They are used by manufacturers for marketing purposes to show the customer that certain hygienic requirements are met. The standards are described shortly in the following:

DIN 10510:2008 Food hygiene – Professional dishwashing with multi-tank conveyor-type dishwashers – Hygiene requirements, procedure testing

This standard defines minimum hygiene requirements of professional multi-tank conveyor-type dishwashers. In particular it gives advice for hygienic and professional use, for cleaning and disinfection of the items to be cleaned, and for maintenance of the devices. Furthermore it covers details regarding the appropriate spatial-functional alignment of the devices within the kitchen area and regarding appropriate and hygienic organisation of the handling of the items to be cleaned. Also the procedures to test the hygienic operation of the devices are described.

DIN 10511:1999 Food hygiene – Professional glasswashing with glasswashing machines – Hygiene requirements, testing

This standard defines the technical and hygienic requirements for professional glasswashing with glasswashing machines and the washing results, to ensure hygiene when washing glasses. It also describes the procedure for testing machines.

DIN 10512:2008 Food hygiene – Professional dishwashing with one-tank-dishwashers – Hygiene requirements, type testing

This standard defines minimum hygiene requirements of professional one-tank-dishwashers. In particular it gives advice for hygienic and professional use, for cleaning and disinfection of the items to be cleaned, and for maintenance of the devices. Furthermore it contains details regarding the appropriate spatial-functional alignment of the devices within the kitchen area and regarding appropriate and hygienic organisation of the handling of the items to be cleaned. Also the test procedures for the hygienic operation of the devices are described.

Hygienic requirements to some extent also influence the use and composition of the treatment agents for dishwashing machines. The hygiene requirements for glass- and dishwashing machines inter alia require a decontamination performance of 5 $\log_{10}$ stages for 90% of the wash ware. In order to provide for these hygiene requirements the standards for multi-tank conveyor-type dishwashers (DIN 10510) and for one-tank dishwashers (DIN 10512) require the following process temperatures depending on the use of detergents with or without disinfection or oxidising component:

Table 7 Process temperatures for professional multi-tank conveyor-type dishwashers depending on the use of detergents with or without disinfection or oxidising component

DIN 10510 – Multi-tank conveyor-type dishwashers	**Temperature without disinfection component**	**Temperature with sufficient amount of disinfection component**
Pre-wash zone (fresh water)	up to 40°C	25 – 40°C
Pre-wash zone (wash tank)	40 – 50°C	40 – 50°C
Cleaning zone (wash tank)	60 – 65°C	55 – 65°C
Rinse zone (wash tank)	60 – 70°C	60 – 70°C
Final rinse zone (fresh water)	80 – 85°C	80 – 85°C

Table 8 Process temperatures for professional one-tank dishwashers depending on the use of detergents with or without disinfection or oxidising component

DIN 10512 – One-tank dishwashers	**Temperature without disinfection or oxidising component in alkaline detergent solution**	**Temperature with sufficient amount of disinfection or oxidising component in alkaline detergent solution**
Cleaning zone (wash tank)	60 – 65°C	55 – 65°C
Rinse zone (fresh water)	80 – 85°C	80 – 85°C

DIN 10512 explicitly requires the use of detergents with disinfection or oxidising components if the above given requested temperatures cannot be maintained or to improve the decontamination performance.

DIN 10522:2006 Food hygiene – Professional cleaning of reusable boxes and reusable containers for unpackaged foodstuffs – Hygiene requirements, testing

Analogue to the standards DIN 10510, 10511 and 10512, this standard defines minimum hygiene requirements with regard to the professional cleaning of reusable boxes and reusable containers for unpackaged foodstuffs and describes the test procedures for the hygienic operation of dishwashers used for these purposes.

The main focus of these standards is the hygienic performance. There are minimum requirements for the decontamination performance (e.g. in case of glasswashers and one-tank dishwashers a certain reduction of 5 $\log_{10}$ stages shall be achieved for 90% of the wash ware, for all dishwashers only a certain, maximum number of colony forming units (cfu) is allowed per surface area of the wash ware) measured according to a certain test procedure. The standards also require certain minimum temperatures and contact times in order to achieve the given decontamination performance. The cleaning and drying performance of the respective dishwashers are not covered in a detailed manner but only assessed by a "pass-of-fail" indication (see e.g. DIN 10511, Section 5.3.2 on hygienic requirements: "the glasses shall be optically clean" and "the outside of the glasses shall be dry 2 minutes after being removed from the glasswasher basket, whereby remaining droplets on the base and a remnant dampness inside the glass may be tolerated.")

The German standards DIN 10510, 10511, 10512 and 10522 are currently under revision by a working group[47] under the Food and Agricultural Products Standards Committee (NAL, Normenausschuss Lebensmittel und landwirtschaftliche Produkte) at the German Institute for Standardization (DIN, Deutsches Institut für Normung e.V.). A major point of the revision is that the required minimum temperatures and contact times will be removed. Only minimum requirements regarding the decontamination performance will still be included in the standards. Further goal of the working group is to consolidate the separate standards within one document (planned to be document number DIN SPEC 10534), to translate the new document into English and to publish it via CEN at European level.

On 6 October 2010, the revised document has been adopted as draft standard for publication.[48] After publication as DIN SPEC, it is intended to apply for the preparation of a European standard. In case of rejection at European level, only the current German DIN standards would then be replaced by the new standard at national level.

[47] Working group „Hygieneanforderungen an die maschinelle Reinigung von Lebensmittelbedarfsgegenständen"

[48] http://www.nal.din.de/cmd?contextid=nal&bcrumblevel=1&subcommitteeid=54756512&projid=119887354&level=tpl-proj-detailansicht&committeeid=54738971&languageid=de

3.3 Safety

3.3.1 IEC 60335 (International)

IEC 60335 Household and similar electrical appliances – Safety

- IEC 60335-1: Household and similar electrical appliances – Safety – Part 1: General requirements

  The standard covers safety issues of household and similar electrical appliances. Part 1 defines general elements and is common to all electric motor appliances. Product specific issues are addressed in the Part 2-series. The relevant standards of Part 2 for dishwashers are listed in the following.
- IEC 60335-2: Household and similar electrical appliances – Safety – Part 2:
  - IEC 60335-2-58:2008: Household and similar electrical appliances – Safety – Part 2: Particular requirements for commercial electric dishwashing machines

    Deals with the safety of electrically operated dishwashing machines for washing plates, dishes, glassware, cutlery and similar articles, with or without means of heating water or drying, not intended for household use. The rated voltage being not more than 250 V for single-phase appliances connected between one phase and neutral, and 480 V for other appliances. Appliances within the scope of this standard are used in restaurants, canteens, hospitals, and commercial enterprises such as bakeries, butcheries, etc. Examples of appliances within the scope of this standard are conveyor dishwashers (Lot 24 categories 5 and 6) and batch dishwashers (Lot 24 categories 1 to 4).

3.3.2 EN 50416 (Europe)

EN 50416 Household and similar electrical appliances – Safety – Particular requirements for commercial electric conveyor dishwashing machines

This European Standard deals with the safety of electrically operated conveyor dishwashing machines for washing plates, dishes, glassware, cutlery and similar articles (e.g. trays, food containers), with or without means for water heating or forced hot air drying, not intended for household use, their rated voltage being not more than 250 V for single-phase machines connected between one phase and neutral and 480 V for other machines. These machines are used for example in restaurants, canteens, hospitals, and commercial enterprises such as bakeries, butcheries, etc. Examples of such machines are flight type dishwashers, and rack conveyor dishwashers. These machines are designed to be connected to hot and/or cold water supply.

Requirements to avoid backsiphonage of non-potable water into the public water supply are specified in Annex CC. Machines making use of steam or hot water for heating purposes are also within the scope of this standard. This standard does not apply to

- machines which are moveable,
- gas heating appliances which are part of conveyor dishwashing machines,
- machines intended for disinfection,
- machines intended to be used on board of sea-going vessels and aircraft,
- machines designed exclusively for industrial purposes, for example machines used in the food industry for cleaning receptacles that serve as packaging for final products (e.g. bottle-cleaning machines), and machines used in manufacturing processes,
- separately driven transport devices not confined in the machine, and
- machines intended to be used in locations where special conditions prevail, such as the presence of a corrosive or explosive atmosphere (dust, vapour or gas).

3.3.3 UL 921 (USA / Canada)

UL 921 Commercial dishwashers

This standard covers commercial, freestanding, undercounter, and counter-insert dishwashers, utensil-washers, and glasswashers intended for use in commercial establishments, such as kitchens of restaurants and hospitals, where they are not intended to be accessible to the public. The standard sets requirements in the areas of construction, safety, performance, rating and marking, as well as installation instructions.

Performance tests[49] do not cover any requirements regarding energy, water or detergent consumption or the cleaning and hygienic performance.

[49] General requirements; electrical input test; starting current test; normal temperature test; temperature measuring equipment and enclosure setup; dielectric voltage-withstand test; flexing test; insulation resistance following humidity conditioning test; water exposure tests; flooding of current-carrying parts test; hydrostatic pressure test; reservoir overflow test; liquid containers, seals, and diaphragms tests; limited short-circuit test (motor protection); abnormal operation test; blocked plunger test; overvoltage for electrolytic capacitors test; overload on switches test; transformer overcurrent protection test; transformer burnout test; door interlock endurance test; loading door/drawer moment load test; strain relief test; push-back relief test. Source: http://ulstandardsinfonet.ul.com/tocs/tocs.asp?fn=0921.toc

3.4 Noise

3.4.1 IEC 60704 (International)

IEC 60704:1997 Household and similar electrical appliances – Test code for the determination of airborne acoustical noise

- IEC 60704-1: Household and similar electrical appliances – Test code for the determination of airborne acoustical noise, Part 1: General requirements
  Applies to the methods of determination of airborne acoustical noise emitted by household and similar electrical appliances supplied from mains or from batteries.
- IEC 60704-2-3:2005 Household and similar electrical appliances – Test code for the determination of airborne acoustical noise – Part 2-3: Particular requirements for dishwashers

  This standard applies 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, and for mounting to a wall or on a counter. Limitations for the use of this test code are given in IEC 60704-1.

3.4.2 ISO 3744 (International)

ISO 3744:2010 Acoustics – Determination of sound power levels and sound energy levels of noise sources using sound pressure – Engineering methods for an essentially free field over a reflecting plane

ISO 3744:2010 specifies methods for determining the sound power level or sound energy level of a noise source from sound pressure levels measured on a surface enveloping the noise source (machinery or equipment) in an environment that approximates to an acoustic free field near one or more reflecting planes. The sound power level (or, in the case of noise bursts or transient noise emission, the sound energy level) produced by the noise source, in frequency bands or with frequency A-weighting applied, is calculated using those measurements. The methods specified in ISO 3744:2010 are suitable for all types of noise (steady, non-steady, fluctuating, isolated bursts of sound energy, etc.) defined in ISO 12001.

ISO 3744:2010 is applicable to all types and sizes of noise source (e.g. stationary or slowly moving plant, installation, machine, component or sub-assembly), provided the conditions for the measurements can be met.

The test environments that are applicable for measurements made in accordance with ISO 3744:2010 can be located indoors or outdoors, with one or more sound-reflecting planes

present on or near which the noise source under test is mounted. The ideal environment is a completely open space with no bounding or reflecting surfaces other than the reflecting plane(s) (such as that provided by a qualified hemi-anechoic chamber), but procedures are given for applying corrections (within limits that are specified) in the case of environments that are less than ideal.

Information is given on the uncertainty of the sound power levels and sound energy levels determined in accordance with ISO 3744:2010, for measurements made in limited bands of frequency and with frequency A-weighting applied. The uncertainty conforms to ISO 12001:1996, accuracy grade 2 (engineering grade).

3.4.3 ISO 3746 (International)

ISO 3746:2010 Acoustics – Determination of sound power levels and sound energy levels of noise sources using sound pressure – Survey method using an enveloping measurement surface over a reflecting plane

ISO 3746:2010 specifies methods for determining the sound power level or sound energy level of a noise source from sound pressure levels measured on a surface enveloping a noise source (machinery or equipment) in a test environment for which requirements are given. The sound power level (or, in the case of noise bursts or transient noise emission, the sound energy level) produced by the noise source with frequency A-weighting applied is calculated using those measurements. The methods specified in ISO 3746:2010 are suitable for all types of noise (steady, non-steady, fluctuating, isolated bursts of sound energy, etc.) defined in ISO 12001. ISO 3746:2010 is applicable to all types and sizes of noise source (e.g. stationary or slowly moving plant, installation, machine, component or sub-assembly), provided the conditions for the measurements can be met.

The test environments that are applicable for measurements made in accordance with ISO 3746:2010 can be located indoors or outdoors, with one or more sound-reflecting planes present on or near which the noise source under test is mounted.

Information is given on the uncertainty of the sound power levels and sound energy levels determined in accordance with ISO 3746:2010, for measurements made with frequency A-weighting applied. The uncertainty conforms to that of ISO 12001:1996, accuracy grade 3 (survey grade).

3.4.4 ISO 4871 (International)

ISO 4871:1996 Acoustics – Declaration and verification of noise emission values of machinery and equipment

Gives information on the declaration of noise emission values, describes acoustical information to be presented in technical documents and specifies a method for verifying the noise emission declaration.

3.4.5 ISO 9614 (International)

ISO 9614-2:1996 Acoustics – Determination of sound power levels of noise sources using sound intensity – Part 2: Measurement by scanning

Specifies a method for measuring the component of sound intensity normal to a measurement surface which is chosen so as to enclose the noise source(s) of which the sound power level is to be determined.

3.4.6 ISO 11204 (International)

ISO 11204:2010 Acoustics – Noise emitted by machinery and equipment – Determination of emission sound pressure levels at a work station and at other specified positions applying accurate environmental corrections

ISO 11204:2010 specifies a method for determining the emission sound pressure levels of machinery or equipment, at a work station and at other specified positions nearby, in any environment which meets certain qualification requirements. A work station is occupied by an operator and may be located in open space, in the room where the source under test operates, in a cab fixed to the source under test, or in an enclosure remote from the source under test. One or more specified positions may be located in the vicinity of a work station, or in the vicinity of an attended or unattended machine. Such positions are sometimes referred to as bystander positions. Emission sound pressure levels are determined as A-weighted levels. Additionally, levels in frequency bands and C-weighted peak emission sound pressure levels can be determined in accordance with ISO 11204:2010, if required.

A method is given for determining a local environmental correction (subject to a specified limiting maximum value) to be applied to the measured sound pressure levels to exclude the effects of reflections from reflecting surfaces other than the plane on which the source under test is placed. This correction is based upon the mean sound pressure level on a measurement surface, the sound pressure level measured at a specified position, and either an environmental correction or the equivalent absorption area of the test room.

With the method specified in ISO 11204:2010 results of accuracy grade 2 (engineering grade) or accuracy grade 3 (survey grade) are obtained. Corrections are applied for background noise and, as described above, for the acoustic environment. Instructions are

given for the mounting and operation of the source under test and for the choice of microphone positions for the work station and for other specified positions. One purpose of the measurements is to permit comparison of the performance of different units of a given family of machines, under defined environmental conditions and standardized mounting and operating conditions.

The method specified in ISO 11204:2010 is suitable for all types of noise (steady, non-steady, fluctuating, isolated bursts of sound energy, etc.) defined in ISO 12001. The method specified in ISO 11204:2010 is applicable to all types and sizes of noise sources.

The type of test environment influences the accuracy of the determination of emission sound pressure levels. ISO 11204:2010 is applicable to an indoor or outdoor environment with one or more reflecting planes present, meeting specified requirements. These requirements on the room are less strict than those of ISO 11201, in particular regarding the acoustical quality of the environment. ISO 11204:2010 is applicable to work stations and other specified positions where emission sound pressure levels are to be determined.

Appropriate positions where measurements may be made include the following: a) work station located in the vicinity of the source under test; this is the case for many industrial machines and domestic appliances; b) work station within a cab which is an integral part of the source under test; this is the case for many industrial trucks and earth-moving machines; c) work station within a partial or total enclosure (or behind a screen) supplied by the manufacturer as an integral part of the source under test; d) work station partially or totally enclosed by the source under test – this situation may be encountered with some large industrial machines; e) bystander positions occupied by individuals not responsible for the operation of the source under test, but who may be in its immediate vicinity, either occasionally or continuously; f) other specified positions, not necessarily work stations or bystander positions.

The work station may also lie on a specified path along which an operator moves.

3.5 Electromagnetic fields / Electromagnetic compatibility (EMC)

3.5.1 IEC 62233 (International)

IEC 62233:2005 Measurement methods for electromagnetic fields of household appliances and similar apparatus with regard to human exposure

This standard deals with electromagnetic fields up to 300 GHz and defines methods for evaluating the electric field strength and magnetic flux density around household and similar electrical appliances, including the conditions during testing as well as the measuring of distances and positions. Appliances may incorporate motors, heating elements or their combination, may contain electric or electronic circuitry, and may be powered by the mains,

by batteries or by any other electrical power source. Appliances include such household electrical appliances, electric tools and electric toys. Appliances that are not intended for regular household use but may nevertheless be approached by the public or may be used by laymen are within the scope of this standard. This standard includes specific elements to assess human exposure:

- definition of sensor,
- definition of measuring methods,
- definition of operating mode for appliance under test,
- definition of measuring distance and position.

The measurement methods specified are valid for appliances that range from 10 Hz to 400 kHz. In the frequency range above 400 kHz and below 10 Hz, appliances in the scope of this standard are deemed to comply without testing, unless otherwise specified within the IEC 60335 series.

3.5.2 IEC 61000 (International)

IEC 61000 Electromagnetic compatibility

- IEC 61000-3-2 ed3.2 Consol. with am1&2: Limits – Limits for harmonic current emissions (equipment input current ≤16 A per phase)
- IEC 61000-3-3 ed2.0: Limits – Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems, for equipment with rated current ≤16 A per phase and not subject to conditional connection

3.5.3 EN 50366 (Europe)

EN 50366:2003 Household and similar electrical appliances – Electromagnetic fields – Methods for evaluation and measurement

Several test methods by which the magnetic field emissions from products can be compared to the general public restrictions and levels over the frequency range of 10Hz to 400 kHz.

3.5.4 EN 55014 (Europe)

EN 55014 Electromagnetic compatibility – Requirements for household appliances, electric tools and similar apparatus

- EN 55014-1:2007 Electromagnetic compatibility – Requirements for household appliances, electric tools and similar apparatus, Part 1: Emission (IEC/CISPR 14-1:2005)

- EN 55014-2:2009 Electromagnetic compatibility – Requirements for household appliances , electric tools and similar apparatus, Part 2: Immunity – Product family standard (IEC/CISPR 14-2:1997 + A1:2001 + A2:2008)

3.6 Gas

3.6.1 UL 921 (USA / Canada)

UL 921 Commercial dishwashers (USA / Canada)

This standard covers commercial, freestanding, undercounter, and counter-insert dishwashers, utensil-washers, and glasswashers using water as the principal cleaning medium, hereafter referred to as dishwashers.

The contents of the standard have already been described in Section 3.3.3. However, this standard covers not only electric dishwashers, but also the gas-handling, gas-burning, and gas-control features of gas-fired dishwashers having inputs of 400 000 Btu (420 MJ) per hour or less, limited to 0.5 psig (3.45 kPa) inlet pressure for use with natural gas, manufactured gas, mixed gas, propane gas, liquefied petroleum gases, or LP gas-air mixtures. Thus, UL 921 provides further construction and performance[50] and marking requirements being unique to gas-fired dishwashers.

[50] General requirements, test gases, test pressures and burner adjustments test, normal operation, undervoltage combustion test, combustion air failure test, burner operating characteristics test, pilot ignition systems test, direct ignition systems tests, and flue gas temperature for draft hood appliances test; source: http://ulstandardsinfonet.ul.com/tocs/tocs.asp?fn=0921.toc

3.7 Standardisation needs for the EU

The following table identifies the gaps in current performance test standards.

Standard / work on standards	Scope	Comment	Energy consumption	Water consumption	Cleaning / rinsing performance	Hygiene performance	Drying performance
ASTM standards	Professional dishwashers Cat. 1 to 6	Only applied to *sanitizing* machinery	x	x		x	
EN 50242 / 60436	Dishwashers for household / similar use	not covered: *professional* appliances	x	x	x		x
ISO 15883	Washer disinfectors for medical devices	Not applicable to *dish*washers				x	
NSF/ANSI 3	Professional dishwashers Cat. 1-6	Only applied to *sanitizing* machinery				x	
DIN 10510 / 10511 / 10512	Professional dishwashers Cat. 2-6 (one-tank / multi-tank)	Not covered: cat. 1 (undercounter water-change); including: specific requirements for glasswashers				x	
Work in progress: CENELEC TC59X, SWG 2.1	Professional dishwashers Cat. 1-3 (Undercounter / hood-type dishwashers)	Not covered: cat. 4-6 (utensil/pot; conveyor-types)	x			x	
Work in progress: EFCEM “Energy Performance Standards Committee”	Professional dishwashers Cat. 1-6	Possibly without cat. 4 (utensil/pot)	x	x	x		
Work in progress: DIN	Professional dishwashers Cat. 4 (utensil/pot)	Not covered: cat. 1-3; cat. 5-6	x	x	x	x	

4 Existing legislation and environmental labelling

Aim of this work package is to identify the relevant existing legislation for professional dishwashers subdivided in four parts:

- Legislation and Agreements at European Community level,
- Legislation at Member State level,
- Third Country Legislation, and
- Environmental Labelling.

A short overview of existing legislation and environmental labelling is given, also including legislation on household appliances whose scope has currently been modified to 'household and similar electrical appliances' thus including professional machines.

4.1 European legislation

4.1.1 Machinery Directive (MD) 2006/42/EC (replacing 98/37/EC)

The new Machinery Directive 2006/42/EC[51] is a revised version of Directive 98/37/EC, and is applicable since 29th December 2009. The Directive has the dual aim of harmonising the health and safety requirements applicable to machinery, while ensuring the free circulation of machinery on the Community market. Machinery is defined as an assembly, fitted with or intended to be fitted with a drive system other than directly applied human or animal effort, consisting of linked parts or components, at least one of which moves, and which are joined together for a specific application.

The manufacturer or his authorised representative shall ensure that a risk assessment is carried out for the machinery which he wishes to place on the market. For this purpose, he should determine which are the essential health and safety requirements applicable to his machinery and in respect of which he must take measures. The CE marking should be fully recognised as being the only marking which guarantees that machinery conforms to the requirements of this Directive. All other markings which are likely to mislead third parties as to the meaning or the form of the CE marking, or both, are prohibited.

One of the objectives of the revision of the Machinery Directive was to clarify the borderline between the scope of the Machinery Directive (MD) and the Low Voltage Directive (LVD) 2006/95/EC20[52] (formerly Directive 73/23/EEC as amended) in order to provide greater legal certainty. Article 1 (2) (k) lists the categories of low voltage electrical and electronic machinery that are excluded from the scope of the Machinery Directive, amongst others

[51] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:2006L0042:20091215:EN:PDF

[52] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2006:374:0010:0019:EN:PDF

'household appliances intended for domestic use'. When such machinery has an electrical supply within the voltage limits of the Low Voltage Directive (between 50 and 1000 V for alternating current or between 75 and 1500 V for direct current), it must fulfil the safety objectives of the LVD instead. For machinery beyond these voltage limits the requirements of the Machinery Directive apply.

The Machinery Directive applies to all professional dishwasher categories being in the scope of Lot 24 (for the borderline between machinery for household and professional use, see also Section 2.4). The requirements of the Directive are sufficient to cover all health and safety aspects related to those appliances.

4.1.2 Low Voltage Directive (LVD) 2006/95/EC

The Low Voltage Directive (LVD) 2006/95/EC[52] (formerly Directive 73/23/EEC as amended) seeks to ensure that electrical equipment within certain voltage limits both provides a high level of protection for European citizens and enjoys a Single Market in the European Union.

The Directive requires electrical equipment to have protection against hazards that could arise from within the electrical equipment itself or from external influences. The directive covers all risks arising from the use of electrical equipment, including mechanical, chemical (such as, in particular, emission of aggressive substances). The LVD also covers noise and vibration, and ergonomic aspects which could cause hazards within the scope of the Directive. The LVD covers electrical equipment designed for use with a voltage rating of between 50 V and 1000 V for alternating current and between 75 V and 1500 V for direct current. It should be noted that these voltage ratings refer to the voltage of the electrical input or output, not to voltages that may appear inside the equipment.

Since 29th December 2010 (revision of Machinery Directive (see also Sections 2.4 and 4.1.1), dishwashers being stated by the manufacturer for professional use in the Declaration of Conformity, do clearly not fall under the Low Voltage Directive any more.

4.1.3 Electromagnetic Compatibility Directive (EMC) 2004/108/EC

Directive 2004/108/EC[53] on the approximation of the laws of Member States regulates the electromagnetic compatibility (EMC) of both apparatus and fixed installations. The directive applies to most electrical and electronic apparatuses including professional dishwashers, which are finished products and systems that include electrical and electronic equipment that may generate or be affected by electromagnetic disturbance.

The main objective of the EMC Directive, thus, is to regulate the compatibility of equipment regarding EMC. In order to achieve this objective, provisions have been put in place so that equipment needs to comply with the requirements of the EMC Directive when it is placed on

[53] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2004:390:0024:0037:en:PDF

the market and/or taken into service. On the one hand it has to be ensured that the electromagnetic emissions of this equipment in its intended use do not disturb radio and telecommunication as well as other equipment. On the other hand the Directive also governs the immunity of such equipment to interference and seeks to ensure that this equipment is not disturbed by radio emissions when normally used as intended.

4.1.4 Restriction of Hazardous Substances Directive (RoHS) 2002/95/EC

The Directive on the restriction of the use of certain hazardous substances in electrical and electronic equipment 2002/95/EC[54] (commonly referred to as the Restriction of Hazardous Substances Directive or RoHS) restricts the use of six hazardous substances in the manufacture of various types of electronic and electrical equipment (EEE).

The restrictions apply to EEE belonging to several categories as set out in Annex I A to Directive 2002/96/EC (WEEE). One of the categories of Annex I A falling under the RoHS Directive is category 1 “Large Household Appliances”, covering inter alia washing machines, clothes dryers and dish washing machines.

According to the Commission's "Frequently Asked Questions on Directive 2002/95/EC on the Restriction of the Use of certain Hazardous Substances in Electrical and Electronic Equipment (RoHS) and Directive 2002/96/EC on Waste Electrical and Electronic Equipment (WEEE)"[55] professional equipment, like professional washing machines, dryers and dishwashers, is covered by the RoHS Directive.

Article 5(1) (b) of the Directive provides that materials and components can be exempted from the substance restrictions contained in Article 4(1) if their elimination or substitution via design changes or materials and components which do not require any of the materials or substances referred to therein is technically or scientifically impracticable, or where the negative environmental, health and/or consumer safety impacts caused by substitution outweigh the environmental, health and/or consumer safety benefits thereof.

Currently, there are 39 exemptions listed in the Annex of the RoHS Directive. In the course of Task 4 (Technical analysis of existing products) we will evaluate whether there are existing exemptions which are of importance for the scope of Lot 24 “Professional washing machines, dryers and dishwashers”.

Currently (status January 2011), the Commission proposal for a recast of the RoHS Directive is in the co-decision adoption procedure by the Council and the European Parliament (EP). The Parliament voted in first reading on a compromise text negotiated between the European

---

54 http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2003:037:0019:0023:EN:PDF

55 http://ec.europa.eu/environment/waste/weee/pdf/faq_weee.pdf, FAQ 1.8 “Do the WEEE and the RoHS Directives apply to electrical and electronic products for professional use?” Answer: “The RoHS Directive does not differentiate between households or professional EEE, so products for professional use are covered by the RoHS Directive.”

Parliament and the Council in November 2010. It is now needed to be formally adopted by the Council. The new Directive will enter into force 20 days after its publication in the Official Journal of the European Union. Member States will then have 18 months to transpose it into national law. Until then, the existing RoHS Directive (Directive 2002/95/EC) continues to apply.

The revised Directive aims to improve implementation and enforcement and introduces greater coherence with other EU legislation, such as REACH and the new legislative framework for the marketing of products. Main elements include:[56]

- "The extension of the scope to all electrical and electronic equipment, including medical devices and monitoring and control instruments.
- Electrical and electronic equipment that was outside the scope of the current RoHS Directive but which will be covered by the revised Directive, does not need to comply with the requirements during a transitional period of 8 years, giving producers time to adapt;
- A lighter and more effective mechanism for reviewing or amending the list of banned substances is introduced, enabling further substances to be considered on the basis of scientific evidence and specific criteria, and in line with REACH. Changes may then be made through comitology;
- The rules for granting exemptions from the substance ban are further streamlined to provide legal certainty for the economic operators and to ensure coherence with REACH;
- Important definitions are clarified to ensure the directive is applied in a harmonised manner throughout the EU.
- Better enforcement of the Directive at national level will be achieved through alignment with the marketing of products legislative package."

Should these changes come into force in the near future manufacturers would need to verify whether they still comply with the requirements of the Directive, inter alia:

- If, for example, products were considered out of scope until now, they might be covered by the revision which would possibly entail need for substitution and / or exemption requests.
- In that case, companies will need to link their efforts in respect with REACH to those under the context of RoHS.

[56] http://europa.eu/rapid/pressReleasesAction.do?reference=IP/10/1596&format=HTML

4.1.5 Waste Electrical and Electronic Equipment Directive (WEEE) 2002/96/EC

The Waste Electrical and Electronic Equipment Directive (WEEE Directive) is the European Community Directive 2002/96/EC[57] regulating the collection, treatment, recycling and disposal of WEEE as well the financial provisions for this waste stream's treatment which, together with the RoHS Directive 2002/95/EC (cf. Section 4.1.4), came into force in February 2003. The Directive assigns the responsibility for the management of waste electrical and electronic equipment to the manufacturers of such equipment.

The Directive applies to the product categories set out in Annex I A that includes "Large household appliances". Article 5 differentiates between WEEE from private households and WEEE from other than private households. According to the Commission's "Frequently Asked Questions on Directive 2002/95/EC on the Restriction of the Use of certain Hazardous Substances in Electrical and Electronic Equipment (RoHS) and Directive 2002/96/EC on Waste Electrical and Electronic Equipment (WEEE)"[58] professional equipment, like professional washing machines, dryers and dishwashers, is covered by the WEEE Directive[59].

For WEEE from other than private households, Article 5 (3) points out that "Member States shall ensure that producers or third parties acting on their behalf provide for the collection of such waste." Also Article 9 on financing applies to WEEE from users other than private households. Article 9 (1) sets out that "Member States shall ensure that […] the financing of the costs for the collection, treatment, recovery and environmentally sound disposal of WEEE from users other than private households from products put on the market after 13 August 2005 is to be provided for by producers." Article 9 (2) points out, however, that "producers and users other than private households may, without prejudice to this Directive, conclude agreements stipulating other financing methods."

In parallel to the revision of the RoHS Directive, the WEEE Directive is currently also being revised under the co-decision procedure (status January 2011). The WEEE revision however is progressing at a much slower pace. The European Commission initially wanted to link the RoHS revision to discussions on a strengthening of the WEEE directive, but the Council

---

57 http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2003:037:0024:0038:EN:PDF

58 http://ec.europa.eu/environment/waste/weee/pdf/faq_weee.pdf, FAQ 1.8 "Do the WEEE and the RoHS Directives apply to electrical and electronic products for professional use?" Answer: "The WEEE Directive contains provisions that cover WEEE from households and WEEE from users other than private households. WEEE from private households means WEEE which comes from private households and from commercial, industrial, institutional and other sources which, because of its nature and quantity, is similar to that from private households. WEEE from other users than private households can then be all WEEE that is not defined as WEEE from private households. Financing provisions in respect of WEEE from private households are laid down in Article 8 while Article 9 covers WEEE from users other than private households. In addition, Article 10(3) does not specifically limit the marking obligation to electrical and electronic equipment (EEE) for private households because in some cases it is difficult to distinguish between households and professional electrical and electronic equipment. Therefore, the marking obligation also applies to EEE for professional use."

59 However, e.g. in Germany the general requirements set out in article 9 (1) of WEEE were not yet incorporated into national legislation (ElektroG).

wanted to keep the two dossiers separate. A parliament first reading vote on the WEEE revision is scheduled for February 2011, and the council will not issue its position until after the vote has taken place. Legislators are thus aiming for a second reading agreement late 2011.

The main issues are the possible shift of burden for reaching collection targets to EEE manufacturers as well as new collection targets that are adapted to country specificities and in relation to the number of products placed on the market. “Currently, the majority of member states are resisting a proposal by the European Commission, backed by the European Parliament's environment committee, to set a 65% collection rate for waste from electrical and electronic equipment (WEEE) by 2016. According to a progress report from the Council of Ministers, the Belgian presidency has proposed a phased approach according to which a 45% target would be set four years after the rules' entry into force, followed by a 65% target two years later. A majority of delegations favour this approach though some still want a longer transition period, according to the report.”[60]

Also the scope of the Directive shall be clarified as currently the scope of the WEEE directive is unclear, e.g. types of appliances shall be categorized as household (B2C – business to consumer) and non-household appliances (B2B – business to business). “Twelve countries support giving the WEEE directive an open scope as demanded by the environment committee. Twelve other states want to limit the law's scope to specific products. As a compromise Belgium suggested a narrow definition of what constitutes EEE equipment, which would limit the number of products falling into an open scope. Other issues of disagreement remain, for example whether a producer of electrical and electronic equipment should be defined at national or EU level and whether the cost of managing WEEE should be displayed on product labels.” [60]

Should these changes come into force, industry would be forced to make sure that they control the waste stream more than they do now in order to meet the (more demanding) collection and recycling targets.

4.1.6 Biocide Directive 98/8/EC

This Directive[61] concerns: (a) the authorisation and the placing on the market for use of biocidal products within the Member States; (b) the mutual recognition of authorisations within the Community; and (c) the establishment at Community level of a positive list of active substances which may be used in biocidal products.

Biocidal products are defined as active substances and preparations containing one or more active substances, put up in the form in which they are supplied to the user, intended to

[60] http://www.endseurope.com/25218?referrer=channel%2Dwaste

[61] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:1998:123:0001:0063:EN:PDF

destroy, deter, render harmless, prevent the action of, or otherwise exert a controlling effect on any harmful organism by chemical or biological means.

The guidance document for the Biocidal Products Directive (BPD)[62] provides the following explanations:

- Human hygiene biocidal products: Detergents and cleaning products (auxiliary aids for washing processes like fabric conditioners are included) intended to have a biocidal activity (reliably controlling micro-organisms like fungi and bacteria) are biocidal products. The Commission services and all Member States except Austria agreed to the following clarification: When associated with cleaning products, the word 'hygiene' can be used without immediately causing the product to fall under the scope of the BPD as long as no reference (words, pictures, etc.) to antimicrobial or disinfecting action is made.
- Private area and public health area disinfectants and other biocidal products: Detergents containing in-can preservatives, but not intended to have biocidal effects, are not in the scope of BPD. However, detergents containing a biocidal active substance, *intended to have biocidal effects under conditions of use, with or without biocidal claim*, should be regarded as biocidal products. The definition of a biocidal product in Directive 98/8/EC is that it is "intended" as such and does not necessitate a claim to be made. However, it is reasonable to expect that an intended biocidal action would be reflected in a relevant claim. In the absence of such a claim, on the label or elsewhere, some other relevant matter in the context in which the product is presented beyond its formulation (e.g. presentation of the product, use instruction etc.) would be needed to justify a conclusion that it was 'intended' to be biocidal. The current wording reflects the definition. In case of a divergence of views concerning a particular product between the authorities and the person responsible for placing the product on the market, it is up to the latter to demonstrate that no biocidal effect was intended.

Currently, the approval procedure for biocidal active substances of the product types 1 to 4 (related to disinfectants) is ongoing. Active substances being approved in the EU will be listed in Annex 1 of the BPD in the coming years. Only after that, national product approvals in the Member States will be starting, i.e. the disinfectants with biocidal active substances will be approved at national level according to the BPD. Meanwhile transitional agreements apply.

Both the professional laundry (e.g. in health care laundry) and the dishwashing sector use biocidal detergent systems to achieve a certain level of hygiene; thus being affected by the Biocidal Products Directive. In the dishwashing process, hygienic requirements are usually

[62] Source: Guidance document agreed between the Commission services and the competent authorities of the Member States for the Biocidal Products Directive 98/8/EC (Doc-Biocides-2002/04-Rev3; 31.10.2003); http://ec.europa.eu/environment/biocides/pdf/definitions.pdf

met by a predefined level of process temperatures, however depending on the use of detergents with or without disinfection components of the detergents (see Section 3.2.4).

4.1.7 Gas Appliances Directive (GAD) Directive 2009/142/EC

The Directive regulates appliances burning gaseous fuels used for cooking, heating, hot water production, refrigeration, lighting or washing with (where applicable) a normal water temperature not exceeding 105°C. The GAD applies to all gas heated and combined gas-heated applications. Although the Directive mainly covers common consumer and commercial products, so-called fittings are comprised, too. Appliances specifically designed for use in industrial processes carried out on industrial premises are excluded.

The GAD has been subject to a recent codification which is a process of incorporating a legislative act and all its amendments into a single new act. The new codified version is referred to as Directive 2009/142/EC and came into force on 4 January 2010. From this date, any references to the repealed Directive 90/396/EEC[63] shall be construed as references to Directive 2009/142/EC.

4.1.8 Water Framework Directive (WFD) 2000/60/EC

The Water Framework Directive[64] establishes a legal framework to protect and restore clean water across Europe and ensure its long-term, sustainable use. The directive establishes an innovative approach for water management based on river basins, the natural geographical and hydrological units, and it sets specific deadlines for Member States to protect aquatic ecosystems. The directive addresses inland surface waters, transitional waters, coastal waters and groundwater, and it establishes innovative principles for water management, including public participation in planning and economic approaches, including the recovery of the cost of water services.

Inter alia, the Water Framework Directive introduces two key economic principles. First, it calls on water users – such as industries, farmers and households – to pay for the full costs of the water services they receive. Second, the directive calls on Member States to use economic analysis in the management of their water resources and to assess both the cost-effectiveness and overall costs of alternatives when making key decisions. Under the directive the recovery of costs refers to several elements. The prices users pay for water should cover the operational and maintenance costs of its supply and treatment and the costs invested in infrastructure. The directive goes further and requires that prices paid by users also cover environmental and resource costs. This is a key step towards implementing

63 http://eur-lex.europa.eu/LexUriServ/site/en/consleg/1990/L/01990L0396-19930802-en.pdf

64 http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2000:327:0001:0072:EN:PDF
http://ec.europa.eu/environment/water/participation/notes_en.htm

the economic principle that polluters and users should pay for the natural resources they use and the damage they create.

Further, Articles 4, 10, 11 and 16 and Annexes V, VIII, IX and X of the directive address chemical pollution. By targeting priority substances, the Water Framework Directive focuses on individual pollutants or groups of pollutants that present significant risk to or via the aquatic environment. The substances are identified through rigorous risk assessments, which involve examining scientific evidence of the hazardous properties of the substances, their contamination of European waters, and other factors such as volumes used. Among the 33 chemicals categorised as priority substances, 13 are designated as priority hazardous substances due to their persistence, bioaccumulation and toxicity. The European Commission will review this list every four years, to allow for the inclusion of additional substances of concern. The Water Framework Directive seeks to progressively reduce emissions, discharges and losses of priority substances to waters. Priority hazardous substances are to be phased out completely within 20 years.

None of the 33 listed priority substances is expected to be in detergents used for professional laundry and dishwashing processes. Amongst the 13 substances being designated as priority hazardous substances, EDTA[65] is still used in detergents. In Germany, for example, since 1991 several industrial associations (e.g. IKW and IHO[66]) have voluntarily committed to abandon the use of EDTA to a large extent. Thus, in Germany EDTA is only found in few specialised detergent products of the industrial and institutional (I&I) sector.

In general, the WFD prescribes the creation of incentives for an efficient use of water resources and focuses on improvement of sustainability of production.

4.1.9 Commission Regulation (EC) No. 648/2004 – Detergents

Detergents and rinse aids have to fulfil the requirements laid down by Regulation (EC) No. 648/2004[67] on detergents[68]. This regulation establishes rules designed to achieve the free movement of detergents and surfactants for detergents in the internal market while, at the same time, ensuring a high degree of protection of the environment and human health. For

[65] EDTA (ethylene-diamino-tetra-acetate): A class of synthetic, phosphate-alternative compounds used to reduce calcium and magnesium hardness in water. EDTA is also used to prevent bleaching agents from becoming active before they're immersed in water and as a foaming stabilizer.

[66] IKW: Industrieverband Körperpflege- und Waschmittel; IHO: Industrieverband Hygiene und Oberflächenschutz

[67] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2004:104:0001:0035:EN:PDF

[68] For the purpose of Regulation (EC) No. 648/2004 ‘detergents’ means any substance or mixture containing soaps and/or other surfactants intended for washing and cleaning processes. Detergents may be in any form (liquid, powder, paste, bar, cake, moulded piece, shape, etc.) and marketed for or used in household, or institutional or industrial purposes. Other products to be considered as detergents are: ‘Auxiliary washing mixture’, ‘Laundry fabric-softener’, ‘Cleaning mixture’, ’Other cleaning and washing mixtures’, intended for any other washing and cleaning processes.

this purpose, this Regulation harmonises the following rules for the placing on the market of detergents and of surfactants for detergents:

- the biodegradability of surfactants in detergents;
- restrictions or bans on surfactants on grounds of biodegradability;
- the additional labelling[69] of detergents, including fragrance allergens; and
- the information that manufacturers must hold at the disposal of the Member States competent authorities and medical personnel.

4.1.10 Commission Regulation (EC) No. 842/2006 – Fluorinated GHG

The objective of this Regulation[70] is to contain, prevent and thereby reduce emissions of the fluorinated greenhouse gases covered by the Kyoto Protocol. Annex I to this Regulation contains a list of the fluorinated greenhouse gases currently covered by this Regulation, together with their global warming potentials.

Fluorinated gases are powerful greenhouse gases with global warming potentials many times that of natural greenhouse gases such as carbon dioxide. They also tend to remain much longer in the atmosphere than natural greenhouse gases. Because of this, they are included in the basket of gases controlled by the Kyoto Protocol and Parties to the Protocol that have an emissions target are required to control and reduce emissions of Fluorinated gases. Fluorinated gases are man made substances and Regulation 842/2006 defines them as follows: fluorinated greenhouse gases' means hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6) as listed in Annex I of the Regulation.

This Regulation addresses the containment, use, recovery and destruction of the fluorinated greenhouse gases listed in Annex I; the labelling and disposal of products and equipment containing those gases; the reporting of information on those gases; the control of uses and the placing on the market prohibitions of the products and equipment; and the training and certification of personnel and companies involved in activities provided for by this Regulation.

For professional dishwashers, this Regulation applies in those cases when the appliances are equipped with heat pumps containing refrigerants.

---

[69] The Detergent Regulation sets the requirement for more specific detergent package labelling on issues including the ingredient datasheet, the number of standard washing machine loads and the enterprise's contact details. The labelling requirements vary depending on whether the product is sold to the general public or for use in the industrial sector only. Specific provisions regarding labelling are laid down in Annex VII to the Regulation. In addition, the packaging of detergents regarded as biocides, such as disinfectants, will be required to have special biocidal product labelling following a transitional period.

[70] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2006:161:0001:0011:EN:PDF

4.1.11 Commission Regulation (EC) No. 1275/2008 – Standby

The Regulation[71] sets out eco-design requirements for standby and off mode electric power consumption. The application is limited to products corresponding to household and office equipment intended for use in the domestic environment. 'Electrical and electronic household and office equipment' is defined as energy-using products which:

a) are made commercially available as a single functional unit and are intended for the end-user;

b) fall under the list of energy-using products of Annex I of the Directive (inter alia dishwashing machines);

c) are dependent on energy input from the mains power source in order to work as intended; and

d) are designed for use with a nominal voltage rating of 250 V or below,

also when marketed for non-household or non-office use.

The Standby Directive only covers appliances being in the scope of the Low Voltage Directive (LVD). As professional dishwashers do not fall under the LVD but under the Machinery Directive (see Sections 2.4.2 and 4.1.1), they are also not covered by the scope of the Standby Regulation.

4.1.12 European labelling

So far, there are no European environmental or energy labels that apply to professional dishwashing appliances.

4.2 Legislation at member state level

No legislation at member state level regarding professional dishwashers has been found.

4.3 Third country legislation

4.3.1 USA

The Energy Policy Act of 1992 set standards for certain commercial equipment and set schedules requiring the U.S. Department of Energy (DOE) to make, review, and update standards. DOE currently is active in standards development for a range of commercial products. However, with regard to dishwashers, the US Energy Conservation Standard[72] only applies to residential products; they are not in the scope of the designated commercial

[71] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:339:0045:0052:EN:PDF

[72] Source: http://www1.eere.energy.gov/buildings/appliance_standards/commercial_products.html

equipment to be included (in contrast to commercial clothes washers; cf. EuP Lot 24 Task 1 report, part “Professional washing machines and dryers”).

California's Appliance Efficiency Regulations were established in 1976 in response to a legislative mandate to reduce California's energy consumption. The regulations are updated periodically to allow consideration and possible incorporation of new energy efficiency technologies and methods. The 2009 Appliance Efficiency Regulations, (California Code of Regulations, Title 20, Sections 1601 through 1608)[73] effective August 9, 2009, were adopted by the California Energy Commission (CEC) on December 3, 2008, and approved by the California Office of Administrative Law on July 10, 2009. The Appliance Efficiency Regulations include standards for both federally-regulated appliances and non-federally-regulated appliances. Twenty-one categories of appliances are included in the scope of these regulations. Professional dishwashers do not fall under the scope of the current Californian Appliance Efficiency Regulations.

ENERGY STAR® for commercial dishwashers (USA / Canada)

ENERGY STAR® is a joint voluntary labelling program of the U.S. Environmental Protection Agency and the U.S. Department of Energy supporting energy efficient products and practices. Products that comply with the performance criteria set by ENERGY STAR may use the Energy Star certification mark (after the manufacturer became an ENERGY STAR partner, which comes along with some further, however not product specific requirements).

The ENERGY STAR program key product criteria for commercial dishwashers[74] apply to dishwashing machines, defined as “a machine designed to clean and sanitize plates, glasses, cups, bowls, utensils, and trays by applying sprays of detergent solution (with or without blasting media granules) and a sanitizing final rinse.”

Several dishwasher categories eligible for ENERGY STAR are defined:

- Undercounter dishwashers (corresponding to Lot 24 category 1),
- Stationary rack, single tank, door type dishwashers (subcategories: single and multiple wash tank, double rack, pot, pan and utensil washers, chemical dump type and hooded wash compartment (“hood type”)) (corresponding to Lot 24 categories 2, 3 and 4),
- Single tank conveyor dishwashers (corresponding to Lot 24 category 5),
- Multiple tank conveyor dishwashers (corresponding to Lot 24 category 6).

In each category sanitizing might take place through hot water (high temperature machines) or through chemical sanitizing (low temperature machines).

Efficiency requirements that have to be met cover the idle energy rate (in kilowatt (kW)) and the water consumption (in gallons per rack (gal/rack)). Each ENERGY STAR qualified model

[73] Source: http://www.energy.ca.gov/2009publications/CEC-400-2009-013/CEC-400-2009-013.PDF

[74] http://www.energystar.gov/index.cfm?c=comm_dishwashers.pr_crit_comm_dishwashers

must meet both metrics. There are different requirements for each dishwasher category and both for high temperature and low temperature machines in each category (see also current Commercial Dishwashers Program Requirements Version 1.2).[75]

Table 9 Energy Star Efficiency Requirements for Professional Dishwashers

Machine Type	High Temperature Efficiency Requirements		Low Temperature Efficiency Requirements	
	Idle Energy Rate*	Water Consumption**	Idle Energy Rate*	Water Consumption**
Undercounter	< = 0.9 kW	< = 1.00 gal/rack	< = 0.5 kW	< = 1.70 gal/rack
Stationary Single Tank Door**	< = 1.0 kW	< = 0.95 gal/rack	< = 0.6 kW	< = 1.18 gal/rack
Single Tank Conveyor	< = 2.0 kW	< = 0.70 gal/rack	< = 1.6 kW	< = 0.79 gal/rack
Multiple Tank Conveyor	< = 2.6 kW	< = 0.54 gal/rack	< = 2.0 kW	< = 0.54 gal/rack

** Idle energy rate as measured with door closed and representative of the energy used by the tank heater only*
*** Includes pot, pan, and utensil machines. 1 US Gallon = 3.785 Litres*

Water consumption has to be measured according to the NSF/ANSI 3-2007 standard (Commercial Warewashing equipment, see Section 3.2.2).The idle energy rate has to be measured according to ASTM Standard F1696 (Hot Water and Chemical Sanitizing Under-counter and Stationary Rack Single Tank Door-Type Dishwashers, see Section 3.1.1.12) and to ASTM F1920 (Hot Water and Chemical Sanitizing Single and Multiple Tank Rack Conveyor Dishwashers, see Section 3.1.1.13).

The requirements are effective since October 11, 2007. The market penetration of ENERGY STAR qualified models for the US is estimated at 45 to 50% of the market[76]. According to the "Commercial Dishwashers Qualified Product List" posted on February 16, 2011, around 280 professional dishwashers have qualified for the ENERGY STAR[77]. Due to this high market penetration, US EPA is currently revising the specifications[78]. The updated version 2.0 is expected to become effective from 1 February 2012.

ENERGY STAR specifications based on ASTM and NSF/ANSI requirements apply to hot water and chemical *sanitizing* machines (for further details: see Task 6). These machines and processes, commonly used on the US market, generally require higher (sanitizing) temperatures compared to the (cleaning) temperatures of dishwashers in Europe[79]. This

75 http://www.energystar.gov/ia/partners/product_specs/program_reqs/Commercial_Dishwashers_Program_Requirements.pdf

76 Personal information by US EPA, Climate Protection Partnerships Division / Energy Star

77 http://www.energystar.gov/ia/products/prod_lists/comm_dishwashers_prod_list.pdf

78 For more information on the interim status with regard to draft specifications and stakeholder comments, see http://www.energystar.gov/index.cfm?c=revisions.commercial_dishwasher_spec

higher thermal minimum requirement results in higher energy consumption and lower efficiency, respectively. Therefore the ENERGY STAR requirements are regarded to be not appropriate to cover European requirements and market trends and the label is not applied by European manufacturers.

4.3.2 Canada

Regulations under the Energy Efficiency Act,[80] in effect since 1995, set minimum energy-performance levels for a number of energy-using products such as appliances, lighting, and heating and air-conditioning products. Broadening and strengthening the Act means that 80 percent of the energy used in homes and businesses will soon be regulated. Over time, the set of planned new regulations will address about 20 currently unregulated products such as commercial clothes washers and boilers, and will tighten requirements for 10 products such as residential dishwashers and dehumidifiers. Professional dishwashers[81] do not fall under the scope of the Canadian Energy Efficiency Act.

4.3.3 Australia

A wide range of products are regulated for energy efficiency in Australia. Also, new products are continually being considered for regulation or other types of programs in order to improve energy efficiency. Other than for commercial refrigeration appliances, professional dish-washing appliances do not fall under the (considered) scope of the Australian energy efficiency regulation so far.[82]

4.3.4 China

The China Standard Certification Center (CSC),[83] formerly known as China Certification Center for Energy Conservation Products (CECP), was officially founded in October 1998, by the former China State Economic and Trade Commission (SETC) with an approval from the former State Bureau of Quality and Technical Supervision. CSC has been administrated by China National Institute of Standardization. Over the past several years, CSC has

---

79 Hot water sanitizing: according to NSF/ANSI minimum washing temperatures of 66 to 74°C required depending on the dishwashing machine category; cleaning: according to DIN 10512 washing temperatures of 60 to 65°C required, see Section 3.2.4.

80 Source: http://oee.nrcan.gc.ca/regulations/home_page.cfm

81 Under the new products to be regulated, inter alia there are pre-rinse spray valves. These devices use a spray of water to remove food waste from dishes prior to cleaning in a commercial dishwasher. They are usually placed at the entrance to a commercial dishwasher or may also be located over a sink, in conjunction with a faucet fixture. Therefore, they do not belong to professional dishwashing appliances, but are a separate product category.

82 Source: http://www.energyrating.gov.au/considered.html

83 http://www.cecp.org.cn/english/index.asp

continuously introduced various product certification programs to promote the use of energy conservation, water conservation and environmental-friendly products and equipment. In addition to lighting products, CSC's energy conservation certification programs now cover over other 35 product categories, for example home appliances, electronic, industrial, office equipments, building materials, etc. To date, more than 2 000 individual products from approximately 250 manufacturers have participated in the certification program. However, no information on professional dishwashers has been found.

4.3.5 Russia

No information on Russian regulations with regard to professional dishwashers has been found.

5 Conclusions: Scope of the study

Within Lot 24 we define professional dishwashers as follows (cf. Section 2.4.3):

> '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 of professional dishwashers to dishwashers for household use is determined from the 'intended use' (domestic or commercial / industrial use) as declared by the manufacturer in the product information or the Declaration of Conformity (cf. Section 2.4.2).

Besides this formal distinction, professional and household dishwashers can be distinguished by functional performance and technological differences resulting from different requirements regarding the dishwashing process (see Section 2.4.4). Professional dishwashers need to take into account important framework requirements (short running cycles, high throughput, amount and type of wash ware, spatial requirements) to fulfil their primary function (to clean, rinse, and dry a certain amount of dishware, glassware, cutlery, and/or other cooking utensils). Reflecting these framework requirements and taking into account functional and technological differences, professional dishwashers can be categorised into the following six categories (cf. Section 2.5.5.3):

- Dishwashers with fresh-water system
  - Category 1: Undercounter water-change dishwashers (semi-professional)
- Dishwashers with tank systems
  - One-tank dishwasher
    - Category 2: Undercounter one-tank dishwashers
    - Category 3: Hood-type dishwashers
    - Category 4: Utensil / Pot dishwashers
    - Category 5: One-tank conveyor-type dishwashers (belt/basket)
  - Multi-tank dishwasher
    - Category 6: Multi-tank conveyor-type dishwashers (belt/basket).

6 Sources

For the categorisation of product types, numerous web pages and product brochures of manufacturers and industry associations have been analysed.

Table 10 Manufacturers' and industry associations' web pages screened within EuP Lot 24

Manufacturer	Web address
ASKO	http://www.askousa.com/
Electrolux Professional	http://www.electrolux-professional.de/
Granuldisk	http://www.granuldisk.com/
Hamony Business	http://www.harmonybusiness.co.uk/Products-2.html
Hobart	http://www.hobart-export.com/wExport_en/products/index.php
Industrieverband Haus-, Heiz- und Küchen-technik e.V. (HKI)	http://www.hki-online.de
Krefft	http://www.krefft.de/cms/front_content.php?idcat=11
Maytag	http://www.maytag.com/catalog/all_products.jsp
Meiko	http://www.meiko.info
Miele Professional	http://www.miele-professional.com
Stierlen	http://www.stierlen.de/index-en.html
Verband Gewerbliches Geschirrspülen (VGG)	http://www.vgg-online.de/ (with background information regarding professional dishwashing (see http://www.vgg-online.de/merkblaetter/default_engl.htm))
Wexiödisk	http://www.wexiodisk.co.uk/
Winterhalter	http://www.winterhalter.de/ http://www.winterhalter.co.uk/winterhalter/products/index.html
Zanussi Professional	http://www.zanussiprofessional.com/node584.asp

Further valuable sources for professional dishwashers have been:

- Expertly guided on-site visit at main kitchens of University Medical Hospital Freiburg (Germany)
- Personal information by
  - CENELEC TC59X,
  - Danish Technological Institute DTI
  - HKI,
  - Hobart,
  - Meiko,
  - Miele Professional,
  - VGG, and
  - Winterhalter.

7 Annex

7.1 Questionnaire "Task 1" for stakeholders

The questionnaire is provided separately (EuP_Lot24_Dish_T1_Annex_Questionnaire.pdf).

7.2 Stakeholder feedback to draft versions of Task 1

Please note that the feedback refers to prior versions of Task 1 report; thus the indicated numerations of chapters, tables, figures or pages might have changed.

Feedback		Comment
Hobart (answers to the questions in annex)		
Q-2.1	**Delimitation between professional and private use:** – Performance (number of dishes per hour, power consumption) – Working principle (fresh water rinse versus water-change principle) – Continuous operation (conveyor dishwasher) – Specific dish carriers (racks) – MD 2006/42/EC is applicable to professional dishwasher = work equipment – LVD 2006/95/EC is applicable to dishwashers for private use = consumer Product – Distribution channel – Price	Included in report.
Q-2.2	**Distinction between professional and industrial appliances (machines):** – What means "Industrial"? (Series production, high output, etc.) – What means "Professional"? (Commercial, no private use, may include "industrial"…) – One can't really distinct between "industrial" and "professional" pertaining to dishwashers.	Included in report.
Q-2.3	**Properties of dishwashers:** Additional properties to distinguish between flight type dishwashers: – Fully automated systems (automated cutlery, plate, bowl and tray separation and dishwasher loading as well as unloading and storing of cleaned items) – Semi automated systems (automated cutlery and tray loading as well as unloading) – Manual loading and unloading of dishes	Not seen to be of relevance for the purpose of EuP Lot 24.

Feedback		Comment
Q-2.4	**Categories:** – The given categorisation is OK to us as far as items 1 to 6 are concerned. – Item 7 refers to trolleys which can't be designated as "dishes". This topic should be deleted. – Pass through dishwashers with water-change operation (fill and dump types) are unknown by us. – Pass through dishwashers with two racks which can be cleaned during one single cycle are available – The capacity of program automats ranges from approx. 5 to 70 racks/h. – DW with water-change operation are only known as undercounters. – The technological difference is insignificant between rack conveyor and flight type dishwashers. – "Transport dishwashers" are exclusively used for dishes like plates, cutlery, cups, trays, etc. Similar (maybe identical) machines are sometimes used for other applications like animal cages, industrial products in production lines. These are no DW! – The size of transport dishwashers ranges from 1,5m to 20m in length, from 0,8m to 2m in width and 1,2m to 3m in height. The capacity may range from 1 500 to 14 000 plates/h. – Specialized DW are designed for special applications. This may affect: dish carrier, cycle time respectively conveyor speed, spray pressure, dryer configuration, robustness of the machine, etc.… – Every category can be used for mobile application but the majority of mobile application applies to categories 2 and 3. – There are no significant differences between dishwashers for stationary and mobile applications. – Significant technological differences between granulate DW and comparable utensil washers of category 4 are unknown.	Trolley washers had been already excluded in the report, Rest: Considered in report
Q-2.5	**Legislation and standards:** – EN 50242 / 60456 is exclusively applicable to long cycled cleaning processes. It is impractical to apply this standard to professional dishwashers because of their very short cycle times. Reason: As per EN 50242 / 60456, the soiled items undergo the oven drying procedure for two hours to simulate stubborn soiling which is related to household use. In commercial establishments, the dry-on time is usually very short (less than two hours at room temperature). Thus, the soil remains relatively soft and can be washed-off rapidly. – An accordant standard for measuring the performance of professional dishwashers does not exist. Manufacturers use internal test procedures which allow direct comparison between models of similar performance characteristic. These test procedures are not suitable for a performance classification of professional dishwashers because of insufficient reproducibility.	Included in report (Task 1 and Task 4)

Feedback		Comment
	– Following parameters should be subject of a possibly to be developed standard: - simply to apply - proportional to the task of the EuP-Directive - to ensure minimum performance - to ensure hygienic results as specified in DIN 10510-10512. - energy demand - demand of water, detergent, rinse aid – General aspects of particular importance for standardization: - a possible standard should match the practical utilization. - it shall be prevented that future professional dishwashers are primarily designed to meet the standard requirements and fail under practical use conditions. – Hygiene requirements should be applied to all profess. DW. – Differentiation between “industrial” / “professional” doesn’t make sense in this context because the only difference is the wording.	
Miele		
Table 2, p. 11	**Target group / Applications for Semi-professional Dishwashers: High-end households, offices, small pensions** Please add: hospitals, hotels, Nursing homes, restaurants, community kitchens, Bed & Breakfasts, institutional kitchens, Kindergartens & pre-schools, schools, Supermarkets. Please remove: High-end households	Included in report.
Table 2, p. 11	**Cleaning and Hygienic requirements** Domestic Dishwashers and Semi-professional Dishwashers also have high cleaning and hygienic requirements. The hygienic requirements of Semi-professional Dishwashers are typical similar to Professional Dishwashers, due to the fact that they have similar target groups. In fact some Semi-professional Dishwashers reach final rinse temperatures as high as 90°C. In conjunction with a certain holding time they achieve an “A0 value of 600”, which is considered thermal disinfection (90°C for 60 sec., according EN ISO 15883). Professional Dishwashers reach only an “A0 value of 60”	We do not say that household appliances have low hygienic per-formance. They however do not underlay certain hygienic requirements, and the hygienic performance is no measured in the performance standard (EN 50242/60456). We added hygienic requirements for the semi-professional dishwashers.

Feedback		Comment
Winterhalter		
1.3, p. 10	**Water-change system** It is mentioned, that dishwashers with water-change operation are more hygienic and need less effort for cleaning the machine. We do not believe, that this is proved, so this should not be stated as fact	Sentence deleted.
2.1.2, p. 25	**DIN normatives** It is mentioned, that the DIN Hygiene normatives do not cover cleaning or other performance parameters. But they do. For example in DIN10512 Section 5.4.2 there are requirements concerning cleaning, drying and hygiene. Experience shows, that when hygienic requirements are fulfilled, the basic functionalities for a good cleaning result are a precondition.	Revised in report.
Danish Technological Institute		
Draft final report, Section 3.1.4.1	**First line:** ....has measured data on energy and water consumption... should be changed to: ....has measured data on energy and water consumption and cleaning performance...	Revised in report.
Draft final report, Section 3.1.4.1	**Last sentence:** The last sentence: “However, the VGG standard has not been updated since 40 years and is neither applicable nor used according to feed back at the interim stakeholder meeting of EuP Lot 24” The sentence will give a wrong impression if it is not added that it was said by a couple of manufacturers who said that the work in counting the grains on the dishes in this cleaning test was much too large. I took part in the stakeholder meeting and remember that this was said by Diplom-Ökonom Siegfried Päsler, Geschäftsfürer for VGG, Verband der Hersteller von Gewerblichen Geschirrspülmaschinen E.V. and Markus Gessler from Winterhalter They tried to convince the participants that standardized test for dishwashers were of no use because what the dishwasher was going to wash was not known before it was sold and that they always made good adaption of the machine to the use at the buyer. Karl J. Büttner from Hobart and Matthias Meiwes from Miele told me that they use the method. But they did not mention it during the meeting. Miele helped us in developing the modernised test that we use in Denmark as a voluntary test for suppliers who want their test data on the official web site www.sparelisten.dk/spareopvaskemaskiner We therefore suggest that the last sentence is deleted or changed to: A couple of manufacturers and the Geschäftsfürer for VGG had the opinion that the work in performing the VGG cleaning test is too large.	Specified in report.

Feedback		Comment
Hobart		
Section 3.3	**Safety standards** add: EN 50416 Household and similar electrical appliances – Safety – Particular requirements for commercial electric conveyor dishwashing machines	Included in report.
Section 3.4 Noise	**Noise standards** add: Following Standards apply to professional dishwashers (as per EN 50416 as well as per EN 60335-2-58): EN ISO 3744 Acoustics – Determination of sound power levels of noise sources using sound pressure – Engineering method in an essentially free field over a reflecting plane EN ISO 3746 Acoustics – Determination of sound power levels of noise sources using sound pressure – Survey method using an enveloping measurement surface over a reflecting plane EN ISO 4871 Acoustics – Declaration and verification of noise emission values of machinery and equipment EN ISO 9614-2 Acoustics – Determination of sound power levels of noise sources using sound intensity – Part 2: Measurement by scanning EN ISO 11204 Acoustics – Noise emitted by machinery and equipment – Measurement of emission sound pressure levels at a work station and at other specified positions – Method requiring environmental corrections	Included in report

7.3 Method used by DTI for performance measurement of hood-type dishwashers[84]

The data have been determined according to „VGG Prüfverfahren zur Reinigungs-Index-Bestimmung von gewerblichen Geschirrspülmaschinen, Blatt 1, Kleinmaschinen; Entwurf 1970-06-12 ergänzt 1973-02-15, (Ref 1)" with some modifications. The modifications follow as far as possible the European standard EN 50242 for household dishwashers.

- Ambient conditions: Temperature (23 +/- 2) °C, air humidity (55 +/- 5)% RH
- Power supply: Regulated voltage 230/400 V, 3N, neutral and ground
- Water supply: Temperature (15 +/- 2) °C, pressure (240 +/- 50) kPa, soft water.

The machine was selected, installed and started by the machine supplier including selection of programme (standard dish programme with duration about 2 minutes). Soil has been prepared as in Ref 1 and applied with 7 gram per dish. Washing has been started immediately after the soiling of dishes for the machine was finished.

[84] Source: Danish Technological Institute / 2009-01-22 / J H Kjeldgaard for Danish Energy Association

Detergent in liquid form of the make Dr. Weigert, neodisher, Alka300 is manually dosed in an amount of 2 ml per litre water in the wash tank. After the first five washes an additional amount is supplied corresponding to the amount of water taken in during the first five washes. Rinse agent of make Dr. Weigert, neodisher, TS is added automatically in a rate arranged by the supplier of the machine.

The machine was started from an emptied and cleaned condition, and after being ready, 10 washes were performed successively on the machine all with the prescribed number of soiled dishes arranged as described by the supplier in the delivered baskets. A reference machine was run in parallel to monitor possible variations in test conditions such as e.g. preparation and application of soiling. For every second wash the dishes were inspected for cleaning result as described in Ref 1[85].

The following table provides the mean value of 10 datasheets with regard to the different measured parameters. The detailed results of the machine specific performance tests are published on the internet.[86]

Table 11 Mean value of the results of 10 washes according to method used by DTI for performance measurement of hood-type dish-washers

Data sheet for Tank dishwasher **MEAN** (of machines)	Dishes per wash DN	Energy per wash kWh	Water per wash l	Time per wash sec	Max wash temp C	Max rinse temp C	Wash result front x	Wash result back y	Cleaning index front F	Cleaning index back B	Cleaning index total J	Clean index refmean/ref corr	Cleaning index total *corr Jc
Wash	17,3	0,547	3,77	133	54,0	83,1	17,3	41,1	74,3	70,52	72,40	1,0003	72,39
		Energy kWh	Water l	Time min									
Start to ready mode		3,438	46,86	31,0									
Ready mode 4h		1,273	0,07	240									

Notes:

- Dishes per wash are the number of dishes soiled and washed in each wash.
- Energy per wash is the mean energy consumption for the 10 washes. It is determined as the total energy consumption during the time period for performing the 10 washes subtracted by the energy consumption for the ready mode in an equal period of time.
- Water per wash is the mean water consumption during the wash.

[85] The method used by DTI for measuring the cleaning index is done by counting number of grains on the wash ware. It does not explicitly measure residues of detergent as one Swedish manufacturer asked for. DTI argued against that if the cleaning index is good it means that fresh rinsing water has been applied in an efficient way so that also the detergent will have been rinsed well of. On the other hand, DTI offered to the Danish and Swedish suppliers to develop a method for testing detergent residues if they could agree to finance the development; however there has not been sufficient interest.

[86] http://www.sparelisten.dk/spareopvaskemaskiner/vaskemaskine_liste.asp?m=3

- Time is the mean duration of the wash measured in seconds by a stopwatch from start of the wash until the machine signals that the wash is finished.
- Max wash temp is the mean of maximum wash temperature measured every 10 seconds by a thermocouple placed between the dishes.
- Max rinse temp is the mean of the maximum rinse temperature measured every 1 second by a thermocouple placed in the rinse water flow upstream of the rinse spray arm but as close to the rinse spray arm as possible for the given construction of the machine.
- Wash result front and back is judged by visual inspection as in Ref 1.
- Cleaning index total is the mean of results computed as in Ref 1 for the single wash.
- Clean index ref_{mean}/ref is the correction factor found by dividing the mean value of the cleaning index for the reference machine for all the tests performed in this series of tank washing machine tests with the mean value found for the reference machine when running in parallel with this specific machine.
- Cleaning index $total_{corr}$ is the final cleaning result after correction with the results of the reference machine.
- Start to ready mode The machine has been started from an emptied and ambient temperature condition. Energy and water consumption and time have been measured from the start until the machine has reached a ready mode characterized by the water temperature in the wash tank being in the wash temperature range for this machine and that the energy consumption has stopped. Two tests are performed and the mean value is determined.
- Ready mode 4h Energy and water consumption and time have been measured from a condition where the water temperature in the wash tank is in the wash temperature range for this machine and until 4 hours later where the same situation exists / is established. The test is performed with a closed top if possible. Two tests are performed and the mean value is determined.

Preparatory Studies for Eco-design Requirements of Energy-using Products

Lot 24: Professional Washing Machines, Dryers and Dishwashers

Tender No. TREN/D3/91-2007

February 2011

Final Report, Part: Dishwashers

Task 2: Economic and Market Analysis

Öko-Institut e.V.
Institute for Applied Ecology, Germany
Ina Rüdenauer
Eva Brommer
Markus Blepp
Carl-Otto Gensch
Kathrin Graulich

BIO Intelligence Service, France
Shailendra Mudgal
Raul Cervantes
Thibault Faninger
Lorcan Lyons

Büro Ö-Quadrat, Germany
Dieter Seifried

Öko-Institut e.V.
Freiburg Head Office
P.O. Box 17 71
79017 Freiburg, Germany
Street Address
Merzhauser Str. 173
79100 Freiburg, Germany
Tel. +49 (0) 761 – 4 52 95-0
Fax +49 (0) 761 – 4 52 95-88

Darmstadt Office
Rheinstr. 95
64295 Darmstadt, Germany
Tel. +49 (0) 6151 – 81 91-0
Fax +49 (0) 6151 – 81 91-33

Berlin Office
Schicklerstr. 5-7
10179 Berlin, Germany
Tel. +49 (0) 30 – 40 50 85-0
Fax +49 (0) 30 – 40 50 85-388

www.oeko.de

For reasons of better readability, two Task 2 reports were prepared.

The report at hand covers ***professional dishwashers***.

The Task 2 report on *professional washing machines and dryers* is published separately.

Part: Professional Dishwashers

Table of Contents – Task 2: Economic and Market Analysis

List of tables **V**

List of figures **VI**

1 Introduction **1**

1.1 Objective of Task 2 **1**

2 General economic data **1**

2.1 Production **1**

2.1.1 Unit volume 1

2.1.2 Sales value 3

2.1.3 Unit value 5

2.2 Trade **5**

2.2.2 PRODCOM Imports and Exports 5

2.2.3 INTRA and EXTRA databases 6

2.3 Apparent EU-consumption **7**

3 Market data **10**

3.1 Market structure **10**

3.1.1 Sales and distribution 10

3.1.2 International trade 12

3.2 Manufacturers **12**

3.2.1 Germany 14

3.2.2 Italy 16

3.2.3 Spain 18

3.3 Sales **18**

3.3.1 Sales by product type 19

3.3.1.1 Undercounter water-change and one-tank dishwashers (categories 1 and 2) 21

3.3.1.2 Hood-type dishwashers (category 3) 21

3.3.1.3 Utensil / pot dishwashers (category 4) 21

3.3.1.4 Conveyor-type one-tank and multi-tank dishwashers (categories 5 and 6) 22

3.3.2 Sales by customer 22

3.4 Average product life **24**

3.5 Stock **24**

3.6 Summary of market data **28**

4	**Market trends**	**28**
4.1	**General market trends**	**28**
4.2	**Employment figures**	**32**
4.3	**Redesign cycle**	**32**
4.4	**Product-specific trends**	**32**
4.4.1	Development over the past five to ten years	33
4.4.1.1	Energy and water consumption	33
4.4.1.2	Detergents	34
4.4.1.3	Changes on the demand side	35
4.4.1.4	Marketing of professional dishwashers and technological features	36
4.4.2	Development over the next ten years	36
5	**Consumer expenditure base data**	**37**
5.1	**Purchase costs**	**37**
5.2	**Running costs**	**42**
5.2.1	Energy costs	42
5.2.2	Consumables (detergent, water, etc.)	45
5.2.2.1	Detergent and rinse aid	45
5.2.2.2	Water	46
5.2.3	Interest and inflation rates	48
5.3	**Maintenance and service costs**	**49**
5.4	**Disposal costs**	**50**
5.5	**Summary of end-user expenditure**	**51**
6	**Conclusions**	**51**
7	**Annex**	**53**
7.1	**Questionnaire “Task 2” for stakeholders**	**53**
7.2	**Stakeholder feedback to draft versions of Task 2**	**53**

List of tables

Table 1	Production of professional dishwashing machines by Member State in units, 2005-2008 (thousand units)	2
Table 2	Value of professional dishwashing machines produced in EU-27 by Member State (thousand Euro)	4
Table 3	Unit value of non-domestic dishwashing machines by Member State reporting	5
Table 4	Quantity and value of exports and imports of professional dishwashers, 2008	6
Table 5	Value of exports and imports of professional dishwashers to and from non-Member States (EU-27 EXTRA) and to and from other Member States together (EU-27 INTRA), 2009	7
Table 6	Apparent consumption of non-domestic dishwashers at EU level	8
Table 7	Number of professional dishwasher by inhabitant, by Member State in 2008	9
Table 8	(Non-exhaustive) list of professional dishwasher manufacturers relevant to the European market	12
Table 9	Major German professional dishwasher export destinations, 2009	14
Table 10	Exports of catering equipment from Italy by destination, 2008 (%)	16
Table 11	Estimated production of professional dishwashers by Member State, 2009	19
Table 12	EU professional dishwasher sales, 2009 (estimate)	19
Table 13	Estimated sales of professional dishwashers by category	22
Table 14	Share of professional dishwasher sales by type of purchaser	23
Table 15	Ownership in a survey of 1 000 catering establishments in Italy (%)	23
Table 16	Estimated lifetimes of products in this study based on stakeholder responses	24
Table 17	Calculated stock using Eurostat reported values	25
Table 18	Total stock of professional dishwashers (2010), using H&C trends	27
Table 19	Market data summary, by product type	28
Table 20	Hotel and catering enterprises, assuming 1% increase per year	31
Table 21	Projected market for different types of dishwashers 2009-2025	32
Table 22	Development of energy consumption of professional dishwashers in the past 10 years	33
Table 23	Development of water consumption of dishwashers over the past 10 years	34

Table 24	European average price by machine of similar capacity. Figures from stakeholders and public catalogues. Prices are without VAT	38
Table 25	Electricity rates for industrial customers in EU-27 average 2007-2009 (taxes excluded)	42
Table 26	Electricity rates for professional dishwashing products in Europe based on typical usage scenario	43
Table 27	Natural gas rates for consumers in EU-27, average between 2007 and 2009 (taxes excluded)	44
Table 28	Summary of the rates used for gas for professional dishwashers	45
Table 29	Example detergent prices (products on sale on the internet)	45
Table 30	Water consumption and effective rate for eight European cities	47
Table 31	Interest and inflation rates for EU-27, 2007	48
Table 32	Lifetime maintenance costs of professional dishwasher products in Lot 24	50
Table 33	User expenditure base data	51

List of figures

Figure 1	Value of EU-produced professional dishwashers in EU-27, 2005-2008	3
Figure 2	Distribution channels in the UK for warewashing equipment in 2007	11
Figure 3	European professional dishwasher sales by product type (estimate)	20
Figure 4	Number of Hotel and Catering establishments in EU-25 according to Oxford Research study.	26
Figure 5	Market sales values according to Eurostat	29
Figure 6	Sales trend of non-domestic dishwashers until year 2025, based on data from Eurostat and stakeholders	29
Figure 7	Price and capacity of undercounter one-tank dishwasher machines (dishes/h), 2009-2010	39
Figure 8	Price and capacity of hood-type dishwashers (dishes/h), 2009-2010	40
Figure 9	Price and capacity of utensil/pot dishwashers (rack size in m^2), 2009-2010	40
Figure 10	Price and capacity of one-tank conveyor-type dishwasher equipments (dishes/h), 2009-2010	41
Figure 11	Price and capacity of multi-tank conveyor-type dishwasher equipments (dishes/h), 2009-2010	41
Figure 12	Water cost break down in Rhône region of France for 15 years	46

1 Introduction

1.1 Objective of Task 2

The purpose of this task is to present the economic and market analysis related to professional dishwashers. The aim is, firstly, to place this product group within the total of the European Union (EU) industry and trade policy. Secondly, it provides market and cost inputs for the EU-wide environmental impacts of the product group. Thirdly, it aims to provide insights into the latest market trends. This will be an input for the subsequent tasks such as improvement potential. Finally, practical data on consumer prices and rates is provided to be used later in the Life Cycle Costs (LCC) calculations.

Note that the report at hand only covers professional dishwashers. The Task 2 report on professional washing machines and dryers is published separately.

2 General economic data

The PRODCOM database is useful for an initial analysis as it is transparent and publicly available data provided by Member States of the EU on manufacturing and production information within the EU.

2.1 Production

2.1.1 Unit volume

In 2007, 378 800 professional dishwashers were produced according to Prodcom data. Table 1 shows the number of units produced for 2005-2008, indicating where large manufacturing centres are located. However, it is important to note that data is missing for several Member States and therefore the total has to be considered with caution.

Table 1 Production of professional dishwashing machines by Member State in units, 2005-2008 (thousand units)

Country	2005	2006	2007	2008	% change 2005-2008
Belgium	-	-	-	-	
Bulgaria	-	-	-	-	
Czech Republic	-	-	-	-	
Denmark	1.4	1.4	1.5	1.3	-7%
Germany	62.9	66.2	84.2	83.2	+32%
Estonia	0	0	0	0	
Ireland	0	0	0	0	
Greece	-	-	-	-	
Spain	31.2	36.7	37.0	36.8	+18%
France	2.9	-	2.5	-	
Italy	230.8	218.6	236.1	222.4	-4%
Cyprus	0	0	0	0	
Latvia	0	0	0	0	
Lithuania	0	0	0	0	
Luxembourg	0	0	0	0	
Hungary	0	0	0	0	
Malta	0	0	0	0	
Netherlands	0	-	-	-	
Austria	-	-	0	0	
Poland	-	-	-	-	
Portugal	0.6	-	0.5	0	
Romania	0	0	0	0	
Slovenia	0	-	0	0	
Slovakia	-	-	-	-	
Finland	0	0	0	0	
Sweden	-	-	-	-	
UK	5.8	6.6	7.2	2.3	-60%
EU-27	**346.2**	**343.7**	**378.8**	**357.1**	**+3%**

'-' signifies that the information is unavailable either because it is confidential or estimated or both.
Source: Prodcom.

The Prodcom data suggests that Italy, Germany and Spain are the largest centres of professional dishwasher manufacturing. The UK and France also produce professional dishwashers but a much smaller amount. While this is not an exhaustive or comprehensive analysis, it gives an overview of the professional dishwasher market and indicates in which Member States the analysis can fruitfully be pursued. As for confidential data, 11 100 units were unaccounted for in 2008, produced across nine different Member States. Stakeholders

have commented that Sweden contributes a significant number of units to the market and is thought to have the largest share of the unaccounted units. However, this information is not available in Prodcom. Electrolux is an example of a major international domestic and professional appliance manufacturer based in Sweden.

Based on the above, 97% of total reported unit production in the EU in 2008 is non-confidential and non-estimated data. This means that a very significant share of the total EU-27 market is accounted for by Prodcom data and shows that:

- Italy represents 62% of the units produced in the EU in 2008;
- Germany represents 23%;
- Spain represents 10%.

Therefore, 96% of the dishwasher market in Europe is produced in Italy, Germany or Spain (difference in sum total due to rounding).

2.1.2 Sales value

Figure 1 shows the value of professional dishwashers produced according to PRODCOM.

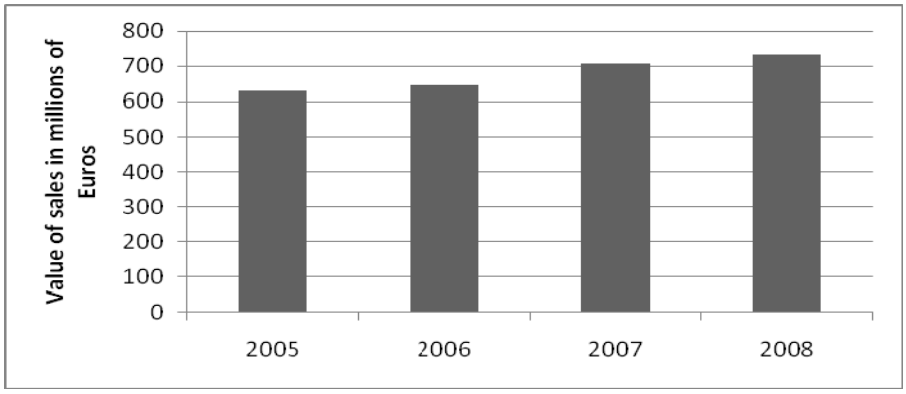


Figure 1 Value of EU-produced professional dishwashers in EU-27, 2005-2008[1]

The sales value of professional dishwashers produced in the EU amounted to about 735 million Euro in 2008. This is almost three times higher than the sales value of professional washing machines and almost four times the sales value of professional dryers. The average annual growth in sales over the past four years is 5.1%. This will be elaborated further in the market trend section (Section 4).

The sales data by Member State show a key distinction between the volume of units produced and the value of the sales. Table 2 shows Germany as having the highest sales in the EU, surpassing Italy, which was shown in Table 1 to produce over twice as many

[1] PRODCOM statistics based on NACE 2 Rev. accessed at: http://epp.eurostat.ec.europa.eu/portal/page/portal/prodcom/data/tables_excel, 18 Jan 2010.

machines. This difference can be explained by the difference in the value of the machines. Germany tends to produce larger, more sophisticated conveyor-type dishwashers while Italy tends to produce simpler undercounter professional dishwashers with lower sales value (cf. Section 3.2).

Table 2 Value of professional dishwashing machines produced in EU-27 by Member State (thousand Euro) [1]

Member State	2005	2006	2007	2008
Belgium	-	-	-	-
Bulgaria	-	-	-	-
Czech Republic	-	-	-	-
Denmark	8 769	10 198	10 837	9 400
Germany	260 683	274 972	311 249	351 575
Estonia	0	0	0	0
Ireland	0	0	0	0
Greece	-	-	-	-
Spain	33 010	38 463	40 208	58 458
France	26 557	-	24 385	-
Italy	262 439	253 760	272 578	237 856
Cyprus	0	0	0	0
Latvia	0	0	0	0
Lithuania	0	0	0	0
Luxembourg	0	0	0	0
Hungary	0	0	0	0
Malta	0	0	0	0
Netherlands	0	-	-	-
Austria	-	-	0	0
Poland	-	-	-	-
Portugal	405	-	358	0
Romania	0	0	0	0
Slovenia	0	-	0	0
Slovakia	-	-	-	-
Finland	0	0	0	0
Sweden	-	-	-	-
UK	10 051	10 872	12 894	16 690
EU-27	631 421	645 554	706 463	732 456

'-' signifies that the information is unavailable either because it is confidential or estimated or both.
Source: Prodcom

Germany and Italy have the largest market value, followed by Spain and the UK. Germany is the most prominent market here despite the fact that in Table 1 Italy had a much larger volume of sales. This can be explained by the difference in unit values reported by Prodcom.

2.1.3 Unit value

Dishwashers have a unit value which is highly dependent on the Member State in question. Table 3 shows the range of unit values for non-domestic dishwashers as reported by Prodcom for the Member States where information is available.

Table 3 Unit value of non-domestic dishwashing machines by Member State reporting [1]

Member State	Unit value (Euro)
Germany	4 227
Spain	1 587
Italy	1 069
United Kingdom	7 375
EU-27	**2 051**

The EU average unit value of 2 051 Euro has been fairly stable for several years. It is a weighted average of several market segments and is heavily weighted to smaller and simpler machines which sell in higher numbers. Section 5.1 further elaborates unit prices for the life cycle cost data for this study.

Overall, Prodcom statistics are not complete for each product and each Member State, so they can only provide a rough overview. Further detail specific to the professional dishwasher market is provided in the following section.

2.2 Trade

2.2.2 PRODCOM Imports and Exports

Table 4 shows imports and exports of professional dishwashers by Member State for the year 2008. In terms of quantity, Germany, Italy and Spain appear as the largest exporters of professional dishwashers while France, the United Kingdom and Spain are the most important importers.

Table 4 Quantity and value of exports and imports of professional dishwashers, 2008[2]

Non-domestic dish-washing machines				
Member State	Exports		Imports	
	Quantity	Value (Euro)	Quantity	Value (Euro)
Austria	1 360	2 280 980	7 911	15 757 830
Belgium	1 626	2 794 570	6 245	11 112 560
Bulgaria	1 051	935 360	4 564	1 930 410
Cyprus	0	0	734	684 130
Czech Republic	785	1 770 820	4 126	7 857 190
Denmark	4 249	6 658 400	19 007	10 703 250
Estonia	247	124 970	2 005	1 075 560
Finland	1 304	4 572 570	4 807	14 755 180
France	3 028	3 398 840	49 579	68 127 490
Germany	52 035	166 952 720	19 621	28 887 900
Greece	2 519	1 455 480	6 976	7 478 230
Hungary	115	400 940	971	1 749 090
Ireland	50	94 100	2 750	3 422 440
Italy	174 377	215 360 610	3 243	7 471 940
Latvia	142	152 590	303	572 870
Lithuania	783	1 270 070	765	1 510 130
Luxemburg	73	70 880	484	831 840
Malta	0	0	225	267 700
Netherlands	2 177	3 061 610	6 986	17 100 450
Poland	372	623 590	8 013	9 540 370
Portugal	345	521 490	8 731	7 265 100
Romania	13	22 550	5 988	2 968 310
Slovakia	31	429 100	2 109	2 319 600
Slovenia	1 008	2 652 050	3 315	4 052 980
Spain	14 424	15 371 910	25 729	19 845 600
Sweden	5 431	24 830 100	7 018	12 423 650
United Kingdom	8 365	5 664 240	35 064	53 789 180

2.2.3 INTRA and EXTRA databases

The Eurostat trade databases INTRA and EXTRA also contain import and export data albeit using the CN8 codification (Combined Nomenclature, which was established to meet the requirements both of the Common Customs Tariff and of the external trade statistics of the European Union), using 8-digit codes. The value of products traded by Member States with other Member States (INTRA) and the value of products traded by Member States with non-Member States (EXTRA) in 2009 are presented in Table 5.

[2] PRODCOM statistics based on NACE 2 Rev. accessed at http://epp.eurostat.ec.europa.eu/portal/page/portal/prodcom/data/tables_excel, 18 Jan 2010.

Table 5 Value of exports and imports of professional dishwashers to and from non-Member States (EU-27 EXTRA) and to and from other Member States together (EU-27 INTRA), 2009[3]

	EU-27 EXTRA (Value in Euros)		EU-27 INTRA (Value in Euros)	
Member State	**Imports**	**Exports**	**Imports**	**Exports**
CN8 84221900 Non-domestic dish-washing machines				
Austria	122 043	863 816	13 989 762	481 141
Belgium	68 275	507 712	9 427 580	2 061 292
Bulgaria	23 370	215 738	810 046	520 357
Cyprus	10 481	:	630 748	:
Czech Republic	7 419	73 738	5 039 819	1 051 605
Denmark	58 818	1 214 430	8 923 394	4 832 103
Estonia	15 010	71 651	370 446	5 564
Finland	5 270	1 733 111	11 781 556	2 253 052
France	626 901	2 055 975	64 799 436	1 481 337
Germany	15 547 330	45 402 587	13 223 612	103 893 536
Greece	181 983	237 862	5 328 585	770 559
Hungary	63 619	32 078	4 921 157	357 584
Ireland	177 592	44 023	2 003 128	19 528
Italy	1 431 372	36 548 332	6 904 378	130 633 774
Latvia	21 586	67 885	192 401	28 307
Lithuania	9 166	602 863	423 787	23 921
Luxembourg	:	11 700	1 091 679	66 391
Malta	:	:	141 834	:
Netherlands	38 216	298 099	12 694 390	2 051 227
Poland	296 061	268 504	6 929 418	230 334
Portugal	:	642 756	6 794 160	530 285
Romania	65 984	17 854	1 392 699	36 981
Slovakia	2 124	308	2 247 409	870 831
Slovenia	39 363	1 168 394	2 709 291	807 032
Spain	265 969	4 715 122	12 786 413	3 192 840
Sweden	80 804	3 417 530	9 255 173	18 209 828
United Kingdom	166 800	1 058 789	44 422 066	3 236 509
EU-27	**19 325 556**	**101 270 857**	**249 234 367**	**277 645 918**

2.3 Apparent EU-consumption

Apparent consumption as shown in Table 6 provides information on the total quantity sold by manufacturers in the EU. It is calculated as follows:

$$Apparent\ consumption_{EU\text{-}27} = Imports_{EU\text{-}27} - Exports_{EU\text{-}27} + Production_{EU\text{-}27}$$

[3] Source: Eurostat trade database EXTRA and INTRA

Apparent consumption can be calculated in currency (Euro) or in physical units. In order to have consistent categories, PRODCOM trade data is used. Note that for several countries, import and export data is reported in PRODCOM but production is reported as zero, or not reported at all (in which case '-' is indicated in the table). These figures should thus be considered with caution (e.g. the apparent consumption of Slovenia in 2007 is negative which is in theory impossible).

Table 6 Apparent consumption of non-domestic dishwashers at EU level[4] [1]

Member State	2005		2006		2007		2008	
	Quantity (in units)	Value (in m€)	Quantity (in units)	Value (in m€)	Quantity (in units)	Value (in m€)	Quantity (in units)	Value (in m€)
Austria	-	-	-	-	6 350	12.11	6 551	13.48
Belgium	-	-	-	-	-	-	-	-
Bulgaria	-	-	-	-	-	-	-	-
Cyprus	744	0.47	725	0.72	754	1.03	734	0.68
Czech Rep.	-	-	-	-	-	-	-	-
Denmark	4 060	9.94	3 810	12.48	7 299	14.16	16 092	13.44
Estonia	399	0.54	116	0.70	6 327	0.72	1 758	0.95
Finland	2 584	4.65	2 848	7.21	3 258	7.85	3 503	10.18
France	36 739	73.98	-	-	61 995	81.22	-	-
Germany	44 953	174.42	43 348	176.10	55 414	188.25	50 751	213.51
Greece	-	-	-	-	-	-	4 457	6.02
Hungary	2 061	2.23	3 289	1.98	1 049	-0.24	856	1.35
Ireland	7 343	4.82	5 163	4.55	5 121	3.87	2 700	3.33
Italy	39 518	83.98	24 671	62.37	59 324	70.80	51 260	29.97
Latvia	423	0.35	436	0.71	289	0.46	161	0.42
Lithuania	452	0.70	361	0.47	498	0.35	-18	0.24
Luxemburg	426	0.65	340	0.95	656	1.13	411	0.76
Malta	5 457	0.25	284	0.19	151	0.15	225	0.27
Netherlands	8 163	9.79	-	-	-	-	-	-
Poland	-	-	-	-	-	-	-	-
Portugal	9 044	5.94	-	-	12 069	7.49	8 386	6.74
Romania	0	1.33	1 572	2.82	2 912	3.48	5 975	2.95
Slovakia	-	-	-	-	-	-	-	-
Slovenia	1 215	0.71	-	-	-1 742	1.17	2 307	1.40
Spain	17 231	40.72	30 483	47.87	70 186	48.04	48 123	62.93
Sweden	-	-	-	-	-	-	-	-
UK	13 309	52.63	30 007	49.75	4 825	54.49	35 019	62.18
EU-27	256 608	552.81	284 881	558.02	298 755	603.45	301 093	609.54

[4] PRODCOM statistics based on NACE 2 Rev. accessed at http://epp.eurostat.ec.europa.eu/portal/page/portal/prodcom/data/tables_excel, 18 Jan 2010.

The Eurostat PRODCOM database has the advantage of being an official EU source that is used and referenced in other EU policy documents regarding trade and economic policy. However, it is not always complete or of high enough quality to serve as a useful market data source for this study. Table 7 shows the number of professional dishwashers by inhabitant and Member State in 2008. For MS where the data is available, the figures show large variation yet this figure is not expected to vary much across countries: between 340 for Denmark and 14 105 for Latvia. This highlights the uncertainties existing about Eurostat data in certain countries. However, several Member States present one machine for approximately 1 000 – 2 000 inhabitants (e.g. Austria, Finland, Germany, Italy, Ireland, Portugal, UK), which also turns out to be the EU-27 average (1 653 inhabitants per machine).

Table 7 Number of professional dishwasher by inhabitant, by Member State in 2008[5]

Member State	2008	
	Population (in inhabitants)	Number of inhabitants for one professional dishwasher
Austria	8 318 592	1 270
Belgium	10 666 866	-
Bulgaria	7 640 238	-
Cyprus	789 269	1 075
Czech Republic	10 381 130	-
Denmark	5 475 791	340
Estonia	1 340 935	763
Finland	5 300 484	1 513
France	64 004 333	-
Germany	82 217 837	1 620
Greece	11 213 785	2 516
Hungary	10 045 401	11 735
Ireland	4 401 335	1 630
Italy	59 619 290	1 163
Latvia	2 270 894	14 105
Lithuania	3 366 357	-187 020
Luxemburg	483 799	1 177
Malta	410 290	1 824
Netherlands	16 405 399	-
Poland	38 115 641	-
Portugal	10 617 575	1 266
Romania	21 528 627	3 603

[5] PRODCOM statistics based on NACE 2 Rev. accessed at http://epp.eurostat.ec.europa.eu/portal/page/portal/prodcom/data/tables_excel, 18 Jan 2010

Member State	2008	
	Population (in inhabitants)	Number of inhabitants for one professional dishwasher
Slovakia	5 400 998	-
Slovenia	2 010 269	871
Spain	45 283 259	941
Sweden	9 182 927	-
United Kingdom	61 191 951	1 747
EU-27	497 683 272	1 653

To double check these statistics, it was necessary to investigate other sources of sales and stock data. Additional information was gathered through questionnaires sent to stakeholders, mainly manufacturers, and is presented in the next section.

3 Market data

Based on the product definition of Task 1, six broad categories have been defined for professional dishwashers that can be used here for market and stock data definition. Based on the market data collected, further refinement will allow the key representative products (or product features) to be analysed in the later stages of the study.

3.1 Market structure

The professional dishwasher market is above all a business-to-business (B2B) market and has some key characteristics:

3.1.1 Sales and distribution

- The majority of smaller manufacturers typically sell and distribute their products to catering equipment dealers/distributors who stock and sell several brands of professional dishwashers and usually other types of catering equipment supplies (ovens, refrigerators, plates, utensils, etc). This is particularly applicable for smaller machines such as the undercounter and hood-type machines. The catering equipment distribution and supplier network for small professional dishwasher machines is very convoluted as several supply routes are available depending on the type of end user, the end application and the type of machine bought. Because of the competition and the saturation of the market, the choice of distribution strategies is very important which is why many different ones have been developed. Machines may be purchased directly from the manufacturers, via wholesalers, various kinds of retailers or on the second-

hand market. For this reason, manufacturers of small appliances generally do not keep close track of where their products end up.

- Professional dishwashers sold directly to users from the manufacturer tend to be larger dishwashers (conveyor-type) and are usually tuned to customer-specific specifications or requirements upon purchase. They indeed require more intensive support services (training, servicing).
- A UK study estimated that the warewashing industry sales in 2007 occurred according to the proportions presented in Figure 2. This figure is also in agreement with German stakeholder comments. A dealer is a company that buys from a manufacturer or importer (sometimes under an exclusive contract), and sells to the end user or operator[6]. A wholesaler is a company that buys equipment in large quantities from manufacturers and generally sells to other retailers/dealers rather than to end users. In practice, the situation may be more complicated as a company can act as a wholesaler for one manufacturer/distributor, while having the role of a dealer for another manufacturer/distributor. Direct distribution arises when a manufacturer negotiates with and sells equipment directly to the end user.

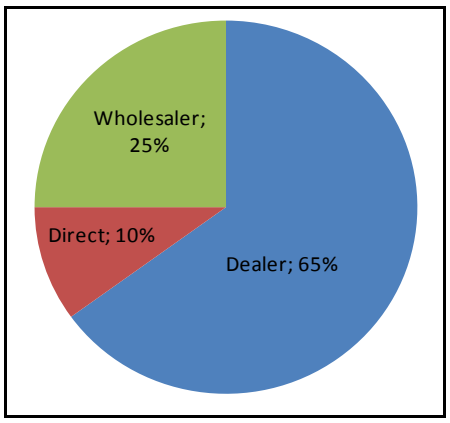


Figure 2 Distribution channels in the UK for warewashing equipment in 2007[7]

- Catering equipment dealers often service and maintain the dishwasher products and can also be dedicated (affiliate) suppliers of one or a few particular dishwasher brands. They do not operate walk in shops but make site visits to the customers. Companies include mostly SMEs with large businesses as well comprising the operators.

6 Because of the European single market, a product manufactured within the EU is 'distributed' to other MS, not 'exported'.

7 Catering Equipment Suppliers' Association (CESA) 2007, *The UK Market for Foodservice Equipment – The authoritative report on the UK market*

Equipment may be sold through several channels depending on the company: in dedicated retail outlets, online or as part of a full project management service.

3.1.2 International trade

- Professional dishwasher imports are not a major market presence in Europe. Foreign brands (Whirlpool, Maytag, etc.) are predominantly American and have established subsidiary manufacturing plants within the EU. Very few sales of professional dishwashers are expected to be direct imports: main provenance countries mentioned by stakeholders are the USA, China, Canada, Turkey, and South Corea. Some machines can be assembled to a certain degree outside EU countries and finalised within EU countries so that they are considered as manufactures in the EU. Without considering these machines as imports, stakeholders have estimated that total EU imports are of the order of 1-2% of total annual production (around 6 000 units).
- Exports outside of the EU are estimated to represent approximately 25-30% of the manufacturing capacity in the EU. While each of the three main EU manufacturing Member States exports their products, it is expected that the majority (approximately 70%) of this trade is done on an intra-EU level. Russia is the largest extra-EU professional dishwasher export market according to stakeholders.

3.2 Manufacturers

The B2B nature of the professional dishwasher market makes it much less transparent than the household dishwasher market. This poses difficulties when attempting to characterise the market in terms of sales, stock, prices and even brands. As there is not a large number of professional dishwasher manufacturers, it is considered relevant to list them for the sake of characterising the market.

The following manufacturers have been identified in the professional dishwasher market in the EU:

Table 8 (Non-exhaustive) list of professional dishwasher manufacturers relevant to the European market

Manufacturer	Country	Manufacturer	Country
Comenda	International (IT)	Eurowash (Eurotek)	Italy
Meiko	International (DE)	Zanussi	Italy
Winterhalter	International (DE)	Mach	(Italy)
Hobart	International (DE)	Jemi	Spain
Fagor Industrial	International (ES)	Difri	Spain
Electrolux	International (SE)	Edesa	Spain
Whirlpool Commercial	International (US)	Linea Blanca	Spain
Miele	International (DE)	Ni-Krom	Spain

Manufacturer	Country	Manufacturer	Country
Rhima	Austria	Sammic	Spain
Jeros	Denmark	Macfrin Grup	Spain
Ken	Denmark	Linea Blanca	Spain
Thirode	France	Sammic	Spain
Solymac International	France	Adler / Crystaline	(Spain)
Bonnet	France	Granuldisk	Sweden
Rosinox	France	Wexiodisk	Sweden
Metos	France	Dc	UK
Jeros	France	Classeq	UK
Palux	Germany	Breakline	(UK)
Stierlen	Germany	Ime – Omniwash	UK
Krefft	Germany	Clenaware	UK
Elviomex "ALFA"	Greece	Chef King	UK
Silanos	Italy	Sherwood	UK
Mareno	Italy	Maidaid Halcyon	UK
Hoonved	Italy	Husky	(UK)
Lasa	Italy	Toucan	(UK)
Lamber	Italy	Diamond	(UK)
Sencotel	Italy	Dexion	(UK)
Nuova Simonelli /	Italy	Alder	(UK)
Univerbar	Italy	Newscan	(UK)
Hemerson	Italy		
Rancilio	Italy	Project Dishwashers	-
Hilta /	Italy	Tiekos	-
Angelo Po	Italy	Futurmat	-
Hilta	Italy	Marels	-
Kromo	Italy	Chef Equip	-
Colged	Italy	Aristarco	-
Elettrobar / Wolk	Italy	Prodis	-
Dihr	Italy	Classic	-
Fabar	Italy	Eurotec	-
Sowebo	Italy	NOSEM Omniwash	-
Ata	Italy	Cimsa	-
Elframo	Italy	ASKO	-

(brackets for country signify apparent country head quarters, '-' signifies that the country was not determined)

The above list is not intended to be exhaustive but it should include a majority of the manufacturers relevant to the European market with a vast majority of the market share covered. It can be seen by the number of manufacturers operating in the Member States that Germany, Spain, Italy, the UK, France and Sweden are the major manufacturing countries in the EU, which confirms the Prodcom data presented in Section 2.1. The 'international' brands listed above tend to be large manufacturers as they are actively operating in multiple Member States and are expected to have large market shares in each country in which they operate.

The Italian market is the most difficult to characterise because of the large number of small- or medium-size (SME) manufacturers operating which are not associated with any national or European manufacturing association.

The key manufacturing Member States, as previously described (Section 2), are Germany, Italy and Spain, accounting for approximately 96% of the manufacturing market in Europe.

There are commercial catering equipment manufacturing associations at the Member State level (e.g. HKI in Germany, CESA in the UK, CECED in Italia). At the European level, the European Federation of Catering Equipment Manufacturers (EFCEM) represents manufacturers of commercial kitchen equipment. It was founded in 1969 and includes the key European national associations in its membership. The national trade associations operate independently and pay a fee to be a member of EFCEM. The total turnover of the 550 companies represented by EFCEM national associations amounts to over 3.6 billion Euro and their products range from utensils to full professional kitchen schemes. EFCEM is the only commercial kitchen equipment group represented in Brussels (via Orgalime of which it is a member). The federation is active in the formulation of standards for the industry and through its meetings seeks to identify and act on issues of common interest.

3.2.1 Germany

Germany exports a very large share of its professional dishwashers. Most exports from German manufacturers are to other EU countries. According to Prodcom, the German market is the largest professional dishwasher market in Europe by value; however, it produces fewer units than the Italian market. Prodcom data suggests that approximately 85 000 units are manufactured in Germany per year, and German data shown in Table 9 and in previous tables 4 and 5 suggest that 50 to 60% of these products are exported, of which about 73% to other EU Member States.

Table 9 Major German professional dishwasher export destinations, 2009[8]

Export destination	Percentage of total export	Units exported
Total	**100%**	**44 553**
EU-27 total	**73%**	**32 408**
Belgium	3%	1 492
Denmark	6%	2 804
Finland	2%	814
France	11%	4 973
Italy	5%	2 011
Latvia	0%	3

[8] Warenverzeichnis Außenhandelsstatistik WA 8422 19 00 Geschirrspülmaschinen – German Commodity Export Statistics for 2009.

Export destination	Percentage of total export	Units exported
Malta	0%	3
Netherlands	7%	3 187
Austria	7%	3 111
Poland	2%	763
Sweden	3%	1 448
UK	21%	9 433
Extra-EU	**27%**	**12 125**
Norway	4%	1 670
Switzerland	8%	3 749
Australia	2%	1 091
Japan	2%	670
China	1%	482
United States	0.4%	191

Imports of professional dishwashers into Germany are significantly less than exports, meaning that Germany has a large trade surplus. Import totals were 17 000 units in the same year, showing that Germany exported approximately 27 000 professional dishwasher units more than it imported in 2009. The total value of German professional dishwasher exports in 2009 was 149 million Euros.

For the purposes of this study, German professional dishwasher manufacturing capacity is estimated at **85 000 units per year**, with a much larger proportion of these products being large conveyor-type dishwashers when compared to the Italian market.
The German market is characterised by large, international, consolidated and vertically integrated manufacturers who often manufacture several types of appliances and machines besides professional dishwashers.

Based on the 2008 General Economic Data presented in Section 2, the value of German manufacturing is the largest of any Member State, just over 350 million Euros.

Two catering equipment manufacturing associations represent the German industry. They are totally independent (no cooperation in general) and manufacturers are split between the two associations (Hobart is not a member of either group):

- HKI (Industrieverband Haus-, Heiz und Küchentechnik e.V. – German association of domestic heating and cooking appliances, represented at European level by EFCEM and Orgalime) (Electrolux Professional GmbH, Miele Professional, PALUX Aktiengesellschaft, Stierlen GmbH, Granuldisk, Scandisk); and
- VGG (Vereinigung Gewerbliches Geschirrspülen – Association of commercial dish-washing) (Meiko, Winterhalter)

Small German professional dishwasher products are typically sold to catering equipment dealers, both in Germany and other Member States. Direct sales from the manufacturer to

the end users are mainly larger conveyor-type dishwashers. However, precise data were not found.

3.2.2 Italy

Italy manufactures the largest number of professional dishwashers of any Member State in Europe. As with the German manufacturing market, many of these units are produced for export within the EU. However, when compared to the German production base, a smaller number of Italian products are manufactured for export, as Italian manufacturers tend to be a mix of SMEs and large multinationals. The Federazione Nazionale Imprese Elettrotecniche ed Elettroniche (National Federation of Electrotechnical and Electronics Industries) collects and surveys market statistics on the entire catering equipment industry in Italy. The statistics for Italian catering equipment exports, as reported in the annual report of 2008[9] is shown in. While this information is aggregated for the entire catering industry, it can be considered a representation of the dishwasher manufacturing situation in Italy. Professional dishwasher equipment is a significant part of the catering equipment industry, and therefore these numbers are relevant to help characterise the Italian market.

Table 10 Exports of catering equipment from Italy by destination, 2008 (%) [9]

Destination	Percentage
Europe	**72**
EU 27	58.7
France	10.7
Germany	8.5
Spain	7
UK	6.6
Non-EU European countries	13.3
Africa	**5.5**
America	**9.3**
Asia	**11.6**
Australia	**1.6**

The total manufacturing capacity of Italian professional dishwasher products is difficult to discern, as there are several conflicting sources of data. Prodcom estimates that around 220 000 units are produced yearly, while stakeholders have estimated an annual manufacturing capacity of 120 000 units. Italy exported 80% more professional catering equipment (not only professional dishwashers, but all catering equipment) in 2008 than it imported. The

[9] Rapporto annual – L'Industria Elettrotecnica ed Elettronica in Italia Dati di settore e attività (2008), accessed 20 March 2010, http://www.anie.it/download.asp?tm=2009_6_30_15_53_36

large difference between stakeholder input and Prodcom data is expected to arise from the nature of the Italian manufacturing market. There are many SMEs in Italy, each with a small proportion of total Italian manufacturing capacity. This market is difficult to characterise and gives rise to greater uncertainty when attempting to estimate the total manufacturing capacity of Italian professional dishwashers.

The value of Italian professional dishwasher production is expected to be slightly less than German professional dishwasher production (Prodcom estimates approximately 30% less), while Italian manufacturers produce approximately twice as many units per year as Germany.

For the purposes of this study, the Italian market will be estimated to produce **170 000 professional dishwashing units per year** (this estimate is a simple average of the two sources). A large proportion of these appliances are smaller undercounter or hood-type dishwashers (one-tank pass through dishwashers), which is in contrast to the German production base of larger, more expensive (conveyor-type) machines. This helps to explain the large difference in value per product produced in these two Member States.

Italy has several large multinational manufacturing facilities owned by foreign manufacturers (Electrolux, Meiko, etc.) and many SMEs, which can be independent or affiliates, subsidiaries or groups of larger multinational corporations (e.g. Ali group). It is expected that due to the convoluted and disorganised nature of the distribution and supply chain of professional dishwasher equipment (especially smaller appliances), many of the products exported to other EU Member States are not put to final use there, but are shipped through other distribution channels, and the final point of use is unknown.

The only Italian manufacturers' association for professional dishwashers is:

- CECED Italia (national association of producers of domestic and professional appliances), representing approximately 60-80% of Italian professional dishwasher manufacturing.[10]

Based on the General Economic Data for 2008 presented in Section 2, the Italian manufacturing sector is the second largest in the EU, at just over 237 million Euros.

Italian professional dishwasher products are sold to catering equipment suppliers, both in Italy as well as in other Member States. No information has been gathered to characterise what proportion of sales occur by other means than catering equipment suppliers (for example directly to customers).

[10] Normally CECED is dedicated to domestic appliances; however in this specific case they represent professional appliance manufacturers. http://www.ceceditalia.it/jsp/index.jsp?id=default&id=default

3.2.3 Spain

The Spanish manufacturing base of professional dishwashers had traditionally been built upon domestic sales, but has continued to increase export sales within the EU and even, to a certain extent, beyond the EU. Overall, the balance of exported products outside the EU is expected to be small. Spanish manufacturers are a mix of SMEs and large multinationals.

Stakeholders estimate that the Spanish manufacturing sector produces **40 000 professional dishwasher units per year**, which is very much in line with Prodcom data and will be the estimated Spanish professional dishwashing manufacturing capacity used in this study.

The only Spanish manufacturers' association for professional dishwashers is:

- FELAC (Federación Española de Asociaciones de Fabricantes de Maquinaria para Hostelería, Colectividades e Industrias Afines – Spanish Federation of Associations of Manufacturers of Machinery for Hospitality, Collectivities and Allied Industries), representing approximately 80% of the Spanish professional dishwasher manufacturing market.

Based on 2008 General Economic Data presented in Section 2, the Spanish manufacturing sector is the third largest in Europe, at just over 58 million Euro.

Spanish professional dishwasher products are sold to catering equipment dealers both in Spain as well as in other Member States. The extent of Spanish exports has not been determined but is not expected to be a significant share of total Spanish production. Looking back at Eurostat data (Table 2 and Table 5), 4.7 millions Euro of professional dishwashers were exported outside the EU-27 in 2008, while 3.2 million Euro were exported to other MS which sums up to 7.9 millions Euro. Compared to the production value of 58.5 million Euros in 2008, exports represent around 14% of production.

3.3 Sales

The aim of this section is to assess the sales volume (number of units sold) for different types of professional dishwashers. Based on the previous market structure data, Table 11 summarises professional dishwasher manufacturing capacity in the EU. Over the period 2005-2008, Germany, Spain and Italy represent 94.4% of the EU-27 professional dishwasher production according to Table 1. The EU-27 total production in 2009 was therefore estimated from the previous figures presented in Germany, Spain and Italy, and from this production share.

Table 11 Estimated production of professional dishwashers by Member State, 2009

EU manufacturing Member State	Professional dishwashers produced per year
Italy	170 000
Germany	85 000
Spain	40 000
Others (UK, France, Sweden, Greece, Denmark, Portugal, Austria, etc.)	17 500
EU total	**312 500**

In total, it is estimated that 312 500 professional dishwashers are manufactured in the EU, and 73% are sold for use within the EU: exportations outside the EU-27 in Euro in 2008 (101 million Euro, Table 5) represent 14% of the total EU production value in 2008 (732 million Euro, Table 2) but these figures come from different databases (PRODCOM and EXTRA) so that the manufacturers estimate of 25-30% exports outside the EU is considered more relevant. Including a small proportion of professional dishwasher imports from outside the EU (approx. 2% of the production), the estimated professional dishwasher sales in Europe are **234 600 units per year**. Table 12 summarises this data.

Table 12 EU professional dishwasher sales, 2009 (estimate)

	Professional dishwashers sold in 2009
EU manufacturing estimate	312 500
minus units exported	- 84 400
plus units imported	+ 6 500
Total EU sales	**234 600**

The distribution of these sales is estimated to be roughly in accordance with each Member State's respective size but is also expected to vary with the different cultural habits of the Member State. The average dishwashing needs per customer in each Member State are not expected to vary much from one region of Europe to another. However, the number of customers per catering establishment and thus the type of machine that is most appropriate for the average catering establishment is expected to vary from region to region in Europe.

The range of products according to the definition of the scope in Task 1 is included in this estimate.

3.3.1 Sales by product type

In general, very little market data on EU professional dishwasher manufacturing and trade exists. This poses several difficulties for an eco-design preparatory study, as the lack of information will prevent clear and informed regulatory decisions from being made. On an

international scale, even fewer data sources are available regarding professional dishwashers; however, in North America, NAFEM (North American Foodservice Equipment Manufacturers) publishes the "Size and Shape" study of the North American market every two years by surveying members of their organisation. Approximately 50% of the market is represented in the survey, with the other 50% extrapolated from observed trends.

Since there should not be significant differences between the US and the EU markets with regards to the number of restaurants or canteens using professional dishwashers, it is useful for approximating how many of each type of product are sold as a proportion of the total (categories as defined in the Task 1 report). This total is assumed to be similar to European sales per capita. European stakeholders have also estimated that the proportions of EU sales by product category are quite similar to those in North America.

Figure 3 shows stakeholder estimates of the shares of product sales in the EU (rounded numbers, further calculations with exact numbers).

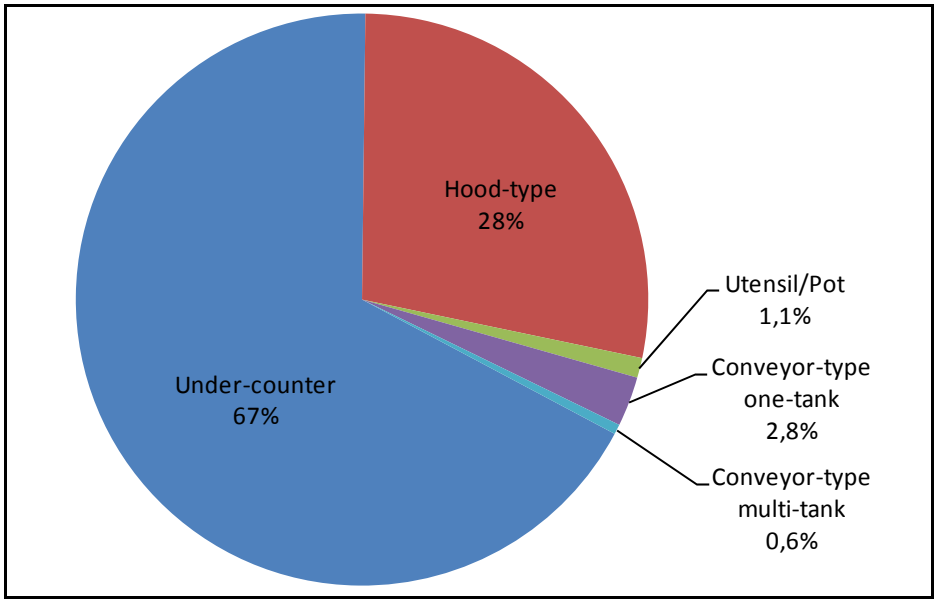


Figure 3 European professional dishwasher sales by product type (estimate)

The NAFEM size and shape study agrees with the above shown proportions very well. The NAFEM information cannot be published here due to copyright issues but the close agreement between the NAFEM size and shape study and European stakeholder comments allows a good level of confidence that such a distribution of product sales accurately reflects actual sales.

The following analysis is divided by the categories of dishwasher as segregated in Task 1 for undercounter water-change/one-tank (categories 1 and 2), hood-type (category 3), utensil/

pot (category 4), conveyor-type one-tank (category 5) and conveyor-type multi-tank (category 6) professional dishwashers.

3.3.1.1 Undercounter water-change and one-tank dishwashers (categories 1 and 2)

These categories of professional dishwashers account for the largest number of dishwashers sold. 'Manually loaded program automats, with water-change operation', 'Manually loaded program automats, with one-tank', and 'Glasswashers' are considered to be part of these categories. 'Manually loaded program automats, water-change operation' have been identified as professional appliances as their intended use concern commercial and semi-commercial customers. These models are thus compliant with the Machinery Directive (see Task 1).

Undercounter dishwashers represent the largest sales volumes for all product groups because they are the smallest and the least expensive, and because they are very flexible and suitable for many commercial catering applications. The customers of these products are the most diverse and have a wide variety of dishwashing needs. Based on the aggregated sales estimate and proportion of products sold in this category as estimated by stakeholders, the yearly sales of undercounter one-tank professional dishwashers (category 2) in the EU are estimated to be **138 200 units per year** (including glasswashers). Undercounter water-change professional dishwashers (category 1) are estimated to be **20 000 units per year**, giving a total of **158 200 units per year** for all undercounter type machines.

3.3.1.2 Hood-type dishwashers (category 3)

Hood-type dishwashers are a middle range product category that represent a dishwashing solution for customers with higher capacity needs than what the typical front load type dishwasher is capable of, but not a high enough capacity need (or spatial possibility) to justify or allow the use of a conveyor-type dishwasher. Most commercial restaurants, in turn estimated to be the largest proportion of customers in this market, use hood-type dishwasher products. Based on the aggregated sales estimate and proportion of products sold in this category as estimated by stakeholders, annual sales of this product type in the EU are **65 900 units per year**.

3.3.1.3 Utensil / pot dishwashers (category 4)

Utensil / pot dishwasher is a mid-range capacity product category which represents a dishwashing solution for customers with larger or more irregular washing needs than the typical front load type dishwasher is capable of. These washers are sold in smaller volumes, as their function is specific to odd-shaped bakeware or large pots and pans that cannot be properly washed in smaller, more typical dishwashers. Based on the aggregated sales

estimate and proportion of products sold in this category as estimated by stakeholders and NAFEM, the sales of this product type are estimated to be **2 600 units per year**.

3.3.1.4 Conveyor-type one-tank and multi-tank dishwashers (categories 5 and 6)

These products are considered by stakeholders to have one of the smallest market shares by number of units sold, but one of the largest by value. The market here is characterised by the type of customer, which is almost exclusively a large restaurant or institutional cafeteria. It is neither cost effective, nor functionally better to implement these types of dishwashers in smaller dishwashing operations, and therefore the conveyor-type dishwasher market is restricted exclusively to large eating establishments with high capacity cleaning requirements. Based on the aggregated sales estimate and proportion of products sold in this category as estimated by stakeholders and NAFEM, yearly sales of this product type are estimated to be **7 900 units** in the EU, of which 6 600 are one-tank conveyor-type dishwashers and 1 300 units are multi-tank conveyor-type dishwashers. Table 13 summarises the sales estimated by product type.

Table 13 Estimated sales of professional dishwashers by category

Product type	Estimated number of units sold per year
Category 1: Undercounter water-change	20 000
Category 2: Undercounter one-tank	138 200
Category 3: Hood-type	65 900
Category 4: Utensil/Pot	2 600
Category 5: Conveyor-type one-tank	6 600
Category 6: Conveyor-type multi-tank	1 300
Total	**234 600**

3.3.2 Sales by customer

Stakeholder responses to questionnaires and interviews have given estimations for the customer profile of professional dishwashers in the EU which is shown in Table 14.[11]

[11] Responses received from: Hobart, Winterhalter, Fagor, Granuldisk

Table 14 Share of professional dishwasher sales by type of purchaser

Type of purchaser	Estimated share of unit sold (%)
Commercial service – Restaurants and hotels	65
Hospitals and other institutional service	23
Commercial food sales – Bakeries, butchers, grocers, other commercial service	10
Other catering activities	2

(Source: Stakeholder interviews and questionnaire responses)

The purchasing habits of each consumer type can be estimated through stakeholder interviews. Institutional service and commercial food preparation businesses are purchasers of larger conveyor-type or utensil/pot dishwashers, while restaurants, hotels and other catering services are purchasers of smaller undercounter and hood-type dishwashers.

It is expected that the variation between Member States of the type of purchaser and the type of professional dishwashing product purchased is small. While there are differences in the number of institutional versus small restaurants between Member States, the dish-washing needs for each customer type are similar and therefore dishwashing product purchases are expected to be quite similar.

A study conducted by CECED Italia shows the ownership rate of different dishwashing machine types in Table 15.

Table 15 Ownership in a survey of 1 000 catering establishments in Italy (%)[12]

Type of appliance	Total	Bar / Cafe	Restaurant	Pizzeria / Pubs	Hotels
Glasswasher	75.2	86.5	74.0	59.6	54.2
Undercounter	23.0	20.8	26.8	27.4	23.1
Conveyor-type	23.0	13.2	35.0	22.6	32.5
Hood-type	21.4	2.1	38.7	22.1	33.9
Utensil/Pot	6.8	3.0	11.1	2.7	9.8
None	6.6	3.2	1.6	21.8	8.0

(The sum in each column can be greater than 100% due to multiple possible answers)

Though the categories used in the table above do not exactly match that given in Task 1, the trends presented above agree with the general assumptions and estimations derived from stakeholder interviews and comments: most bars and restaurants have glasswashers (which can have a rather low capacity), conveyor-types are mainly used in restaurants (cafeterias) and hotels, while utensil/pot dishwashers are not very common.

[12] CECED Italy presentation material

3.4 Average product life

The lifetime of the appliances is of interest in this study as it is a key parameter in assessing life cycle environmental impacts and the LCCs (Life cycle Costs) of the appliances in the later stages of the study (Task 5 and 7). Lifetime can also be used to estimate the stock data based on sales. In the context of the study, the focus is on 'active lifetime', meaning the time in service. Based on responses from the stakeholder questionnaire and discussions during the interim stakeholder meeting, the lifetimes of the products in this study are estimated in Table 16.

Table 16 Estimated lifetimes of products in this study based on stakeholder responses

Type of appliance	Average product life time (in years)
Category 1: Undercounter water-change	12
Category 2: Undercounter one-tank	8
Category 3: Hood-type	8
Category 4: Utensil/Pot	8
Category 5: One-tank conveyor-type	12
Category 6: Multi-tank conveyor-type	17

3.5 Stock

The aim of this section is to assess the total stock of dishwashing appliances in use today for different types of professional dishwashers. No information has been obtained from market studies or stakeholders regarding the stock of professional dishwasher appliances in the EU. Two methods were used to determine the stock. The first method refers to values found from Eurostat[13] for apparent sales in the past years.

First method: based on Eurostat

While it is understood that Eurostat data can often be incomplete, the indication given is useful for comparison and validation of other sources of data.

Eurostat presents the sales in recent years for non-domestic dishwashers (Product code: 28295000). It is assumed that the total sales stated by Eurostat correspond to the six categories considered in the project. Although the statistics are presented from 1995, the first five years were considered non relevant for EU-27 Member States because the data was too irregular and incomplete. The total stock of appliances for 2009 as calculated from Eurostat data is shown in Table 17. The data below corresponds to the 'Volume of Production' +

[13] http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home/

'Imports' – 'Exports' given as 'Apparent Sales' in EU-27, reported from 2000 to 2008, where an increasing trend on apparent sales is shown. The stock is considered as the accumulated value of sales during the lifetime of each product (e.g. 12 years for undercounter equipments – category 1) and is indicated by grey cells in the table. The calculation and extrapolation (for the years 1990-1999) does not take into account the progressive enlargement of the EU. The figures are thus representative of a virtual EU-27 from 1990 onwards.

Table 17 Calculated stock using Eurostat reported values

Year	Sales (units)*	Cat. 1 sales Under-counter water-change (8.51%)	Cat. 2 sales Under-counter one-tank (58.91%)	Cat. 3 sales Hood-type (28.09%)	Cat. 4 sales Utensil/ Pot (1.12%)	Cat. 5 sales One-tank conveyor-type (2.81%)	Cat. 6 sales Multi-tank conveyor-type (0.56%)	Total stock (units)*
1990	*230 017*	19 567	135 500	64 611	2 584	6 461	1 292	*1 832 982*
1991	*233 284*	19 845	137 425	65 529	2 621	6 553	1 311	*1 861 341*
1992	*236 550*	20 123	139 349	66 447	2 658	6 645	1 329	*1 889 699*
1993	*239 817*	20 401	141 273	67 364	2 695	6 736	1 347	*1 918 058*
1994	*243 084*	20 679	143 198	68 282	2 731	6 828	1 366	*1 946 416*
1995	*246 351*	20 957	145 122	69 200	2 768	6 920	1 384	*1 974 775*
1996	*249 617*	21 235	147 046	70 117	2 805	7 012	1 402	*2 003 133*
1997	*252 884*	21 513	148 971	71 035	2 841	7 103	1 421	*2 031 492*
1998	*256 151*	21 791	150 895	71 952	2 878	7 195	1 439	*2 059 850*
1999	*259 417*	22 069	152 820	72 870	2 915	7 287	1 457	*2 088 209*
2000	278 788	23 716	164 231	78 311	3 132	7 831	1 566	*2 116 567*
2001	263 941	22 453	155 484	74 141	2 966	7 414	1 483	*2 144 926*
2002	273 215	23 242	160 948	76 746	3 070	7 675	1 535	*2 173 284*
2003	277 386	23 597	163 405	77 917	3 117	7 792	1 558	*2 201 643*
2004	247 146	21 025	145 591	69 423	2 777	6 942	1 388	*2 230 001*
2005	256 608	21 830	151 165	72 081	2 883	7 208	1 442	2 258 360
2006	284 881	24 235	167 820	80 023	3 201	8 002	1 600	2 286 718
2007	298 755	25 415	175 993	83 920	3 357	8 392	1 678	2 315 077
2008	301 040	25 609	177 339	84 562	3 382	8 456	1 691	2 334 189
2009	*292 085*	24 848	172 064	82 046	3 282	8 205	1 641	2 363 737
Stock 2009		**279 829**	**1 314 323**	**626 718**	**25 069**	**92 399**	**25 400**	**2 363 737**

**Values in red/italic are extrapolated from figures presented by Eurostat.*

Second method: based on H&C sector trend

According to stakeholders, the Hotel and Catering (H&C) sector represents 65% of dishwashing machines sales. It is logical to conclude that the evolution of this industry has a big impact on the evolution of dishwashing machines.

The number of establishments for H&C is shown in Figure 4.[14]

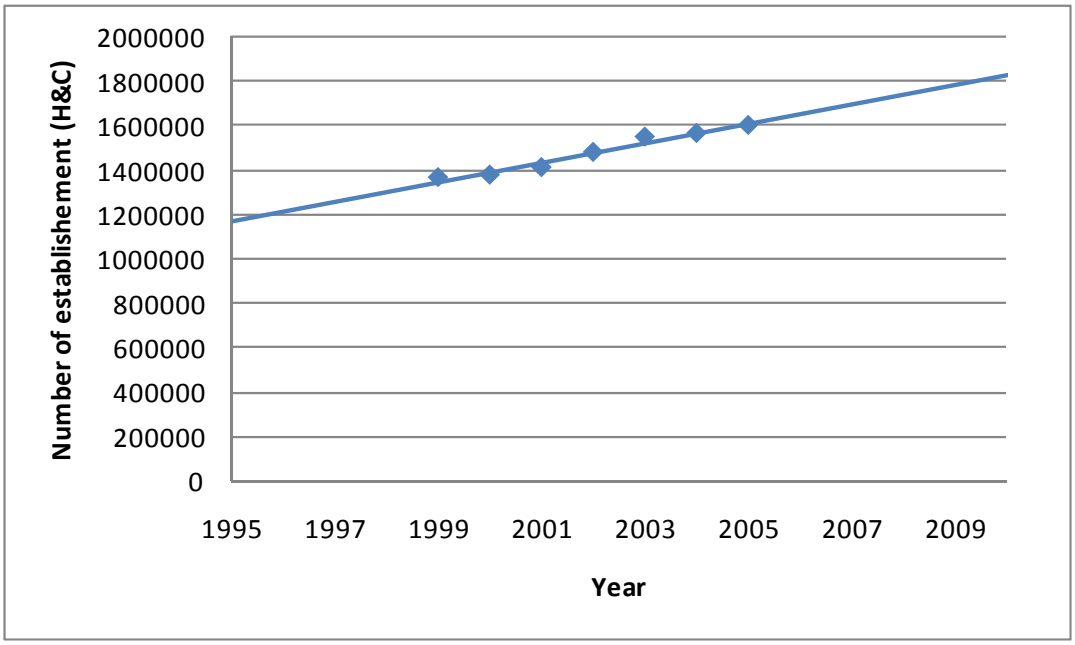


Figure 4 Number of Hotel and Catering establishments in EU-25 according to Oxford Research study.

The trend of consumption of dishwashing machines is likely to be similar to the trend followed by H&C establishments. The market share for each category was considered constant for all equipments. These values are shown in Table 18. The total stock of professional dishwashers has been calculated from sales estimations and in this model it is thus assumed that all the professional dishwashers sales are represented by the H&C sector (Table 13): the calculated demand is considered proportional to the number of H&C establishments (with a rate of proportionality set thanks to the annual sales in 2009), and the growth rate of the H&C sector is used as the average growth rate for all dishwashers sold.

[14] Oxford Research. *Comprehensive sectoral analysis of emerging competencies and economic activities in the European Union. Lot 12 – Restaurants and Hotels*. 2009.

Table 18 Total stock of professional dishwashers (2010), using H&C trends

Year	H&C Establish.*	Calcu-lated demand (i.e. annual sales in units)*	Cat. 1 sales Under-counter water-change (8.51%)	Cat. 2 Sales Under-counter one-tank (58.91%)	Cat. 3 sales Hood-type (28.09%)	Cat. 4 sales Utensil/ Pot (1.12%)	Cat. 5 sales One-tank conveyor-type (2.81%)	Cat. 6 sales Multi-tank conveyor-type (0.56%)	Total stock (units)*
1993	*1 085 973*	*142 656*	12 136	84 037	40 072	1 603	4 007	801	*1 023 931*
1994	*1 129 718*	*148 402*	12 625	87 422	41 686	1 667	4 169	834	*1 072 795*
1995	*1 173 464*	*154 149*	13 113	90 807	43 300	1 732	4 330	866	*1 121 659*
1996	*1 217 209*	*159 895*	13 602	94 192	44 914	1 797	4 491	898	*1 170 522*
1997	*1 260 955*	*165 642*	14 091	97 578	46 529	1 861	4 653	931	*1 219 386*
1998	*1 304 701*	*171 388*	14 580	100 963	48 143	1 926	4 814	963	*1 268 250*
1999	1 366 670	*179 529*	15 272	105 758	50 429	2 017	5 043	1 009	*1 319 508*
2000	1 378 144	*181 036*	15 401	106 646	50 853	2 034	5 085	1 017	*1 366 526*
2001	1 411 853	*185 464*	15 777	109 255	52 097	2 084	5 210	1 042	*1 412 226*
2002	1 481 050	*194 554*	16 551	114 609	54 650	2 186	5 465	1 093	*1 461 269*
2003	1 550 247	*203 644*	17 324	119 964	57 203	2 288	5 720	1 144	*1 513 656*
2004	1 566 668	*205 801*	17 507	121 235	57 809	2 312	5 781	1 156	*1 562 453*
2005	1 603 148	*210 593*	17 915	124 058	59 155	2 366	5 916	1 183	*1 610 296*
2006	*1 654 665*	*217 360*	18 491	128 044	61 056	2 442	6 106	1 221	*1 659 160*
2007	*1 698 411*	*223 107*	18 980	131 430	62 670	2 507	6 267	1 253	*1 705 914*
2008	*1 742 156*	*228 853*	19 468	134 815	64 285	2 571	6 428	1 286	*1 756 404*
2009	*1 785 902*	234 600	19 957	138 200	65 899	2 636	6 590	1 318	*1 808 056*
Stock 2009			**207 223**	**1 012 355**	**482 728**	**19 309**	**68 425**	**18 015**	**1 808 056**

**Values in red/italic are extrapolated from those presented in the Oxford Research study or calculated from figures provided by stakeholders.*

The actual number of dishwashing units is likely to be between these two figures (1 808 056 – 2 363 737). **The second method is considered more reliable due to the sources of data for market trends and annual sales (Eurostat 2008): statistics on the number of H&C establishments are considered more reliable the production of non-household dishwashers reported (which shows important variations from one year to another). Therefore the figures presented in Table 18 will be used within the study.** A sensitivity analysis in Task 8 will study the influence of the uncertainty of these market figures.

3.6 Summary of market data

Table 19 summarises the market data presented in the previous sections. This data will be useful in later tasks (Task 5-7-8) for estimating life cycle properties of these products and build scenarios at the EU level.

Table 19 Market data summary, by product type

Product type	Estimated number of units sold per year (2009)	Estimated stock (2009)	Average product lifetime (in years)
Undercounter water-change	20 000	207 223	12
Undercounter one-tank	138 200	1 012 355	8
Hood-type	65 900	482 728	8
Utensil/Pot	2 600	19 309	8
Conveyor-type one-tank	6 600	68 425	12
Conveyor-type multi-tank	1 300	18 015	17
Total	**234 600**	**1 808 056**	**-**

4 Market trends

4.1 General market trends

This subtask aims to provide market trends indicating market structures and relevant trends in product design. The analysis is done following two different methods. In the first method, historical sale figures from Eurostat[15] are considered and their linear trends are set. The second method considers information provided by stakeholders regarding the biggest market sector (hotel and catering industry) for the appliances. This method assumes that the sales trend for dishwashers will be directly related to the trend for H&C.

First method based on Eurostat:

Eurostat presents past annual sales for non-domestic dishwashers (Product code: 28295000). The total sales are assumed to represent only the six main categories presented in the study. Although the statistics are presented from 1995, the first five years were considered not relevant for EU-27 Member States because the data was too irregular and incomplete. The red line in the figure below corresponds to the volume of Apparent Sales (Production + Imports – Exports) in EU-27, reported from 2000 to 2008, and an increasing trend is shown.

[15] http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home/

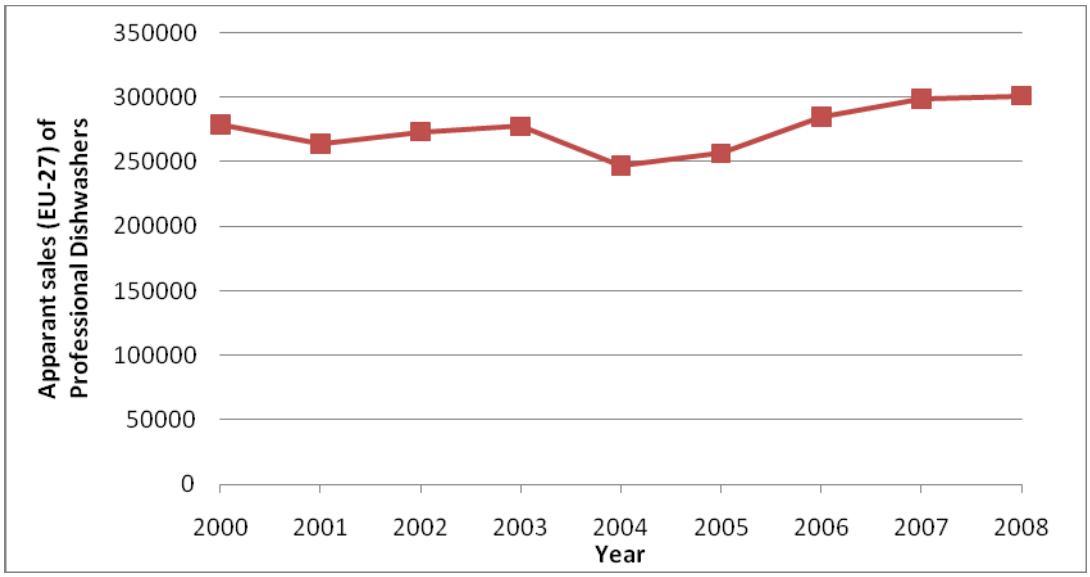


Figure 5 Market sales values according to Eurostat

Based on Eurostat values it is also possible to establish a linear sales trend for the years until 2025. This is shown in Figure 6. Stakeholder estimates for 2009 (see Section 3.2) are not considered for the trend, since they are not directly extracted from Eurostat. Instead, they are expressed as a single point in the graph.

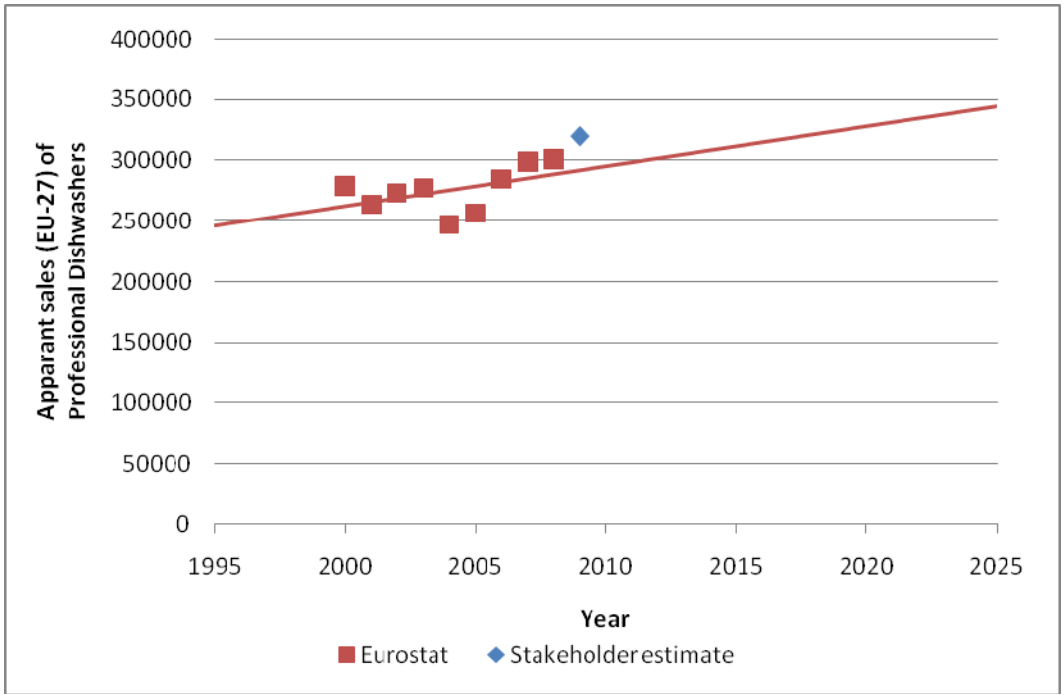


Figure 6 Sales trend of non-domestic dishwashers until year 2025, based on data from Eurostat and stakeholders

According to this result, around 340 000 units are expected to be sold per year in 2025. The yearly increase is estimated around 1%.

Second method (based on H&C sector trend):

According to the information provided by stakeholders, the main market for professional dishwashers is hotels and catering/restaurant services (around 65%). The second biggest market share for dishwashers is institutions such as hospitals (see Table 14). It is logical to expect that the evolution in the market of these machines is closely related to the evolution of these two sectors.

The market is also changing as environmental awareness increases. This concern for the environment is producing technology change in the machines used within the hotel and catering sector – machines that consume less energy are increasing their market share.[16] Several companies have already started to produce appliances with energy efficiency features, some of them claiming to save up to 80% of energy.[17] The current trend for the hotel industry is to outsource tasks in order to simplify internal processes,[18] e.g. cooking, cleaning and administrative tasks. However, dishwashing (not requiring skilled personnel) is not likely to follow this path, as the transport of crockery can represent an additional cost and be unpractical. Regarding competition in the hotels market, the same study mentions that regardless of the size of the company, new technologies including environmentally-friendly products and IT systems must be adopted in order to maintain market share. This means that market demand for environmentally-friendly products exists and is probably growing.

Based on the feedback of stakeholders, the market share of large-capacity (conveyor-type) appliances has been increasing in recent years.

In a study conducted by Oxford Research,[19] the growth trend of the hotel and catering sector was estimated to be 1% per year for the combination of different scenarios and considering an estimated total of 1 750 000 enterprises in 2008 (Table 20).

---

16 European Foundation for the Improvement of Living and Working Conditions (2005) *Policies, issues and the future. The hotels and catering sector.*

17 Source: Fagor Industrial brochure, www.fagorindustrial.com/upload/productos/subcategorias/catalogos/fr/advance_def_ENG_FRA_.pdf

18 European Foundation for the Improvement of Living and Working Conditions (2005) *Visions of the future. The hotels and catering sector*.

19 Oxford Research (2009). *Comprehensive sectoral analysis of emerging competencies and economic activities in the European Union Lot 12: Hotels and restaurants.*

Table 20 Hotel and catering enterprises, assuming 1% increase per year

Year	Estimated number of hotel and catering enterprises
2008	1 750 000
2010	1 785 000
2015	1 875 000
2020	1 970 000

This matches a CESA study of the UK foodservice industry where warewashing equipment was found to represent 9% of the overall foodservice equipment industry in 2007, which grew annually by 1.7%.[20]

Since no studies presenting the actual size of the dishwasher sector have been identified, the trend for the hotel and catering sector and hospitals is assumed to reflect the behaviour of dishwasher sales for the coming years.

An estimation of the future market for dishwashers must consider the following aspects:

- growth of the hotel and catering industry (accounting for 65% of the dishwasher market): the estimation of this figure is between 1% and 3% per year; in order to be conservative with the projection it has been decided to use 1% per year;
- evolution of sales for big capacity equipments (one-/multi-tank conveyor-type) provided by stakeholders: this evolution indicates that the sales have increased more importantly for these appliances than for the others, over the past 5 years;
- overall market growth provided by CESA (1.7%).

By assuming that the market growth is **1%** for undercounter, hood-type and pot/utensil dishwashers, and **2%** for conveyor-types dishwashers, the estimation of sales and stock for 2015, 2020 and 2025 are obtained and presented in Table 21. Water-change appliances are included within undercounter units. Total sales of professional dishwashers in 2009 were estimated at 234 600 units (Table 12).

[20] Catering Equipment Suppliers' Association (CESA) 2007, *The UK Market for Foodservice Equipment – The authoritative report on the UK market*.

Table 21 Projected market for different types of dishwashers 2009-2025

Type of equipment	2009	Estimation 2015		Estimation 2020		Estimation 2025	
	Sales	Sales	Stock	Sales	Stock	Sales	Stock
Undercounter	158 200	165 600	1 294 600	174 100	1 360 600	182 900	1 430 100
Hood-type	65 900	69 200	512 400	72 700	538 600	76 400	566 000
Utensil/Pot	2 600	2 800	20 500	2 900	21 500	3 100	22 600
Conveyor-type one-tank	6 600	7 900	77 100	8 800	85 100	9 700	93 900
Conveyor-type multi-tank	1 300	1 600	20 300	1 800	22 400	1 950	24 700
Total	**234 600**	**249 000**	**1 924 900**	**261 700**	**2 028 200**	**274 785**	**2 137 400**

4.2 Employment figures

The employment figures concerning direct jobs in the manufacturing companies were estimated during the stakeholder meeting, after consultation of all manufacturers: around 7 500 people are employed in dishwasher manufacturing companies, of which 5 000 in Italy, 2 500 in Germany, 1 000 in Spain, 300 in France, 300 in Sweden, 200 in the UK and 150 in Denmark.

4.3 Redesign cycle

According to information provided by stakeholders, the redesign cycle varies with the category of equipment and the objective of the process. Designing equipment “from scratch” with completely new characteristics can take between 12 to 13 years for bigger units (categories 5 and 6) and from 5 to 10 years for categories 1 to 4.

Redesigning a single part of the appliance, such as sprinklers, baskets, etc. can take between 6 and 36 months depending on its complexity: the required time is very specific to the design changes so that it is not realistic to indicate an average or typical timing. Normally these redesign processes are intended to improve the water or energy efficiency.

4.4 Product-specific trends

Manufacturer brochures and websites were analysed to identify important product-specific developments and trends in professional dishwashers. Furthermore a short questionnaire was sent to stakeholders to confirm the identified market trends and developments and also to receive some quantitative data.

4.4.1 Development over the past five to ten years

4.4.1.1 Energy and water consumption

In general, the market has changed towards dishwashers with reduced energy and water use in recent years. According to manufacturers, customers today pay more attention to low energy consumption compared to five years ago. This applies to all market segments.

As the following table shows, the average energy consumption of dishwashers has decreased by approximately 20 to 30% over the last ten years. The energy consumption of the best available products today compared to an average product ten years ago has decreased by more than 50% in some categories. The figures are based on estimations by stakeholders that are not measured according to a common standard as currently no European applicable measurement standard for professional dishwashers exists (see also Task 1).[21]

Table 22 Development of energy consumption of professional dishwashers in the past 10 years

Dishwasher (DW) category	Consumption of a ten year old DW in kWh/100 dishes[22]	Consumption of an average new DW in kWh/100 dishes	Consumption of the best DW in kWh/100 dishes	Improvement between ten year old and new product
Undercounter water-change	-	3.7	2.3	-
Undercounter one-tank	2.3	1.6	1.2	30%
Hood-type	2.4	1.7	1.2	29%
Utensil/Pot	0.7 (per cycle)	0.5 (per cycle)	0.4 (per cycle)	29%
Conveyor-type one-tank	3.1	2.0	1.0	37%
Conveyor-type multi-tank	3.1	2.0	0.8	37%

Also, the average water consumption of professional dishwashers sold decreased by approx. 20%, as the following table shows. When considering BAT products, this decrease is even greater.

[21] ASTM as well as NSF/ANSI standards (being basis for US ENERGY STAR requirements) only apply to sanitizing dishwashers widespreadly used at the US market. Sanitizing dishes by hot water generally requires higher (sanitizing) temperatures compared to the (cleaning) temperatures of dishwashers in Europe. Thus, the thresholds of the US ENERGY STAR label and consumption values of US dishwashers are not particularly ambitious compared to the performance of the European dishwashers

[22] "Standard" dish/plate: material: China, 24 cm diameter and 600 g weight. In case of utensil/pot-dishwashers the figures apply to an average dishwashing cycle. No accepted measuring standard exists yet.

Table 23 Development of water consumption of dishwashers over the past 10 years

Dishwasher (DW) category	Consumption of a ten year old DW in litres/100 dishes[22]	Consumption of an average new DW in litres/100 dishes	Consumption of the best DW in litres/100 dishes	Improvement between ten year old and new product
Undercounter water-change		58	28	-
Undercounter one-tank	19 (= 3.4 per cycle)	16 (=2.9 per cycle)	9 (=1.6 per cycle)	16%
Hood-type	19 (=3.4 per cycle)	16 (=2.9 per cycle)	13 (=2.3 per cycle)	16%
Utensil/Pot	6.5 per cycle	5.2 per cycle	5.2 per cycle	20%
Conveyor-type one-tank	20	13 11-15	6	35%
Conveyor-type multi-tank	18	12 11-13	5	33%

In most cases, the water savings are directly connected with savings of detergent and rinse aid.

One reason for the observed reductions in energy and water demand is that manufacturers increasingly offer special features like heat recovery from exhaust air, heat recovery from waste water, heat pump or enhanced rinsing systems for their dishwashers. It is assumed that this trend will continue in the future.

4.4.1.2 Detergents

Companies in the industrial and institutional (I&I) market provide a variety of detergent products and services that make their business fundamentally different from the household products market. The products and services that are offered cater for specialised cleaning and hygiene needs.

According to A.I.S.E.[23] the large majority of the market uses liquid detergents, while a minority uses powders and tablets. There is a market for powder detergents particularly for the larger machines, but the dosing point needs to be close to the machine whereas liquids can be dosed from a further distance.

[23] International Association for Soaps, Detergents and Maintenance Products. Its memberships currently totals 37 National Associations in 42 countries, comprising more than 900 companies – ranging from small- and medium sized enterprises (SMEs) to multinationals, primarily in Europe.

There is a growing market for multi component systems offerings which depend on the country, water conditions and the type of soil in order to use the correct chemicals at optimum concentrations.

In most processes a separate rinse aid is used to provide proper drying and good visual appearance of the substrates. First products are entering the commercial market in which the rinse aid function is built in the main wash detergent. Besides simplicity, this would also provide product, packaging and transport savings to the customer.

Machine operations have changed in recent times to techniques using less water. At the same time the detergents have become more concentrated, leading to less detergent consumption for the same cleaning performance. More concentrated products also lead to reduced packaging waste. Further, there are trends towards more environmentally friendly types of packaging, like e.g. bag-in-box or reusable packs.

4.4.1.3 Changes on the demand side

The demand for professional dishwashers has also changed significantly over the last five years:

- Today, energy and partly also water consumption are important arguments for many customers. End-users pay more attention to energy consumption than they did five years ago. Water consumption does not play as important a role as energy consumption (the prices for water differ a lot within the EU and thus also the pressure for low water consumption of dishwashers).
- Today, life cycle costs play a more important role than five years ago. Life cycle costs have become a stronger criterion in sales pitches, especially for high value products. Growing consumer awareness has led some to be willing to pay more for energy-saving features if the investment pays back within a reasonable time span (usually around three to five years).
- In some markets however, the purchase price of the dishwasher on its own is still more important than the more comprehensive life cycle cost. Therefore, products with a low purchase price are preferred, even though their life cycle costs might be higher than the life cycle costs of more expensive (but more efficient) products. A reason for this is that the purchase of a professional dishwasher usually happens at the end of the process of installing a professional kitchen, when most other purchasing decisions have already been made.
- Due to budget cuts, life cycle costs play a lower role in governmental installations compared to private companies, although governmental institutions are obliged to consider not only investment cost but the whole life cycle cost. This relationship has not changed over the last five years. Governmental installations are expected to make up a small share of the total.

According to stakeholders, consciousness of climate change and the environment in purchase decisions will further rise, but only if technological features result in corresponding monetary savings.

Especially in the case of premium products, life cycle cost calculation will become more important. This will be even more the case if prices for energy, water and detergent rise.

The importance of life cycle considerations to commercial and public customers obviously depends on the general economic environment (both the economy in general and customers in particular).

4.4.1.4 Marketing of professional dishwashers and technological features

In relation to influencing customer behaviours, important aspects of manufacturers' communications regarding professional dishwashers are:

- functionality,
- economic and environmental aspects of the use phase (i.e. costs of energy and water consumption),
- comfort / ergonomics,
- health / sanitation.

When analysing the most recent brochures, it was observed that functional aspects in combination with their energy and water consumption, and resulting economic saving potential, are used to advertise the latest generation of dishwashers. Some examples of technological features in high-end appliances:

- Optimised rinse system
- Rinse with steam
- Automatic load adjustment systems
- Heat recovery systems: waste-water heat recovery and exhaust heat recovery
- Heat pumps

The detailed descriptions, further best available technologies and a more detailed analysis of the market shares of improvement options are provided in Task 6.

4.4.2 Development over the next ten years

Regarding the next ten years, the reduction of energy and water consumption is assumed to continue. According to only one stakeholder responding to our questionnaire, the average energy and water consumption of the future sold dishwashers (over all product categories in EU in comparison to stock) is expected to further decline between 2010 and 2020 by approximately 20%. Detergent consumption is also expected to decrease by a similar degree

as it is correlated to the water consumption. This rough estimation will be counterchecked by further calculations within Task 7 (improvement potential compared to current base cases).

5 Consumer expenditure base data

Based on the categories defined in Task 1, average consumer prices including VAT (in Euro), as well as applicable rates for running costs (e.g. electricity, water, repair and maintenance, disposal) and other financial parameters (e.g. taxes, interest and inflation rates) will be determined.

The total lifetime costs of a dishwasher can be divided into five relevant categories:

- Purchase costs – the cost incurred to purchase the dishwasher
- Installation costs – the costs required to install a professional dishwasher
- Running costs – the costs incurred to operate the dishwasher throughout a typical lifetime. They may include electricity costs and costs of consumables (detergents, water, filters, etc.)
- Repair and maintenance costs – the costs incurred by the owner of the professional dishwashers throughout the lifetime of the machines to ensure their proper and effective operation
- Disposal costs – the quantifiable costs (or benefits) borne by the owner of the machine at the end of life of professional machines
- Labour costs are neglected as they are assumed to be not relevant for the study at hand.

5.1 Purchase costs

In the context of this study, average appliance consumer prices are of interest as they are required as an input for the LCC calculations that will be performed in Task 5.

Prices within an appliance category can vary widely. Parameters that are the most critical for fixing the price are the capacity, followed by the technical features and functional options chosen by the end-user.

Undercounter, front-loaded machines (categories 1 and 2) tend to start at 1 000 Euro though can vary widely by Member State and can cost more than 4 500 Euro. Glasswashers and lighter load machines tend to occupy the cheaper end of the market.

Hood-type machines (category 3) tend to be more expensive than undercounter machines as they have higher capacities and often are part of a larger integral package which includes

wash spaces, shelves, a sink and accessories. These products typically have been found to start at 2 000 Euro and can cost more than 6 000 Euro.

Appliances designed for heavier or larger wash ware (pots, bakeware, etc. as defined by category 4) tend to occupy a much more expensive portion of the market. Washing capacity and digital programmes tend to be the differentiating factors between purchasing prices of products in this study and have been found to cost approximately 10 500 Euro.

Transport machines (categories 5 and 6) are the most complex, tend to have the highest capacities and are therefore the most expensive dishwashers on the market. Their price range is much larger than other types and therefore they are more difficult to characterise on a broad European level.

The average prices for the machines within the classification are shown in the following table. The figures were obtained from manufacturers' brochures and information provided directly by the stakeholders. An average value for machines of similar capacity was then calculated. Figures for water-change appliances are included with undercounter classification, given their small market share and comments from stakeholders indicating they are not always relevant for professional markets.

Table 24 European average price by machine of similar capacity. Figures from stakeholders and public catalogues. Prices are without VAT

Type of appliance	Approximate capacity	Average price (Euro)
Undercounter water-change	200 dishes/hour	3 200
Undercounter one-tank	550 dishes/hour	3 500
Hood-type	860 dishes/hour	4 700
Utensil/Pot	0.42 m^2 (rack area) 20 cycles/hour	10 500
Conveyor-type one-tank	1 750 dishes/hour	15 000
Conveyor-type multi-tank	3 600 dishes/hour	45 000

The price of conveyor-type dishwashers is influenced not only by the capacity (dishes/hour), but also a lot by its configuration (the different features, components and washing/drying stages of the appliance). The most expensive models can include: one or more pre-washing zones, two or more washing zones, two or more rinsing zones, one or more drying zones, heat recovery features, etc. The machine configuration depends very much on the intended capacity and application wanted by the customer.

The prices presented in Table 24 will be used later in the study in Task 5 during the life cycle assessment, to help determine the LCCs of these products in the base case analysis.

The results presented in the following figures show the relationship between the capacities of the machines and their prices. The relationship between these two parameters is expected to

be directly proportional. The reference prices were found all over Europe. The difference for a machine of the same capacity but purchased in a different country can reach up to 50%.

In Figure 7 to Figure 11, a single trend line shows the average of prices versus capacity for different product types. The difference in prices for the same capacity is related to the country where the equipment is sold. Southern Europe prices are less expensive than those found in Northern countries.

Figure 7 shows that the price of the machines is directly related to their capacity. The global trend line is an average of different sources and manufacturers from different countries within the EU. In comparison with this figure, the average price of 550 dishes/hour undercounter one-tank dishwashers presented in Table 24 was slightly corrected following stakeholders comments: based on the figure, a 550 dishes/hour undercounter one-tank dishwashers should cost approximately 3 100 Euro, but this estimation judged too low has been raised to 3 500 Euro.

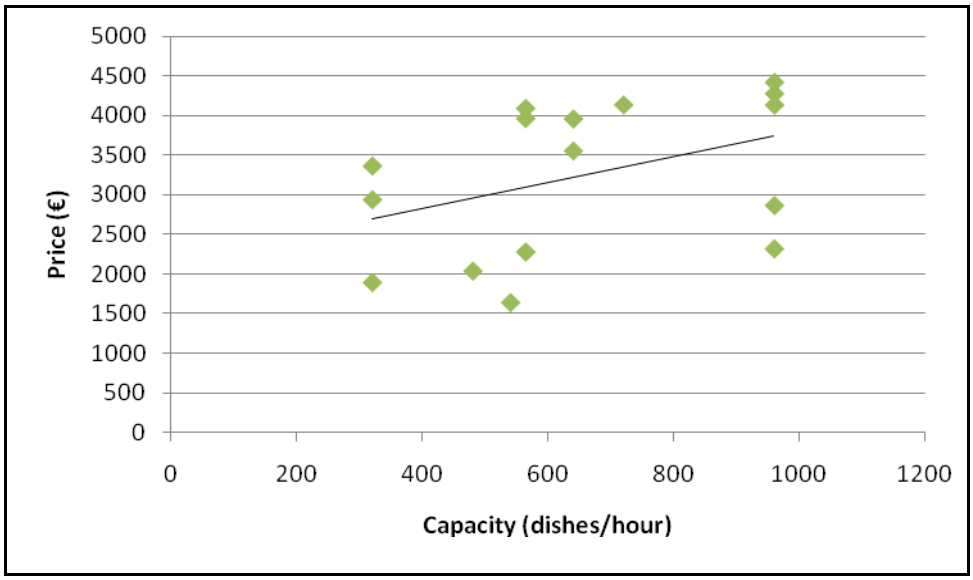


Figure 7 Price and capacity of undercounter one-tank dishwasher machines (dishes/h), 2009-2010

The trend for hood-type dishwashers matches other product types also. The price increases with the capacity. The differences in price for the same capacity correspond to the different technologies involved in the process, e.g. drainage pumps, multi rinsing, pre-rinsing, etc. and different brands on the market.

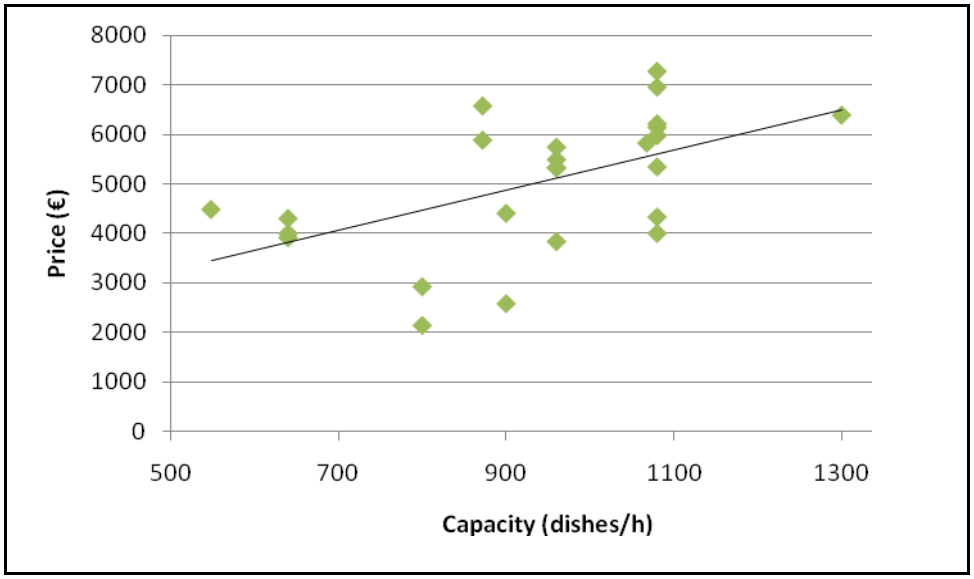


Figure 8 Price and capacity of hood-type dishwashers (dishes/h), 2009-2010

Although utensil/pot dishwashers are common, their capacities and prices remain somewhat reserved by the manufacturers. Figure 9 shows a panel of pot dishwashers prices, related to their rack surface. Among the models found, there is a relationship between price and capacity, but there can be important differences between manufacturers.

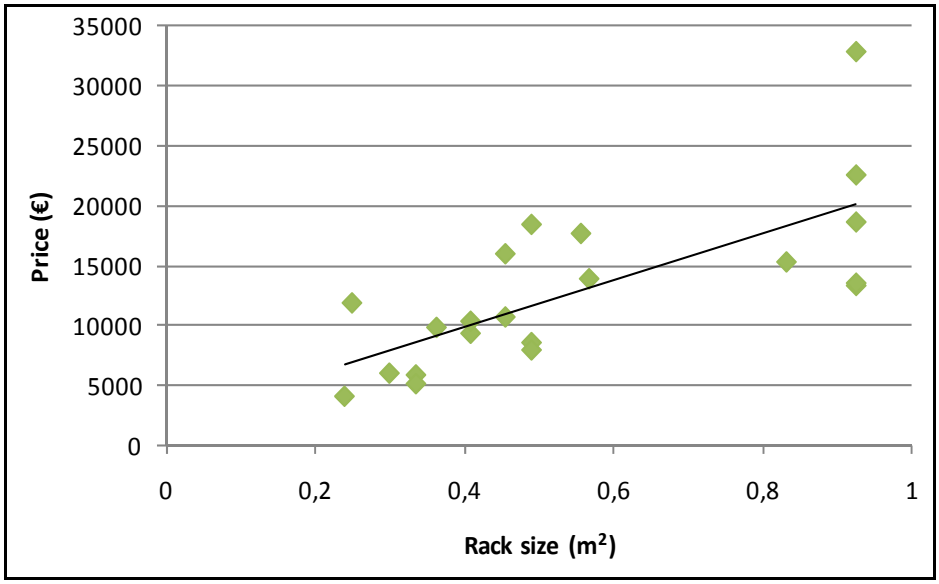


Figure 9 Price and capacity of utensil/pot dishwashers (rack size in m^2), 2009-2010

One-tank and multi-tank conveyor-type dishwasher prices are shown in the following two figures (Figure 10 and Figure 11). For one-tank machines the price is related to the capacity.

The prices found for larger capacities correspond to different manufacturers, which is the main reason for the dispersion of the data.

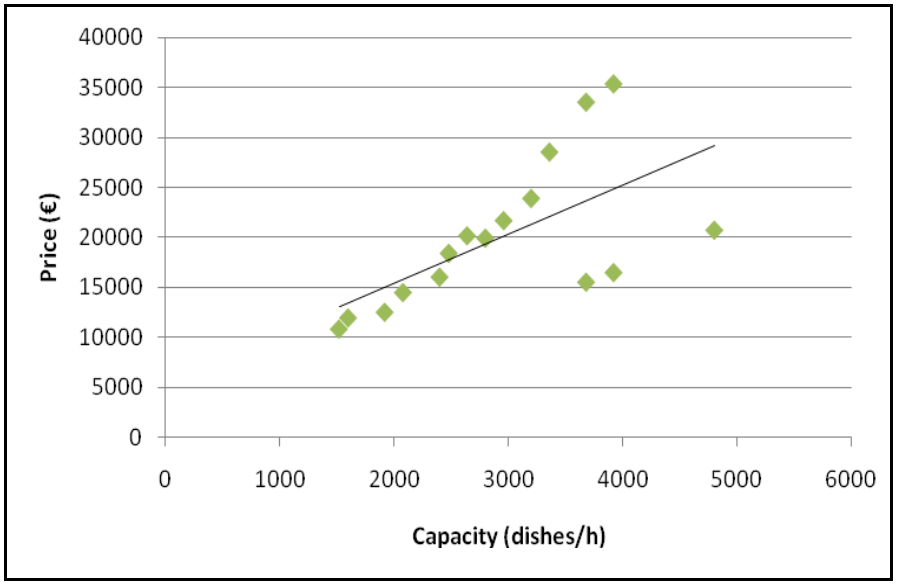


Figure 10 Price and capacity of one-tank conveyor-type dishwasher equipments (dishes/h), 2009-2010

In the case of multi-tank conveyor-type dishwasher prices, in the figure below, two sets of data are shown due to the difference in prices relative to the country (data obtained from UK and Spain manufacturers, with the lower group corresponding to Spain).

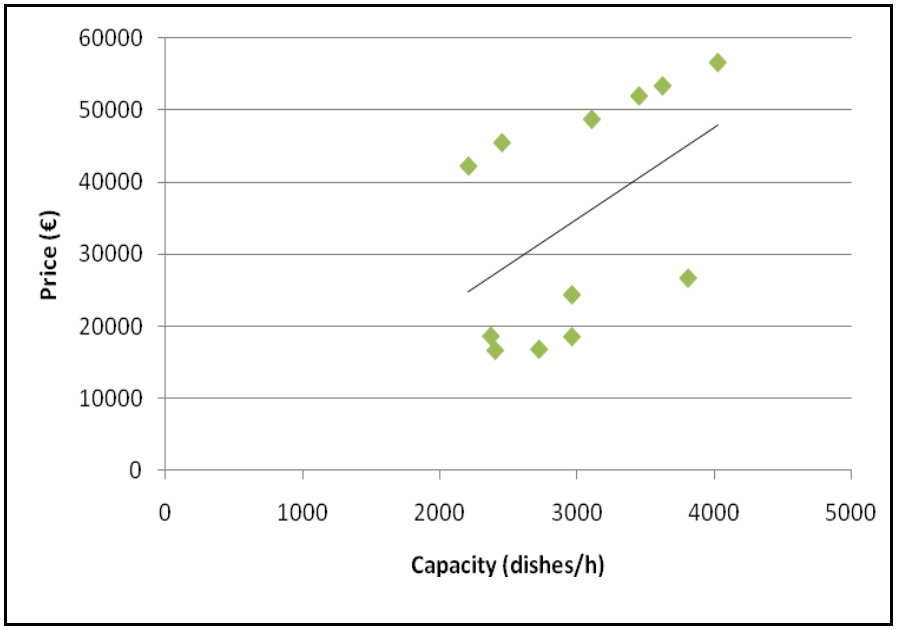


Figure 11 Price and capacity of multi-tank conveyor-type dishwasher equipments (dishes/h), 2009-2010

5.2 Running costs

Running costs, understood as costs generated by the use of the appliance, can be split into:

- Energy costs (electricity, gas)
- Consumable costs (water, detergent, rinse, paper filters, etc.)
- Maintenance and repair costs

5.2.1 Energy costs

Energy costs are a significant running cost of dishwashers. The latest electricity and gas rates for industrial customers in Member States are presented below, according to the different consumption classes. The EU average will be used in LCC calculations at a later stage of the study (Task 5 and Task 7).

Electricity rate

A typical fast food restaurant uses approximately 350-400 MWh of electricity per year[24]. Small restaurants are estimated to use less, while large institutional facilities would use much more (normally including electricity consumption not related to the preparation or washing of catering products). The electricity rate in Europe depends on the consumption and therefore will vary depending on the customer types (which can be attributed to certain product types too). Three consumption bands are presented below for the electricity rate at industrial rates (IA – < 20 MWh, IB – 20-500 MWh, and IC – 500-2 000 MWh) in Table 25.

Table 25 Electricity rates for industrial customers in EU-27[25] average 2007-2009 (taxes excluded)

Member States	Consumption Band Rate (Euro/kWh)		
	Industrial – IA < 20MWh	**Industrial – IB** 20MWh – 500MWh	**Industrial – IC** 500MWh – 2 000MWh
Belgium	0.141	0.120	0.097
Bulgaria	0.073	0.069	0.061
Czech Republic	0.161	0.129	0.106
Denmark	0.102	0.086	0.079
Germany	0.156	0.112	0.093
Estonia	0.071	0.059	0.055
Ireland	0.165	0.144	0.127
Greece	0.136	0.108	0.087
Spain	0.148	0.119	0.100
France	0.099	0.075	0.059

[24] McDonald's Switzerland Environmental report 2006, www.environment.mcdonalds.ch/EN/Achievements/Restaurants

[25] Eurostat (2009); Environment and Energy, Data in focus, 48/2009; extracted 12/08/2010

Member States	Consumption Band Rate (Euro/kWh)		
	Industrial – IA < 20MWh	**Industrial – IB** 20MWh – 500MWh	**Industrial – IC** 500MWh – 2 000MWh
Italy	:	:	:
Cyprus	0.160	0.160	0.144
Latvia	0.110	0.086	0.077
Lithuania	0.107	0.094	0.083
Luxembourg	0.162	0.116	0.100
Hungary	0.128	0.125	0.116
Malta	0.151	0.148	0.137
Netherlands	0.161	0.103	0.088
Austria	0.111	0.104	0.086
Poland	0.136	0.101	0.085
Portugal	0.121	0.093	0.083
Romania	0.109	0.102	0.088
Slovenia	0.145	0.122	0.094
Slovakia	0.185	0.150	0.126
Finland	0.077	0.071	0.062
Sweden	0.108	0.078	0.068
United Kingdom	0.134	0.112	0.102
EU-27	**0.138**	**0.105**	**0.090**

As an assumption for which dishwashing products use which rates, the general assumption can be made that smaller dishwashers tend to be used in smaller establishments and hence have a higher electricity rate as given in the table. Larger dishwashers would be used in facilities with higher electricity consumption and thus lower electricity rates. The resulting electricity rates for appliances for LCC calculations are given in Table 26.

Table 26 Electricity rates for professional dishwashing products in Europe based on typical usage scenario

Type of appliance	Assumed consumption band	Electricity rate (Euro/kWh)
Undercounter (water-change)	IA	0.138
Undercounter (one-tank)	IA	0.138
Hood-type	IB	0.105
Utensil/Pot	IB	0.105
Conveyor-type (one-tank)	IC	0.090
Conveyor-type (multi-tank)	IC	0.090

Natural gas rates

Natural gas rates have to be taken into account for professional dishwashers which use natural gas fuel for heating. Additional investment costs are required for gas-heated dishwashers and national safety regulations for gas appliances are further significant obstacles against this technology.

The evolution of natural gas rates between 2007 and 2009 as well as rates that vary depending on the end users' consumption as reported by Eurostat are presented in Table 27.

Table 27 Natural gas rates for consumers in EU-27[26], average between 2007 and 2009 (taxes excluded)

Member States	Consumption band rate (Euro/GJ)		
	Industrial – IA < 1 000 GJ	**Industrial – IB** 1 000–10 000 GJ	**Industrial – IC** 10 000–100 000 GJ
Belgium	12.4820	10.6260	8.7920
Bulgaria	7.2216	7.0365	6.5722
Czech Republic	10.4181	9.1017	8.4341
Denmark	13.7775	13.0929	7.0364
Germany	12.2960	11.5920	10.6360
Estonia	7.7399	7.2829	6.6899
Ireland	13.4760	10.8900	9.6740
Spain	10.6561	8.7573	7.9959
France	11.7276	10.2872	9.2532
Italy	11.0010	10.6386	9.0520
Latvia	10.2443	9.7811	9.0292
Lithuania	9.3861	9.1367	8.7945
Luxembourg	11.8760	10.5800	10.2420
Hungary	11.4618	10.7835	9.3420
Netherlands	11.8480	10.3720	8.7142
Austria	10.6300	10.4400	:
Poland	10.1192	9.2683	8.2000
Portugal	13.8253	10.7658	8.6272
Romania	5.5257	5.5080	5.6072
Slovenia	13.3580	12.6800	9.8840
Slovakia	11.7883	10.5191	9.9378
Finland	:	:	7.5800
Sweden	14.7633	13.1448	11.2499
United Kingdom	10.8420	8.4012	7.1704
EU-27	11.2115	10.0097	8.7921

[26] Eurostat (2009); Environment and Energy, Data in focus, 49/2009; extracted 12/08/2010

The three consumption bands available for natural gas have been shown here to determine the natural gas rates as they are assumed to be the applicable bands for professional dishwasher customers (as was the case for electricity consumption bands). All dishwasher appliances which use natural gas heating are larger appliances and thus the most applicable bands are the IB and IC bands.
To summarise, the following gas rates in Table 28 will be used for professional dishwasher LCC calculations.

Table 28 Summary of the rates used for gas for professional dishwashers

Type of appliance	Assumed consumption band	Gas rate (Euro/GJ)
Undercounter (water-change)	IA	11.21
Undercounter (one-tank)	IA	11.21
Hood-type	IB	10.01
Utensil/Pot	IB	10.01
Conveyor-type (one-tank)	IC	8.79
Conveyor-type (multi-tank)	IC	8.79

Preliminary information suggests that gas may not be relevant for smaller dishwasher types; this will be elaborated in Task 3.

5.2.2 Consumables (detergent, water, etc.)

The costs of consumables will be discussed in this section.

5.2.2.1 Detergent and rinse aid

There is wide variation in the prices of detergents found in Europe. Example prices for France, the UK and Germany are given for some detergent brands aimed at professional dishwashers in Table 29.

Table 29 Example detergent prices (products on sale on the internet)

Price per litre in Euro
34 € / 20 litres
69 € / 20 litres
20 € / 10 litres
43 € / 20 litres
79 € / 18 litres

For the purposes of this study, a mid-range cost of detergent of **3.0 Euro/litre** will be assumed, based on the range of prices found during internet research and stakeholders comments. In particular, the price can vary depending on the quality of the detergent, and the quantity sold. This will translate into a direct cost for the consumer for each wash cycle in later tasks when the amount of water, concentration of detergent and frequency of use is characterised (Tasks 3 and 4).

Rinsing aid (rinse agent) prices were found to vary as much as detergent prices throughout Europe, depending on location and perceived quality. A cost similar to detergent was found through distributor brochures and advertisements, and therefore, rinse aid costs of **3.0 Euro/litre** will be used in the study for LCC calculations.

Detergents represent a particularly important aspect of the performance and environmental impacts of dishwashers in general. The type of detergent used can affect the temperature and amount of water required as well as the time that each wash cycle must run before the wash ware is clean. This will be further evaluated in Task 3.

5.2.2.2 Water

The cost of water to consumers can be difficult to evaluate as it is either based on a variable rate which corresponds to consumption or a fixed rate which is set by local utilities.

An indication of water prices in France is shown in Figure 12, where a breakdown in the cost of water to consumers is given over 15 years.

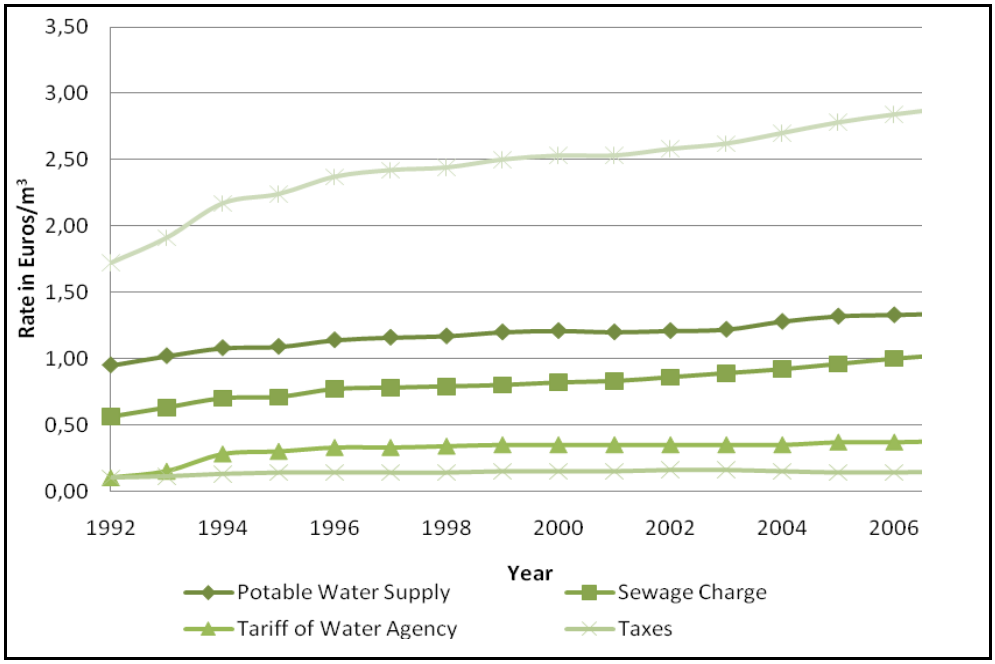


Figure 12 Water cost break down in Rhône region of France for 15 years

A final water tariff to the consumer can be observed at 2.90 Euro/m^3 with an average increase of 0.064 Euro/m^3 per year, suggesting a current water tariff in this region of France of 3.08 Euro/m^3.

The eco-design preparatory study for Lot 14 (domestic dishwashers and washing machines) proposed a water rate of 3.70 Euro/m^3 for domestic water use in 2008 across Europe. Domestic water prices are not directly applicable to this study as professional dishwashers are not operated in a domestic environment.

Furthermore, BIPE analysed the water rate for eight major European cities in 2006. The relevant information is presented in Table 30.

Table 30 Water consumption and effective rate for eight European cities[27]

City	Water Consumption (m^3/capita/year)	Average persons per household	Average water bill per household (Euro)	Effective water rate (Euro/m^3)
Amsterdam	57	2.3	506	3.86
Athens	61	2.7	171	1.04
Berlin	43	1.8	360	4.65
London	54	2.4	312	2.41
Madrid	61	2.9	207	1.17
Paris	52	1.9	229	2.32
Rome	104	2.6	229	0.85
Stockholm	77	2.0	302.5	1.96

Based on the population of the above cities, the weighted average water rate for the eight cities cited by BIPE is 2.38 Euro/m^3.

Based on the above sources, a water rate extrapolated from the weighted average of the eight largest cities in the EU to the year 2010 based on the change in the water price in France over 15 years gives a water price of **2.64 Euro/m^3** for the EU-27.

This figure will be used to calculate the LCCs of dishwashers in Task 5 of this study and may impact the LCCs of these appliances when considered on the scale of the entire European dishwashers market. As water consumption is arguably central to dishwasher efficiency, this figure will be used in a sensitivity analysis to determine how variations in this price affect the LCC of professional dishwasher products. This will also help to evaluate the high variability in water prices found in the above analysis.

[27] Consumption, persons per household and average water bill per household taken from: BIPE, Analysis of Drinking Water and Wastewater Services in Eight European Capitals: the Sustainable Development Perspective, 2006

Starting from 2010, the Water Framework Directive[28] requires Member States to improve their water management strategy through setting pricing and policy incentives to preserve the natural water systems of Member States. It can be expected that in years to come, the price of water will become an increasingly important concern for professional dishwasher manufacturers and likewise, professional dishwasher users, as Member States gradually increase the cost of water to reflect environmental and resource use costs more adequately, as defined in the Directive (see also Task 1).

5.2.3 Interest and inflation rates

Table 31 shows the latest reliable national inflation and interest rates for the EU-27 as published by Eurostat and the European Central Bank (ECB). Figures from 2007 have been given as more recent data is unavailable.

Table 31 Interest and inflation rates for EU-27, 2007

Member State	Inflation rate (%)[29]	Interest rate (%)[30]
Austria	2.9	4.29
Belgium	2.8	4.33
Bulgaria	10.9	4.54
Cyprus	3.4	4.48
Czech Republic	5.1	4.28
Denmark	2.3	4.29
Estonia	9.3	5.69
Finland	2.5	4.29
France	2.5	4.30
Germany	2.7	4.22
Greece	3.7	4.50
Hungary	7.2	6.74
Ireland	3.1	4.31
Italy	2.7	4.49
Latvia	13.8	5.28
Lithuania	8.6	4.55
Luxembourg	3.5	4.56
Malta	2.3	4.72

[28] Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy. Available at: http://europa.eu/legislation_summaries/agriculture/environment/l28002b_en.htm accessed 01 Feb 2010.

[29] 12 month average rates May 08-07 / May 07-06. Source: Eurostat, http://europa.eu/rapid/pressReleasesAction.do?reference=STAT/08/85&format=HTML&aged=0&language=EN&guiLanguage=en

[30] European Central Bank long-term interest rates; 10-year government bond yields, secondary market. Annual average (%), 2007, http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-30-08-410/EN/KS-30-08-410-EN.PDF

Member State	Inflation rate (%)[29]	Interest rate (%)[30]
Poland	3.6	5.48
Portugal	2.6	4.42
Romania	6.7	7.15
Slovakia	2.6	4.49
Slovenia	5.3	4.52
Spain	3.7	4.31
Sweden	2.4	4.17
Netherlands	1.7	4.29
UK	n.a.	5.06
EU-27 average	**3.0**	**4.58**

The above rates have changed significantly since 2007. For reasons of simplification, the European Commission has recommended a discount rate assumption for this project of **4.0%**.

5.3 Maintenance and service costs

Stakeholders have commented that service contracts are usually included as part of the purchase of professional dishwashing products. The exact nature of the contracts can vary and depends on the type of equipment, complexity and capital cost. Normally, more sophisticated and expensive machines have more elaborate and comprehensive service contracts to help ensure a long product lifetime and payback period on capital investments.

For smaller appliances, dealers or wholesalers may provide warranty services to clients on behalf of the manufacturer, or they may also provide the warranty services at their own expense as part of the dealer arrangement between the manufacturers.

For larger more complex products, especially conveyor-type dishwashers, the manufacturer typically services the product as these products are also typically sold directly from the manufacturer themselves.

As a preliminary estimate of the maintenance and service costs of professional dishwashing appliances, an indication can be taken from the size of the new equipment market versus the "spares and service" (spare parts including accessories, repairs and maintenance) market in the UK. In total, the UK spares and service market was 44% of the value of the new food-service equipment market in 2006.[7] This indicates that for the entire lifetime of a foodservice product, the total **maintenance costs are 44% of the initial purchase costs**. This value will be used to estimate the life cycle costs of dishwashing products later in the study (it is therefore assumed that the professional dishwashers have average maintenance and repairs costs, in comparison with other foodservice equipment, including prime cooking and refrigeration equipment). Table 32 presents the resulting maintenance costs that will be assumed for each product type when calculating the life cycle costs of professional

dishwashing products in this study. Stakeholders indicated that for undercounter water-change, maintenance costs represented approximately 37.5% of the product price. This seems to make sense as smaller (and simpler) machines are expected to require less repair services.

Table 32 Lifetime maintenance costs of professional dishwasher products in Lot 24

Type of appliance	Lifetime maintenance costs (Euro)
Undercounter water-change	1 200
Undercounter one-tank	1 540
Hood-type	2 068
Utensil/Pot	4 620
Conveyor-type one-tank	6 600
Conveyor-type multi-tank	19 800

Stakeholders have commented that the most common items for maintenance on professional dishwasher products are water pumps, control panels, heating elements and doors. All of these components in professional dishwashers are easily replaceable and generally justify maintenance rather than replacing the entire dishwasher. According to manufacturers, the most common cause for professional dishwasher breaking is operator misuse or abuse.

5.4 Disposal costs

In general, most professional catering service establishments need a working dishwasher for daily operation. As a result, for all replacement sales, the old dishwasher unit is removed at the same time as the new unit is provided.

Stakeholders have commented that many professional dishwasher units can be refurbished and resold as second-hand products by dealers in a fairly buoyant second-hand market (around 5-10% of the annual sales, according to manufacturers' estimates). These products generally are given new water pumps, control panels and heating elements, as the most common items to fail.

According to stakeholders, dishwashers that are not refurbished are almost always recycled for scrap parts. A large majority of the materials in professional dishwashers is valuable metallic parts (stainless steel) and the value for scraps is high. As a result, most dealers or manufacturers will offer to remove the old dishwashers on purchase and delivery for new dishwashers, and may even provide the customer with a discount for the salvaged product.

As a result, this study will assume the **disposal costs for professional dishwashers are 0 Euro per product.**

5.5 Summary of end-user expenditure

Table 33 summarises the end-user expenditure data presented in the previous sections. This data will be useful in later tasks (Task 5) for estimating life cycle properties of these products.

Table 33 User expenditure base data

Category	Cost items	Units	Value
Purchase	Purchase price	€/product	3 200–45 000
Use	Electricity rate	€/kWh	0.090–0.138
Use	Gas	€/GJ	8.79–11.21
Use	Water rates	€/m^3	2.64
Use	Detergent	€/L	3.0
Use	Rinse	€/L	3.0
Use	Interest-inflation rate	%	4.0
Maintenance	Servicing and repair	€/product	1 200–19 800
Disposal	Removal and disposal / recycling	€/product	0

6 Conclusions

In conclusion, Task 2 presents the professional dishwasher market sector with generic economic data extracted from the Eurostat database, completed by information obtained directly from the main manufacturers.

The main manufacturing Member States identified are Germany, Italy and Spain. Under-counter one-tank dishwashers are the most sold product type by far, followed by hood-type machines and undercounter water-change machines. Conveyor-type dishwashers have low sales as these machines are reserved for heavy duty installations. Their environmental impacts should not be neglected, however, due to the intensity of use and the large capacities of these machines.

The task also contains the consumer expenditure data that will serve as a basis for the economic analysis of the base cases (Task 5) and the improvement options (Task 7). Purchase prices of professional dishwashers are comprised between 3 200 and 45 000 Euro. As a general remark, customers show an interest in more energy-efficient products, provided that these products result in cost savings in the long term.

7 Annex

7.1 Questionnaire "Task 2" for stakeholders

This paper is provided separately (EuP_Lot24_Dish_T2_Annex_Questionnaire.pdf).

7.2 Stakeholder feedback to draft versions of Task 2

Please note that the feedback refers to prior versions of draft Task 2 report; thus the indicated numerations of chapters, tables, figures or pages might have been changed.

Feedback		Comment
Hobart		
2.2.4, p. 20	**Table 2-12** The average product life time should read: 12, 8, 8, 8, 12, and 17 (top –down) as per outcome of the discussion during the interim stakeholder meeting. Nevertheless we have reviewed the average lifetime for multi-tank conveyor dishwashers and came to the conclusion that it should be reduced to 12 years.	The figure that was commonly agreed during the stakeholder meeting (17 years) will be kept in the final version of the report. No similar comments have been received from other stakeholders justifying an update of this parameter.
2.3.2, p. 29	**Employment** Hobart Germany has approx. 900 employees	Thank you for this input.
2.3.4, p. 31	**Changes on the demand side (last paragraph)** Governmental institutions have the obligation to consider more than just investment cost. The first decision criterion has to be the LCC. This rule is quite often not followed today. This study might be an opportunity to exert influence on the actual practice	Included in the text.
2.3.4, p. 33	**Optimised rinse system** The text refers to rack conveyor and flight type dishwashers while Fig 2-11 is related to undercounter and hood type dishwashers	Modified in the text.
2.3.4, p. 34	**Heat pumps** Energy saving of 25 to 35 kW/h seems to be unrealistic high.	The detailed description has been removed from Task 2. A thorough analysis and the savings potential of improvement options is provided in Task 6.
2.3.4, p. 34	**Rinse with steam** The rinsing system uses steam in addition to water, not instead. The advantage is savings of water, detergent and rinse aid, not energy savings. The cited Hobart brochure reads: VAPO RINSE ECO The primary task of rinsing is to remove detergent from the wash item. The switchable steam rinse cycle VAPO RINSE	The detailed description has been removed from Task 2. A thorough analysis and the savings potential of improvement options is provided in Task 6.

Feedback		Comment
	ECO works in two phases. In the first phase, the detergent is rinsed off with water. The following VAPO RINSE ECO fills the wash chamber completely with steam which forms a microscopically thin film on the wash items and removes residual alkalinity. The self-drying effect of the wash items is additionally enhanced by the increased temperature penetration into the wash items. The steam rinse cycle VAPO RINSE ECO reduces the consumption of fresh water to 1.5 litres per cycle. Compared to standard machines, this represents a saving of up to 55 % in water and detergent as well as up to 70 % in rinse aid.	
2.3.4, p. 35	**Table 2-20** Are these really stakeholders assumptions? They seem to be unrealistic. We are unable to prophesy future market shares of the listed technologies.	This table has been removed from Task 2 and the current market shares of the technologies will be assessed in Task 6.
2.3.4, p. 37	**Table 2-21** “90 litres” is not a capacity for Universal / Pot washers capacity should be given in “cycles per hour” or “sprayed horizontal plane of utensil carrier (rack) per hour” with respect to the non standardized rack sizes.	Has been changed in the new version.
2.3.4, p. 37	**First paragraph** The price of conveyor dishwashers is mainly influenced by its configuration. i. e. number of washing zones, number of drying zones, heat recovery system, usable width, usable height, etc. The machine configuration depends very much on the intended capacity (plates per hour) and on the specified application. The most expensive models can include: one or more pre-washing zones, two or more washing zones, two or more rinsing stages, drying zone(s), heat recovery/heat pump, etc.	Included in the text
2.4.2, p. 44	**Gas heating** It should be mentioned that additional investment costs are required for gas heated dishwashers. Country-specific safety regulations for gas appliances are further significant obstacles against this technology.	Included in the text.
Miele		**Comment**
Table 2-4, p. 9	**List of professional dishwasher manufacturers** Please add Miele as a manufacturer of Professional dishwashers. Our current product offering includes water-change models, undercounter models and hood type models (categories 1, 2 and 3). Among all those categories Miele has a significant market share.	It is already included (row 8 of the table, first column)
2.2.3, p. 17	**Industry stakeholders have identified […] ‘water-change operation‘ are not true a true commercial dishwashing product […]** As quoted in Draft 1 and as stated in the machinery directive, the intended use determines if a dishwasher is considered commercial or residential appliances. In case of Miele’s product offering of water-change models the manufacturer clearly states “commercial applications” as the	Corrected in the text.

Feedback		Comment
	intended use. All models are compliant with the machinery directive. As a matter fo fact they are primarily used in those target groups stated in Task 1 table 2 (Office, Pensions, restaurants, B&Bs, Nursing homes, etc.). The fact that Miele has a unique position with its water-change machine and that most manufacturers offer Tank systems doesn't make water-change models less commercial.	
Winterhalter		**Comment**
2.3.4, p. 33	**Figure 2-11** The text above the schedule mentions saving with rack-conveyor and flight-type machines – the Winterhalter schedule shown covers undercounter and pass-through machines, so the text does not fit to the schedule	Text corrected.
2.3.4, p. 35	**Table 2-20** From our opinion and our experience neither the functionality, nor the ecological and economical sense of the mentioned technology "rinse with steam" is proved. So we cannot see any rationale for a future market-share.	This table will be removed from Task 2 and the current market shares of the technologies will be assessed in Task 6. However, this option will be kept as a potential BAT and investigated further.
Danish Technological Institute		**Comment**
2.2.2, p. 9	**Manufacturers in Denmark** JEROS A/S Nyborgvej 8, DK-5750 Ringe - Phone +45 63 62 39 13 - email: jeros@jeros.dk , www.jeros.com KEN A/S Bøgebjergvej 60, DK-5672 Broby, Phone: +45 62 63 10 91, Fax: +45 62 63 16 07, e-mail: ken@ken.dk, www.ken.dk	Included in the text.

Preparatory Studies for Eco-design Requirements of Energy-using Products

Lot 24: Professional Washing Machines, Dryers and Dishwashers

Tender No. TREN/D3/91-2007

February 2011

Final Report, Part: Dishwashers

Task 3: Consumer Behaviour and Local Infrastructure

Öko-Institut e.V.
Institute for Applied Ecology, Germany
Ina Rüdenauer
Markus Blepp
Eva Brommer
Carl-Otto Gensch
Kathrin Graulich

BIO Intelligence Service, France
Shailendra Mudgal
Raul Cervantes
Thibault Faninger
Lorcan Lyons

Büro Ö-Quadrat, Germany
Dieter Seifried

Öko-Institut e.V.
Freiburg Head Office
P.O. Box 17 71
79017 Freiburg, Germany
Street Address
Merzhauser Str. 173
79100 Freiburg, Germany
Tel. +49 (0) 761 – 4 52 95-0
Fax +49 (0) 761 – 4 52 95-88

Darmstadt Office
Rheinstr. 95
64295 Darmstadt, Germany
Tel. +49 (0) 6151 – 81 91-0
Fax +49 (0) 6151 – 81 91-33

Berlin Office
Schicklerstr. 5-7
10179 Berlin, Germany
Tel. +49 (0) 30 – 40 50 85-0
Fax +49 (0) 30 – 40 50 85-388

www.oeko.de

For reasons of better readability, two Task 3 reports were prepared.

The report at hand covers ***professional dishwashers***.

The Task 3 report on *professional washing machines and dryers* is published separately.

For the benefit of the environment, this document has been optimised for **double-sided printing**.

Part: Professional Dishwashers

Table of Contents – Task 3: Consumer Behaviour and Local Infrastructure

List of tables V

List of figures V

1 Introduction 1

1.1 Objective 1

1.2 Methodology and assessment of data quality 1

1.3 Sinner's Circle principle ("Sinner'scher Kreis") 3

2 Typical capacity and use intensity of professional dishwashers 5

3 Ideal user behaviour 10

3.1 Ideal operating conditions and user behaviour 10

3.2 Energy, water and detergent consumption under ideal conditions 10

4 Real life user behaviour 12

4.1 Influence of user behaviour 12

4.1.1 Partial workload 12

4.1.2 Use of other programmes 14

4.1.3 Maloperation 16

4.2 Influence of initial filling and heating of tanks 17

4.3 Influence of low-power modes consumption 19

4.4 Influence of external process steps 21

4.5 Energy, water and detergent consumption under real-life usage conditions 21

5 Measures to optimise user behaviour and consumption parameters 22

5.1 Education, incentives and responsibilities 22

5.2 Automatic information and control systems 23

5.3 One button machine – easy operation to reduce maloperation 23

5.4 Sensor systems regulating the water consumption 23

6 Local Infrastructure 24

6.1 Water supply 24

6.2	**Water heating**	**25**
7	**Maintenance and repairs, end-of-life behaviour**	**28**
8	**Annex**	**31**
8.1	**Working Paper “Task 3” and additional questions for stakeholders**	**31**
8.2	**Stakeholder involvement**	**31**
8.3	**Stakeholder feedback to draft versions of Task 3**	**33**

List of tables

Table 1	Main applications and market segments of professional dishwashers according to spatial requirements	6
Table 2	Typical intensity of use of the regarded dishwasher categories	8
Table 3	Specific energy, water and detergent consumption of an average current device of different dishwasher categories during continuous operation under ideal conditions	10
Table 4	Annual energy, water and detergent consumption of different professional dishwashers under ideal condition	11
Table 5	Additional consumption at real-life workload	13
Table 6	Programme selection and its influence on energy, water and detergent consumption	15
Table 7	Input parameters for calculation of consumption through initial filling and heating of wash tanks	18
Table 8	Energy, water and detergent consumption for initial filling and heating of wash tanks	19
Table 9	Typical time in low-power modes and standby consumption of professional dishwashers	20
Table 10	Annual energy, water, and detergent consumption (real life conditions) of dishwasher categories	22
Table 11	Number of water inlet valves of professional dishwashers	24
Table 12	Water connection of professional dishwashers	25
Table 13	Types of water heating in professional dishwashers	26
Table 14	Electricity consumption in case of warm water supply and alternative heating	27
Table 15	Estimation of revenues from scrap metal fraction exemplified for an undercounter one-tank dishwasher (category 2)	29
Table 16	Documentation of enquiry addressees and their responses	31

List of figures

Figure 1	Factors influencing the dishwashing process: Sinner’s Circle ("Sinner’scher Kreis")	3

1 Introduction

1.1 Objective

Consumer behaviour can – in part – be influenced by product-design but overall it is a very relevant input for the assessment of the environmental impact and the Life Cycle Costs of a product. One aim of this task is to quantify relevant user-parameters that influence the environmental impact during product-life. A second aim is to identify barriers and restrictions to possible eco-design measures, due to e.g. infra-structural factors. As currently no European applicable measurement standard for professional dishwashers exists (cf. Task 1), the data might be the basis for the development of new standard test conditions. These data serve for calculations of life cycle environmental impacts and costs in later tasks.

The choice of the appropriate dishwasher type depends, amongst other criteria, on the amount of wash ware to be cleaned in the establishment. Thus, section 2 provides a first overview of the main application areas and capacity ranges of the different product categories. Combined with the typical use intensity for each dishwasher category, the total number of cleaned dishes or cycles per year for each product category is calculated.

In section 3, ideal user behaviour is described in general, which is intended to correlate to the specific consumption values (i.e. per dish or cycle) given by manufacturers. By multiplying the typical number of dishes cleaned with each dishwasher category per year with the specific consumption values, the energy, water and detergent consumption per product category and year under ideal conditions are calculated.

In section 4 aspects of real life operating conditions are described and their influence on the consumption of the appliances is quantified (if possible). In section 5, possible measures to optimise real life user behaviour with regard to consumption parameters are proposed. Section 6 identifies and describes barriers and opportunities relating to the local infra-structure. Finally, section 7 gives information about the end-of-life behaviour, e.g. the economical product life (=actual time to disposal) and the repair- and maintenance practice.

1.2 Methodology and assessment of data quality

In order to derive information on user behaviour and its influence on resource consumption a stepwise approach was taken. All information provided in Task 3 was collected through a self-administrated survey amongst the stakeholders (see Annex, sections 8.1 and 8.2). For this purpose, a draft version including preliminary assumptions was prepared on the basis of discussions with stakeholders and literature. The working paper was then circulated to

stakeholders (manufacturers, industry associations, user associations). The feedback was used to adjust the preliminary assumptions.

Four German manufacturers (Hobart, Meiko, Miele professional and Winterhalter) and CECED Italia answered on the working document. As outlined in Task 2, Germany represents 23% and Italy 62% of the units produced in Europe. Regarding the sales value, Germany represents 48%, Italy 33% of the units produced in Europe. CECED Italia represents around 60 to 80% of the Italian professional dishwashers manufacturing. This means that the manufacturers responding to our survey cover between 67 and 74% of the market in terms of units produced and 60 to 73% of the market in terms of sales value. This also includes the Eastern European market as the responding manufacturers also sell and represent the major market share in these countries. Further, German and Italian manufacturers have their main focus on different dishwasher categories: Germany tends to produce rather large conveyor-type dishwashers, whereas Italy tends to produce rather the smaller undercounter dishwashers (see Task 2). Therefore, with German and Italian manufacturers answering to the survey, expert-knowledge regarding dishwashers of both main operating principles (programme automats and conveyor-type dishwashers) could be obtained.

Unfortunately, the user side of professional dishwashers or their associations have not participated in the survey. However, approximately 10 percent of professional dishwashers are usually sold directly from manufacturers to the users and tuned to customer specific requirements upon purchase. This is especially true for the larger conveyor-type dishwashers, but also partly for the other professional and semi-professional dishwashers. Thus, manufacturers' estimations on typical user behaviour can be judged as viable.

Due to the lack of a mandatory European measurement standard it is difficult to assess and compare the compiled consumption data for the energy, water, detergent and rinse aid of professional dishwashers. Instead, the information by manufacturers on consumption values is usually given with their own testing procedures under "ideal" use conditions. These ideal conditions, however, are somewhat hypothetical, as e.g. the initial heating of the wash tanks, standby times or partial loading of dishwashers are neglected. Additionally, as the exact measuring conditions may vary between different manufacturers, the information on specific consumption values (e.g. kWh per cycle) has to be handled with care. This applies particularly because the information is often used for promotional purposes and tends to understate the consumption.

1.3 Sinner's Circle principle ("Sinner'scher Kreis")

To achieve a certain degree of cleaning performance with professional dishwashers, four interdependent factors[1] interact and have to be optimally adjusted (so called "Sinner's Circle", see also Figure 1).[2]

- Temperature (thermal energy consumption);
- Mechanics (mechanical energy consumption);
- Chemistry (type and concentration of detergent and rinse aid);
- Time.

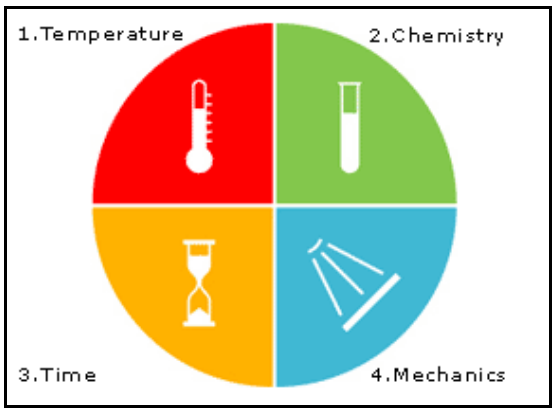


Figure 1 Factors influencing the dishwashing process: Sinner's Circle ("Sinner'scher Kreis")[3]

As most of these factors might also be influenced by consumer behaviour, the Sinner's Circle principle should be taken as theoretical background for Task 3.

1. Temperature: A very important factor in the cleaning process is the temperature. Most dishwashers usually work with a tank temperature of 55–65°C as in the current German DIN standards on food hygiene (see Task 1) a minimum temperature of 55°C is mandatory to ensure sufficient germ reduction.[4] The rinse process is normally carried out with higher temperatures of 80–85°C. In case of special glasswashers also lower

---

1 These factors are similar in each washing or cleaning process, i.e. also for household dishwashing or in case of laundry treatment.

2 See e.g. aid Infodienst (2005) and DIN 10510.

3 http://www.winterhalter.biz/winterhalter/information/dishwashing-hygiene/index.html

4 As the required germ reduction can also be achieved at lower temperatures (e.g. through longer contact times of the wash ware with the detergent solution) dishwashers partly also work with other tank temperatures. Thus, the currently developed revision of the German DIN standards (10510-10512 and 10522) will not include certain mandatory minimum temperatures anymore (see also Task 1).

temperatures around 60–65°C are used for the final rinsing to avoid damaging the wash ware.[5]

2. Chemistry: Type and concentration of detergent and rinse aid. To get a good cleaning result, a certain concentration of detergent has to be maintained in the detergent solution. If the concentration is too low, the cleaning performance is inferior. Conversely, a too high concentration of detergent might cause corrosion of wash ware. Additionally, if the concentration is higher than necessary, the detergent is wasted, leading to negative impacts on the environment; further, the cleaning process will not be cost effective and the rinse process can be affected adversely. The usage of detergent and rinse aid depends on the following factors:
   - Responsibility of the cleaning process (manufacturer, special service company, or operator of the dishwashing machine),
   - Precision of the dosage device,
   - Regular adjustment and control of the dosage device,
   - Composition of detergent and rinse aid and
   - Changes of the formulation over time.
3. Time: To obtain an acceptable dishwashing result and for hygienic reasons the detergent must be able to develop its effect during time. That is why the program cycles usually take around 90 seconds (which is the minimum duration as defined in the German DIN standards) and is normally 120 seconds in the standard programme[6] (excluding drying time). The time required for the dishwashing process influences the consumption of the other parameters. For professional dishwashers, however, a short duration of a running cycle is an essential labour cost factor and thus a key purchasing criterion. The duration can therefore only be extended to a limited degree.
4. Mechanics: Another component of the Sinner's Circle is the mechanical action of the machine. A higher pump power leading to higher water pressure could reduce the necessary running time of the dishwashing cycle or the process temperature. However, the power of the pumps has to be limited as otherwise the dishware (especially more deli-

[5] For comparison: The international ASTM or NSF/ANSI standards (cf. Task 1) are applied for hot water and/or chemical sanitizing machines. Compared to cleaning with dishwashers, the sanitizing process usually requires higher process temperatures due receive the considered reduction of micro organisms. For example, NSF/ANSI requires 66 to 74°C as minimum wash temperatures and 74 to 82°C as minimum sanitizing temperatures for hot sanitizing machines, depending on the respective machine category.

[6] Currently no mandatory standard / standard programme to measure the consumption of energy, water and detergent of professional dishwashers exists. In this section, "standard" programme is equatable with the most used programme.

cate materials like glass) would suffer under the high pressure of the cleaning and rinsing water.

If a certain degree of cleaning performance shall be achieved, one factor can only be reduced (e.g. temperature, resulting in lower energy demand), if another factor is accordingly increased (e.g. time). This effect can be observed in case of household dishwashers: the duration of the most energy efficient programme has been increasing significantly to up to 3 hours per dishwashing cycle. The fact is also visible, when the share of the four factors in hand dishwashing and machine dishwashing is compared: In case of hand dishwashing, mechanical action is much more important than in case of machine dishwashing, where higher temperatures are used and the chemicals are more aggressive instead. However, both processes (should) lead to the same result.

Without increasing another factor, the contribution of one factor can only be reduced, if the cleaning performance can be decreased (maybe because the wash ware is less soiled). This can be seen in case of professional dishwashers where longer programmes have a higher cleaning performance (i.e. they are used for more heavily soiled wash ware). As temperature, chemistry and mechanic action are held constant compared to a shorter programme, the longer time results in higher cleaning performance. It also results in higher energy consumption, as opposed to household dishwashers where longer program duration leads to lower energy consumption.

In addition to the four cleaning factors, water also plays an important role since it serves as solvent for soluble substances and as carrier for cleaning chemicals and thermal energy. The amount of water influences the energy consumption. In addition, the water quality influences the washing process.

In short, the Sinner's Circle explains two facts:

a) Only the interaction of all factors leads to the required cleaning performance.

b) The reduction of one factor necessitates additional use of other factors if the cleaning performance shall be held constant. Of course, this is only possible within certain limits.

In the following sections, the user parameters and the influence of different user behaviour on these factors is described in detail.

2 Typical capacity and use intensity of professional dishwashers

Different customer requirements result in a range of professional dishwasher categories available on the market (see Task 1).

Table 1 gives an overview of the main applications and the respective capacity ranges of these dishwasher categories thus providing a first indication of a possible use intensity of professional dishwashers.

Table 1 Main applications and market segments of professional dishwashers according to spatial requirements

Dishwasher category	Applications / Market Segments	Main operator / User type	Spatial requirements	Capacity range (in brackets: typical capacity) [dishes/hour]
No 1 Undercounter water-change	Bars, bistros, (small) restaurants, offices, community centres, clubhouses, motorway service areas, hospitals, hotels, bed & breakfasts, institutional kitchens, Kindergartens & pre-schools, schools, supermarkets.	Mainly private customers and non trained personnel (with few exemptions)	Rather small amount of space available / necessary	80-300[7] **(200)**
No 2 Undercounter one-tank	(Small) restaurants, hotels, conference centres, bars, clubhouses, gas filling stations, motorway service areas, day-care-homes, bakeries, butcheries, old age homes.	Non and trained personnel	Rather small amount of space available / necessary	300-800 **(550)**
No 3 Hood-type	Institutional kitchens, care homes, bars, school canteens, small business canteens, filling stations, motorway service areas, restaurants, bakeries, butcheries.	Non and trained personnel	Medium amount of space necessary. Used in separate kitchen or dishwashing rooms.	500-1 300 **(860)**
No 4 Utensil/Pot	Institutional kitchens, bread and bakery, industry butcheries, hypermarkets.	Trained personnel	Medium amount of space necessary.	10-30 cycles/ hour[8] **(20 cycles/ hour)**
No 5 Conveyor-type one-tank	Medium business canteens, hospitals, cafeterias, caterers, hotels.	Trained personnel	Medium to large amount of space required.	1 500-2 000[9] **(1 750)**
No 6 Conveyor-type multi-tank	Big business canteens, hospitals, cafeterias, caterers.	Trained personnel	Large amount of space required.	1 700-6 000[10] **(3 600)**

Undercounter water-change appliances (category 1) are mostly used in semi-professional contexts like bars, small restaurants or offices with mainly non trained personnel. The machines are very similar to dishwashers for household use (both technologically and with regard to user conditions) and are usually used if the conditions are equivalent or similar to

7 Different throughput rates with cold water supply at 15°C or cold and hot water supply (hot water 65°C).

8 The capacity of utensil/pot dishwashers is measured in cycles per hour as no dishes but large cooking utensils are cleaned that considerably vary in size.

9 Some dishwashers of category 5 on the market use extreme high capacity of up to 5 000 dishes per hour. This is however not considered as "typical" capacity range.

10 Some dishwashers of category 6 on the market use extreme high capacity of up to 14 000 dishes per hour. This is however not considered as "typical" capacity range.

household conditions, e.g. only a rather small amount of wash ware is to be cleaned per day and time does not matter as much as in other professional applications (cycle times are longer compared to tank machines, however much shorter than in household dishwashers).

Undercounter tank machines (category 2) are usually used in bars, bistros, small restaurants, offices, clubhouses, hotels, conference centres, gas stations, motorway service stations, day-care homes, bakeries, butcheries and elderly homes. Due to the shorter cycle time, they have a higher capacity than semi-professional water-change models. They make only sense if a certain amount of wash ware has to be cleaned as the water in the tank has to be heated and the dishwasher is kept in ready-to-use-mode between the dishwashing cycles. As defined in Task 1, category 2 also includes specialised glasswashers.[11]

Hood-type dishwashers (category 3) are more ergonomically to handle compared to undercounter dishwashers as the baskets are put on a table next to the dishwasher and pushed into the machine after loading. The filled (quite heavy) basket usually does not have to be carried by the user but only the empty ones. They are used if enough space is available and usually if more wash ware is to be cleaned compared to undercounter dishwashers. They are more seldom used in small restaurants or bars.

Utensil/pot dishwashers (category 4) are used to clean heavily soiled pots and pans as well as other large utensils. They are frequently used in institutional kitchens, restaurants, bread and bakery industry, butcheries, hypermarkets etc.

Conveyor-type dishwashers with one or more tanks (category 5 and 6) require a quite high amount of wash ware to be cleaned per day and also a large amount of space. They are therefore used in medium and large business canteens, hospitals, caterers, and hotels.

Overall, the cleaning capacity ranges from 80 to 14 000 plates per hour. However, for the calculations in the further Task reports, for each category the typical capacity as stated in the brackets in Table 1 will be used.

Annual number of cleaned wash ware

Table 2 shows the assumptions due to stakeholder feedback from the survey with regard to the following parameters:

[11] According to stakeholder feedback (cf. Annex, section 8.3), glasswashers do have slightly different usage (lower number of wash ware per year) and consumption parameters (slightly higher specific energy and water consumption) compared to undercounter one-tank machines used as generalists. However, specific consumption values as presented in Table 3 represent averaged values from different stakeholders' input data and are assumed to include also glasswashers. The global economic and environmental outcomes of Base Case 2 (cf. Task 5) should be similar to the potential results of a thorough analysis of glasswashers (the absolute values would differ but the base case is supposed to be close to an EU average).

- Maximum capacity:[12] number of dishes per cycle (categories 1, 2 and 3), number of dishes per hour (categories 5 and 6),
- number of dishwashing cycles per day (applicable to categories 1 to 4),
- time span per day in active mode,
- working days per year, and
- typical workload (in %).

With these input data, the annual number of dishes[13] (cat. 4: cycles) cleaned per category is calculated serving as input for the further calculations of the energy, water and detergent consumption per dish and/or per cycle and also per year under ideal and real conditions.

Table 2 Typical intensity of use of the regarded dishwasher categories

Dishwasher category	Average capacity per cycle or per hour	Number of cycles per day	Time in active mode per day[14]	Working days per year	Typical workload of basket/belt[15]	Number of dishes / cycles per year
No 1 Undercounter water-change	30 dishes/cycle[16]	5	1h 30	200	80%	24 000 dishes
No 2 Undercounter one-tank	18 dishes/cycle	55	1h 50	300	80%	237 600 dishes
No 3 Hood-type	18 dishes/cycle	80	2h 40	300	80%	345 600 dishes
No 4 Utensil/Pot	not applicable	30	2h 08	300	60%	9 000 cycles
No 5 Conveyor-type one-tank	1 750 dishes/hour	not applicable	3h 30	330	75%	1 515 900 dishes
No 6 Conveyor-type multi-tank	3 600 dishes/hour	not applicable	4h 30	330	75%	4 009 500 dishes

(Source: own calculations based on stakeholder feedback from survey)

[12] In case of rack (basket) dishwashers the capacity is mostly given in “racks per hour”. In case of belt conveyor dishwashers the capacity is given in dishes per hour. Here, “dishes per hour” is chosen to make the numbers comparable between the categories and because the capacity in racks per hour is ambiguous as the rack size (i.e. the number of dishes per rack) varies between manufacturers. Assumed conversion factors: 30 dishes per rack (category 1) and 18 dishes per rack (categories 2, 3, 5 and 6).

[13] For comparison of the capacity rating and typical use intensities of different professional dishwasher categories, the term “dishes” usually refers to standard sized plates of the same size.

[14] Calculations based on stakeholder feedback with regard to distributed usage of different program durations.

[15] The typical workload is included in this table to calculate the typical number of dishes cleaned per year. Its influence on the specific consumption values will be considered in Table 5.

[16] Undercounter water-change dishwashers work with two or three baskets. These are usually designed for a mixed loading, i.e. including cups, saucers, large and small plates plus cutlery. For reasons of better comparability with the other dishwasher categories in the study at hand a capacity of 30 dishes is taken as basis.

Detergent consumption

According to A.I.S.E.[17] customers generally ask for good wash performance (i.e. fewer cases of rewash) with the lowest cost per wash (i.e. with the possible lowest detergent concentration). Safety and simplicity combined with a good service level are further requests of customers.

The use of the types of detergents and rinse aids available depends on the type and size of the dishwashing machine, but in the majority of professional dishwashing machines the dosage of the detergent and rinse aid is made automatically.[18] There is a focus on safe dosing applications via closed systems, i.e. no customer contact with the product.

The smaller undercounter dishwashers usually use a detergent and rinse aid in one product, usually in tablet form or have an internal pump that is used to dispense liquid detergents and rinse aids. The larger hood-type or one-tank machines, and the larger conveyor-type machines tend to use liquid detergent and rinse aids that are dosed through pumps.

According to A.I.S.E.[19] there are differences in water hardness across Europe and even within countries. These result in the need for different detergents products or different dosing levels to cope with the water hardness. Country differences also exist in the type of soil that needs to be cleaned. For example, Germany tends to need products that can handle with high levels of starch whereas the UK is more concerned with tea and coffee staining and the ability to clean them. Customer perception of product effectiveness can depend on whether the product can clean these specific soils. Together with different cost acceptance by customers, these lead to significant variations in product dosage over various European countries.

Usually the concentration of detergent is between 2 and 4 g/litre and the concentration of rinse aid is about 0.2 to 0.5 g/litre. During the course of our study, stakeholders agreed on an average value for the composition and the use of detergent and rinse aid across different EU countries. Therefore, for all dishwasher categories the following concentration values have been taken:

- Concentration of detergent: 3.00 g/litre,
- Concentration of rinse aid: 0.35 g/litre.

Rinse aid consumption will not be regarded separately. It is assumed that rinse aid is directly correlated with the water and detergent consumption and therefore it is integrated with the

[17] International Association for Soaps, Detergents and Maintenance Products

[18] „Küche und Technik, Handbuch für gewerbliche Küchen“ (Kitchen and technology; handbook for commercial kitchens), p. 69

[19] International Association for Soaps, Detergents and Maintenance Products

detergent consumption. An integrated detergent and rinse aid concentration of **3.35 g/litre** is assumed.

3 Ideal user behaviour

3.1 Ideal operating conditions and user behaviour

Information by manufacturers about energy, water and detergent consumption of professional dishwashers is usually given under "ideal" use conditions. This means, that

- the machine is in an optimum condition;
- the manually, external pre-wash of wash ware is not included;
- the initial filling and preheating of the machine is not included;
- "standard" washware is used (e.g. plates made of china, diameter 26 cm, weight 600 g with a certain degree of soiling), whereas this type of wash ware may be different between manufacturers;
- the capacity of the dishwasher is fully used;
- the detergent and rinse aid are used in the required form and concentration, and
- the mostly used dishwashing programme is used;
- energy consumption in low-power modes (e.g. ready-to-operate or end-of-programme mode) is not included;
- the appliances run continuously;
- the cleaning of the machine at the end of the day is not included.

3.2 Energy, water and detergent consumption under ideal conditions

Table 3 provides an overview of the specific average energy, water and detergent consumption of the different dishwasher categories during continuous operation (source: stakeholder feedback from the survey). The figures show the consumption values of dishwashers with average technology (not including special BAT) being offered currently on the market. They are used to preliminary calculate the energy, water and detergent consumption during the use phase under ideal conditions in order to give an impression on the environmental relevance of the different dishwasher categories and to subsequently determine the influence of other parameters of user behaviour which are not included under ideal conditions (see section 4)

Table 3 Specific energy, water and detergent consumption of an average current device of different dishwasher categories during continuous operation under ideal conditions

Dishwasher category	Energy consumption (range)	Water consumption (range)	Detergent / rinse aid consumption
	kWh/100 dishes[20]	litre/100 dishes	g/100 dishes
No 1 Undercounter water-change	4.3[21]	80	268
No 2 Undercounter one-tank	1.6 (1.2-2.0)	16 (equals 2.9 l per cycle)	54
No 3 Hood-type	1.7 (1.5-2.0)	16	54
No 4 Utensil/Pot	0.5 kWh per cycle	5.2 litre per cycle	17 g per cycle
No 5 Conveyor-type one-tank	2.0 (1.8-2.3)	13 (11-15)	44
No 6 Conveyor-type multi-tank	2.0 (1.6-2.3)	12 (11-13)	40

Based on the annual number of dishes or cycles given in Table 2, the following Table 4 shows the annual consumption of energy, water and detergent (including rinse aid) for each of the six dishwasher categories under ideal conditions.

Table 4 Annual energy, water and detergent consumption of different professional dishwashers under ideal condition

Dishwasher category	Number of dishes / cycles per year	Energy consumption	Water consumption	Detergent/rinse aid consumption
		kWh/year	litres/year	kg/year
No 1 Undercounter water-change	24 000 dishes	1 032	19 200	64
No 2 Undercounter one-tank	237 600 dishes	3 802	38 016	128
No 3 Hood-type	345 600 dishes	5 875	55 296	187
No 4 Utensil/Pot	9 000 cycles	4 500	46 800	153
No 5 One-tank conveyor-type	1 515 900 dishes	30 318	197 067	667
No 6 Multi-tank conveyor-type	4 009 500 dishes	80 190	481 140	1 604

[20] In case of category 4, values are given per cycle.

[21] Programme „Universal“, cold water supply (direct electricity consumption of the dishwasher is lower when connected to warm water supply (1.7 kWh/100 dishes)).

An undercounter water-change dishwasher (category 1) cleaning about 24 000 dishes per year will consume about 1 030 kWh energy and 19 200 litres of water during continuous operation under ideal conditions. The water consumption is connected with a detergent and rinse aid consumption of 64 kg per year.

The energy and water consumption of a multi-tank conveyor-type dishwasher lies in another dimension: about 80 200 kWh energy and 481 100 litres water, as well as 1.6 tons of detergent and rinse aid are consumed to wash 4 010 Mio dishes per year.

4 Real life user behaviour

In technical information sheets of dishwashers, the energy, water and detergent/rinse aid consumption is usually specified under ideal conditions as described in section 3.1. However, there are several reasons why there are considerable differences between ideal and real consumption:

- The **user behaviour** during continuous operation is usually not “ideal”:
  - Workload: Baskets and belts are not fully loaded, leading to a higher consumption per dish.
  - Other programs: The consumption data usually represent the consumption of the most used program. However, the machines are also used in other programs.
  - Maloperation: Mistakes in user behaviour lead to increased consumption. Several types of maloperation can be distinguished (e.g. incorrect dosage of detergent and rinse aid).
- The energy and water consumption for the **initial filling** of the tanks (water and detergent consumption, heating) as well as for the heating up and cleaning of the machines is not included in the consumption data.
- When switched on, the dishwasher is often in operating in low-power modes (e.g. ready-to-use or left-on mode), which might represent a quite long period of time and additional **standby consumption** accordingly.

In the following sections we will describe these parameters in more detail and show their possible influence compared to the consumption under ideal conditions.

4.1 Influence of user behaviour

4.1.1 Partial workload

According to stakeholders’ feedback from the survey, Table 5 shows the average additional consumption of energy, water and detergent/rinse aid (in percent) at typical workload in comparison with full load utilisation of the devices.

Table 5 Additional consumption at real-life workload

Dishwasher category	Average work-load	Increase of … due to partial workload		
		specific energy consumption	specific water consumption	specific detergent / rinse aid consumption
No 1 Undercounter water-change	80%	15%	25%	25%
No 2 Undercounter one-tank	80%	7.5%	25%	25%
No 3 Hood-type	80%	7.5%	25%	25%
No 4 Utensil/Pot	60%	7.5%	30%	30%
No 5 Conveyor-type one-tank	75%	10%	10%	10%
No 6 Conveyor-type multi-tank	75%	10%	10%	10%

For example, for category 1 a partial workload of the basket at 80% will result in an increased energy consumption of about 15% compared to full load. This results from the fact that nearly the same amount of energy is used for 20% less dishes. As a result, the energy consumption per cleaned dish increases. Because fewer dishes have to be heated compared to full load, the additional energy consumption is not 25% (as it would be when the absolute energy consumption would be identical in both cases) but only about 15%. The additional water consumption for the same category of dishwashers is 25%. The dishwasher does not recognise the partial load and therefore the same amount of water is used as in case of full load.

The concentration of the detergent solution has always to be kept at a constant level (less concentration would lead to insufficient cleaning results; overdosage on the other hand should be avoided as it might result in undesirable detergent remains on the wash ware and also is a cost factor). The concentration of the detergent depends on the amount of water used for cleaning the wash ware. Thus, the proportionally increased water consumption due to partial load leads to an equivalent increase of the detergent consumption.

A lower workload of dishwashers of categories 2, 3 and 4 typically causes only small additional energy consumption due to several reasons: Fewer dishes have to be heated compared to category 1 (cf. Table 1); energy that is not used for rinsing is used for heating the tanks resulting in some savings of energy consumption.

In the case of conveyor-type dishwashers (categories 5 and 6) it is assumed that a part of the machines recognise[22] empty places in the basket or belt and in consequence use less water for the rinsing process, resulting in less energy, water and detergent consumption. De-

[22] This design option will further be elaborated in Task 6 on best available technologies (BAT).

spite the partly adaptation of the dishwashing process, the reduced load leads to an increase of energy, water and detergent consumption of about 10% at a workload of 75%[23].

4.1.2 Use of other programmes

The selection of the dishwashing programme also influences the energy, water and detergent/rinse aid consumption.

In addition to the "standard"[24], i.e. most used programme, two other common programmes for the six professional dishwasher categories are specified in the following table. These programmes mainly differ from the standard programme by their duration and the respective cleaning performance. To get a good hygienic result, the detergent needs some time to dissolve the soil. Hence, a minimum time of the washing process is necessary.

Furthermore, the performance of the dishwashing process depends on four factors (see section 1.3):

- thermal action (i.e. water temperature),
- mechanical action,
- chemical action (i.e. detergent concentration), and
- time.

Professional dishwashers are in general characterised by their high cleaning capacity through short programme duration. A single cleaning process (without drying) in the standard programme of a tank-operated dishwasher usually takes about 120 seconds (cf. Table 6). To receive a good cleaning result the other factors have to be accordingly adjusted.

Short running cycles, which take between 60 and 90 seconds (cf. Table 6), are associated with a reduced cleaning performance of the dishwashing process, as the other influencing parameters (water temperature, mechanical action and detergent concentration) are kept constant compared to the "standard" programme. Thus, shorter running circles are usually only used for less soiled wash ware. Accordingly longer running cycles have a better cleaning performance and are usually used for more heavily soiled wash ware.

In case of water-change appliances the situation is slightly different. As it is easier to change e.g. the water temperature (as not a full wash tank has to be heated), shorter programme durations do not necessarily lead to lower cleaning performance, as they can be combined

[23] According to DIN 10510:2008 (Professional dishwashing with multi-tank conveyor-type dishwashers – Hygiene requirements, procedure testing; page 17), in practice the average workload of these appliances is about 75 to 90%.

[24] Currently no mandatory standard / standard programme to measure the consumption of energy, water and detergent of professional dishwashers exists. In this section, "standard" programme is equatable with the most used programme.

with higher temperatures. Several programmes can be chosen depending on the type of wash ware, the degree of soiling and the temporal requirements of the situation at hand.

In the following table, in comparison to the "standard" programme (programme "universal") a shorter and a longer programme are depicted that show the same characteristics as those of professional tank dishwashers: in case of the shorter programme the other parameters are kept (mainly) constant, resulting in lower cleaning performance (i.e. appropriate for less soiled wash ware) and lower consumption parameters. In case of the longer programme the situation is to the contrary.

Key parameters that are specified in Table 6 are:

- Duration of the dishwashing cycle,
- Frequency of use of the different programmes,
- Influence of other programmes on energy, water and detergent consumption compared to the basic setting (which is assumed to be 100%).

Table 6 Programme selection and its influence on energy, water and detergent consumption

Type of programme		Duration of programme	Share of programme	Relative consumption of		
				Energy	Water	Detergent
No 1: Undercounter water-change						
A	Basic setting	16 min	80%	-	-	-
B	Short running cycle	6 min	10%	-54%	-35%	0%
C	Long running cycle	20 min	10%	+16%	+31%	0%
Average consumption in comparison to standard consumption				*96%*	*100%*	*100%*
No 2: Undercounter one-tank						
A	Basic setting	120 sec	70%	-	-	-
B	Short running cycle	60 sec	25%	-10%	0%	0%
C	Long running cycle	180 sec	5%	+10%	0%	0%
Average consumption in comparison to standard consumption				*98%*	*100%*	*100%*
No 3: Hood-type						
A	Basic setting	120 sec	80%	-	-	-
B	Short running cycle	60 sec	15%	-10%	0%	0%
C	Long running cycle	180 sec	5%	+10%	0%	0%
Average consumption in comparison to standard consumption				*99%*	*100%*	*100%*
No 4: Utensil / Pot dishwashers						
A	Basic setting	150-360 sec	60%	-	-	-
B	Short running cycle	90-180 sec	5%	-10%	0%	0%
C	Long running cycle	300-540 sec	35%	+10%	0%	0%
Average consumption in comparison to standard consumption				*103%*	*100%*	*100%*

Type of programme		Duration of programme	Share of programme	Relative consumption of		
				Energy	Water	Detergent
No 5: One-tank conveyor-type						
A	Basic setting	120 sec[25]	90%	-	-	-
B	Short running cycle	90 sec	10%	-25%	-25%	-25%
C	Long running cycle	180 sec	0%	+50%	+50%	+50%
Average consumption in comparison to standard consumption				*98%*	*98%*	*98%*
No 6: Multi-tank conveyor-type						
A	Basic setting	120 sec[25]	80%	-	-	-
B	Short running cycle	90 sec	10%	-25%	-25%	-25%
C	Long running cycle	180 sec	10%	+50%	+50%	+50%
Average consumption in comparison to standard consumption				*103%*	*103%*	*103%*

(Source: stakeholder feedback from survey)

It can be seen that depending on the technology and the dishwashing process the energy and water consumption, as well as the detergent/rinse aid consumption can be different in the long and short running cycles compared to the "standard" programme.

Within the EU member states there is a different appraisal concerning the use of the short and long running cycle: While stakeholders from Italy see the short running cycle as the most frequently used programme besides the standard programme, the German stakeholders see the long running cycle as the most frequently used programme besides the standard programme.

The impact of these differences, however, is quite small in comparison to the total real life consumption of energy and water (see rows "Average consumption in comparison to standard consumption" in Table 6).

4.1.3 Maloperation

Maloperation of professional dishwashers can influence the energy, water, detergent and rinse aid consumption. There are following main reasons for the maloperation of professional dishwashers:

- The wrong programme is chosen and the dishwashing process has to be repeated because the result of the washing process is not satisfactory.
- The concentration of the detergent and rinse aid is not sufficient and the result of the cleaning process therefore not acceptable. The dishwashing process has to be repeated. This occurs when the container for the detergent or rinse aid is empty and the user does not pay attention to the corresponding signal.

[25] Contact time (plate in cleaning zone)

- The concentration of detergent is too high with the result of cords and stripes (residues of detergent on wash ware).
- Belt conveyor dishwashers usually stop when the items are not taken off at the end of the belt. If such breaks occur and the device is not switched into standby mode, the specific energy and water consumption increases considerably.

The dosage of the detergent and rinse aid can be decided upon by

- Special service providers,
- The manufacturers of the dishwashers or
- The operators of the dishwashers.

In the first two cases, incorrect dosage of the detergent rarely occurs because service providers and manufacturers have a strong interest to deliver good dishwashing results with least possible detergent input and will therefore pay high attention to ensure that the right concentration of detergent and rinse aid will be available. In the third case, incorrect dosage might occur from time to time, e.g. in the case of non-trained personnel.

The impact of maloperation is difficult to quantify as it can be very different from user to user and also depends on the organisation of the dishwashing process in general. For example, in market segments with professional dishwashers used by manual programme settings and dosage are rather untrained personnel, the error rate might be higher than in market segments with highly trained personnel and machines with higher automatisation rate. Thus, due to lack of differentiated feedback from customers, for the purposes of the study we assume that the influence on the consumption of energy, water and detergent is on average in the range of

- **Categories 1 to 4: +10%** of the nominal consumption of the dishwashers,
- **Categories 5 and 6: + 5%** of the nominal consumption of the dishwasher.

4.2 Influence of initial filling and heating of tanks

Consumption data of dishwashing machines does not include the initial filling and heating of the wash tanks at the beginning of the process (applicable to all tank machines, i.e. categories 2 to 6). This amount of energy, water and detergent has to be taken into account as it might account for a substantial share of the consumption figures. Of course the importance depends on the use intensity of the dishwashers. The more dishwashing cycles (or cleaning hours) are conducted the lower is the share of the energy and water consumption for the initial filling and heating of the wash tanks relative to the total operating consumption.

Further, it is relevant if the initial filling is done with cold or warm water (see section 6). In case of warm water there is no additional energy demand of the dishwasher itself.

To calculate the annual water and energy demand of the initial filling and heating of the wash tanks the following parameters have to be specified:

- Number of working days per year,
- Number of working shifts per day (as the wash tanks have to be emptied and refilled each time),
- Volume of the wash tanks,
- Temperature of inlet water and operating temperature of wash tanks (i.e. temperature difference for heating),
- Heat capacity of water and
- Efficiency of the heating process.

The following table specifies the parameters for the different dishwasher categories.

Table 7 Input parameters for calculation of consumption through initial filling and heating of wash tanks

Dishwasher category	Number of working days per year[26]	Number of working shifts per day	Volume of wash tank(s) (assumed average)	Operating temperature of wash tanks[27] (assumed average)
No 1 Undercounter water-change	200	n.a.	n.a.	n.a.
No 2 Undercounter one-tank	300	2	7-20 litres **(15)**	55-65°C **(60°C)**
No 3 Hood-type	300	2	16-60 litres **(40)**	55-65°C **(60°C)**
No 4 Utensil / Pot	300	2	60-130 litres **(100)**	55-65°C **(60°C)**
No 5 One-tank conveyor-type	330	2	110-130 litres **(120)**	55-65°C **(60°C)**
No 6 Multi-tank conveyor-type	330	2	130-750 litres **(230)**	40°C prewash 55-65°C wash tank **(60°C)**

n.a. not applicable

For all dishwasher categories

- the water inlet temperature is assumed to be 15°C in case of filling with cold water, and 60°C in case of warm water filling. In case of warm water filling there is no additional di-

[26] cf. Table 2

[27] In the current German DIN standards on food hygiene (see Task 1) a minimum temperature of 55°C is mandatory to ensure sufficient germ reduction. As the required germ reduction can also be met at lower temperatures, other temperatures are also applicable. Thus, the currently developed revision of the German DIN standards will not include certain mandatory minimum temperatures. Currently, however, most dishwashers use the tank temperatures depicted in this table.

rect energy needed by the dishwasher for heating up the detergent solution of the initial filling,

- the heat capacity of water is 4.19 kJ/(kg*K) and
- the efficiency of the heating process is assumed to be 90%.

With these assumptions the energy, water and detergent demand of the initial filling and heating can be calculated.

Table 8 Energy, water and detergent consumption for initial filling and heating of wash tanks

	Energy consumption[28]		Water consumption	Detergent consumption
	Cold water filling	Warm water filling		
Dishwasher category	**kWh/year**	**kWh/year**	**litres/year**	**kg/year**
No 1 Undercounter water-change	n.a.	n.a.	n.a.	n.a.
No 2 Undercounter one-tank	236	262	4 500	15.1
No 3 Hood-type	629	698	12 000	40.2
No 4 Utensil/Pot	1 257	1 397	24 000	80.4
No 5 One-tank conveyor-type	1 728	1 920	33 000	110.6
No 6 Multi-tank conveyor-type	3 975	4 417	75 900	254.3

n.a. not applicable

The column ‘cold water filling’ shows the amount of electricity which will be used to heat up the cold water (15°C) to a temperature of 60°C. The column ‘warm water filling’ shows the amount of energy (for example gas) which is necessary to heat up the water (same temperature difference (60°C – 15°C = 45°C). In the third column (warm water filling), the amount of energy is slightly higher because of the efficiency losses of the boiler.

4.3 Influence of low-power modes consumption

Due to their wash tank that has to be preheated and kept on a certain heat level, categories 2 to 6 have to be kept in a “ready-to-use-mode” between the dishwashing cycles. For category 1, there is no ready-to-use-mode applicable; due to their water-change technology they

[28] I.e. only direct energy demand by the dishwasher itself.

can immediately be used. However, they might not be switched off directly after the end of the programme and therefore remain a certain time in “left-on mode”.

With assumptions on the average active operating time as outlined in Table 2 and the total time switched on,[29] the standby time (ready-to-use mode for tank dishwashers, left-on-mode for water-change dishwashers) of each category has been calculated (see Table 9).

The power consumption in off-mode has not been considered: For the smaller dishwashing machines, the off-mode consumption is negligible compared to the overall energy consumption,[30] according to stakeholders’ feedback, large conveyor-type dishwashing machines are disconnected by a power switch from the circuit so that no power is consumed during off-mode at all. Therefore, off-mode will not be taken into account in the subsequent sections and tasks.

Table 9 Typical time in low-power modes and standby consumption of professional dishwashers

Dishwasher category	Time in low power modes in hours per day		Standby consumption (in kWh/h)
	Ready-to-use-mode	Left-on-mode	
No 1 Undercounter water-change	n.a.	2.6	0.01
No 2 Undercounter one-tank	8.4	n.a.	0.25
No 3 Hood-type	7.5	n.a.	0.35
No 4 Utensil / Pot	7.4	n.a.	1.00
No 5 One-tank conveyor-type	6.5	n.a.	0.80
No 6 Multi-tank conveyor-type	5.5	n.a.	2.00

n.a. not applicable

As can be seen, the standby times of the dishwasher with higher capacity and a higher intensity of use are lower. On the other hand, the standby power consumption of those devices is higher, which is mainly caused by the energy losses from the tanks. Keeping the water tanks at high temperatures causes losses through convective heat transfer and through steam building. Additional consumption from the ventilation system and the electronic control system may arise. The highest standby consumption occurs in multi-tank conveyor-type dishwashers. The average standby energy consumption of those machines is estimated to

[29] According to stakeholders’ feedback, the machines of category 2 to 6 are usually switched on for approximately 10 hours a day, while category 1 is switched on for 4 hours.

[30] Assumption: Cat. 1 is comparable to household dishwashers. Within Task 5 of Lot 14, the off-mode consumption of household dishwashers has been calculated with 0.00016 kWh/h for 8 000 hours/year being in off-mode; leading to an annual off-mode consumption of around 1 kWh. In the professional context, this consumption might even be lower as machines are more often operating thus reducing the hours in off-mode.

be about 2 kWh per hour. On the other hand water-change dishwashers (category 1) have only low energy consumption values in low-power modes, although they clearly exceed the standby consumption of household dishwashers.[31]

For household dishwashers, the aim is to reduce the standby consumption (in case the user does not switch off the appliance after operation). Normally, the low standby requirements do not influence the usability of the appliance. Compared to household appliances, the higher standby consumption of professional dishwashers is caused by the continuous heating of the tank in order to avoid long preheating times (ready-to-use mode).

4.4 Influence of external process steps

The manual pre-cleaning of the wash ware as well as the manual cleaning of the dishwashing machines after the running cycles might cause considerably further water and energy consumption in the whole washing process.

The inclusion of the whole process from dirty to clean (including the pre-soak and pre-cleaning of the wash ware as well as the machine cleaning) would be rather desirable. However, the water and energy[32] consumption is strongly dependent on the specific user behaviour, the soiling of the wash ware and the machines, the existing infrastructure and other factors[33]. Further, there is no standard measurement method and thus no reliable data to record the average consumption through external pre-cleaning of the wash ware or cleaning of the machines. Thus, the manual process steps outside the dishwashing machines were excluded from the scope of this study (cf. Task 1) and are not included in the consumption values under real-life usage conditions.

4.5 Energy, water and detergent consumption under real-life usage conditions

The following table summarises[34] the different influence parameters of the sections above and shows the annual consumption of energy, water and detergent (incl. rinse aid) for each of the six dishwasher categories under real-life usage conditions. The results show that un-

[31] Note: Formally, professional dishwashers do not fall under the Commission Regulation (EC) No. 1275/2008 (Standby Directive, cf. Task 1).

[32] Energy consumption: due to the use of warm water for cleaning.

[33] For example, the use of active filter systems can reduce the dirtiness of the wash water through the separation of food residues during the dishwashing process and transporting them out of the machine.

[34] The detailed calculations for each category will be presented in Task 4.

der real-life conditions the additional consumption of energy, water, detergent and rinse aid might be about plus 20 to 25% compared to ideal conditions.

Table 10 Annual energy, water, and detergent consumption (real life conditions) of dishwasher categories

Dishwasher categories	Annual energy consumption per appliance (kWh)	Annual water consumption per appliance (litres)	Annual detergent consumption per appliance (kg)
Undercounter water-change	1 254	25 920	87
Undercounter one-tank	5 253	55 822	188
Hood-type	8 258	86 650	292
Utensil/pot	8 913	89 520	294
One-tank conveyor-type	37 703	255 686	865
Multi-tank conveyor-type	102 229	643 645	2 146

5 Measures to optimise user behaviour and consumption parameters

It is evident that a better use of the dishwasher can save a substantial amount of resources and costs. On the other hand, the additional consumption which is due to real-life conditions and behaviour will be reduced with the development and use of more efficient dishwashers. .

The additional consumption through real-life use results from five major reasons. While the initial heating cannot be influenced through better organisation or optimised behaviour, the other factors could be improved by the following measures. However, they only provide possible improvement options with regard to user behaviour. A more detailed discussion of technical improvement options (BAT) will be accomplished in Task 6.

5.1 Education, incentives and responsibilities

It is important to explain the consequences of partial loading the machine to users as this aspect leads to increased energy, water and detergent/rinse aid consumption.

To avoid maloperation during the dishwashing process, responsibilities clearly assigned to users might be helpful, e.g. concerning the dosage of the detergent and rinse aid or the cleaning of the machine.

In case of dishwasher operators not being well informed about standby consumption, a first step could be to educate them about the standby consumption in order to facilitate reduced standby times of the machines (e.g. not switching on machines until needed, considering time for initial heating of wash tanks).

5.2 Automatic information and control systems

Some professional dishwashers have built-in metering devices which automatically record all activities of the dishwasher and log information of the operating personnel. For example conveyor speed, on/off times, temperatures of the dishwashing process and standby times are recorded. This data can be used for optimising the use of resources (energy, water and detergent/rinse aid) and the related costs and environmental impacts. It can also be used to analyse dysfunction and show maloperation of the machine. This information can be used as a basis to train and educate the operators of the dishwashing machines. The information can also be used to optimise maintenance and therefore reduce deadlock times and save costs.

Sensors which recognise the soiling of the filters or which can detect deficient concentration of detergent or rinse aid could help to avoid maloperation of the dishwashing appliances.

5.3 One button machine – easy operation to reduce maloperation

Dishwashing personnel might not be well educated in all cases. Hence, a general aspect is that dishwashers should be easy to operate and that controls should be intuitive to handle for everybody. “Keep it simple” should be the leading principle for the operation of dishwashers. Easy operation is already a criterion partly used for differentiation in the market; however it might not be self-evident to all manufacturers that through this aspect also maloperation and thus increased consumption could be avoided.

One bottom control and self-explanatory signs of the operating status may be conducive to the design of dishwashers. The display or signs should also show the washing progress in such a way that personnel are able to organise their work more efficiently. If detergent or/and rinse aid is missing, in addition to visual signals, buzz warning may be installed. Further, an automatic switch off of the appliance, e.g. in case of missing detergent or deficient water quality might help to avoid unsatisfactory dishwashing results and in consequence a rerun of the machine.

5.4 Sensor systems regulating the water consumption

In case of conveyor-type dishwashers some manufacturers offer a sensor system to reduce energy and water consumption. The sensor system adjusts the water and rinse aid consumption to the actual load of conveyor-type dishwashers. The system detects the amount of wash ware as well as empty conveyor belt sections and reduces the consumption of water to a minimum. With such technology the losses due to partial load can be reduced. However, to date there is no reliable information available concerning the effect of the sensor system on reducing the additional energy and water consumption. Thus, data in Table 5 are based on first estimations by stakeholders’ feedback. A more detailed analysis of this design option will be presented in Task 6 (best available technologies).

Rebound effects also have to be considered: If the operators know that the machine will automatically adjust the water consumption it could be that they do not take care of fully loaded belts and racks anymore.

6 Local Infrastructure

6.1 Water supply

Professional dishwashers can either be connected to cold and/or warm water supply. Water-change dishwashers (category 1) have two valves, enabling to connect them either to only cold tap water or to cold and warm tap water. According to stakeholders' feedback connection to only warm water does not make sense as also low temperature programmes are available and in these cases the temperature of the warm water would be too high; further, when options such as heat recovery or water treatment system (softening) are included, the appliance requires cold water at the input. The connection to warm water tap is more common for category 1 as per cycle more water has to be heated up to the desired temperature (cf. Table 12).

One-tank undercounter and hood-type dishwashers (categories 2 and 3) mostly have only one valve for the water supply. Both the water for the initial filling of the wash tanks and the water for continuous operation are taken through this valve. Thus either cold water or warm water supply is possible.

A minor percentage of hood-type, utensil/pot and one-tank conveyor-type dishwashers (categories 3, 4 and 5) and a major share of multi-tank conveyor-type dishwashers have two (or more) valves, whereas the first valve is used for continuous operation, the other(s) for the separate filling of the tank(s). It is then possible to have the initial filling of the wash tanks with warm water and use cold water for the continuous operation of the dishwashing process. Filling of the tanks with warm water leads to shorter duration of the initial heating of the wash tanks to be in the ready-to-use mode.

Table 11 Number of water inlet valves of professional dishwashers

Dishwasher category	1 valve	2 and more valves
No 1 Undercounter water-change	0%	100%
No 2 Undercounter one-tank	100%	0%
No 3 Hood-type	99%	1%
No 4 Utensil/Pot dishwashers	80%	20%
No 5 One-tank conveyor-type	60%	40%
No 6 Multi-tank conveyor-type	20%	80%

The following table gives an overview of possible options and the share of dishwashers sold or installed with the respective option.

Table 12 Water connection of professional dishwashers

Dishwasher category	Only cold water connection	Cold and warm water (continuous operation)	Warm water (initial filling) Cold water (final rinse)	Only warm water connection (for initial filling and final rinse)
No 1 Undercounter water-change	50%	50%	-	-
No 2 Undercounter one-tank	80%	-	-	20%
No 3 Hood-type	75%	-	-	25%
No 4 Utensil/Pot dishwashers	70%	-	5%	25%
No 5 One-tank conveyor-type	60%	-	35%	5%
No 6 Multi-tank conveyor-type	60%	-	35%	5%

(Source: stakeholder feedback from survey)

Typical water inlet temperature is 15°C (cold water). Tank temperatures are between 55°C and 65°C (warm water) (see section 4.2).

In general, warm water connection leads to shorter programme times and lower energy consumption of the dishwasher itself. However, the overall environmental and economic advantage of the connection to warm water supply strongly depends on the type of water heating outside the appliance and other infrastructural parameters, like length and insulation of the stub water line.

6.2 Water heating

Regarding the heating of the water inside the dishwasher there are different options. The basic possibility is electric heating.

Undercounter or hood-type dishwashers (categories 1, 2 and 3) are only available with electric heating. According to stakeholders other types of heating do not make sense as it would be too much effort for only little advantage as the throughputs are lower and often the necessary infrastructure is not available.

In case of dishwasher categories 4, 5 and 6 heating can additionally be done by low pressure steam or hot water or by direct gas heating. According to stakeholder feedback from the survey, the following table shows the share of dishwashers sold or installed with the different types of water heating.

Table 13 Types of water heating in professional dishwashers

Dishwasher category	Electricity in %	Low pressure steam and hot water in %	Natural gas in %
No 1 Undercounter water-change	100	-	-
No 2 Undercounter one-tank	100	-	-
No 3 Pass through ('hood type')	100	-	-
No 4 Utensil / Pot dishwashers	90-95	5-10	0
No 5 One-tank conveyor-type	~80	20	0-1
No 6 Multi-tank conveyor-type	~70	30	0-1

The following findings can be summarised:

- The detergent and rinse aid solution of dishwasher categories 2 and 3 is exclusively heated up by electricity.
- For categories 4 to 6 the share of dishwashers being (partly) heated by steam lies between 5 and 30%.
- Within the EU Member States tank heating by natural gas is uncommon and the share represents only about zero to 1% of all conveyor-type dishwashers. One reason for this might be strict building regulations regarding ambient air conditions.
- Heating the water tanks with solar energy is not yet adopted in practice. The producers of dishwashers do not have any experience in this field.

No significant deviation of the existing infrastructure between the different EU Member States has been reported by stakeholders.

In the past years a reduction of sales of dishwashers with steam heating could be observed. Recently only about 20 to 30% of the conveyor-type dishwashers are delivered with steam heating features. The provision of steam can be provided by either direct injection or by indirect use via heat exchange coil. According to manufacturers, in theory direct injection of steam could result in higher efficiency compared to indirect use of the thermal energy using a heat exchange coil. However, in steam supply systems corrosion inhibitors are used which would contaminate the dishware when using direct steam. Additionally there would be the need of making up the corrosion inhibitors. Therefore at least in Europe steam supply for dishwashers is done using heat exchange coils.

It can be expected that in future even a higher fraction of dishwashers will be heated exclusively by electricity. As it is documented in Task 2, it can be expected that professional dishwashers become more efficient in the future. A higher efficiency of the dishwashing process will make the additional investment for using steam or hot water from other processes less cost-effective.

Another trend can be seen: With a higher awareness for energy efficiency and decreasing energy consumption in buildings some customers might change from steam system to a heat distribution system with lower distribution losses and lower costs. In consequence the dish-

washers formerly connected with steam heating have to be converted to other energy sources (usually electricity).

The impact of the infrastructure on the environmental impact of professional dishwashers is limited as only a small share of the dishwashers are equipped with steam and hot water heating. On the other hand, the environmental impacts can only be quantified if it is known how the hot water and steam is produced (energy source, efficiency, emissions, and steam as waste product or combined production).

In Table 14, stakeholders' feedback on the electricity consumption of warm water supply and alternative heating compared to electric heating with cold water supply is presented. In both cases **continuous operation** (in kWh/100 dishes) is assumed.

Table 14 Electricity consumption in case of warm water supply and alternative heating

	Electricity consumption (range) [kWh/100 dishes][35]		
Dishwasher category	**Electric heating[36]**	**Warm water supply**	**Alternative heating**
No 1 Undercounter water-change	4.3	1.7	not applicable
No 2 Undercounter one-tank	1.6 (1.2-2.0)	n.a.	n.a.
No 3 Pass through ('hood type')	1.7 (1.5-2.0)	n.a.	n.a.
No 4 Utensil / Pot dishwashers	0.5 kWh per cycle	0.25-0.3 kWh per cycle	0.17 kWh per cycle
No 5 One-tank conveyor-type	2.0 (1.8-2.3)	1.0-1.2	0.25-0.35
No 6 Multi-tank conveyor-type	2.0 (1.6-2.3)	1.0-1.2	0.20-0.35

n.a. no information available

It can be seen that with alternative heating (e.g. steam) the electricity consumption can be minimized. However, it has to be taken into account that the respective exhaust air will be very hot and humid. A heat-recovering system is not applicable as it needs cold water for final rinsing. Therefore, the exhaust air has to be ventilated outside the building e.g. with an extra ventilation system which would reduce the initial energy savings of alternative heating.

[35] In case of category 4, values are given per cycle.

[36] Numbers are taken from Table 3.

7 Maintenance and repairs, end-of-life behaviour

Professional dishwashers with high dishwashing capacity usually are regularly maintained, i.e. at least once a year. The maintenance of the devices has a preventive function and signs of wear can be detected and removed early. Thus companies with a high demand of dishwashing (and therefore a high risk in case of failure) usually have a service and inspection contract with the manufacturer or a special service provider. For smaller devices (under-counter dishwashers) this is less often the case. The repairs are almost exclusively done at the customers' premises. No additional transport of the devices is necessary.

If the dishwashing demand of a customer changes over time, he can sell the dishwasher on the second hand market. The market for used dishwashers is about 5-10% of annual sales (cf. Task 2). Disadvantage for purchasers might be that they usually get no warranty for the product. In some cases manufacturers or their sellers can act as brokers, if one of their customers wants to exchange a still operating appliance, and another customer is looking for a used device.

Almost no professional dishwasher will end at a landfill, as the materials (mostly stainless steel) are too valuable. For this reason, the products would always either be refurbished or recycled for scrap parts or materials. At the end of their life,[37] large dishwashing machines are usually received in payment by the manufacturer of the new machine as the largest proportion of the machine is of valuable stainless steel. Some parts of the machine can directly be reused; the rest of the machine will be sold to recycling companies. The smaller under-counter machines are collected by certified scrap dealers. According to stakeholder feedback, the owner of the old dishwasher will usually get small revenue of about 50 to 100 Euro from the scrap dealer, depending on the prices of commodities. Own calculations support this statement, see following table.

[37] The life time of the dishwasher categories differ: While the large conveyor-type machines with one and more water tanks can last for 17 years in average, the smaller machines will only have an average lifetime of about 8 years (for details, see also Task 2, section 2.2.4).

Table 15 Estimation of revenues from scrap metal fraction exemplified for an undercounter one-tank dishwasher (category 2)

Material / Component	Weight in g	Revenues from scrap (€/kg)[38]	Resulting revenues
Stainless steel	49 760	1.30	64.69 €
Pumps (copper)	2 500	5.20	13.00 €
Pumps (stack of sheets)	2 500	0.05	0.13 €
Pumps (stainless steel wave)	2 250	1.30	2.93 €
Pumps (Al)	2 250	0.70	1.58 €
Cable (copper)	1 100	1.40	1.54 €
Total	**83.85 €**		

[38] http://www.hein-schrotthandel.de/pages/schrottpreise.php, sighted on 16/02/2011

8 Annex

8.1 Working Paper "Task 3" and additional questions for stakeholders

The working paper and additional questions concerning warm water issues are provided separately in the following documents:

- EuP_Lot24_Dish_T3_T4_Annex_Workingpaper.pdf
- EuP_Lot24_Dish_T3_Annex_Additional_Questions_I.pdf
- EuP_Lot24_Dish_T3_Annex_Additional_Questions_II.pdf

8.2 Stakeholder involvement

The working paper containing preliminary assumptions on aspects regarding main applications of professional dishwashers, the typical user behaviour, the influence of real life conditions on ideal consumption and specific consumption values (see previous section) was circulated to the following stakeholders. The table also indicates from whom a response has been received.

Table 16 Documentation of enquiry addressees and their responses

Working paper use phase (covering Task 3 and some aspects of Task 4)		
	Sent out	**Feedback**
Manufacturers and Industry Associations		
Hobart (currently not member of an industry association)	Yes	Yes
VGG (Verband der Hersteller von Gewerblichen Geschirrspülmaschinen (Association of commercial dishwashers), representing the manucturers Winterhalter and Meiko).	Yes	Yes, feedback by both member companies
EFCEM (European Federation of Catering Equipment Manufacturers) European umbrella associations of nine national catering equipment manufacturers' associations.	Yes	Spread working document to member associations
SYNEG, France		
HKI, Germany, representing ▪ Electrolux professional ▪ Miele professional ▪ Palux ▪ Stierlen		HKI spread the working document to member companies. Feedback received by Miele.
CEA, Ireland		
CECED Italia, Italy		Yes, feedback by association.
NVLG, Netherlands		

Working paper use phase (covering Task 3 and some aspects of Task 4)		
	Sent out	**Feedback**
FELAC, Spain	Received working document via EFCEM and was additionally directly contacted.	
BFS, Sweden		
TUSID, Turkey		
CESA, United Kingdom		
User associations		
HOTREC (Trade association of hotels, restaurants and cafes in the European Union)	Yes, twice	Response on e-mail but no comment on working paper.
IHRA (International Hotel and Restaurant Association)	Yes, twice	
ACE (Association of Catering Excellence)	Yes, twice	
CLITRAVI (Liaison Center for the Meat Processing Industry in the European Union)	Yes	Feedback that they do not feel responsible.
C.E.B.P. (European Confederation of Bakers and Confectionary Organizations)	Yes, twice	
HCI (Health Caterers International	Yes, twice	Response on e-mail but no comment on working paper.
IFSA (International Flight Service Association)	Yes, twice	
ITCA (International Travel Catering Association),	Yes, via contact form on the internet	
Others		
CSFG (Catering for a Sustainable Future Group)	Yes, via contact form on the internet	

8.3 Stakeholder feedback to draft versions of Task 3

Please note that the feedback refers to prior versions of draft Task 3 report; thus the indicated numerations of chapters, tables, figures or pages might have changed.

Feedback		Comment
Hobart		
1.2, p. 6	**Survey** It is noted in this section that the input from users "is a major weakness of the data compiled in this report". The project team is kindly asked to gather required user input.	The project team repeatedly, however unsuccessfully, tried to receive feedback on these issues from user organisations (see annex, section 8.1).
3.3, p. 13	**Footnote 7** Energy consumption is considered to be identical for cold as well as for warm water connection. Reason: The energy demand to heat water with the central heating system of the building is identical as for water heating in the dishwasher.	It is correct that the end-energy demand which is needed to heat up a certain amount of water to a defined temperature is the same independently from the energy source. However the connected primary energy demand or environmental impacts depend on the type of end-energy used. The footnote is revised.
4.2, p. 17	**Table 6** A footnote should be added to clarify that the "standby mode" is in fact a "ready to use mode" because the tank water is to be kept at operating temperature for instant operation readiness.	Considered in revision.
7, p. 33	**Table 8** No 1 dishwashers have usually 100% electrical heating. The 50% for those machines in the "steam or hot water" column is misleading as explained at the stakeholder meeting 13. July 2010.	Considered in revision.
7, p. 34	**2nd Paragraph** There is no direct applicable technology available yet to use solar energy for heating of commercial dishwashers.	Considered in revision.
8, p. 35	**Table 8** – there is already a "Table 8" on page 33 (should be re-named) – the content of this table should be consistent with Table 2-12 of the Task 2 report.	Considered in revision.

Feedback		Comment
Miele		
2, p. 8	**Most stakeholders do not consider these appliances as professional dishwashers […]** As quoted in Draft 1 and as stated in the machinery directive, the intended use determines if a dishwasher is considered commercial or residential appliances. In case of Miele's product offering of water-change models the manufacturer clearly states "commercial applications" as the intended use. All models are compliant with the machinery directive. As a matter of fact they are primarily used in those target groups stated in Task 1 table 2 (Office, Pensions, restaurants, B&Bs, Nursing homes, etc.). The fact that Miele has a unique position with its water-change machine and that most manufacturers offer Tank systems doesn't make water-change models less commercial.	Considered in revision.
Table 7, p. 19	**Basic setting 12 min** Basic setting has to be 16 min, instead of 12 min	Considered in revision.
Table 8, p. 33	**Infrastructure** – Semi-professional Dishwashers are equipped with one or two inlet valves for cold and/or warm water. – Water supply could be cold water and/or cold and warm water. Maximum temperature of warm water is 60 °C. – Heating with hot water is not possible and has to be deleted.	Considered in revision.
Table 2, p. 5, line 2	**(small) restaurants, offices, community centres, club houses** Please add: hospitals, hotels, Bed & Breakfasts, institutional kitchens, Kindergartens & pre-schools, schools, Supermarkets	The Annex shows the working document that has been sent to stakeholders. Thus, table 2 in the Annex cannot be changed. In table 1 of the main report, the items have been added.
Danish Technological Institute		
Section 3+4, p. 13-15	**Besides consumption also performance should be considered: Cleaning performance and Temperatures for washing and rinsing** Starting 2008 the Danish Technological Institute has performed test of water, energy and time consumption for – Start to ready (for wash) mode – Standby in ready (for wash) mode – Standard programme for wash including – cleaning performance and washing and rinsing temperatures – for "hood type" machines.	Thank you for the input. Considered in revision (test method has been included in Task 1, results of measurements in Task 4).

Feedback		Comment
	Please see attached data sheet for an average of the first machines tested in the project and a description of the test method in short. Later tests may be seen on www.sparelisten.dk/spareopvaskemaskiner, see Sparelisten – We have to agree on some common test methods for consumption and performance as indicated in Task 3 report. – The machines shall efficiently transform certain consumptions to certain performances	
Feedback at Interim Stakeholder Meeting		
Table 1	**Capacity ranges of dishwashers** – Category 5: typical range is between 1 500 and 2 000 dishes/hour, 5 000 dishes/hour is a rather extreme value. – Category 6: typical range is between 1 700 and 6 000 dishes/hour. 14 000 dishes/hour is a rather extreme value.	Considered in revision.
Table 2	Unit of capacity (dish per hour) shall be harmonised with Task 2 (dishes/hour). Typical capacity of category 5 dishwashers should be lower than 2 000 dishes/hour as this would be the upper end of the typical range. Typical number of cycles per day for hood-type dishwashers (120) is a rather hard use and should be changed to 80 cycles/day.	Considered in revision.
CECED Italia		
Section 2ff, p. 8-10-11	**General considerations on Glasswasher/ Undercounter** We deem that glasswashers, being a relevant product within professional dishwasher machines, cannot be assimilated to other products categories. In fact glasswashers have different technical parameters from “general” undercounter machines. Please find attached several data we have assessed in order to show the different features. Please note that we made also different considerations on undercounter one-tank machines. Moreover, we have assessed an evaluation for Italian manufacturers’ machines sales in EU; it results that the ratio undercounter-glasswasher is approx. 1:1.5. In other words even if the energy consumption for the single glasswasher machine is lower than for undercounter, the total consumption is absolutely comparable.	Thank you for your input. Please be aware that the scope of the study including categories 1-6 to be regarded (cf. Task 1), has already been decided on at the interim stakeholder meeting; thus at this final stage of the study there is no possibility to open the scope again to another separate category (glasswashers) with implications on all further Task reports and calculations. As discussed at the final stakeholder meeting, as well as stated by your last sentence: the global economic and environmental outcomes of Base Case 2 (cf. Task 5) should be similar to the potential results of a thorough analysis of glasswashers (the absolute values would differ but the BC is supposed to be close to an EU average).

Feedback		Comment
		With regard to your new input on consumption values of categories 2 and 3 tables 3 and 4 (with implications on table 10 and all further Task reports), please note that the input as given in Table 3 (source: manufacturers' prospects plus responses of 3 manufacturers' responses on our working paper) has already been presented at the interim stakeholder meeting in July 2010, and again at the final stakeholder meeting in December 2010 with no particular comments at that times. Thus, we hope for your understanding that at this final stage of the study we unfortunately cannot take this input into account anymore, especially as potential changes cannot be agreed upon with the other stakeholders.

Preparatory Studies for Eco-design Requirements of Energy-using Products

Lot 24: Professional Washing Machines, Dryers and Dishwashers

Tender No. TREN/D3/91-2007

February 2011

Final Report, Part: Dishwashers

Task 4: Technical Analysis Existing Products

Öko-Institut e.V.
Institute for Applied Ecology, Germany
Ina Rüdenauer
Markus Blepp
Eva Brommer
Carl-Otto Gensch
Kathrin Graulich

BIO Intelligence Service, France
Shailendra Mudgal
Raul Cervantes
Thibault Faninger
Lorcan Lyons

Büro Ö-Quadrat, Germany
Dieter Seifried

Öko-Institut e.V.
Freiburg Head Office
P.O. Box 17 71
79017 Freiburg, Germany
Street Address
Merzhauser Str. 173
79100 Freiburg, Germany
Tel. +49 (0) 761 – 4 52 95-0
Fax +49 (0) 761 – 4 52 95-88

Darmstadt Office
Rheinstr. 95
64295 Darmstadt, Germany
Tel. +49 (0) 6151 – 81 91-0
Fax +49 (0) 6151 – 81 91-33

Berlin Office
Schicklerstr. 5-7
10179 Berlin, Germany
Tel. +49 (0) 30 – 40 50 85-0
Fax +49 (0) 30 – 40 50 85-388

www.oeko.de

For reasons of better readability, two Task 4 reports were prepared.

The report at hand covers ***professional dishwashers***.

The Task 4 report on *professional washing machines and dryers* is published separately.

For the benefit of the environment, this document has been optimised for **double-sided printing**.

Part: Professional Dishwashers

Table of Contents – Task 4: Technical Analysis Existing Products

List of tables **IV**

List of figures **VI**

1 Introduction **1**

1.1 Objective **1**

1.2 Methodology and assessment of data quality **1**

2 Technical analysis production phase **2**

2.1 Main operating principles of dishwashers **2**

2.1.1 Water-change operation 3

2.1.2 Tank operation 5

2.1.2.1 Program automats (one-tank) 5

2.1.2.2 Conveyor-type (one-tank / multi-tank) 7

2.1.3 Differences between water-change and tank operated dishwashers 10

2.2 Main characteristics and material composition of dishwashers **12**

2.2.1 Category 1: Undercounter water-change dishwashers 12

2.2.2 Category 2: Undercounter one-tank dishwashers 14

2.2.3 Category 3: Hood-type dishwashers 16

2.2.4 Category 4: Utensil / pot dishwashers 18

2.2.5 Category 5: One-tank conveyor-type dishwashers 21

2.2.6 Category 6: Multi-tank conveyor-type dishwashers 23

2.2.7 Overview of all dishwasher categories 25

2.3 Other materials **26**

3 Technical analysis distribution phase **27**

4 Technical analysis use phase (product) **28**

4.1 Energy flow in professional dishwashers **28**

4.2 Typical composition of detergents and rinse aids for professional dishwashers **32**

4.3 Energy, water and detergent consumption **33**

4.3.1 Category 1: Undercounter water-change dishwashers 34

4.3.2 Category 2: Undercounter one-tank dishwashers 35

4.3.3 Category 3: Hood-type dishwashers 35

4.3.4 Category 4: Utensil / pot dishwashers 37

4.3.5 Category 5: One-tank conveyor-type dishwasher 38
4.3.6 Category 6: Multi-tank conveyor-type dishwasher 38
4.3.7 Overview of all dishwasher categories 39
5 Technical analysis use phase (system) 39
6 Technical analysis end-of-life phase 41
7 Recommendation on mandates 42
8 Annex 45
8.1 Stakeholder enquiries 45
8.1.1 Working paper “Task 4” for stakeholders 45
8.1.2 Excel enquiry – production, distribution and end-of-life phase 47
8.1.3 Additional questions – production, distribution, end-of-life phase 50
8.1.4 Documentation of stakeholder response to enquiries 51
8.2 Stakeholder feedback to draft versions of Task 4 52

List of tables

Table 1 Categorisation of professional dishwashers 2
Table 2 Different configuration of a multi-tank conveyor-type dishwasher (category 6) 10
Table 3 Comparison of freshwater and tank system 11
Table 4 Main characteristics of a typical undercounter water-change dishwasher (category 1) 12
Table 5 Material composition of an undercounter water-change dishwasher (category 1) 13
Table 6 Main characteristics of a typical undercounter one-tank dishwasher (category 2) 15
Table 7 Material composition of an undercounter one-tank dishwasher (category 2) 15
Table 8 Main characteristics of a typical hood-type dishwasher (category 3) 17
Table 9 Material composition of a hood-type dishwasher (category 3) 17
Table 10 Main characteristics of a typical utensil / pot dishwasher (category 4) 19
Table 11 Main characteristics of an exemplary pot dishwasher with granulate 20
Table 12 Material composition of a utensil / pot dishwasher (category 4) 20

Table 13 Main characteristics of a typical one-tank conveyor-type dishwasher (category 5) 22
Table 14 Material composition of a one-tank conveyor-type dishwasher (category 5) 22
Table 15 Main characteristics of a typical multi-tank conveyor-type dishwasher (category 6) 24
Table 16 Material composition of a multi-tank conveyor-type dishwasher (category 6) 24
Table 17 Material input for the different categories of professional dishwashers (material categories according to MEEuP, including packaging) 25
Table 18 Share of material categories (according to MEEuP) for the different categories of professional dishwashers (including packaging) 26
Table 19 Average volume and weight of the final packaged product in the different categories of professional dishwashers 28
Table 20 Standard composition of detergents for one-tank dishwashing machines 33
Table 21 Standard composition of rinse agents for one-tank dishwashing machines 33
Table 22 Energy, water and detergent consumption of a professional undercounter water-change dishwasher (cold water connection) 34
Table 23 Energy, water and detergent consumption of a professional undercounter one-tank dishwasher (cold water connection, electric heating) 35
Table 24 Energy, water and detergent consumption of a professional hood-type dishwasher (cold water connection, electric heating) 35
Table 25 Comparison of performance data for hood-type dishwashers 36
Table 26 Energy, water and detergent consumption of a professional utensil/pot dishwasher (cold water connection, electric heating) 37
Table 27 Energy, water and detergent consumption of a professional one-tank conveyor-type dishwasher (cold water connection, electric heating) 38
Table 28 Energy, water and detergent consumption of a professional multi-tank conveyor-type dishwasher (cold water connection, electric heating) 38
Table 29 Annual energy, water, and detergent consumption (real life conditions) of all dishwasher categories 39
Table 30 Documentation of enquiry addressees and their responses 51

List of figures

Figure 1	Construction of an undercounter water-change dishwasher (category 1)	4
Figure 2	Construction of a one-tank program automat (categories 2 to 4)	5
Figure 3	Circular movement of the spray arms in tank operated program automats (categories 2 to 4)	6
Figure 4	Filter and heating system of an undercounter one-tank dishwasher (category 2)	7
Figure 5	Example of a multi-tank conveyer-type dishwasher (category 6)	8
Figure 6	Arrangement of wash arms and nozzles	9
Figure 7	Principle of a basket conveyor dishwasher (left) and a belt conveyor dishwasher (right)	9
Figure 8	Undercounter front loader with water-change operation (category 1)	12
Figure 9	Manually loaded undercounter front loader with one-tank (category 2)	14
Figure 10	One-tank pass-through (hood-type) dishwasher (category 3)	16
Figure 11	Example of an utensil / pot dishwasher (category 4)	18
Figure 12	Granulates to foster the cleaning process	19
Figure 13	One-tank basket conveyer dishwasher (category 5)	21
Figure 14	Multi-tank basket conveyer dishwasher (category 6)	23
Figure 15	Energy flow in a conveyor-type dishwasher (category 6)	29
Figure 16	Energy in- and output of an exemplary conveyor-type-dishwasher	30
Figure 17	Share of energy output in a conveyor-belt dishwasher	30
Figure 18	Energy flow in a hood-type dishwasher (category 3)	31
Figure 19	Energy flow in a water-change dishwasher (category 1)	32

1 Introduction

1.1 Objective

Task 4 entails a general technical analysis of current dishwasher products on the EU-market. It comprises the whole life cycle (production, distribution, use phase (product and system), and end-of-life phase) of the six product categories identified in Task 1. Thus, Task 4 provides general input for the definition of the base cases (Task 5) as well as the identification of part of the improvement potential (Task 7), i.e. the part that relates to the best existing products on the market.

1.2 Methodology and assessment of data quality

All information has been collected through a self-administrated survey amongst the stakeholders. For this purpose, a draft version has been prepared including preliminary assumptions on the basis of discussions with stakeholders and available literature (cf. section 8.1). The working paper was mainly developed to inquire the use phase (Task 3), but also covered certain aspects of Task 4. It has been circulated to stakeholders (manufacturers, industry associations, user associations, see section 8.1.1) for both Task 3 and Task 4. The feedback was used to adjust the preliminary assumptions. Additionally, for Task 4 an Excel file and further questions with respect to the manufacturing, distribution and end-of-life phase (see section 8.1.2 and 8.1.3) have been distributed amongst manufacturers and their industry associations (see section 8.1.4).

Four German manufacturers and CECED Italia answered on the first working document on the use phase. As outlined in Task 3 their answers can be judged as quite viable with regard to information on user behaviour. The same argumentation is true for the appliance specific information asked for in the working document: the manufacturers answering to the working document represent a substantial share of the European manufacturer market (60 to 75%) which also includes the Eastern European market as the responding manufacturers also sell and represent the major market share in these countries. Further, expert-knowledge regarding dishwashers of both main operating principles (program automats and conveyor-type dishwashers) can be expected from the responding manufacturers. The lack of responding users / user associations is not of relevance for Task 4, as it can be expected that they cannot contribute on the technical analysis of products in such detail.

With regard to the excel file and the additional questions with respect to the manufacturing, distribution and end-of-life phase, feedback of three German manufacturers has been received. Thus, information of Italian (and Spanish) manufacturers that also represent a substantial share of the European market, are unfortunately not included in the data compiled in this report.

2 Technical analysis production phase

The technical analysis of the production phase provides product weight and Bill-of-Materials (BOM), distinguishing the weight of different materials fractions and electronics modules at the level of the EuP EcoReport Unit Indicators as proposed in the MEEUP report. This includes packaging materials and an assessment of the primary scrap production during sheet metal manufacturing.

2.1 Main operating principles of dishwashers

The following table gives an overview of the six categories identified in Task 1 and their main properties. For a more detailed description see Task 1.

Table 1 Categorisation of professional dishwashers

<table>
<tr><th>Category-Number</th><th>Water supply</th><th>Number of tanks</th><th>Operating principle</th><th>Type of loading</th><th>Type of washware</th><th>Application</th></tr>
<tr><td>No. 1
Undercounter water-change</td><td>Water-change operation</td><td>0</td><td rowspan="4">Program automats</td><td rowspan="2">Front loaders</td><td rowspan="3">Mainly dishes, glasses, cups, cutlery.</td><td>Semi-professional</td></tr>
<tr><td>No. 2
Undercounter one-tank</td><td rowspan="4">Tank operation</td><td rowspan="3">1</td><td rowspan="4">Professional</td></tr>
<tr><td>No. 3
Hood-type</td><td>Pass-through</td></tr>
<tr><td>No. 4
Utensil/pot</td><td>Front loaders and pass-through</td><td>Black cookware and large utensils.</td></tr>
<tr><td>No. 5
Conveyor-type one-tank</td><td rowspan="2">Conveyor-type</td><td>n.a.</td><td rowspan="2">Mainly dishes, glasses, cutlery, also tablets, black cookware.</td></tr>
<tr><td>No. 6
Conveyor-type multi-tank</td><td>2 and more</td><td>n.a.</td></tr>
</table>

n.a. = not applicable

There are differences between each of the six categories; however some of the categories can be grouped together: e.g. all dishwashers of categories 2 to 6 work with a tank system, where the detergent solution is circulated within the machine and not fully changed between the dishwashing cycles. On the contrary, dishwashers of category 1 use fresh water for each cycle. Similar groups of certain properties apply for other aspects, like operating principle, type of loading, etc.

With regard to the technology there is no essential difference between the dishwasher categories under consideration. Therefore, most important components of all categories are:

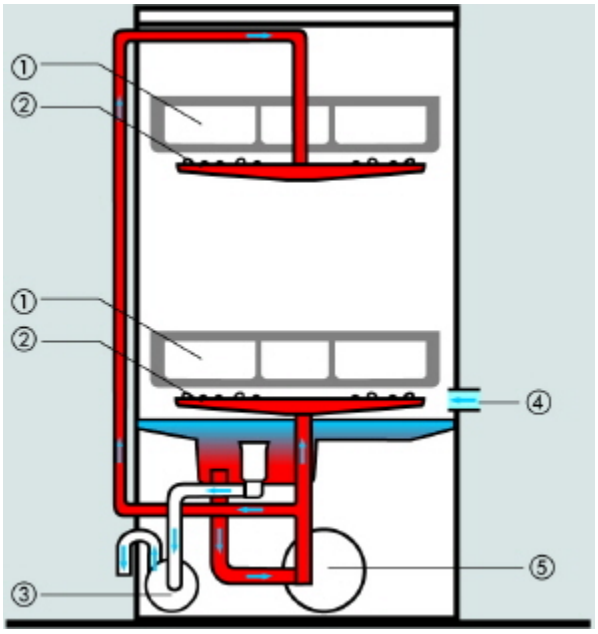
- containment and support structure;
- tanks and / or boilers;
- heating elements;
- motor and pumps;
- spray arms;
- filter system;
- control and display, electronics and sensors, electrics, and,
- where applicable, heat exchangers or heat pumps.

Many parts of a dishwasher, such as the external panelling, the tank, the washing and rinsing water circuits, the piping, the jets, the filters and the support structure are made of stainless steel. Because these parts have to withstand harsh environments and constant use, all manufacturers use this material for their machines. As shown in section 2.2, the stainless steel share of all dishwasher categories is therefore higher than 50% for category 1 and even higher than 70% for categories 2 to 6 (measured as weight percent of net weight, without packaging materials).

In the following sections, the principal function of dishwashers with water-change operation (section 2.1.1) and tank operation (section 2.1.2) is described. Dishwashers with tank operation can further be subdivided into program automats and conveyor-type dishwashers. Section 2.1.3 summarises the differences between water-change and tank operated dishwashers.

2.1.1 Water-change operation

The following illustration provides an overview of the construction and principal function of dishwashers with water-change operation.



Legend

1 Basket / rack
2 Spray arm cleaning and rinsing
3 Drain pump
4 Fresh water inlet
5 Circulating pump

(Source: Miele)

Figure 1 Construction of an undercounter water-change dishwasher (category 1)

The following steps can be distinguished in the dishwashing cycle:

- Pre-wash period: rinsing with cold water (optional);
- Wash period: spraying with warm/hot leach;
- Final rinse period: rinsing with hot water and rinse aid;
- Drying period: drying by use of fresh air or by the residual heat of the final rinse period.

In general dishwashers work with the mechanical force of water jets. The water jets spray against every spot on the dish surface, separate the food-soil from the dish and wash it away. The water is circulated and again sprayed onto the dishes.

Dishwashers of this category work with one set of rotating spray arms for both cleaning and rinsing (2). Sideward-pointing nozzles are placed on the spray arms to create an inclined plane of water jets to clean the dishes and rotate the spray arms through the backlash of the water.

The water is drawn from the fresh water inlet (4) and heated in the wash chamber by means of heating coils. It is then pumped into the spray arms by a circulating pump (5). The drained detergent solution is collected and large dirt and food particles are removed through a filter to avoid damage or blockage of the narrow jet nozzles. The filtered detergent solution is then pumped into the spray arms (2) again. After the wash period the detergent solution is drained by a drain pump (3). For the final rinse, fresh water is used that has to be heated using heating coils.

2.1.2 Tank operation

Professional dishwashers with tank operation can be subdivided into program automats with one-tank (categories 2-4) and conveyor-type dishwashers (categories 5 and 6), either one- or multi-tank. Program automats need much less space than the spacious conveyor-type dishwashers. However, the latter allow continuous dishwashing of large amounts of dishes in a short time.

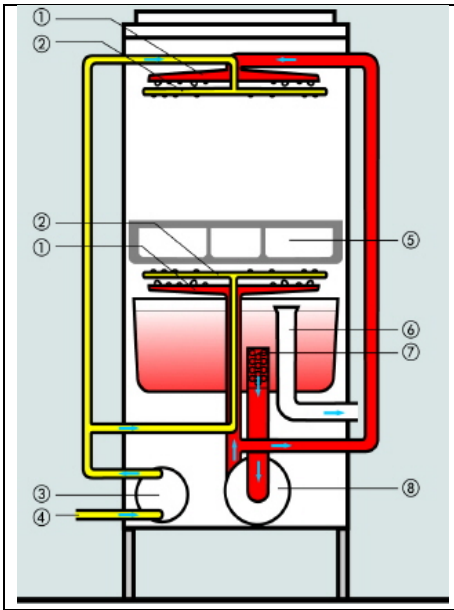
2.1.2.1 Program automats (one-tank)

The following steps can be distinguished in a dishwashing process of one-tank program automats:

- Wash period: spraying with warm/hot leach (usually between 55°C and 65°C);
- Final rinse period: rinsing with hot water and rinse aid (usually between 80 and 85°C; in case of special glasswashers also lower temperatures between 60 and 65°C possible);
- Drying period: drying by use of fresh air or by the residual heat of the final rinse period; this period often takes place outside the machine.

The pre-cleaning is usually performed manually before the items are put into the dishwasher.

The following illustration provides an overview of the construction and principal function of tank operated dishwashers.



Legend

1 Spray arm cleaning
2 Spray arm rinsing
3 Boiler for rinsing solution
4 Fresh water inlet
5 Basket / rack
6 Overflow pipe
7 Intake filter
8 Circulating pump

(Source: Miele)

Figure 2 Construction of a one-tank program automat (categories 2 to 4)

Tank operated program automats work with the mechanical force of water jets. However, they use two separate water cycles and therefore usually work with two sets[1] of rotating spray arms (principle: see Figure 3 below) that are each placed on the top and the bottom of the tub (see Figure 2 above): one set for cleaning (1, red), and one set for rinsing (2, yellow).

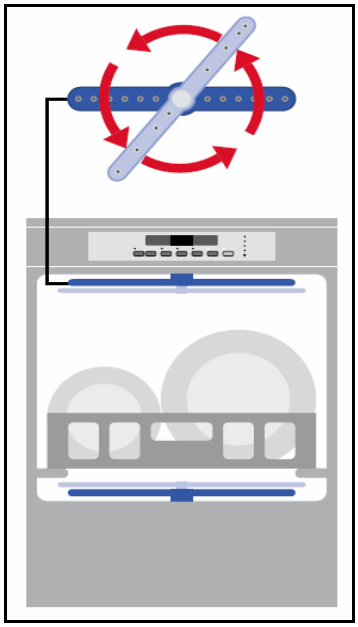


Figure 3 Circular movement of the spray arms in tank operated program automats (categories 2 to 4)

At the beginning of the day the wash tanks of tank operated dishwashers have to be filled with detergent solution and heated to operating temperature (usually between 55 and 65°C). During the day, standby energy consumption occurs because the tank temperature has to be kept on the defined temperature level by the tank heating system (ready-to-use-mode).

During the dishwashing process, the stored detergent solution is continuously pumped into the spray arms for cleaning (1) by the circulating pump (8). The drained detergent solution is collected and large dirt and food particles are removed through a filter (7) (usually a set of different filters) to avoid damage or blockage of the narrow jet nozzles (see also Figure 4). The filtered detergent solution is then pumped into the spray arms for cleaning (1) again. The detergent solution is not changed between two program cycles, but only partly replaced by hot fresh water from the final rinse process (so-called regeneration of detergent solution).

For the rinse process, hot fresh water heated in a separate boiler (3) is sprayed onto the dishes through a different set of spray arms (2). The excess detergent solution (through additional water from final rinse process) is drained through the overflow pipe (6). Once a day or after each working shift the detergent solution in the wash tank is fully changed.

[1] There are also tank dishwashers using only one set of spray arms with 2 tubes for the different water circles.

The following figure shows the filter and heating system of a one-tank program automat.



(Source: Hobart)

Figure 4 Filter and heating system of an undercounter one-tank dishwasher (category 2)

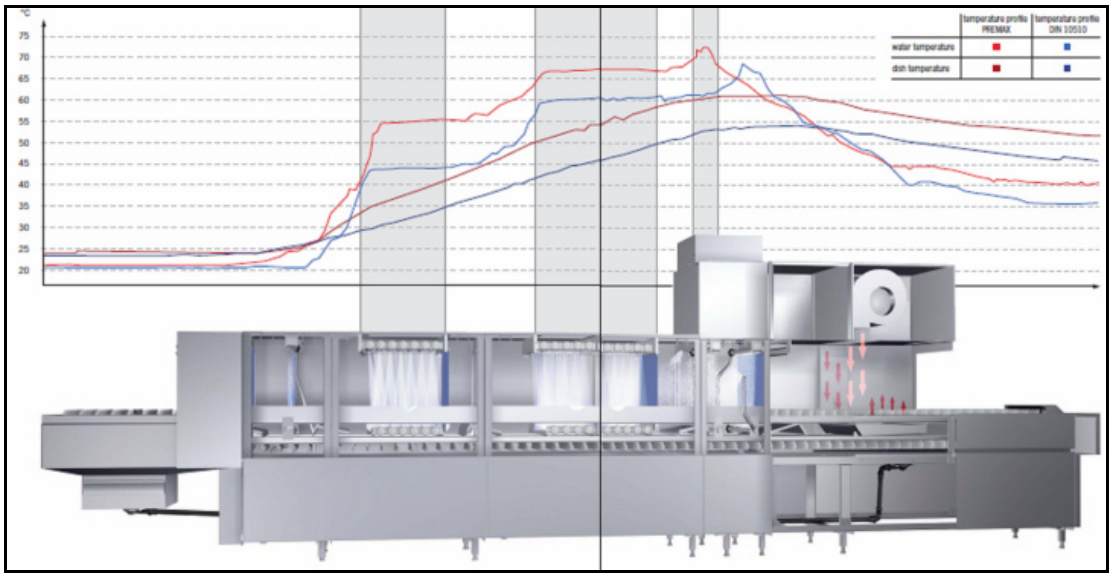
2.1.2.2 Conveyor-type (one-tank / multi-tank)

In principle, the dishwashing process of a conveyor-type dishwasher is the same compared to tank operated program automats. The following steps can be distinguished in a dish-washing process.

- Pre-wash period: rinsing with cold water;
- Wash period: spraying with warm/hot leach (usually between 55 and 65°C);
- Intermediate-rinse period: removal of leach with warm water;
- Final rinse period: rinsing with hot water and rinse aid (usually between 80 and 85°C);
- Drying period: drying by use of fresh air or by the residual heat of the final rinse period, might take place outside the machine.

The main difference to program automats is that with conveyor-type dishwashers the different steps of the dishwashing process are allocated to several individual treatment zones, i.e. the wash ware is transported through these zones. Depending on the type of dishes, the degree of soiling and the available space, conveyor-type dishwashers are provided with one or several wash tanks.

In Figure 5, a multi-tank belt conveyor with one pre-wash zone and one cleaning zone is shown. The red lines in the graph show the temperature of the water (light red) and the dishes (dark red) in the different zones.



(Source: Hobart)

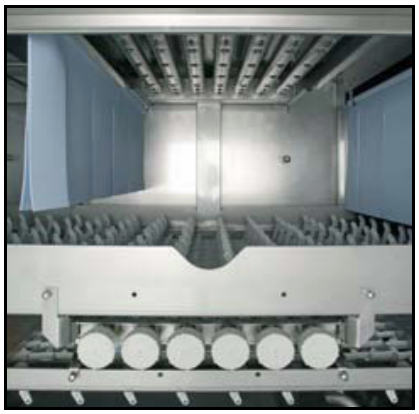
Figure 5 Example of a multi-tank conveyer-type dishwasher (category 6)

As with one-tank program automats the wash tank(s) of conveyor-type dishwashers have to be filled with detergent solution and heated to operating temperature (around 40°C for the pre-wash period and between 55 and 65°C for the wash period) at the beginning of the day/shift. During the day, standby energy consumption occurs because the tank temperature has to be kept on the defined temperature level (ready-to-use-mode).

The different steps of the dishwashing program work in principle as in program automats:

For the pre-washing and for the cleaning process, detergent solution is stored in the wash tanks from where it is continuously pumped into the spray arms by a circulating pump. The drained detergent solution is collected and large dirt and food particles are removed through filters to avoid damage or blockage of the jet nozzles. The filtered detergent solution is then pumped into the spray arms again. The detergent solution is not changed between two program cycles, but only partly regenerated. For the rinse process, hot fresh water heated in a separate boiler is sprayed onto the dishes through another set of spray arms. The excess detergent solution (through additional water from final rinse process) is drained through an overflow pipe at the first of the wash tanks (counter flow principle: the fresh water is used for rinsing, replacing water in the last wash tank. Excess water from this tank flows into the previous wash tank and so on). At the end of the dishwasher there might also be a drying zone, where the dishes are dried by hot air (see red arrows in Figure 5 above). Once a day or after each working shift the detergent solution in the wash tank is fully changed.

In contrast to program automats, the spray arms in conveyor-type dishwashers do not rotate but usually are fixed tubes on top and bottom of the dishwashing channel. In some machines, the spray arms are also installed at the sides in order to achieve uniform wetting.



(Source: Hobart)

Figure 6 Arrangement of wash arms and nozzles

Two different conveyor systems are available (see also Task 1):

- *Basket conveyor dishwashers* (Figure 7, left): the wash ware is put into baskets which are manually put into the machine and then automatically transported through the dishwasher.
- *Belt conveyor dishwashers* (Figure 7, right): the wash ware is put directly on a conveyor belt which continuously moves through the dishwasher.





Figure 7 Principle of a basket conveyor dishwasher (left) and a belt conveyor dishwasher (right)

Based on rather different capacity requirements and the economic consequences, conveyor-type dishwashing machines are equipped with quite different technological features. In Task 6 (Best available technologies) the differences and their impact on energy and water

consumption are described in detail, while the following table only provides a short overview.[2]

Table 2 Different configuration of a multi-tank conveyor-type dishwasher (category 6)

	Model A Series	**Model B Series**
Energy Management	n. a.	x
Heat recovery exhaust air	optional	x
Insulation	optional	x
Heat pump	n. a.	optional
Optimised final rinse	n. a.	x
Water consumption management	n. a.	x
Data documentation	optional	x

n. a. = not available for the model; x = technology is part of the series or option

2.1.3 Differences between water-change and tank operated dishwashers

A fundamental difference exists between water-change (category 1) and tank operated dishwashers (categories 2–6): While dishwashers in category 1 use fresh water for each step of the program, all other machines work with a tank system of one (categories 2–5) or more tanks (category 6).

The advantage of tank operation compared to water-change dishwashers is that the detergent solution in the wash tank is kept at a constant temperature thus enabling much shorter cleaning cycles and a high throughput per hour as the detergent solution does not have to be heated each time before a dishwashing cycle. Higher water temperatures and higher pressure additionally shorten the cleaning process itself. Depending on the connected load (230 or 400 Volt), cycle times and thus the capacity of the same dishwasher vary to a certain extent. Because the detergent solution is only regenerated and not fully replaced they also use less water per dishwashing cycle, resulting in lower energy and detergent consumption.

The following table gives a summary of the differences between water-change and tank operated dishwashers.

[2] Note: Example by one manufacturer; other manufacturers might have different sets of optional configurations.

Table 3 Comparison of freshwater and tank system

Aspect	Water-change (freshwater) system	Tank system
Principal function	Fresh water for every washing and rinsing step	Only fresh water for rinsing
Filtration	Water filtration necessary	Intensive water filtration necessary
Program duration	Medium to long, as the heating of water needs some time.	Very short duration possible, as hot water is stored in wash tanks.
Output per hour	Medium to low	High
Capacity	Two racks possible	Usually only one rack / conveyor belt
Water and energy consumption	Higher, as fresh water is used for each cycle which has to be heated.	Lower, as water is recycled and used for several cycles / racks.
Standby losses	0.01 kW	0.25 kW – 2 kW

2.2 Main characteristics and material composition of dishwashers

In the following sections the main characteristics of the different dishwasher categories are described providing also basic data on the weight of different materials fractions. For details with regard to the data on energy and water consumption, see also Task 3.[3]

2.2.1 Category 1: Undercounter water-change dishwashers

The following illustration shows a typical undercounter water-change dishwasher.



(Source: Miele)

Figure 8 Undercounter front loader with water-change operation (category 1)

Table 4 gives an overview of the characteristics of a typical appliance of this category.

Table 4 Main characteristics of a typical undercounter water-change dishwasher (category 1)

Main characteristics	**Data**
Program	
Number of dishwashing programs	10 (dishwashing process can be adjusted to task)
Washing capacity, ideal	2–20 racks/h (depending on program)
Cycle time	6–27 minutes (depending on program)
Program temperature	Depending on program (between 20–60°C, rinsing temperature up to 93°C)
Construction details	
Height/width/depth	820/600/600 mm
Weight (without packaging)	ca. 50 kg
Tank volume	not applicable

[3] Main characteristics in this section are based on the analysis of technical product information sheets and shall reflect a typical model within the respective categories. On the contrary, usage data compiled in Task 3 are based on direct stakeholder input and provide average values of the categories. Hence, values in Task 4, e.g. on the ideal washing capacity, might differ slightly to information given on the typical use intensity in Task 3.

Main characteristics	Data
Electricity and water connection	
Voltage	Normal (230 V) or high-load connection (400 Volt) possible
Total load	9 kW
Power of pump	0.4 kW

(Source: Miele)

According to stakeholders the material composition is equivalent to that of a household dishwasher as described in the preparatory study on washing machines and dishwashers (Lot 14). Therefore, the following Bill of Materials (BOM) is taken from Lot 14 Task 4 report.[4]

Table 5 Material composition of an undercounter water-change dishwasher (category 1)

Material / component	weight in g	weight in ratio %	Material category
Stainless Steel	24 560	51.0	3-Ferro
Steel Sheet galvanized	403	0.8	3-Ferro
Cast Iron	2 303	4.8	3-Ferro
Polypropylen (PP)	4 980	10.3	1-BlkPlastics
Polyamid (PA)	399	0.8	2-TecPlastics
Polymethylmetacrylate (PMMA)	6	0.0	2-TecPlastics
Acrylonitrile Butadiene Styrene (ABS)	751	1.6	1-BlkPlastics
Plystyrene (PS)	512	1.1	1-BlkPlastics
Styropor expandable polystyrene (EPS)	40	0.1	1-BlkPlastics
Polybutylene Terephthalate (PBT)	35	0.1	1-BlkPlastics
Polyvinylchlorid (PVC)	403	0.8	1-BlkPlastics
EPDM-rubber	524	1.1	1-BlkPlastics
POM	230	0.5	1-BlkPlastics
PE	187	0.4	1-BlkPlastics
Plastics others	268	0.6	1-BlkPlastics
Aluminium	273	0.6	4-Non-ferro
Cu wire	1 006	2.1	4-Non-ferro
CuZn38 cast	23	0.0	4-Non-ferro
Chrom	71	0.1	4-Non-ferro
Bitumen	6 089	12.6	7-Misc.
Concrete	1 263	2.6	7-Misc.
Cotton	452	0.9	7-Misc.
Epoxy	609	1.3	2-TecPlastics
Wood	2 034	4.2	7-Misc.
others (Paper)	285	0.6	7-Misc.
Electronics (control)	448	0.9	6-Electronics
Total net	**48 154**	**100.0**	

[4] See http://www.ecowet-domestic.org/

Material / component	weight in g	weight in ratio %	Material category
Packaging	**2 542**		
EPS	724		1-BlkPlastics
PE-Foil	172		1-BlkPlastics
wood	1 011		7-Misc.
cardboard	635		7-Misc.
Total weight	**50 696**		

2.2.2 Category 2: Undercounter one-tank dishwashers

The following figure shows a typical undercounter one-tank dishwasher.



(Source: Zanussi 2009)

Figure 9 Manually loaded undercounter front loader with one-tank (category 2)

In case of undercounter one-tank dishwashers, usually only one basket can be placed into the dishwasher (loading and unloading from the front side), as the tank needs space as well.

Undercounter dishwashers can be constructed as “generalists” for different items (dishes, glasses, and cutlery) or as specialised versions, i.e. only for dishes, for glasses or for cutlery respectively. As the temperature and mechanical action vary for different adjustments, the related energy and water consumption varies to a certain extent.

For example, glasswashers are also available in smaller dimensions (undercounter models that are only 415 to 475 mm wide). These models are often used in bar areas. The basic mode of operation is the same as in the 600 mm wide models; however, they usually work with lower temperatures to avoid damage of the sensitive washware.

Table 6 gives an overview of the characteristics of a typical undercounter one-tank dishwasher (category 2).

Table 6 Main characteristics of a typical undercounter one-tank dishwasher (category 2)

Main characteristics	**Data**
Program	
Number of dishwashing programs	3
Washing capacity, ideal	40 racks/h (with 400 Voltage) 25 racks/h (with 230 Voltage)
Cycle time	60-360 sec (with 400 Voltage) 140 / 180 / 360 sec (with 230 Voltage)
Tank temperature	usually between 55°C and 65°C
Boiler temperature	usually between 80°C and 85°C (glasswashers: also 60-65°C possible)
Construction details	
Height/width/depth	820/600/650 mm (glasswashers: 415-475 mm width)
Weight (without packaging)	ca. 70 kg (glasswashers: ~ 50 kg)
Tank volume	7-20 litres, average 15 litres
Electricity and water connection	
Voltage	230 Volt or 400 Volt
Total load	With 400 Voltage: 7.7 kW With 230 Voltage: 3.6 kW
Power of pump	0.2-0.8 kW, typical 0.6 kW

The following table shows the BOM of a typical dishwasher of category 2, the shares of the different materials and the category to which the materials are assigned. The packaging material is listed separately.

Table 7 Material composition of an undercounter one-tank dishwasher (category 2)

Material / component	**Weight in g**	**Fraction in %**	**Material category according to MEEuP**
Stainless steel	49 760	71.2	3-Ferrous
Polypropylene (PP)	4 565	6.5	1-BlkPlastics
Polyamide (PA)	500	0.7	2-TecPlastics
Epoxy	1 000	1.4	2-TecPlastics
Acrylonitrile Butadiene Styrene (ABS)	70	0.1	1-BlkPlastics
Pumps (copper)	2 500	3.6	4-Non-ferrous
Pumps (stack of sheets)	2 500	3.6	3-Ferrous
Pumps (stainless steel wave)	2 250	3.2	3-Ferrous
Pumps (Al)	2 250	3.2	4-Non-ferrous
Cable (copper)	1 100	1.6	4-Non-ferrous
Cable sheath (PVC)	600	0.9	1-BlkPlastics
Cable sheath (silicone, EDPM)	300	0.4	1-BlkPlastics
Electronics (control)	500	0.7	6-Electronics
Gaskets (EDPM)	2 040	2.9	1-BlkPlastics

Material / component	Weight in g	Fraction in %	Material category according to MEEuP
Total net	**69 935**	**100.0**	
Packaging	**9 250**		
polystyrene	500		1-BlkPlastics
wood	6 000		7-Misc.
cardboard	2 750		7-Misc.
Total weight	**79 185**		

2.2.3 Category 3: Hood-type dishwashers

The following figure shows a typical hood-type (pass-through) dishwasher.



(Source: Hobart)

Figure 10 One-tank pass-through (hood-type) dishwasher (category 3)

In case of hood-type dishwashers the baskets are put into the dishwasher from one side and are taken out of the dishwasher from the other side. As in case of other tank dishwashers, only one basket can be cleaned at one level, as the tank also needs space. There are appliances, however, where two baskets can be cleaned next to each other, integrated in one housing at the same time. Such appliances are like a double or twin appliance.

Hood-type dishwashers are ergonomically easier to operate than undercounter dishwashers, because the filled baskets stay at working level and can easily be moved into and out of the dishwasher. Additionally, the separation of a dirty and a clean area is possible when using the pass-through type. They are usually constructed as “generalists” for different items, such as dishes, glasses, cutlery, etc.

Table 8 gives an overview of the main characteristics of a hood-type dishwasher (category 3).

Table 8 Main characteristics of a typical hood-type dishwasher (category 3)

Main characteristics	**Data**
Program	
Number of dishwashing programs	3
Washing capacity, ideal	60 racks/h
Cycle time	60-180 sec
Tank temperature	usually between 55°C and 65°C
Boiler temperature	usually between 80°C and 85°C
Construction details	
Height/width/depth (with open door)	2 000/760/820 mm
Weight (without packaging)	ca. 120 kg
Tank volume	16-60 litres, average 40 litres
Electricity and water connection	
Voltage	400 Volt
Total load	7 kW
Power of pump	0.75-1.5 kW, typical 0.9 kW

The following table shows the BOM of a typical dishwasher of category 3, the shares of the different materials and the category to which the materials are assigned. The packaging material is listed separately.

Table 9 Material composition of a hood-type dishwasher (category 3)

Material / component	**Weight in g**	**Weight in ratio %**	**Material category**
Stainless steel	93 090	79.1	3-Ferrous
Polypropylene (PP)	4 310	3.7	1-BlkPlastics
Polyamide (PA)	1 000	0.8	2-TecPlastics
Epoxy	800	0.7	2-TecPlastics
Acrylonitrile Butadiene Styrene (ABS)	70	0.1	1-BlkPlastics
Pumps (copper)	3 000	2.5	4-Non-ferrous
Pumps (stack of sheets)	3 000	2.5	3-Ferrous
Pumps (stainless steel wave)	2 500	2.1	3-Ferrous
Pumps (Al)	3 000	2.5	4-Non-ferrous
Cable (copper)	1 700	1.4	4-Non-ferrous

Material / component	Weight in g	Weight in ratio %	Material category
Cable sheath (PVC)	1 000	0.8	1-BlkPlastics
Cable sheath (silicone, EDPM)	500	0.4	1-BlkPlastics
Electronics (control)	600	0.5	6-Electronics
Gaskets (EDPM)	3 085	2.6	1-BlkPlastics
Total net	**117 655**	**100.0**	
Packaging	**17 500**		
polystyrene	500		1-BlkPlastics
wood	12 250		7-Misc.
cardboard	4 750		7-Misc.
Total weight	**135 155**		

2.2.4 Category 4: Utensil / pot dishwashers

The following illustration shows a typical utensil / pot dishwasher.



(Source: Winterhalter)

Figure 11 Example of an utensil / pot dishwasher (category 4)

The main difference to one-tank undercounter and pass-through dishwashers is that utensil / pot dishwashers are especially constructed for the cleaning of items other than dishes, glasses and cutlery, i.e. black cookware, pots, pans, containers, trays or other mostly large utensils. Therefore, the dimensions are often larger than those of undercounter front loaders or pass-through dishwashers for dishes, glasses and cutlery as the items to be cleaned are also bulkier. Further, the cleaning performance is usually higher, e.g. by means of higher scavenging pressure or other stronger mechanical and chemical treatment in order to dissolve incrustations. Due to their high scavenging pressure, they cannot be loaded with glass or ordinary crockery.

Two construction types can be distinguished:

- Front loading dishwashers;
- Pass-through dishwashers.

The pass-through dishwashers are usually loaded manually, however, some manufacturers offer special roller containers that can be filled outside the machine and then pushed into the dishwasher. Table 10 gives an overview of the characteristics of a typical utensil / pot dishwasher (category 4).

Table 10 Main characteristics of a typical utensil / pot dishwasher (category 4)

Main characteristics	**Data**
Program	
Number of dishwashing programs	3
Washing capacity, ideal	20 racks/h
Cycle time	90–540 sec
Tank temperature	usually between 55°C and 65°C
Boiler temperature	usually between 80°C and 85°C
Construction details	
Height/width/depth (with open door)	2 000/876/900 mm
Weight (without packaging)	ca. 200 kg
Tank volume	60-130 litres, average 100 litres
Electricity and water connection	
Voltage	400 Volt
Total load	13.0 kW
Power of pump	typical 1.6 kW

A special type of pot dishwasher is the so called granulate dishwasher. With these dishwashers (both front loaders and pass-through) the mechanical cleaning is intensified through scouring of the wash ware (mainly black cookware) with plastic granules of different size. A granule collector catches the plastic pellets during the granule washing program.

The following illustration shows the working principle of granulates.



(Source: Granuldisk)

Figure 12 Granulates to foster the cleaning process

The granules can subsequently be cleaned out in a sink with a pipe-mounted sprayer. The special advantage of this process is that less water and energy is needed to clean the pots and other black cookware. Pre-rinsing is not necessary. Granulates are reused in the machine. After about 2 500 cycles they are worn out and have to be replaced.

The following table shows the main characteristics of an exemplary granulate dishwasher.

Table 11 Main characteristics of an exemplary pot dishwasher with granulate

Main characteristics	**Data**
Program	
Number of dishwashing programs	3
Cycle time	120–310 sec
Tank temperature	usually between 55°C and 65°C
Boiler temperature	usually between 80°C and 85°C
Construction details	
Loading volume	190 litres
Height/width/depth (with open door)	2 400/850/900 mm
Weight (without packaging)	413 kg
Tank volume	83 litres
Electricity and water connection	
Voltage	400 Volt
Total load	15 kW
Power of pump	2.6 kW

(Source: Granuldisk)

The following table shows the BOM of a typical dishwasher of category 4 (without granulates[5]), the shares of the different materials and the category to which the materials are assigned. The packaging material is listed separately.

Table 12 Material composition of a utensil / pot dishwasher (category 4)

Material / component	**Weight in g**	**Weight in ratio %**	**Material category**
Stainless steel	165 000	80.1	3-Ferrous
Polypropylene (PP)	3 000	1.5	1-BlkPlastics
Polyamide (PA)	4 000	1.9	2-TecPlastics
Epoxy	0	0.0	2-TecPlastics
Ethylene Propylene Dien M-class rubber (EPDM)	4 000	1.9	1-BlkPlastics
Acrylonitrile Butadiene Styrene (ABS)	0	0.0	1-BlkPlastics

[5] Granulate dishwashers are not seen as typical for category 4 but rather as special case. The material composition is thus based on a pot dishwasher without granulates. Granulate dishwashers will be further analysed in Task 6.

Material / component	Weight in g	Weight in ratio %	Material category
Pumps (copper)	5 000	2.4	4-Non-ferrous
Pumps (stack of sheets)	4 000	1.9	3-Ferrous
Pumps (stainless steel wave)	3 000	1.5	3-Ferrous
Pumps (Al)	5 000	2.4	4-Non-ferrous
Cable (copper)	2 400	1.2	4-Non-ferrous
Cable sheath (PVC)	1 400	0.7	1-BlkPlastics
Cable sheath (silicone, EDPM)	1 100	0.5	1-BlkPlastics
Electronics (control)	2 100	1.0	6-Electronics
Gaskets, etc. (EDPM)	6 000	2.9	1-BlkPlastics
Total net	**206 000**	**100.0**	
Packaging	**20 000**		
polystyrene	500		1-BlkPlastics
wood	16 000		7-Misc.
cardboard	3 500		7-Misc.
Total weight	**226 000**		

2.2.5 Category 5: One-tank conveyor-type dishwashers

The following illustration shows a typical one-tank conveyor-type dishwasher.



(Source: Winterhalter)

Figure 13 One-tank basket conveyer dishwasher (category 5)

One-tank conveyor-type dishwashers use one wash tank for cleaning and fresh water for the final rinsing. Pre-cleaning is normally performed manually (i.e. outside the dishwasher). The detergent and rinse aid are automatically dosed from a reservoir. The dishwashers can be used for different wash ware: dishes, glasses, cutlery, more seldom also for black cookware

(pots and pans) and utensils. The following table gives an overview of the characteristics of a typical one-tank conveyor-type dishwasher (category 5).

Table 13 Main characteristics of a typical one-tank conveyor-type dishwasher (category 5)

Main criteria	**Data**
Program	
Number of dishwashing programs	2–3
Washing capacity, ideal	70–110 racks/h
Cycle time	90–180 sec
Tank temperature	usually between 55°C and 65°C
Boiler temperature	usually between 80°C and 85°C
Construction details	
Width/depth/height	1 300/800/1 420 mm (without preparing zone)
Depth/height of passage height	500/460 mm
Weight (without packaging)	ca. 900 kg
Tank volume	110-130 litres, average (120 litres)
Electricity and water connection	
Voltage	400 V
Power of pump	typical 1.5 kW

The following table shows the BOM of a typical dishwasher of category 5, the shares of the different materials and the category to which the materials are assigned. The packaging material is listed separately.

Table 14 Material composition of a one-tank conveyor-type dishwasher (category 5)

Material / component	**Weight in g**	**Weight in ratio %**	**Material category**
Stainless steel	642 250	72.06	3-Ferrous
Polypropylene (PP)	55 500	6.23	1-BlkPlastics
Polyamide (PA)	6 140	0.69	2-TecPlastics
Polyvinyl chloride (PVC)	4 600	0.52	1-BlkPlastics
Polystyrene (PS)	4 430	0.50	1-BlkPlastics
Acrylonitrile Butadiene Styrene (ABS)	5 000	0.56	1-BlkPlastics
Pumps (copper)	16 825	1.89	4-Non-ferrous
Pumps (stack of sheets)	15 625	1.75	3-Ferrous
Pumps (stainless steel wave)	12 335	1.38	3-Ferrous
Pumps (Al)	17 470	1.96	4-Non-ferrous
Condenser (AL)	4 720	0.53	4-Non-ferrous
Condenser (Cu)	7 080	0.79	4-Non-ferrous
Ventilator, fan (AL)	17 440	1.96	4-Non-ferrous
Ventilator, fan (Cu)	10 160	1.14	4-Non-ferrous
Drive motor (AL)	4 000	0.45	4-Non-ferrous
Drive motor (Cu)	5 000	0.56	4-Non-ferrous

Material / component	Weight in g	Weight in ratio %	Material category
Cable (copper)	16 300	1.83	4-Non-ferrous
Cable sheath (PVC)	8 640	0.97	1-BlkPlastics
Cable sheath (silicone, EDPM)	5 170	0.58	1-BlkPlastics
Electric contactor (copper)	10 000	1.12	4-Non-ferrous
Electronics (control)	9 800	1.10	6-Electronics
Gaskets (EDPM)	12 800	1.44	1-BlkPlastics
Total net	**891 285**	**100.00**	
Packaging	**81 940**		
polystyrene	2 940		1-BlkPlastics
wood	63 500		7-Misc.
cardboard	15 500		7-Misc.
Total weight	**973 225**		

Category 5 (one-tank) conveyor-type dishwashers are also available with a steam heating system. In this case the additional material input for the heating system is estimated to be 150 kg (mainly stainless steel).

2.2.6 Category 6: Multi-tank conveyor-type dishwashers

The following illustration shows a typical multi-tank conveyor-type dishwasher.



(Source: Winterhalter)

Figure 14 Multi-tank basket conveyer dishwasher (category 6)

These dishwashers comprise at least one pre-wash zone using a wash tank, one cleaning zone using a wash tank and a final rinse zone using fresh water. The dishwashers can be used for different wash ware: dishes, glasses, cutlery, and more seldom black cookware (pots and pans) and utensils.

Multi-tank dishwashers are usually a combination of different modules for pre-washing and cleaning. These modules can be quite different in size and determine the washing capacity of the machine (plates/hour). Also the passage width and height can be different.

Table 15 gives an overview of the characteristics of a typical multi-tank conveyor-type dishwasher (category 6).

Table 15 Main characteristics of a typical multi-tank conveyor-type dishwasher (category 6)

Main criteria	**Data**
Program	
Number of dishwashing programs	3
Washing capacity	1 700–6 000 dishes/h
Cycle time	90–180 sec
Tank temperature	usually between 55°C and 65°C
Boiler temperature	usually between 80°C and 85°C
Construction details	
Width (without packaging)	4 700–7 400 mm (without preparing zone)
Depth/height of passage height	Different modules available
Weight	ca. 1 300 kg
Tank volume	130-750 litres, average 230 litres
Electricity and water connection	
Voltage	400 Volt
Total load	39–51 kW
Power of pump	no data available

The following table shows the BOM of a typical dishwasher of category 6, the shares of the different materials and the category to which the materials are assigned. The packaging material is listed separately.

Table 16 Material composition of a multi-tank conveyor-type dishwasher (category 6)

Material / component	**Weight in g**	**Weight in ratio %**	**Material category**
Stainless steel	980 000	76.3	3-Ferrous
Polypropylene (PP)	58 000	4.5	1-BlkPlastics
Polyamide (PA)	18 660	1.5	2-TecPlastics
Epoxy	0	0.0	2-TecPlastics
Ethylene Propylene Dien M-class rubber (EPDM)	12 000	0.9	1-BlkPlastics
Acrylonitrile Butadiene Styrene (ABS)	0	0.0	1-BlkPlastics
Pumps (copper)	39 020	3.0	4-Non-ferrous
Pumps (stack of sheets)	37 070	2.9	3-Ferrous
Pumps (stainless steel wave)	25 370	2.0	3-Ferrous

Material / component	Weight in g	Weight in ratio %	Material category
Pumps (Al)	44 880	3.5	4-Non-ferrous
Cable (copper)	19 800	1.5	4-Non-ferrous
Cable sheath (PVC)	11 440	0.9	1-BlkPlastics
Cable sheath (silicone, EDPM)	8 360	0.7	1-BlkPlastics
Electronics (control)	15 400	1.2	6-Electronics
Gaskets, etc. (EDPM)	15 000	1.2	1-BlkPlastics
Total net	**1 285 000**	**100.0**	
Packaging	**180 000**		
polystyrene	5 290		1-BlkPlastics
wood	141 180		7-Misc.
cardboard	33 530		7-Misc.
Total weight	**1 465 000**		

Category 6 (multi-tank) conveyor-type dishwashers are also available with a steam heating system. In this case the additional material input for the heating system is estimated to be 200 kg (mainly stainless steel).

2.2.7 Overview of all dishwasher categories

An overview of the material input in the different categories of professional dishwashers is shown in the following tables (both absolute values and shares of material categories according to MEEuP, including packaging material).

Table 17 Material input for the different categories of professional dishwashers (material categories according to MEEuP, including packaging)

Materials-category	Unit	No.1	No. 2	No. 3	No. 4	No. 5	No. 6
Bulk Plastics	g	8 826	8 075	9 465	16 000	99 080	110 090
TecPlastics	g	1 014	1 500	1 800	4 000	6 140	18 660
Ferrous	g	27 266	54 510	98 590	172 000	670 210	1 042 440
Non-ferrous	g	1 373	5 850	7 700	12 400	108 995	103 700
Coating	g	0	0	0	0	0	0
Electronics	g	448	500	600	2 100	9 800	15 400
Misc.	g	11 769	8 750	17 000	19 500	79 000	174 710
Total weight	g	50 696	79 185	135 155	226 000	973 225	1 465 000

For classification details see the legend to the following Table 18.

Table 18 Share of material categories (according to MEEuP) for the different categories of professional dishwashers (including packaging)

Materials-category	Unit	No.1	No. 2	No. 3	No. 4	No. 5	No. 6
Bulk Plastics	g	17.4%	10.2%	7.0%	7.1%	10.2%	7.5%
Tec Plastics	g	2.0%	1.9%	1.3%	1.8%	0.6%	1.3%
Ferrous	g	53.8%	68.8%	72.9%	76.1%	68.9%	71.2%
Non-ferrous	g	2.7%	7.4%	5.7%	5.5%	11.2%	7.1%
Coating	g	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Electronics	g	0.9%	0.6%	0.4%	0.9%	1.0%	1.1%
Misc.	g	23.2%	11.1%	12.6%	8.6%	8.1%	11.9%
Total weight	**g**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**

No. 1 Undercounter front loaders with water-change operation
No. 2 Undercounter front loaders with one-tank
No. 3 Hood-type dishwashers
No. 4 Utensil / pot dishwashers
No. 5 One-tank conveyor-type dishwashers
No. 6 Multi-tank conveyor-type dishwashers

In all categories, the share of ferrous metal (mainly stainless steel) is with approximately 55% to 75% (including packaging) predominant.

International standards like ASTM or NSF/ANSI as well as standards in Europe (for example DIN 10510) require the use of corrosion resistant material for surfaces exposed to wash and rinse water according to the intended use environment (cf. Task 1).

2.3 Other materials

According to MEEuP, certain material categories are assessed. In professional dishwashers, there are some further materials not covered by MEEuP which are described below.

- **Mercury**: According to stakeholders the dishwashers of all six categories do not contain mercury. All materials used within the products comply with the restrictions set out in the RoHS Directive.[6]
- **Refrigerants**: Dishwashers of categories 5 and 6 might be equipped with a heat pump containing refrigerant. The refrigerant used is R-134a (tetrafluorodichlorethene), R-407C (a hydrofluorocarbon blend of R-32, R-125, and R-134a) and others with an average filling of 3 to 4.5 kg. As the use of heat pumps is considered as BAT (Best Available Technology) this aspect is further elaborated in Task 6.
- **Silver ions**:

[6] Directive on the restriction of the use of certain hazardous substances in electrical and electronic equipment 2002/95/EC (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2003:037:0019:0023:EN:PDF) (see Task 1).

- Application: Nowadays there is a wide range of products containing silver because of its antibacterial activity. Individually silver applies as a solution, as a suspension and in nanoparticular form. Whenever silver contacts wetness, silver ions are emitting. Their antibacterial characteristic is used in following scopes and products: Water treatment, washing, medical applications, impregnation of fibres etc[7].
- Advantages: Silver ions provide advantages e.g. when they are added to wall paints which are used in surgeries to improve the hygienic conditions. Used in dishwashers, silver ions are supposed to prevent retention of bacteria on dishes after the cleaning process.
- Disadvantages: There are also negative aspects which have to be mentioned. For example, due to the increasing use of silver as a bactericide, environmental impacts could be bacterial resistance of silver ions because of a pollution of sludge in sewage plants. Further, there are knowledge gaps and uncertainties concerning possible impacts of silver ions, e.g. toxicity for terrestrial and sediment organisms, material flows in municipal wastewater, characteristic and quantity of emissions from products containing silver, toxicity of silver nanoparticles in comparison to silver compounds, occurring of different reactions in the environment, etc.
- Use of silver ions in dishwashers: According to stakeholders' feedback, the use of silver ions due to their antimicrobial properties is not applied anymore. In Germany, warnings from the German Federal Institute for Risk Assessment[8] with regard to possible harmful aspects and missing comprehensive data to allow conclusive risk assessments, especially for nano silver, caused the market to rethink. Moreover, according to stakeholders there is no need of silver ions in dishwashers, because there are other possibilities (temperature, chemistry, steam) to guarantee the same hygienic standard. Therefore, use of silver is no alternative anymore, as negative aspects increase.

3 Technical analysis distribution phase

The following table shows an overview of the average volume and weight of the final packaged product. These values are used to calculate the environmental impacts resulting from distribution.

[7] http://www.umweltdaten.de/publikationen/fpdf-l/3673.pdf

[8] Bundesinstitut für Risikobewertung (BfR) www.bfr.bund.de

Table 19 Average volume and weight of the final packaged product in the different categories of professional dishwashers

Dishwasher category	Average volume of the final packaged product	Average weight of the final packaged product	Source of information
Undercounter water-change	0.40 m^3	ca. 50 kg	According to Lot 14
Undercounter one-tank	0.48 m^3	ca. 80 kg	Information provided by stakeholders
Hood-type	1.03 m^3	ca. 135 kg	Information provided by stakeholders
Utensil/pot	4.95 m^3	ca. 225 kg	Based on dimensions given in Table 10
Conveyor-type one-tank	12.25 m^3	ca. 975 kg	Information provided by stakeholders
Conveyor-type multi-tank	16.58 m^3	ca. 1 465 kg	Assumed dimensions Length/depth/height (in mm) 6 700/1 100/2 250

4 Technical analysis use phase (product)

This section provides an assessment of the annual resources consumption (energy, water, detergent) and direct emissions during product life. Usually, the consumption values should be measured according to existing test standards. However, currently no European applicable measurement standard for quantifying the energy and water consumption of professional dishwashers exists (see Task 1). Therefore, the assessment of data quality and comparability in the following sections should be seen with regard to this context.

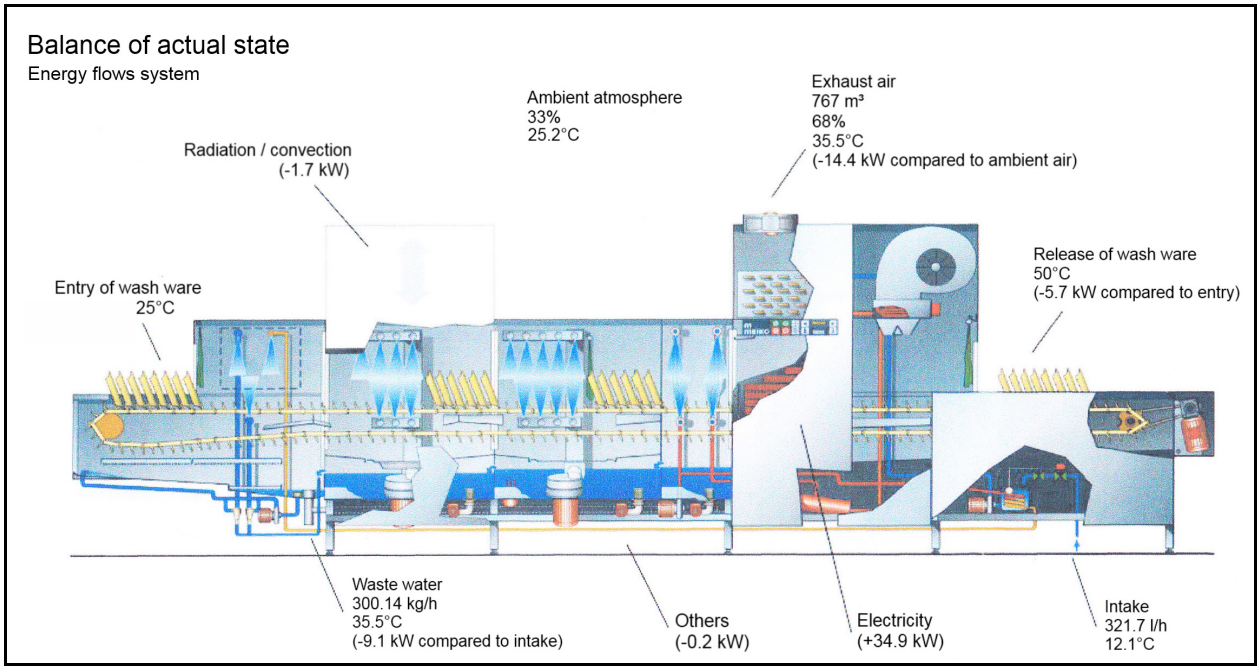
As introduction, in section 4.1 we first provide an overview of energy flows and energy losses in professional dishwashers. In section 4.2, the energy, water and rinse aid consumption of different dishwasher categories under ideal and real-life conditions are shown.

4.1 Energy flow in professional dishwashers

This section exemplifies how much energy is used for the different process steps in a typical dishwashing process. As outlined in Task 3, electric energy is the usual energy form used for heating in the dishwasher examples below (other heating options could be steam/hot water or direct gas heating). Figure 15 to Figure 17 show the respective energy flows of a conveyor-type dishwasher as exemplary illustration,[9] in absolute numbers and as percentage.

[9] Note: The energy flow of conveyor-type dishwashers is very specific for different machine configurations. There is wide range of energy input and output which depends mainly on the machine capacity (dishes per hour) and its configuration (type and number of sections, heat recovery system). Thus, the heat losses of the

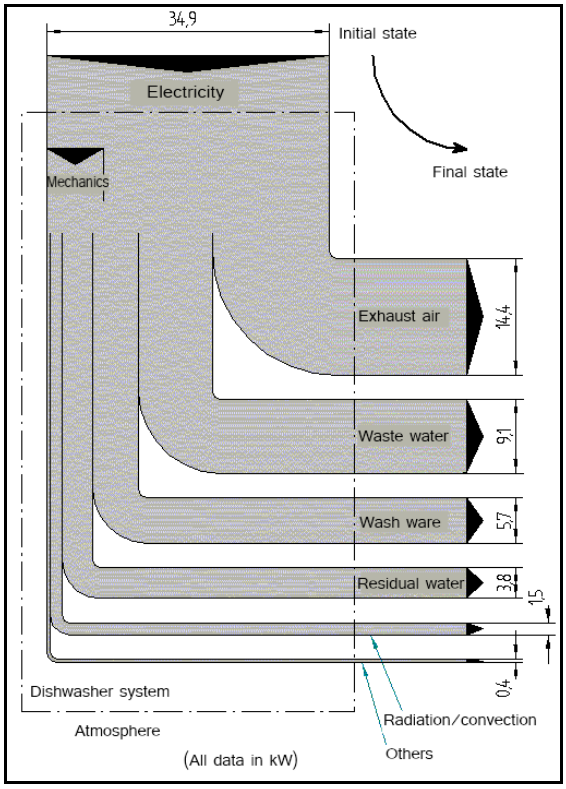
Figure 15 shows the temperature levels of the ambient air and of the specific dishwasher components (including water and dishes) in the different sections, together with the related energy flows. Figure 16 summarises the resulting energy input and output flows, Figure 17 shows the respective share of the different forms of energy output.



(Source: Meiko)

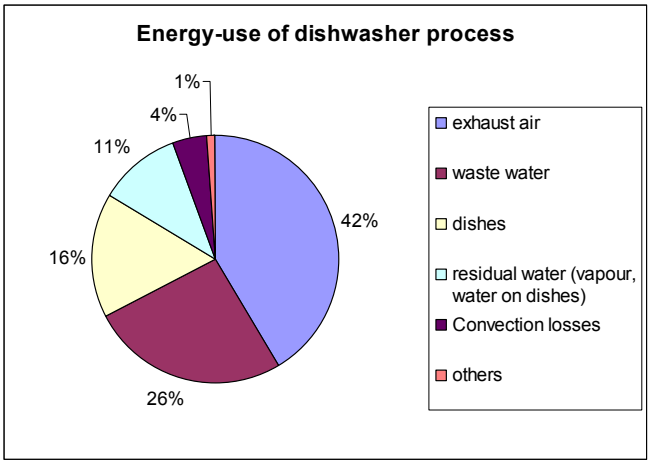
Figure 15 Energy flow in a conveyor-type dishwasher (category 6)

sample conveyor-type dishwasher described in this section can differ from other models and shall only show possible ranges.



(Source: Meiko)

Figure 16 Energy in- and output of an exemplary conveyor-type-dishwasher



(Source: own calculation based on data from Meiko)

Figure 17 Share of energy output in a conveyor-belt dishwasher

About 22% of the incoming energy is used to drive motors, pumps, ventilation, and the conveyor belt as well as to control the whole system. Most of the energy input, however, is used to heat up the water, the dishes and the air.

On the other hand, most of the energy is lost through exhaust air (42%), even though the dishwasher in the example above is equipped with a heat recovery system using the heat from the exhaust air to preheat the fresh water. Through this device, the air is expelled with a temperature of 35.5°C. Without heat exchanger, the exhaust air temperature would be around 60°C[10] and the heat loss correspondingly higher.

The second largest energy loss comes from the waste water. According to Figure 15, every hour 300 litres of warm water (temperature 35.5°C) leave the wash-cycle process and take 9.1 kWh/h of heat out of the system. This equates to 26% of the total energy consumption of the dishwashing process.

[10] However, according to stakeholder feedback, not all existing technologies work with exhaust temperatures around 60°C. There are also long practised existing technologies with exhaust temperatures below 40°C even without heat recovery unit.

Another relevant energy loss occurs to the heat which is transported out of the system through hot dishes. Usually, the dishes leave the dishwasher with a temperature of about 50°C. In the example described, the losses amount to 5.7 kWh/h which is equal to 16% of the total energy consumption. This share depends on the type and material of wash ware as the heat contained depends on the weight and the heat capacity of the material.

Further, 3.8 kWh/h or around 11% of the total energy consumption is lost through water vapour. As can be seen in Figure 15, about 322 litres of water enter the machine and only about 300 litres leave the dishwasher as waste water. That means that 22 litres of water leave the system in the form of vapour or adherent to the dishes. The losses through heat convection are relatively small: Only 1.5 kWh/h or 4% of the total energy consumption of the dishwashing process is related to heat convection.

As another example, Figure 18 below shows the energy flow of a hood-type dishwasher (category 3). Compared to the energy output in a conveyor-type dishwasher (see Figure 17 above), the differences in the fragmentation of the energy losses occur due to the different construction and working principle as well as due to the different water consumption of both machine types.

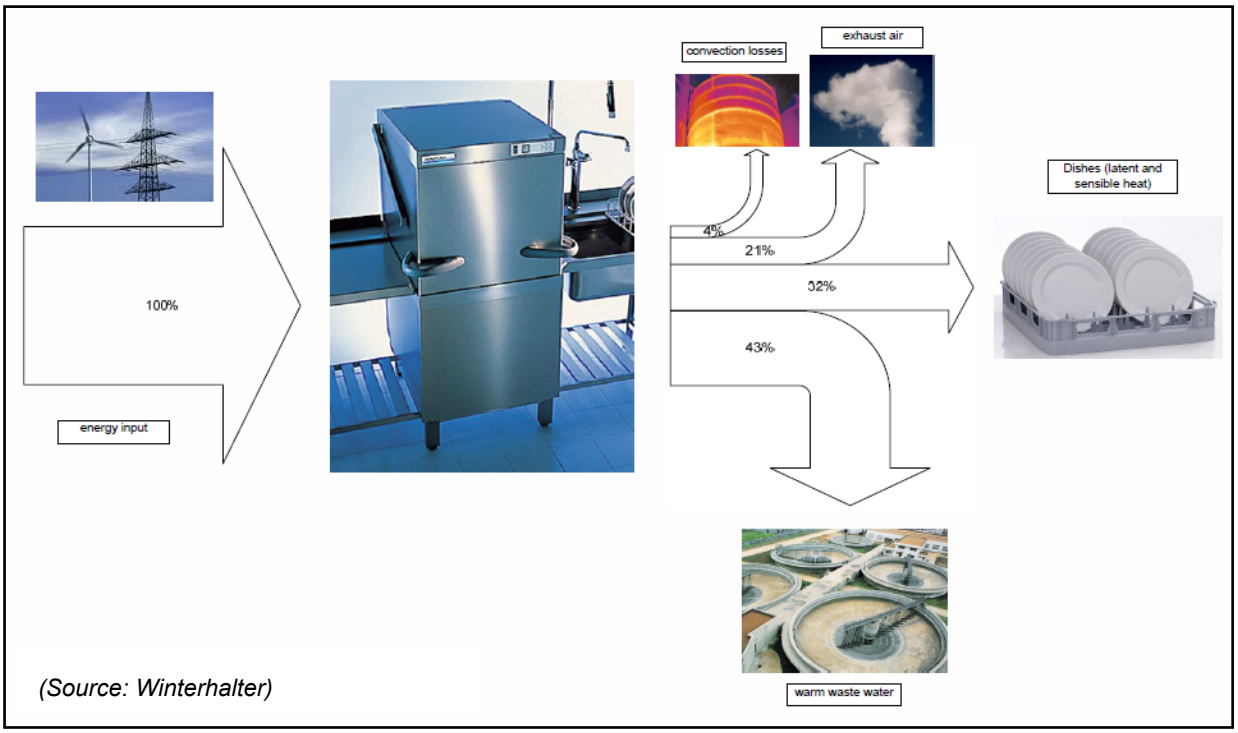
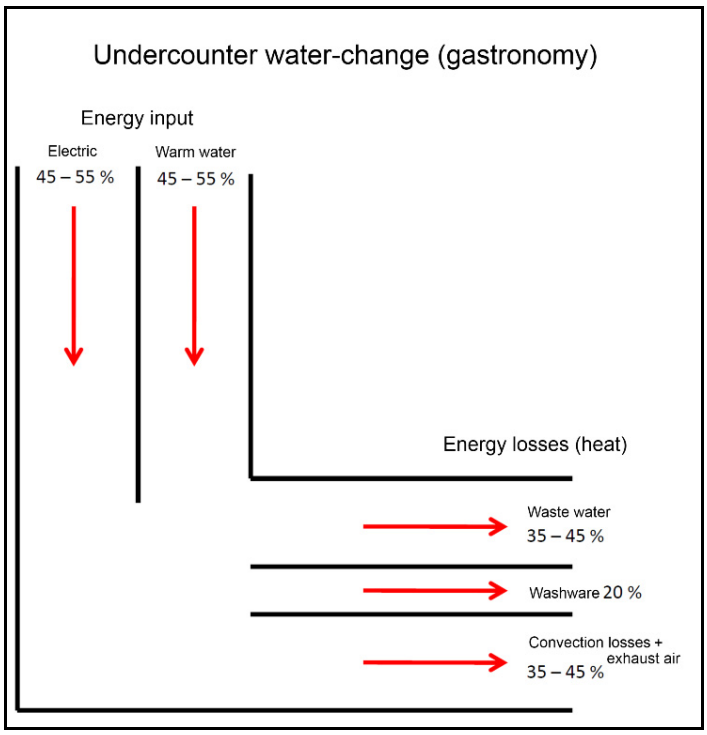


Figure 18 Energy flow in a hood-type dishwasher (category 3)

Finally, Figure 19 shows a rough estimation of energy flows and losses in a water-change program automat (category 1). The values of the different categories may vary depending on the used dishwasher program.



(Source: Miele)

Figure 19 Energy flow in a water-change dishwasher (category 1)

In summary, the examples of the three different dishwasher categories show that the most important losses occur in the following areas:

- exhaust air,
- waste water, and
- hot, clean dishes.

They sum up to approximately 90% of the total energy losses.

In Task 6, we will further use these results to derive potential improvement options and to describe best available technologies (BAT) to overcome the specific losses.

4.2 Typical composition of detergents and rinse aids for professional dishwashers

DIN 10512 defines standard compositions of detergents and rinse agents for testing one-tank dishwashers. The tests with the standard treatment agents shall provide evidence that the dishwashing machine fulfils the hygiene requirements (see Task 1).

Although these standard treatment agents are not commercially available, their compositions comply with commercially available detergents and rinse aids. The standard detergent consists of potassium hydroxide, sodium silicate (water glass) and potassium tripoly-phosphate whereas the standard rinse agent consists of non-ionic surfactants, citric acid and

hydrotropes as sodium cumolsulfonate to increase the solubility of the detergent in the product (Table 20 and Table 21).

Table 20 Standard composition of detergents for one-tank dishwashing machines

Component	Range (%)
Potassium tripolyphospate solution, 50 % (mass fraction)	20
Potassium hydroxide, 50 % (mass fraction)	36
Sodium silicate (water glass)	23
Oxidising agent[a)]	0–4
De-ionised water	ad 100

a) Oxidising agents are not part of the standard test detergent defined in DIN 10512. However, one manufacturer of dishwashing machines named oxidising agents as typical component in dishwashing detergents.

Table 21 Standard composition of rinse agents for one-tank dishwashing machines

Component	Range (%)
Citric acid-monohydrate, crystalline	5
Non-ionic surfactants, fatty alcohol$_{C12/C14}$ + 5 EO + 4 PO	20
Sodium cumolsulfonate	5
De-ionised water	ad 100

Bleaching or oxidizing agents typically used in detergents are mainly based on either oxygen (hydrogen peroxide/sodium percarbonate, sodium perborate[11]) or chlorine (hypochlorite). The advantage of chlorine bleaches like hypochlorite is that they provide effective bleaching and disinfection (hygiene) even at low (ambient) temperatures whereas sodium percarbonate and sodium perborate exhibit less bleaching efficiency at temperatures below 60°C. Furthermore, compared with chlorine and other disinfectants, hydrogen peroxide is not a very powerful disinfectant.

4.3 Energy, water and detergent consumption

The following input parameters were specified to define the respective energy, water, and detergent consumption of professional dishwashers during the use phase (see also Task 3):

- Initial filling (only relevant for tank operated dishwashers);
- Operation consumption;
  - Ideal conditions;
  - Real life conditions:

[11] The use of sodium percarbonate has gained importance in those countries in which boron is either banned or restricted for environmental and regulatory reasons, or is negatively discussed.

- Influence of real life workload on consumption;
- Influence of use of other programmes on consumption;
- Influence of maloperation;

- Standby consumption (ready-to-use mode or left-on mode).[12]

In case of water-change dishwashers (category 1), energy, water and detergent consumption only occurs during the dishwashing cycle and energy consumption during the left-on-mode.

In case of tank operated dishwashers (categories 2–6), first the wash tanks are filled with (water and) detergent solution, which has to be heated up to the operating temperature[13]. As the detergent solution has to be maintained at the set temperature (i.e. ready-to-use mode), standby energy is consumed as long as the dishwasher is in this stage. Finally, energy, water and detergent consumption occurs during a certain time of the day when the dishwasher is operating in its main function, i.e. cleaning dishes.

The use phase parameters have already been compiled and discussed in Task 3. Therefore, the following sections only summarise the annual consumption assumptions of the different dishwasher categories, differentiated according to the processes.

4.3.1 Category 1: Undercounter water-change dishwashers

Table 22 Energy, water and detergent consumption of a professional undercounter water-change dishwasher (cold water connection)

	Energy	Water	Detergent
Typical use intensity: Number of dishes p.a.	24 000		
Specific consumption	4.3 kWh/100 dishes	80 litres/100 dishes	268 g/100 dishes
Operation mode (annual consumption, ideal conditions)	*1 032 kWh*	*19 200 litres*	*64 kg*
Real-life user behaviour			
Additional consumption through partial workload	+15%	+25%	+25%
Consumption through use of other programmes in comparison to standard programme	96%	100%	100%
Additional consumption through maloperation	+10%		
Operation mode (annual consumption, real life user behaviour)	*1 249 kWh*	*25 920 litres*	*87 kg*
Initial filling (annual consumption)	not applicable	not applicable	not applicable
Standby (annual consumption, left-on-mode)	5 kWh	-	-
Total annual consumption (real life)	***1 254 kWh***	*25 920* ***litres***	***87 kg***

[12] Ready-to-use mode: reactivations function; left-on mode: information status.

[13] In the following sections, the energy consumption for the initial filling of the tank is based on cold water filling.

4.3.2 Category 2: Undercounter one-tank dishwashers

Table 23 Energy, water and detergent consumption of a professional undercounter one-tank dishwasher (cold water connection, electric heating)

	Energy	Water	Detergent
Typical use intensity: Number of dishes p.a.	237 600		
Specific consumption	1.6 kWh/100 dishes	16 litres/100 dishes	54 g/100 dishes
Operation mode (annual consumption, ideal conditions)	*3 802 kWh*	*38 016 litres*	*128 kg*
Real-life user behaviour			
Additional consumption through partial workload	+7.5%	+25%	+25%
Consumption through use of other programmes in comparison to standard programme	98%	100%	100%
Additional consumption through maloperation	+10%		
Operation mode (annual consumption, real life user behaviour)	*4 391 kWh*	*51 322 litres*	*173 kg*
Initial filling (annual consumption)	236 kWh	4 500 litres	15 kg
Standby (annual consumption, ready-to-use mode)	626 kWh	-	-
Total annual consumption (real life)	***5 253 kWh***	***55 822 litres***	***188 kg***

4.3.3 Category 3: Hood-type dishwashers

Table 24 Energy, water and detergent consumption of a professional hood-type dishwasher (cold water connection, electric heating)

	Energy	Water	Detergent
Typical use intensity: Number of dishes p.a.	345 600		
Specific consumption	1.7 kWh/100 dishes	16 litres/100 dishes	54 g/100 dishes
Operation mode (annual consumption, ideal conditions)	*5 875 kWh*	*55 296 litres*	*187 kg*
Real-life user behaviour			
Additional consumption through real-life workload	+ 7.5%	+25%	+25%
Consumption through use of other programmes in comparison to standard programme	99%	100%	100%
Additional consumption through maloperation	+10%		
Operation mode (annual consumption, real life user behaviour)	*6 845 kWh*	*74 650 litres*	*252 kg*
Initial filling (annual consumption)	629 kWh	12 000 litres	40 kg
Standby (annual consumption, ready-to-use mode)	784 kWh	-	-
Total annual consumption (real life)	***8 258 kWh***	***86 650 litres***	***292 kg***

For comparison:

The Danish Technological Institute (DTI)[14] has measured data on energy and water consumption for a total of ten hood-type dishwashers. The data have been determined according to „VGG Prüfverfahren zur Reinigungs-Index-Bestimmung von gewerblichen Geschirrspülmaschinen, Blatt 1 Kleinmaschinen; Entwurf 1970, ergänzt 1973“, with some modifications. The modifications follow as far as possible the European standard EN 50242 for household dishwashers (for details, cf. Task 1).

The following table gives an overview of the DTI results compared to the data provided from manufacturers for EuP Lot 24.

Table 25 Comparison of performance data for hood-type dishwashers

	Energy consumption use phase per 100 dishes (kWh)		Water consumption use phase per 100 dishes (litres)		Energy consumption ready-mode per hour (kWh/h)	
Source[15]	**DTI**	**EuP Lot 24**	**DTI**	**EuP Lot 24**	**DTI**	**EuP Lot 24**
Lowest value	1.4	1.5	12.0	-	0.19	-
Highest value	4.9	2.0	32.1	-	0.54	-
Average value	**2.9**	**1.7**	**20.7**	**16**	**0.34**	**0.35**

The DTI results show a high spread: the dishwasher with the highest energy consumption needs 3.5 times more energy compared to the most efficient one. Looking at the water consumption there is a factor 2.7, and for standby consumption a factor 2.8 between the best and the most consuming machine. Compared to the data provided by manufacturers in the context of EuP Lot 24, the standby consumption is in the same dimension; the water consumption used in EuP Lot 24 is about 23% lower than the average value of DTI; the EuP values for the energy consumption in on-mode are about 41% lower than the values resulting from DTI measurements.

However, according to information from DTI at the final stakeholder meeting[16] and via feedback form (cf. Annex section 8.2), the information provided by the DTI test results is not necessarily comparable as not all of the dishwashers and programmes tested are designed to only clean dishes with the “VGG type” of soiling[17], although they have been evaluated

[14] www.dti.dk

[15] Source DTI: mean value out of 10 dishwashers measured by Danish Technological Institute. Source EuP Lot 24: mean value according to manufacturers’ feedback; for water and standby consumption, only average values available.

[16] www.ecowet-commercial.org/open_docs/Minutes_Final%20SH%20meeting%20dishwashers_09.12.2010.pdf

[17] Also it should be noted that the measurement results for water, energy and time as well as the measured temperatures are determined on the test conditions provided Task 1, Annex 7.3 and will be independent of the soiling and the soiling method as long as the dishwasher is not equipped with sensors that can make the dishwasher react on the soiling in the wash water or the soiling on the dishes. The soiling is used to see

under the same conditions. Some of the machines tested by DTI are indeed made for tougher jobs and soiling (machines using a higher rinsing temperature also have higher energy consumption). This might be a reason for the differences between the DTI test results and the values of EuP Lot 24. Further, according to DTI it is not for sure that the ten tested machines are representative of the market in terms of performance level in Europe, as the machines were submitted by manufacturers for testing on a voluntary basis.

Therefore, the results back the urgency for a standardised methodology for performance measurements (for details, see also section 7).

For further calculations in the following tasks, we will take the data provided directly by manufacturers in the context of EuP Lot 24. They have been confirmed at the interim stakeholder meeting and the approach is consistent to the other dishwasher categories.

4.3.4 Category 4: Utensil / pot dishwashers

Table 26 Energy, water and detergent consumption of a professional utensil/pot dishwasher (cold water connection, electric heating)

	Energy	Water	Detergent
Typical use intensity: Number of dishes p.a.	9 000 cycles		
Specific consumption	0.5 kWh/cycle	5.2 litres/cycle	17 g/cycle
Operation mode (annual consumption, ideal conditions)	*4 500 kWh*	*46 800 litres*	*153 kg*
Real-life user behaviour			
Additional consumption through real-life workload	+7.5%	+30%	+30%
Consumption through use of other programmes in comparison to standard programme	103%	100%	100%
Additional consumption through maloperation	+10%		
Operation mode (annual consumption, real life user behaviour)	*5 423 kWh*	*65 520 litres*	*214 kg*
Initial filling (annual consumption)	1 257 kWh	24 000 litres	80 kg
Standby (annual consumption, ready-to-use mode)	2 233 kWh	-	-
Total annual consumption (real life)	***8 913 kWh***	***89 520 litres***	***294 kg***

possible effects of change in temperatures, water pressure, water distribution, and amount as well as washing time etc. The “VGG type” soiling may be exchanged with other types of soiling.

4.3.5 Category 5: One-tank conveyor-type dishwasher

Table 27 Energy, water and detergent consumption of a professional one-tank conveyor-type dishwasher (cold water connection, electric heating)

	Energy	Water	Detergent
Typical use intensity: Number of dishes p.a.	1 515 900		
Specific consumption	2.0 kWh/100 dishes	13 litres/100 dishes	44 g/100 dishes
Operation mode (annual consumption, ideal conditions)	*30 318 kWh*	*197 067 litres*	*667 kg*
Real-life user behaviour			
Additional consumption through real-life workload	+10%	+10%	+10%
Consumption through use of other programmes in comparison to standard programme	98%	98%	98%
Additional consumption through maloperation	+5%		
Operation mode (annual consumption, real life user behaviour)	*34 259 kWh*	*222 686 litres*	*754 kg*
Initial filling (annual consumption)	1 728 kWh	33 000 litres	111 kg
Standby (annual consumption, ready-to-use mode)	1 716 kWh	-	-
Total annual consumption (real life)	***37 703kWh***	***255 686 litres***	***865kg***

4.3.6 Category 6: Multi-tank conveyor-type dishwasher

Table 28 Energy, water and detergent consumption of a professional multi-tank conveyor-type dishwasher (cold water connection, electric heating)

	Energy	Water	Detergent
Typical use intensity: Number of dishes p.a.	4 009 500		
Specific consumption	2.0 kWh/100 dishes	12 litres/100 dishes	40 g/100 dishes
Operation mode (annual consumption, ideal conditions)	*80 190 kWh*	*481 140 litres*	*1 604 kg*
Real-life user behaviour			
Additional consumption through real-life workload	+ 10%	+10%	+10%
Consumption through use of other programmes in comparison to standard programme	103%	103%	103%
Additional consumption through maloperation	+5%		
Operation mode (annual consumption, real life user behaviour)	*94 624 kWh*	*567 745 litres*	*1 892 kg*
Initial filling (annual consumption)	3 975 kWh	75 900 litres	254 kg
Standby (annual consumption, ready-to-use mode)	3 630 kWh	-	-
Total annual consumption (real life)	***102 229 kWh***	***643 645 litres***	***2 146 kg***

4.3.7 Overview of all dishwasher categories

The following Table 29 summarises the annual energy, water, and detergent consumption to be used as input data for Task 5 (environmental impact assessments of base cases).

Table 29 Annual energy, water, and detergent consumption (real life conditions) of all dishwasher categories

Dishwasher categories	Annual energy consumption per appliance (kWh)	Annual water consumption per appliance (litres)	Annual detergent consumption per appliance (kg)
Undercounter water-change	1 254	25 920	87
Undercounter one-tank	5 253	55 822	188
Hood-type	8 258	86 650	292
Utensil/pot	8 913	89 520	294
One-tank conveyor-type	37 703	255 686	865
Multi-tank conveyor-type	102 229	643 645	2 146

5 Technical analysis use phase (system)

Almost every product has a clear interface with the surrounding system. The technical analysis of the systemic use phase describes the functional system to which the product in question belongs and – if possible – quantifies those product features that can reduce the environmental impact not only of the product but of the system as a whole. However, the scope of the system analysis is restricted only to those issues that can be influenced by technical features of the products under investigation. Furthermore, the system analysis serves as an addition to the more traditional product-specific analysis in section 4, i.e. to design product-specific legislation (if any) in such a way that it would not make system-oriented innovations impossible.

Professional dishwashers are used in various applications like restaurants, clinics, and canteens etc. (see Task 3). The corresponding surroundings can be quite different and might influence the energy and water consumption of the dishwashers. This section provides an overview of different determining factors influencing the energy, water and detergent consumption of professional dishwashers.

Type of dishes: As shown in section 4.1 the dishes have to be heated by the dishwasher. A considerable part of the energy contained in the dishes gets lost through hot dishes and other wash ware at the end of the dishwashing process. The amount of energy needed to heat up the dishes and the losses depend on the type of wash ware (i.e. its weight and heat capacity). For example, the material china has a heat capacity of about 1 080 J/kg*K.

Input temperature of dishes: The energy consumption of dishwashers also depends on the input temperature of the wash ware, which depends on the general ambient temperature.

Soiling: The soiling of the wash ware can vary significantly from case to case. Especially in category 3 (utensil / pot dishwasher), heavy soiling of the washware might lead to additional pre-wash prior to the regular dishwashing cycle (outside of the machine). Another consequence of heavy soiling could be that users choose different programs. Longer running cycles, used for more heavily soiled dishes, usually have a better cleaning performance but also a higher energy and water consumption (see Task 3). Heavy soiling finally might lead to additional running cycles, if the result of the dishwashing process is not satisfying.

Quality of water: The information about water, energy and detergent consumption is usually based on ideal conditions. This means for example, that water hardness should be below 6°dH. Higher water hardness results in higher energy, water and/or detergent consumption. Therefore often a special softening plant is installed in order to obtain a good dishwashing performance.

Input water temperature: The water used for the dishwashing process (about 120 to 160 litres of water per 1 000 plates) has to be heated up from the input temperature to the tank or rinsing temperature. Every degree the input water being colder would cause an additional energy input of 0.14 kWh to 0.19 kWh (related to 120 litres and 160 litres per 1 000 dishes respectively).

Ambient temperature: The washing process produces heat and moisture which has to be expelled from the room. The energy consumption of the respectively needed ventilation and/or the air conditioning is related to the dishwashing process and also depends on the technology used. In case of a dishwasher with heat recovery system or heat pump, less energy is needed by a ventilation and/or air conditioning system to keep the ambient temperature and humidity within a comfortable range.

Infrastructure: The existing infrastructure has an influence on the electricity consumption:

- Water supply: The initial filling of the tanks with warm or hot instead of cold water at the beginning of the first dishwashing process might reduce electricity consumption.
- Alternative heating: Heating with natural gas or steam will not lead to a reduced end-energy demand but to a reduction of electricity consumption and in most cases also to a reduction of CO_2 emissions and other air polluting gases such as NO_x and SO_2. The environmental impact is dependent on the technology of the water heating and the steam process on the one hand, and on avoided emissions of the electricity system on the other hand.

6 Technical analysis end-of-life phase

This section shall provide considerations regarding the end-of-life of the professional dishwashers' material flows for handling as pure waste (landfill, pyrolytic incineration), heat recovery (non-hazardous incineration optimised for energy recovery) and/or re-use or closed-loop recycling.

At the end of their life time (for details, cf. Task 3), almost no professional dishwasher will end at a landfill, as materials are too valuable. For this reason, most products will either be refurbished or recycled for scrap parts or materials. We assumed that only 5% by weight of the products are not recovered (i.e. go to landfill) during the end-of-life phase. Indeed, in principle, almost all materials in the dishwashers' composition are recovered (assumption: 95% in post-WEEE conditions according to MEEuP) and follow one of the following options:

- Metals are recycled;
- Paper, cardboard, and plastics are incinerated (thermal recycling with possible benefits of energy recovery) or mechanically recycled. Plastics may also be directly reused;
- Other types of waste (concrete, bitumen) go to landfill. Hazardous waste consists only of electronic components, which are considered easy to disassemble and are in limited quantity (around 1% of the total weight).

The plastic share of professional dishwashers is mostly less than 10% related to its overall weight (see Table 18 in section 2.2.7). Regarding the recovered plastic fraction, the following end-of-life management options were estimated for all BCs, based on stakeholders' feedback:

- Thermal recycling: 70 %.
- Material (or mechanical) recycling: 29 %
- Re-use, closed loop recycling: 1 %

Printed wiring boards (PWB) are used in dishwashing machines of all categories. According to stakeholder information, these parts are easy to dismantle and are completely recycled by certified scrap dealers.

If a dishwasher with an installed heat pump is dismantled, specialized technicians will extract the refrigerant from the heat pump. In this process, only a technically unavoidable, small amount of refrigerant will escape.

7 Recommendation on mandates

On the basis of the analysis carried out in Tasks 1 to 4, this section shall include first recommendations for the content of possible mandates to be issued by the European Commission to the European standardisation organisations on (measurement) standards for professional dishwashers. Overall, as already initiated by CENELEC TC59X (see Task 1), a standardised definition of the terms and respective appliances “professional, commercial, and industrial” will be necessary.

To date, there are no directives or regulations in Europe and not even voluntary agreements between manufacturers concerning a consistent measurement methodology of consumption and performance data for professional dishwashers. This means that data provided by manufacturers is currently neither comparable nor subject to any control. Therefore, consumers who want to buy a professional dishwasher with low environmental impact and least life-cycle costs are confronted with the following challenges:

- In many cases no data on the energy consumption of professional dishwashers are provided at all.
- The information in brochures and catalogues concentrates on the figures for energy reduction (for example 30%) compared to an undefined product of a competing company or of an own product without a certain feature. The worse comparative value is frequently not communicated at all or en detail.
- If the energy consumption is noted, it is not really comparable to information on other appliances of other or maybe even the same manufacturer, because there is no standard method for measuring the consumption parameters of professional dishwashers.

This in turn results in the following:

- Consumers base their purchasing decision on non-comparable information.
- Competition between manufacturers is distorted.
- Manufacturers who provide realistic information on energy and water consumption are disadvantaged compared to those who communicate over-optimistic information.
- The further development of efficient technologies is slowed.
- Additional environmental impacts result from purchasing decisions made on the basis of insufficient information.
- Economic damage might result at EU level as a result of misdirecting the demand and insufficient allocation of resources.

A further consequence of the current situation is that important instruments of an efficiency policy cannot be applied. The application of minimum standards, efficiency labelling of devices, the introduction of binding life-cycle cost accounting, financial incentives for optimum devices as well as other instruments, presuppose a reliable data basis for assessing the

consumption of the devices. This makes it advisable to develop and introduce a generally applicable and binding measuring method for determining the consumption of professional dishwashers at European level. Note: The existing approaches and considerations have already been set out in Task 1.

A prerequisite for determining the efficiency of a professional dishwashing process and dishwasher respectively is the implementation of standardised measuring methods. The following aspects would need to be defined for each of the dishwashing categories in order to deliver comparable results of the performance and consumption parameters[18]:

- Ambient temperature and humidity;
- Input water temperature;
- Input temperature for the wash ware;
- Selection of program ('standard' dishwashing program);
- Cleaning capacity (dishes per hour);
- Type (formulation) and dosage of detergent and rinse aid;
- Standard wash ware in terms of size, surface and heat capacity;
- Soiling of the items including dry-on time of the soiling.

The following parameters would need to be evaluated / measured:

- Cleaning results and hygienic performance;
- Energy and water consumption during continuous use (conveyor-type dishwashers) or per cycle (program automats);
- Energy demand in standby modes (ready-to-use, left-on, and if applicable: off mode); if possible, the termination of standby modes should follow the definitions of Commission Regulation (EC) No. 1275/2008 on Standby.
- Real-life use conditions: Energy and water consumption in partial load / discontinuous operation; possibly consumption in other than 'standard' program

Standard conditions should represent real-life conditions as precisely as possible. However, as there is a great variation in the user behaviour of professional dishwashers even within the categories identified, the energy and water consumption in day-to-day operation may still differ from that under standard test conditions.

Regarding the hygienic performance, stakeholders pointed out that they would prefer to define certain hygienic requirements (e.g. germ reduction by five log10 levels) and leave it up to the manufacturers how they solve this issue over certain mandatory minimum temperatures as defined in the current German DIN standards. Also in the revised DIN standards (currently under development) there will be no mandatory minimum temperatures

[18] The draft energy efficiency standard for commercial dishwashers by EFCEM might be an example of such a standard.

defined anymore. Similar arguments apply for the amount and type of detergent: manufacturers are in favour of not defining a standard detergent in the measurement standards. To avoid a possible shift of environmental burdens from those through energy consumption (e.g. Global Warming Potential, GWP) to those through ingredients of detergents (e.g. aqua toxicity, human toxicity) such information would need to be given as well when measuring the consumption parameters according to the standard that has to be developed.

8 Annex

8.1 Stakeholder enquiries

8.1.1 Working paper “Task 4” for stakeholders

Questions with regard to the technical analysis of the use phase have already been included into the working paper for Task 3 (cf. EuP_Lot24_Dish_T3_T4_Annex_Workingpaper.pdf).

8.1.2 Excel enquiry – production, distribution and end-of-life phase

EuP Lot 24: Professional washing machines, dryers and dishwashers

Task 4 - Technical Analysis of Existing Products - Part on Professional Dishwashers

The data is used to determine the environmental profile and impact analysis of the identified product categories with the "EuP-EcoReport" tool for:

1. Production Phase
2. Assembling / Distribution Phase
3. Use Phase*
4. End of Life Phase

* data collection included in seperate working paper on use phase, including user behaviour

PRODUCTION (including packaging material)

Main Materials Category type	Material (EuP EcoReport)	Example Average data Dishwasher 12ps model (data from Lot 14) [g]	Manually loaded program automats, under counter front loaders with water change operation [g]	Manually loaded program automats, under counter front loaders with one tank [g]	One-tank pass through dishwasher ('hood type dishwasher') [g]	Wareashing Utensil / Pot dishwasher [g]	One-Tank transport dishwasher [g]	Multi-Tank transport dishwasher [g]		
								Exclusively electricity	steam and hot water	gas
Bulk Plastics	Low-density polyethylene (LDPE)	695								
	High-density polyethylene (HDPE)	417								
	linear low density polyethylenes (LLDPE)									
	Polypropylene (PP)	4.980								
	Plystyrene (PS)	512								
	Styropor expandable polystyrene (EPS)	764								
	High Impact Polystyrene (HI-PS)									
	Polyvinylchlorid (PVC)	403								
	Styrol-Acrylnitril (SAN)									
	Acrylonitrile Butadiene Styrene (ABS)	751								
Bulk Plastics		***8.522***	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
TecPlastics	Polyamide (PA)	399								
	Plolycarbonate (PC)									
	Polymethylmetacrylate (PMMA)	6								
	Epoxy									
	Rigid-Pur									
	Flex - Pur									
	Talcum filler									
	E-glass fibre									
	Aramid fibre									
TecPlastics		***405***	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Ferrous metals	Steel Sheet galvanized	403								
	Steel tube/profile	15.869								
	Cast Iron	2.303								
	Ferrite									
	Stainless 18/8 coil	8.691								
Ferrous metals		***27.266***	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*

Non ferrous metals	Al sheet/extrusion	269								
	Al diecast									
	Cu winding wire									
	Cu wire	1.006								
	Cu tube/sheet									
	CuZn38 cast	23								
	ZnAl4 cast	4								
	MgZn5 cast									
Non ferrous metals		***1.302***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***
Coating	pre-coating coil									
	powder coating									
	Cu/ni/Cr plating									
	Au/Pt/Pd									
Coating		***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***
Electronics	LCD per m² scrn									
	CRT per m² scrn									
	big caps & coils									
	slots / ext. Ports									
	IC´s avg., 5% Si, Au									
	IC´s avg., 1% Si									
	SMD/LED´s avg.									
	PWB 1/2 lay 3.75kg/m²									
	PWB 6 lay 4.5kg/m²									
	PWB 6 lay 2kg/m²									
	Solder SnAg4Cu0.5									
	controller board									
Electronics		***448***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***
Miscellaneous	Glass for Lamps									
	Bitumen	6.089								
	Cardboard	3.677								
	Office Paper	209								
	Concrete	1.263								
Miscellaneous		***11.238***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***

OUT of Scope EUP **	others	59									
	Resins	120									
	thermostat	10									
	Cotton	452									
	Cotton+Resins noise absorbers	489									
	adhesive	10									
	PBT polybutylene terephthalate	35									
	Plastics, others	268									
	wood	0									
	PU Foam - Insulation	2									
	Cr	71									
OUT of Scope EUP		***1.516***	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	
TOTAL		**50.697**									

** For some materials no correspondance with EuP EcoReport is possible, in that case please allocated the materials in the main category "out of scope"

ASSEMBLING / DISTRIBUTION

		Example Average data Dishwasher 12ps model (data from Lot 14)	Manually loaded program automats, under counter front loaders with water change operation	Manually loaded program automats, under counter front loaders with one tank	One-tank pass through dishwasher ('hood type dishwasher')	Wareashing Utensil / Pot dishwasher	One-Tank transport dishwasher	Multi-Tank transport dishwasher		
								Exclusively electricity	steam and hot water	gas
Energy (kWh)										
Electricity		17,31								
Heat		9,2								
Mechanical										
Water (m3)		0,09								
Other materials (g)		315								
Volume of packaged final product (m3)		0,4								
Transport average (km)		652								

END OF LIFE

			Manually loaded program automats, under counter front loaders with water	Manually loaded program automats, under counter front loaders with one	One-tank pass through dishwasher ('hood type dishwasher')	Wareashing Utensil / Pot dishwasher	One-Tank transport dishwasher	Multi-Tank transport dishwasher		
			in %	in %	in %	in %	in %	in %	in %	in %
Landfill (fraction of products not recovered)			5	5	5	1	1	1		
Recycling of plastics										
Re-use, closed loop recycling			0	0	0	0	0	0		
Materials Recycling			80	80	80	80	90	90		
Thermal Recycling (%)			20	20	20	20	10	10		
Total			**100**	**100**	**100**	**100**	**100**	**100**		

8.1.3 Additional questions – production, distribution, end-of-life phase

Together with the excel-file (see section 8.1.2), stakeholders were kindly asked to fill in the following data:

1. Production:

- Material composition of the defined product categories (incl. packaging material)

  The data should be valid for electrically heated dishwashers (as we assume this as standard). If possible, we would like to ask you to specify the additional materials required for other heating possibilities in case of transport dishwashers (steam / hot water and gas heating respectively, therefore 3 columns there), either as percentage or in absolute values possible. The data should be valid for a "typical" dishwasher of each category. We know that especially in case of transport dishwashers there are quite big differences.

2. Assembling, Distribution:

- Energy, water and other material demand for the manufacturing process at the dishwasher manufacturer. It is obvious, that this can be only rough values, perhaps not differentiated per category, as it is difficult to allocate them to specific products.
- Volume of packaged final product
- Transport average (manufacturer – user)

3. End of life

- Fraction of products not recovered ("landfill" in any sense)
- Fraction of plastics that 1) is re-used, 2) goes to material recycling or 3) goes to thermal recycling (you find an assumption in the excel-file already)

Additionally, we would like to ask the following questions:

- Which percentage of the used sheetmetal is made of scrap metal?
- Are the PWB (printed wiring boards) easy to disassemble?
- Do the products contain refrigerants? If yes, which and how much? We assume that this is the case, if the waste steam condensation takes place with a heat pump, which, however we assume not as "standard" but rather as BAT.
- How is the refrigerant of the heat pumps being disposed of in the end-of-life phase? Which fraction of it is retained?
- Do the products contain mercury? If yes, how much and for which purpose? Which fraction is retained in the end-of-life phase?

8.1.4 Documentation of stakeholder response to enquiries

The following table shows to which stakeholders the working paper and an additional Excel file including questions with regard to production, distribution and end-of-life phase were circulated. The table also indicates from whom a response has been received.

Table 30 Documentation of enquiry addressees and their responses

	Working paper use phase (covering Task 3 and use phase aspects of Task 4)		Excel-File + additional questions on production, distribution and end-of-life-phase	
	Sent out	**Feedback**	**Sent out**	**Feedback**
Manufacturers and Industry Associations				
Hobart (currently not member of an industry association)	Yes	Yes	Yes	Yes
VGG (Verband der Hersteller von Gewerblichen Geschirr-spülmaschinen (Association of commercial dishwashers), representing the manucturers Winterhalter and Meiko)	Yes	Yes, feedback by both member companies Meiko and Winterhalter	Yes	Yes, feedback by both member companies Meiko and Winterhalter
EFCEM (European Federation of Catering Equipment Manufacturers) European umbrella associations of nine national catering equipment manufacturers' associations:	Yes	Spread working document to member associations	Yes	Spread working document to member associations
SYNEG, France	via EFCEM		via EFCEM	
HKI, Germany, representing ▪ Electrolux professional ▪ Miele professional ▪ Palux ▪ Stierlen	via EFCEM	HKI spread the working document to member companies. Feedback received by Miele.	via EFCEM	HKI spread the file and questions to member companies. No feedback by manufacturers.
CEA, Ireland	via EFCEM		via EFCEM	
CECED Italia, Italy	via EFCEM	Yes, feedback by association.	via EFCEM and was additionally contacted directly.	CECED Italia spread the file and questions to member companies. No feedback by manufacturers.
NVLG, Netherlands	via EFCEM		via EFCEM	
FELAC, Spain	via EFCEM and was additionally contacted directly.		via EFCEM	
BFS, Sweden	via EFCEM		via EFCEM	
TUSID, Turkey	via EFCEM		via EFCEM	

	Working paper use phase (covering Task 3 and use phase aspects of Task 4)		Excel-File + additional questions on production, distribution and end-of-life-phase	
	Sent out	**Feedback**	**Sent out**	**Feedback**
CESA, United Kingdom	via EFCEM		via EFCEM	
User associations				
HOTREC (Trade association of hotels, restaurants and cafes in the European Union)	Yes, twice	Response on e-mail but no comment on working paper.	No	
IHRA (International Hotel and Restaurant Association)	Yes, twice		No	
ACE (Association of Catering Excellence)	Yes, twice		No	
CLITRAVI (Liaison Center for the Meat Processing Industry in the European Union)	Yes, twice	Feedback that they did not feel responsible.	No	
C.E.B.P. (European Confederation of Bakers and Confectionary Organizations)	Yes, twice		No	
HCI (Health Caterers International)	Yes, twice	Response on e-mail but no comment on working paper.	No	
IFSA (International Flight Service Association)	Yes, twice		No	
ITCA (International Travel Catering Association)	Yes, via contact form on the internet		No	
Others				
CSFG (Catering for a Sustainable Future Group)	Yes		No	

8.2 Stakeholder feedback to draft versions of Task 4

Please note that the feedback refers to prior draft versions of Task 4 report; thus the indicated numerations of chapters, tables, figures or pages might have changed.

Feedback		Comment
Hobart		
3.5.1, 3.5.2, 3.5.3, p. 13, 15, 18	**Table 5, Table 7, Table 9** – Tank temperature according to DIN 10512: 55 to 65°C – Boiler temperature according to DIN 10512: 80 to 85°C – The aforementioned temperatures may go above or below these limits as long as the specified hygiene requirements are met. (Some machines are designed to operate at a different temperature profile). – Rinse water consumption should be expressed in litres/cycle not litres/hour (Table 7).	Considered in revision.
3.6, 3.6.1, 3.6.2, p. 20, 24, 26	**Text, Table 12, Table 14** – Tank temperature according to DIN 10510/10512: 55 to 65°C – Boiler temperature according to DIN 10510/10512: 80 to 85°C – The aforementioned temperatures may go above or below these limits as long as the specified hygiene requirements are met. (some machines are designed to operate at a different temperature profile)	Considered in revision.
5.1, p. 30ff.	**Entire section** – Energy flow of conveyor-type dishwashers is very specific for different machine configurations. – There is wide range of energy input and output which depends mainly on the machine capacity (plates per hour) and its configuration (type and number of sections, heat recovery system). – The sample conveyor dishwasher described in this section has a heat loss through dishes of only 5,7 kWh/h. We have major doubts if this is an appropriate value for a machine with a capacity of approx. 2 500 plates per hour.	Considered in revision
5.2.7, p. 36	**Table 23** the content of this table should be consistent with Table 2-12 of the Task 2 report	Section has been deleted in revision as part of task 5 report.
Miele		
3.4, p. 7	**The water is drawn from the fresh water inlet (4) and heated in a boiler. […] For the final rinse fresh water is used that has to be heated by the boiler again.** Water-change models don't have a boiler in its classical meaning (like one-tank program automats). They use heating coils that are located in the inner cabinet (wash chamber). Therefore it should say: "The water is drawn from the fresh water inlet (4) and heated in the wash chamber by the means of heating coils. […] For the final rinse fresh water is used that has to be heated again using the heating coils.	Considered in revision.
3.4, p. 7	**Table 2, 3 to 27 minutes, depending on program** correct is: 6 to 27 minutes	Considered in revision.
3.5.1, p. 13	**Table 5, Height/Width/depth** There are also undercounter models that are only 415–475 mm wide. These models are often used in bar areas and usually used	Included in the text

Feedback		Comment
	as glasswashers. These models are a significant portion of the overall undercounter market. The basic mode of operation is the same as in the 600 mm wide models.	
Winterhalter		
3.5.3, p. 17	**Figure 9** The machine shown is not very typical because it is probably the smallest and only undercounter potwasher on the market. I will provide a picture of a typical machine in about the dimensions mentioned on page 18	Considered in revision.
3.6, p. 20	**Wash temperatures** It is mentioned, that the leach-temperature is usually 65°C. The usual temperature-range – depending on the whole cleaning process – is 55–65°C (mentioned in DIN 10512). There are only some systems on the market that prefer higher temperatures – common temperatures are about 60°C.	Considered in revision.
3.6, p. 22	**Swinging Wash-arms** We do not know conveyor machines on the market, where the spraywash-arms swing. In utensil – washers some do so ….	Considered in revision
3.6.2, p. 26	**Table 14, Tank-temperature** See above mentioned. I only know one process from one manufacturer that works with this tank temperature. So it is not typical as mentioned below table 14.	Considered in revision.
5.1, p. 32	**Exhaust air temperature** Not all existing technologies work with exhaust temperatures around 60°C. There are also long practised existing technologies with exhaust temperatures below 40°C even without heat recovery unit.	Considered in revision.
CECED Italia		
2, p. 3	**Sinner Circle** 55°C is the range required from detergent manufacturer. It should not be a must, because it means to pose a limit to research and energy reduction.	Considered in revision.
2, p. 3	**Sinner Circle (90 seconds)** These values are defined from DIN standards it is possible to have good performance with lower time, it must be an opportunity of manufacturer to choice value for the four factors.	Considered in revision.
3.2, p. 5	**Main components of professional dishwashers** Air ventilation and dryer?	Considered in revision.
3.6.2, p.28	**Table 16, Energy management TOP TEMP** Every manufacturer has different set of optional available.	Considered in revision.
3.6.4, p. 29	**Hazardous materials** The refrigerant used is R134a, R407C and other…	Considered in revision.
5.1, p. 30	**Energy flow** In the text: “As outlined in Task 3, typically only electric energy is used.” => Steam energy too.	Considered in revision.

Feedback		Comment
5.1, p. 33	**Improvement potential** – "The heat losses through china…" It should compromise dryer performance: Cold dishes require more hot air or other solutions. – Sanitizing is not obtained by temperature in dishwasher. Thermal disinfection requires completely different process.	Considered in revision.
5.2.2, p. 34	**Table 2** In the table: "specific consumption detergent 3.35 g/l" => this value depend to detergent specification, we consider typically 2g/litre	The assumption is derived in task 3 and included rinse aid consumption. It seems that there is a quite big variation of detergents on the market. We therefore keep 3.35 g/l for the base case calculations.
8, p. 42	**Performance and consumption parameters** Refer to CECED proposal	Considered in revision.
Granuldisk		
p. 19, table 10	We want to complement table 10 on page 19 in Task 4 Report with the following information: – Energy consumption in operation: 0.4–0.7 kWh/cycle (depending on program and/or cold/hot water connection) – Energy consumption in ready-to-use mode: 1 kWh/h	Considered in revision. Thank you for this information.
Hobart		
p. 42	Replace "(e.g. germ reduction by three log10 levels)" by "(e.g. germ reduction by five log10 levels)"	Considered in revision.
Danish Technological Institute (DTI)		
p. 35, table 25 + comments	We agree in the figures shown from the DTI measurements It should however be noted that not all dishwashers and programmes tested are made only to clean dishes with the "VGG type" of soiling. Some of them are indeed made for tougher jobs and soiling. Also it should be noted that the measurement results for water, energy and time as well as the measured temperatures are determined on the conditions given in Report for part 1 section 7 Annex 7.3 and will be independent of the soiling and the soiling method as long as the dishwasher is not equipped with sensors that can make the dishwasher react on the soiling in the wash water or the soiling on the dishes. The soiling is used to see possible effects of change in temperatures, water pressure, water distribution, and amount as well as washing time etc. The "VGG type" soiling may be exchanged with other types of soiling.	Considered in revision.

Preparatory Studies for Eco-design Requirements of Energy-using Products

Lot 24: Professional Washing Machines, Dryers and Dishwashers

Tender No. TREN/D3/91-2007

February 2011

Final Report, Part: Dishwasher

Task 5: Definition of Base Case

Öko-Institut e.V.
Institute for Applied Ecology, Germany
Ina Rüdenauer
Markus Blepp
Eva Brommer
Carl-Otto Gensch
Kathrin Graulich

BIO Intelligence Service, France
Shailendra Mudgal
Raul Cervantes
Thibault Faninger
Lorcan Lyons

Büro Ö-Quadrat, Germany
Dieter Seifried

Öko-Institut e.V.
Freiburg Head Office
P.O. Box 17 71
79017 Freiburg, Germany
Street Address
Merzhauser Str. 173
79100 Freiburg, Germany
Tel. +49 (0) 761 – 4 52 95-0
Fax +49 (0) 761 – 4 52 95-88

Darmstadt Office
Rheinstr. 95
64295 Darmstadt, Germany
Tel. +49 (0) 6151 – 81 91-0
Fax +49 (0) 6151 – 81 91-33

Berlin Office
Schicklerstr. 10
10179 Berlin, Germany
Tel. +49 (0) 30 – 40 50 85-0
Fax +49 (0) 30 – 40 50 85-388

www.oeko.de

For reasons of better readability, two Task 5 reports were prepared.

The report at hand covers ***professional dishwashers***.

The Task 5 report on *professional washing machines and dryers* is published separately.

Part: Professional Dishwashers

Table of Contents – Task 5: Definition of Base Case

List of tables V

List of figures VI

1 Introduction 1

1.1 Objective of Task 5 1

2 Product-specific inputs 2

2.2 Inputs in the production phase 4

2.3 Inputs in the distribution phase 7

2.4 Inputs in the use phase 8

2.4.1 Electricity consumption 8

2.4.2 Water consumption 9

2.4.3 Detergent and rinse aid consumption 9

2.4.4 Travelling effort for maintenance and repair over the product life 9

2.5 Inputs in the end-of-life phase 10

2.6 Economic inputs 11

3 Base case environmental impact assessment 13

3.1 Base case 1: Undercounter water-change 14

3.2 Base case 2: Undercounter one-tank 17

3.3 Base case 3: Hood-type 20

3.4 Base case 4: Utensil/pot 23

3.5 Base case 5: Conveyor-type one-tank 26

3.6 Base case 6: Conveyor-type multi-tank 29

3.7 Conclusions 32

4 Base case life cycle costs 33

5 EU Totals 35

5.1 Market data 35

5.2 Life Cycle Environmental Impacts 35

5.3 Life Cycle Costs 39

6	**EU-27 total system impact**	**41**
7	**Conclusions**	**42**
8	**Annex**	**43**
8.1	**Detailed bills of materials of the six base cases**	**43**
8.2	**Stakeholder feedback to draft versions of Task 5**	**49**

List of tables

Table 1	Description of the base cases	3
Table 2	Composition of the six base cases, by category of materials (packaging included)	5
Table 3	Life cycle impact assessment of missing individual components (part 1), for 1 kg	6
Table 4	Life cycle impact assessment of missing individual components (part 2), for 1 kg	7
Table 5	Volume of packaged product for base cases	7
Table 6	Electricity consumption per year for all base cases	8
Table 7	Water consumption per year for all base cases	9
Table 8	Detergent consumption per year for all base cases	9
Table 9	Travelling effort for maintenance and repair over the product life, by base case	10
Table 10	EcoReport economic inputs of the base cases	11
Table 11	Energy, water and consumables rates, by base case	12
Table 12	Overall improvement ratios for all base cases	12
Table 13	Life Cycle Impact (per unit) of base case 1 – Undercounter water-change	14
Table 14	Life Cycle Impact (per unit) of base case 2 – Undercounter one-tank	17
Table 15	Life Cycle Impact (per unit) of base case 3 – Hood-type	20
Table 16	Life Cycle Impact (per unit) of base case 4 – Utensil/pot	23
Table 17	Life Cycle Impact (per unit) of base case 5 – Conveyor-type one-tank	26
Table 18	Life Cycle Impact (per unit) of base case 6 – Conveyor-type multi-tank	29
Table 19	EcoReport outcomes of the LCC calculations of the six base cases	33
Table 20	Market and technical data for all base cases in 2009	35
Table 21	Environmental impacts of the EU-27 stock in 2009 for all base cases	36
Table 22	Energy consumption of professional dishwashers in the USA, 2008	38
Table 23	Total Annual Consumer expenditure in EU-27 in 2009	40

List of figures

Figure 1	Simplified material flow diagram for life cycle analysis	1
Figure 2	Distribution of environmental impacts of BC 1 per life cycle phase	16
Figure 3	Distribution of environmental impacts of BC 2 per life cycle phase	19
Figure 4	Distribution of environmental impacts of BC 3 per life cycle phase	22
Figure 5	Distribution of environmental impacts of BC 4 per life cycle phase	25
Figure 6	Distribution of environmental impacts of BC 5 per life cycle phase	28
Figure 7	Distribution of environmental impacts of BC 6 per life cycle phase	31
Figure 8	Breakdown of base cases' LCC	34
Figure 9	Base cases' share of the environmental impacts of the stock in 2009	37
Figure 10	Base cases' share of the electricity consumption of the stock in 2009	38
Figure 11	Professional Dishwashers Primary Energy Consumption by Washer Type, in the USA, 2008	39
Figure 12	Base cases' share of the total consumer expenditure in 2009	40

1 Introduction

1.1 Objective of Task 5

For this assessment, one or two average European Union (EU) product(s) have to be defined or a representative product category as the “base case” (BC) for the whole of the EU has to be chosen. On this base case most of the environmental and Life Cycle Cost (LCC) analyses will be built throughout the rest of the study. The base case is a conscious abstraction of reality, necessary one for practical reasons (budget, time). Having said that, the question if this abstraction leads to inadmissible conclusions for certain market segments will be addressed in the impact and sensitivity analysis.

In principle, the aim of a base case assessment is to quantify the environmental impacts of a service or product throughout its life. This includes the extraction of the materials contained within its components, to the disposal of these materials at the end-of-life. The method used to develop these impacts is life cycle analysis (LCA).

First, all incoming and outgoing flows of materials and energy are detailed for each step of the life cycle (manufacturing and design, transport, use, end-of-life). Figure 1 shows an example of how materials and energy flows are summarised for a simplified life cycle analysis.

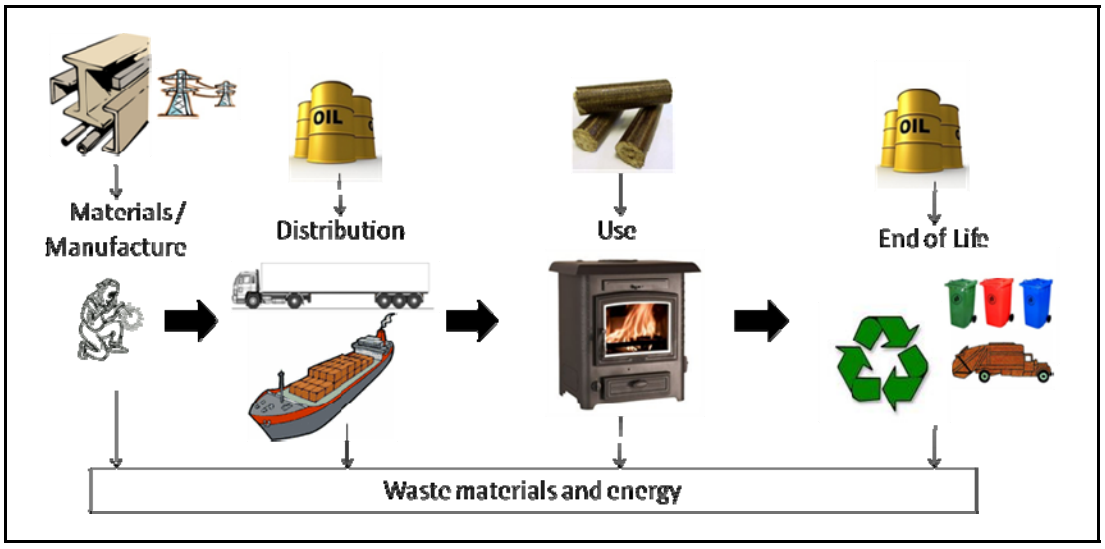


Figure 1 Simplified material flow diagram for life cycle analysis

These material and energy flows are then aggregated over the life time of the product to compute total environmental impacts. These environmental impacts can be expressed in

many different ways, but are expressed in this study with 17 environmental indicators that were predefined for all Ecodesign studies. These indicators will be described in more detail later in the report. As the results are presented through several indicators of environmental impact, the LCA is a multi-criteria approach.

The benefit of the LCA approach is that one can understand all the resources consumed, as well as all the environmental side effects caused by a product. The drawback of this approach is that each product on a market has a different life cycle and it can be difficult to determine the net environmental impact of an entire market or of a range of product groups. To help overcome this problem, BCs are created to represent a theoretical approximation of the 'average' products on the EU market and use these to extrapolate the environmental impacts of the entire market of professional dishwashers.

While this study has been completed as comprehensively and accurately as possible, it relies on data which has been extrapolated from literature and stakeholder input. The performance of real appliances can vary substantially from the data provided in this report. This is understood and mitigated to an extent as much as possible while manipulating and calculating the data during the analysis, however rough approximations are ultimately unavoidable. When assumptions are made, it is also important to assess and check their influence on the final results. Thus, some parameters might have negligible impacts on the overall results so that assumptions can be easily accepted. If that is not the case, the sensitivity analysis in Task 8 will ensure the consistency of the results by studying the influence of the most important parameters. The results of the study are consequently estimated valuable as they represent the best indication to date of the environmental impacts of professional dishwashers in the EU.

The description of the BCs is the synthesis of the results of Tasks 1 to 4. Most of the environmental and life cycle cost analyses are built on these BCs throughout the rest of the study and it serves as the point-of-reference for Task 6 (technical analysis of BAT), Task 7 (improvement potential), and Task 8 (policy, impact and sensitivity analysis).

2 Product-specific inputs

This section describes the technical analysis of typical professional dishwashers which exist on the EU market. This data will cover the production phase, the distribution phase, the use phase and the end-of-life phase. Bill of materials (BOM) and resource consumption during product life are some of the important parameters to be looked at[1]. This will be used as the general input for the base case environmental impact assessment, in section 3.

[1] Necessary input into the EcoReport tool.

Definition of base cases

The objective of this subsection is to define and describe the base cases, based on the previous tasks and the information recovered from stakeholders and literature review. The base cases are "a conscious abstraction of reality" and have to cover the wide variety of existing professional dishwashers in order to be as representative of the EU market as possible. Thus, BCs are not necessarily representative of real products. When two products have similar bill of materials and technical parameters, they may be represented by a single BC. The number of base cases is optimized to be small enough to enable a simplified analysis of the market but large enough to deal with the technological spectrum of professional dishwashers.

Although the MEEuP methodology foresees one or two BCs to cover the entire EU market for the products considered in each preparatory study, in this study six BCs emerged for the dishwasher part only. Such a high number of BCs is necessary to appropriately cover the broad range of technical specifications and functionalities of professional dishwashers. Table 1 gives an overview of the six defined base cases which are products that have already been presented in previous tasks.

Discussions on glasswashers have been held during the interim and final stakeholder meetings[2]. It appears that technical parameters of glasswashers and undercounter one-tank dishwashers are very similar: glasswashers can be considered as smaller capacity undercounter one-tank machines. The global economic and environmental outcomes of base case 2 should be similar to the potential results of a thorough and separate analysis of glasswashers (the absolute values would differ but the base case is supposed to be representative of an EU average).

Table 1 Description of the base cases

Base case	Name	Short Description	Average capacity
BC 1	Undercounter water-change	- Manually loaded program automats, undercounter front loaders with water-change operation - Used for dishes, glasses, cutlery, pots, pans, utensils (semi-commercial and commercial applications)	200 dishes/hour
BC 2	Undercounter one-tank	- Manually loaded program automats, undercounter front loaders with one-tank - Used for mainly plates, glasses, cups, cutlery; also includes specialized glasswashers (commercial applications)	550 dishes/hour

[2] 13th July 2010 in Brussels and 9th December 2010 in Paris
cf. http://www.ecowet-commercial.org/meetings.php

Base case	Name	Short Description	Average capacity
BC 3	Hood-type	- Program automats, one-tank pass through dishwashers - Used for mainly plates, glasses, cups, cutlery (commercial applications)	860 dishes/hour
BC 4	Utensil/Pot	- Universal / warewashing / utensil / pot dishwasher, program automat, front loader or pass through - Used for black cookware and large utensils (commercial applications)	0.42 m^2 (rack area) 20 cycles per hour
BC 5	Conveyor-type one-tank	- Conveyor-type (basket transport system or belt conveyor) with one-tank - Used for plates, glasses, cups, cutlery, trays (heavy commercial applications)	1 750 dishes/hour
BC 6	Conveyor-type multi-tank	- Conveyor-type (basket transport system or belt conveyor) with four zones: one pre-wash zone (one-tank), one main wash zone (one-tank), one rinse zone and one drying zone (no tank). - Used for mainly plates, glasses, cups, cutlery, trays (heavy commercial applications)	3 600 dishes/hour

2.2 Inputs in the production phase

Production phase data related to typical EU professional dishwashers consists of the BOM and the sheet metal scrap generated during production. The BOMs have already been presented in Task 4. In Table 2, they are structured according to the different categories of materials (e.g. bulk plastics, ferrous materials)[3] and packaging material is included.

[3] The full composition can be found in Annex A.

Table 2 Composition of the six base cases, by category of materials (packaging included)

Base case	Unit	1 Bulk Plastics	2 Tech. Plastics	3 Ferro	4 Non-ferro	5 Coating	6 Electronics	7 Misc.	Total
BC 1	g	8 826	1 014	27 266	1 373	0	448	11 769	50 696
	%	17.4	2.0	53.8	2.7	0.0	0.9	23.2	100.0
BC 2	g	8 075	1 500	54 510	5 850	0	500	8 750	79 185
	%	10.2	1.9	68.8	7.4	0.0	0.6	11.1	100.0
BC 3	g	9 465	1 800	98 590	7 700	0	600	17 000	135 155
	%	7.0	1.3	72.9	5.7	0.0	0.4	12.6	100.0
BC 4	g	16 000	4 000	172 000	12 400	0	2 100	19 500	226 000
	%	7.1	1.8	76.1	5.5	0.0	0.9	8.6	100.0
BC 5	g	99 080	6 140	670 210	108 995	0	9 800	79 000	973 225
	%	10.2	0.6	68.9	11.2	0.0	1.0	8.1	100.0
BC 6	g	110 090	18 660	1 042 440	103 700	0	15 400	174 710	1 465 000
	%	7.5	1.3	71.2	7.1	0.0	1.1	11.9	100.0

We notice that all base cases except BC 1 have around 70% of ferrous materials in their BOMs. It is expected that the impacts of the production and manufacturing phases will be mainly due to this category of materials.

Because the EcoReport was initially designed as a simple and generic tool for Ecodesign preparatory studies, its database does not include some materials found in professional dishwashers. These are listed below:

- polybutylene terephthalate (PBT);
- ethylene propylene diene monomer (EPDM) rubber;
- polyoxymethylene (POM);
- chromium;
- cotton (used for acoustic attenuation);
- wood (included in packaging).

When possible, the materials not present in the database have been re-allocated to the most similar materials available:

- EPDM rubber was considered as low density polyethylene (LDPE);
- POM as high density polyethylene (HDPE);
- wood as cardboard.

These equivalent materials were determined based on the composition of the initial materials (“closest” material available in EcoReport): for instance, EPDM is made of around 60% of LDPE usually. The choices were also supported by preliminary environmental analysis (see

Table 3, all results were obtained using the method CML 2 baseline 2000 V2.04). EPDM and LDPE on one hand have very close environmental impacts for most of the indicators. POM was not found in any Life Cycle Inventory and could thus not be compared to HDPE. Cardboard has impacts around twice as more important as wood impacts but this approximation is considered acceptable as soon as packaging is not identified as a major contributor to any type of environmental impact in the base cases analysis.

Table 3 Life cycle impact assessment of missing individual components (part 1), for 1 kg[4]

Impact category	Unit	EPDM rubber	LDPE	Wood	Cardboard
Abiotic depletion	kg Sb eq.	4.33E-02	4.16E-02	3.37E-03	5.71E-03
Acidification	kg SO_2 eq.	2.91E-02	2.74E-02	3.43E-03	7.29E-03
Eutrophication	kg PO_4^{3-} eq.	1.32E-03	1.02E-03	2.71E-04	6.77E-04
Global warming (GWP100)	kg CO_2 eq.	3.24E+00	3.07E+00	-2.41E+00	-1.05E+00
Ozone layer depletion (ODP)	kg CFC-11 eq.	7.94E-06	8.32E-06	2.88E-07	6.79E-07
Photochemical oxidation	kg C_2H_4	1.07E-02	3.92E-03	2.71E-04	3.53E-04

No equivalent materials were found for chromium, cotton and PBT so only the 'category' cell (e.g. bulk plastics, ferrous material) and the weight were completed for these materials. Consequently, the specific impacts due to the nature of the material are not taken into account for these three categories but their weight is nonetheless included in the environmental analysis. This assumption is considered as acceptable since these materials are only found in BC 1 and the share of these material categories in the total weight of the dishwasher is very low (1% altogether).

A preliminary environmental analysis supports this assumption, by showing that these three materials have impacts in the same order of magnitude as (or smaller than) stainless steel (which represents more than 50% of the mass of BC 1) which justifies the fact that these materials are neglected based on the low mass allocated to them (see Table 4, all results were obtained using the method CML 2 baseline 2000 V2.04). Only for the ozone layer depletion indicator, the three materials have much higher impacts than stainless steel but this indicator is not taken into account in EcoReport. PBT was not found in any Life Cycle Inventory so that it was assumed that the impacts of PBT were similar to the ones of PET, to compare with the stainless steel.

[4] All materials from ETH-ESU 96 database

Table 4 Life cycle impact assessment of missing individual components (part 2), for 1 kg[5]

Impact category	Unit	Stainless Steel	PET	Chromium	Cotton
Abiotic depletion	kg Sb eq.	2.35E-02	3.46E-02	1.92E-01	7.92E-02
Acidification	kg SO_2eq.	1.68E-01	9.77E-03	1.02E-01	1.34E-01
Eutrophication	kg PO_4^3eq.	1.22E-03	3.00E-03	7.83E-03	2.81E-02
Global warming (GWP100)	kg CO_2eq.	3.68E+00	2.73E+00	2.65E+01	1.20E+01
Ozone layer depletion (ODP)	kg CFC-11 eq.	5.26E-09	1.21E-07	1.85E-06	3.27E-07
Photochemical oxidation	kg C_2H_4	7.22E-03	6.23E-04	5.54E-03	4.10E-03

Regarding the sheet metal scrap percentage generated during the production phase, a rate of **5%** has been assumed, based on information contained in the preparatory study on washing machines and dishwashers (Lot 14).

2.3 Inputs in the distribution phase

Input data related to the distribution phase of the product to be used in the MEEuP EcoReport calculations are based on the volume of the packaged product. These volumes are exposed in Table 5 below.

Table 5 Volume of packaged product for base cases

Base case	Volume of packaged product (in m^3)
BC 1 Undercounter water-change	0.40
BC 2 Undercounter one-tank	0.48
BC 3 Hood-type	1.03
BC 4 Utensil/Pot	4.95
BC 5 One-tank conveyor-type	12.25
BC 6 Multi-tank conveyor-type	16.58

Two other pieces of information are required in this section. These parameters will be common for all BCs:

- Is it an ICT or Consumer Electronics product <15 kg: **No**
- Is it an installed appliance: **Yes**

[5] All materials from EcoInvent 2.0 database

2.4 Inputs in the use phase

Task 3 has shown that products have different efficiencies whether ideal user behaviour or real-life user behaviour is considered. According to Task 1, no EU or national standard is currently used to measure the energy, water or detergent consumption/efficiency of professional dishwashers. The analysis of the environmental impacts of the use phase is based on the real-life consumption of energy, water and detergent in each category. Based on the ideal use, the data takes into account the consumption for initial filling, the consumption in standby mode and the additional consumption through real-life user behaviour (partial workload, deviation from the use of the standard programs and mal-operation, see Task 3).

Besides, all BCs are considered having only cold water input and an electrical heating system as these options are the most commonly found. This ensures that most of the improvement options considered later will be applicable for implementation on the BCs (for instance, a heat pump system is only relevant for a machine with a cold water input). Furthermore, the infrastructure for the alternatives to electrical heating (warm water supply, heating with steam or hot water) is not available in every place.

2.4.1 Electricity consumption

The electricity consumption during the use phase (see Task 3 and 4) is expected to be a major contributor to the environmental impacts of a professional dishwasher. The annual electricity consumption is required as an input in EcoReport, as well as the product lifetime which was evaluated in the market analysis (see Task 2). These inputs will also be used to calculate the Life Cycle Costs (LCC) of the BCs.

Table 6 presents the annual electricity consumption of the six BCs.

Table 6 Electricity consumption per year for all base cases

Base case	Total Electricity consumption (in kWh per year)
BC 1 Undercounter water-change	1 254
BC 2 Undercounter one-tank	5 253
BC 3 Hood-type	8 258
BC 4 Utensil/Pot	8 913
BC 5 One-tank conveyor-type	37 703
BC 6 Multi-tank conveyor-type	102 229

2.4.2 Water consumption

Table 7 presents the annual water consumption of the six base cases (cf. Task 3 and 4).

Table 7 Water consumption per year for all base cases

Base case	Water consumption (in m^3 per year)
BC 1 Undercounter water-change	25.92
BC 2 Undercounter one-tank	55.82
BC 3 Hood-type	86.65
BC 4 Utensil/Pot	89.52
BC 5 One-tank conveyor-type	255.68
BC 6 Multi-tank conveyor-type	643.64

2.4.3 Detergent and rinse aid consumption

Table 8 presents the annual detergent consumption of the six base cases (cf. Task 3 and 4).

Table 8 Detergent consumption per year for all base cases

Base case	Detergent consumption (in kg per year)
BC 1 Undercounter water-change	87
BC 2 Undercounter one-tank	188
BC 3 Hood-type	292
BC 4 Utensil/Pot	294
BC 5 One-tank conveyor-type	865
BC 6 Multi-tank conveyor-type	2 146

2.4.4 Travelling effort for maintenance and repair over the product life

The number of kilometres travelled for maintenance and repair for one machine was estimated to be proportional to the product price of the appliance, according to discussions during the final stakeholder meeting. 200 km was taken as a basis for BC 2, in order to extrapolate linearly the other figures. Therefore it varies for each BC but the influence of this parameter on the outcomes of the environmental analysis is low. Table 9 presents the input figures by BC.

Table 9 Travelling effort for maintenance and repair over the product life, by base case

Base case	Number of kilometres
BC 1 Undercounter water-change	183
BC 2 Undercounter one-tank	200
BC 3 Hood-type	269
BC 4 Utensil/Pot	600
BC 5 One-tank conveyor-type	857
BC 6 Multi-tank conveyor-type	2 571

2.5 Inputs in the end-of-life phase

None of the BCs contains dangerous substances that can be released into the environment during the end-of-life phase, e.g. refrigerant or mercury. According to stakeholder feedback, the use of silver ions due to their antimicrobial properties is not applied anymore. Due to warnings from the German Bundesinstitut für Risikobewertung BfR (Federal Institute for Risk Assessment)[6], especially for nano silver, the market seems to rethink. Possible harmful aspects, resistances of bacteria, and missing comprehensive data to allow conclusive risk assessments are the main reasons for the warnings (for more details see also Task 4).

Heat pumps for heat recovery are considered as improvement options so the refrigerants these devices contain will be taken into account in Tasks 6 and 7 only. Reflection of the market in Task 6 supports this consideration: heat pumps are usually not yet applied in smaller dishwasher categories due to lower profitability. With high-throughput machines (conveyor-type), the profitability is better, but pumps for heat recovery are still usually offered only as an option, and not as standard equipment. Therefore, they do not have a significant market share and it is justified that they are not included into the BCs.

It is assumed that an important share of the professional dishwashers' materials are recycled and reused. We assumed that during the end-of-life phase (cf. Task 4):

- 5% by weight of the products are not recovered (i.e. go to landfill)
- 95% by weight recovery rate; the materials follow one of the following options:
  - Metals are recycled;
  - Paper, cardboard, and plastics are incinerated (thermal recycling with possible benefits of energy recovery) or mechanically recycled. Plastics may also be directly reused;

6 More information at www.bfr.bund.de

– Other types of waste (concrete, bitumen) go to landfill. Hazardous waste consists only of electronic components, which are considered easy to disassemble and are in limited quantity (around 1% of the total weight).

Regarding the plastic fraction, the following end-of-life management options were estimated for all BCs, based on stakeholders' feedback:

- Re-use, closed loop recycling: 1%
- Material (or mechanical) recycling: 29%
- Thermal recycling: 70%.

2.6 Economic inputs

Economic data used for the calculations of the LCCs were elaborated in Task 2 (in particular product lifetime and product prices, electricity rates, and water and consumables rates). The product prices were estimated with the data aggregation used for the definition of the BCs and based on stakeholders' comments.

Table 10 presents the lifetimes, sales and stock figures and product prices for all six BCs. The installation of the dishwashers is taken into account in the product price so that there are no separate installation costs. The disposal costs were considered to be zero, as the machines are never landfilled but taken care of by recyclers.

Table 10 EcoReport economic inputs of the base cases

Base case	Product lifetime (in years)	Sales (units)	Stock (units)	Product price (in €)	Maintenance costs (in €)
BC 1 Undercounter water-change	12	20 000	207 223	3 200	1 200
BC 2 Undercounter one-tank	8	138 200	1 012 355	3 500	1 540
BC 3 Hood-type	8	65 900	482 728	4 700	2 068
BC 4 Utensil/Pot	8	2 600	19 309	10 500	4 620
BC 5 One-tank conveyor-type	12	6 600	68 425	15 000	6 600
BC 6 Multi-tank conveyor-type	17	1 300	18 015	45 000	19 800

The running costs will be calculated based on the user behaviour and the consumables rates presented in Table 11.

Table 11 Energy, water and consumables rates, by base case

Base case	Electricity rate (Euro/kWh)	Gas rate (Euro/GJ)	Water rate (Euro/m^3)	Detergent/Rinse aid rate (Euro/kg)
BC 1 Undercounter water-change	0.138	11.21	2.64	3.00
BC 2 Undercounter one-tank				
BC 3 Hood-type	0.105	10.01		
BC 4 Utensil/pot				
BC 5 One-tank conveyor-type	0.090	8.79		
BC 6 Multi-tank conveyor-type				

The discount rate was provided by the European Commision: **4%** will be used for all BCs.

There is a significant efficiency difference between the appliances being sold today and the appliances being used in the stock. This is a direct result from the steady progress that the industry has been making in environmental efficiency, combined with the quite long lifetimes of products in this study. This could lead to an underestimation of the environmental impacts of the products in this study as the BCs all represent products currently sold on the market. The overall improvement ratios (market over stock, during use phase) which are required in EcoReport are used here as correction factors for this parameter. They were calculated from data presented in Task 2 and reminded in Table 12. For each BC, this improvement ratio indicates the difference of global efficiency during the use phase between the new sales and the current stock. We assumed that a representative product of the current stock was “half the product lifetime” old (e.g. 4 years for hood-type dishwashers) and we scaled down (proportionally) the global improvement exposed in Table 12, which is related to a ten years gap. For BC 1, a ratio of 1.00 was considered as manufacturers stated that these products have not really changed in the past decade.

Table 12 Overall improvement ratios for all base cases

Base case	Improvement between ten year old product and new product			Overall improvement ratio
	Energy consumption	Water consumption	Global improvement[7]	
BC 1 Undercounter water-change	-	-	-	1.00
BC 2 Undercounter one-tank	30%	16%	23%	1.09
BC 3 Hood-type	29%	16%	22.5%	1.09
BC 4 Utensil/Pot	29%	20%	24.5%	1.10
BC 5 One-tank conveyor-type	37%	35%	36%	1.22
BC 6 Multi-tank conveyor-type	37%	33%	35%	1.30

[7] Simple average between energy and water consumptions.

3 Base case environmental impact assessment

The aim of this subtask is to assess the environmental impact of each base case following the MEEuP (EcoReport Unit Indicators) for each life cycle stage:

- Raw Materials Use and Manufacturing (Production phase);
- Distribution;
- Use;
- End-of-Life.

The base case environmental impact assessment will lead to an identification of basic technological design parameters being of outstanding environmental relevancy[8]. These parameters will be listed as they will serve as an important input to the identification of eco-design options. The assessment results are tracked back to the main contributing components, materials and features of the professional dishwashers.

Seventeen environmental indicators are considered in EcoReport. Of these, 13 are relevant to professional dishwashers, while others have none to very little impact:

- Total Gross Energy Requirement, in MJ primary;
- Electricity, in kWh_e;
- Process Water, in litre;
- Hazardous Solid Waste, in g;
- Non-hazardous waste, in g;
- Global Warming Potential (GWP), in CO_2 equivalent;
- Acidification potential, in SO_2 equivalent;
- Volatile Organic Compounds (VOC), in mg;
- Persistent Organic Pollutants (POP), in I-Teq;
- Heavy Metals (HM), in Nickel equivalent;
- Polycyclic Aromatic Hydrocarbons (PAH), in Nickel equivalent;
- Particulate Matter;
- Eutrophication Potential, in PO_4 equivalent.

[8] As far as the MEEuP EcoReport allows the identification of such indicators.

3.1 Base case 1: Undercounter water-change

Table 13 shows the environmental impacts of an undercounter water-change dishwasher over its whole life cycle. The total energy consumption for the whole life cycle of the BC 1 is 196.5 GJ, of which 159 GJ (i.e. 15.1 MWh_e) electricity.[9]

Table 13 Life Cycle Impact (per unit) of base case 1 – Undercounter water-change

Nr	Life cycle Impact per product:								Date	Author	
1	Under counter, w ater change									BIO	
	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	**Total**	**BUTION**		Disposal	Recycl.	**Total**	
	Materials	**unit**									
1	Bulk Plastics	g			**8523**			5966	2557	**8523**	**0**
2	TecPlastics	g			**1014**			710	304	**1014**	**0**
3	Ferro	g			**27266**			1363	25903	**27266**	**0**
4	Non-ferro	g			**1302**			65	1237	**1302**	**0**
5	Coating	g			**0**			0	0	**0**	**0**
6	Electronics	g			**448**			448	0	**448**	**0**
7	Misc.	g			**11317**			566	10751	**11317**	**0**
	Total weight	g			**49870**			9118	40752	**49870**	**0**
	Other Resources & Waste							see note! debet	credit		
8	Total Energy (GER)	MJ	3274	792	**4066**	**496**	**191896**	641	587	**54**	**196511**
9	of w hich, electricity (in primary MJ)	MJ	592	474	**1066**	**1**	**158015**	0	11	**-11**	**159071**
10	Water (process)	ltr	2246	7	**2253**	**0**	**322392**	0	7	**-7**	**324637**
11	Water (cooling)	ltr	1199	221	**1420**	**0**	**421358**	0	58	**-58**	**422720**
12	Waste, non-haz./ landfill	g	48858	2660	**51518**	**233**	**222449**	3117	41	**3076**	**277276**
13	Waste, hazardous/ incinerated	g	350	0	**350**	**5**	**4414**	6676	6	**6670**	**11439**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	220	44	**265**	**31**	**8390**	48	36	**12**	**8697**
15	Ozone Depletion, emissions	mg R-11 eq.	negligible								
16	Acidification, emissions	g SO2 eq.	2043	190	**2233**	**92**	**49402**	98	50	**48**	**51776**
17	Volatile Organic Compounds (VOC)	g	56	0	**56**	**8**	**80**	2	1	**1**	**145**
18	Persistent Organic Pollutants (POP)	ng i-Teq	222	14	**236**	**1**	**1257**	22	0	**22**	**1516**
19	Heavy Metals	mg Ni eq.	3793	32	**3825**	**12**	**3417**	175	0	**175**	**7429**
	PAHs	mg Ni eq.	172	0	**173**	**20**	**474**	0	1	**-1**	**666**
20	Particulate Matter (PM, dust)	g	1844	29	**1874**	**1367**	**2686**	878	2	**876**	**6803**
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	2427	0	**2427**	**0**	**1043**	52	0	**52**	**3523**
22	Eutrophication	g PO4	71	0	**72**	**0**	**55965**	3	0	**3**	**56039**
23	Persistent Organic Pollutants (POP)	ng i-Teq	negligible								

Figure 2 exposes the contribution of each life cycle phase to each impact. The total impact of a category is shown as 100%, but it does not mean that each of the impacts in each category

9 In MEEuP, a conversion factor of 10.5 MJ/kWh_e for the public grid is specified.

is equally important. The categories are not comparable. Several observations can be made from this analysis:

- Within the production phase, the manufacturing impacts are very small: the maximum contribution is 1% in non-hazardous waste, because of the sheet metal and plastic scrap generated during the manufacturing process. The material extraction and production are responsible for the important contributions of this phase to the quantity of landfilled waste (18%) because of the general metal content, VOC (38%) emissions and PM (27%) because of the bitumen content and HM (51%) and POP (15%) emissions because of the stainless steel contained in the product.
- As expected, the use phase is by far the main contributor to the following impacts: total energy (97.7%) and electricity consumption (99.3%), water for processing (99.3%), non-hazardous waste (80%), greenhouse gases emissions (96%), acidification (95%), POP (83%), PAHs (71%) and eutrophication (99.8%). The water use during the use phase is the main contributor for the water processing impact. The detergent is the source of almost 100% of the eutrophication impact during the use phase, and also makes a slight contribution for waste generation, GWP and POP emissions. The maintenance and repair services are the main reason for the PM and PAHs emissions because of the travels. For the remaining shares, the electricity consumption is the main source for the impacts especially total energy and electricity, GWP and acidification.
- The distribution phase is negligible for all impacts except for PM for which it accounts for around 20% of the total emissions, and for VOC emissions (6%). This is due to the product transportation.
- The end-of-life is also negligible for all impacts except for the generation of hazardous waste (58%) and PM (13%). This is due to the high recycling rate (because of the plastics and metals content) which partly counterbalances the negative impacts of incinerating or landfilling the few non recyclable materials. When the red bar is placed below the x-axis on the figure, it means that the end-of-life actually results in a small credit in the impact category considered: in particular, this is the case for energy and electricity consumption.

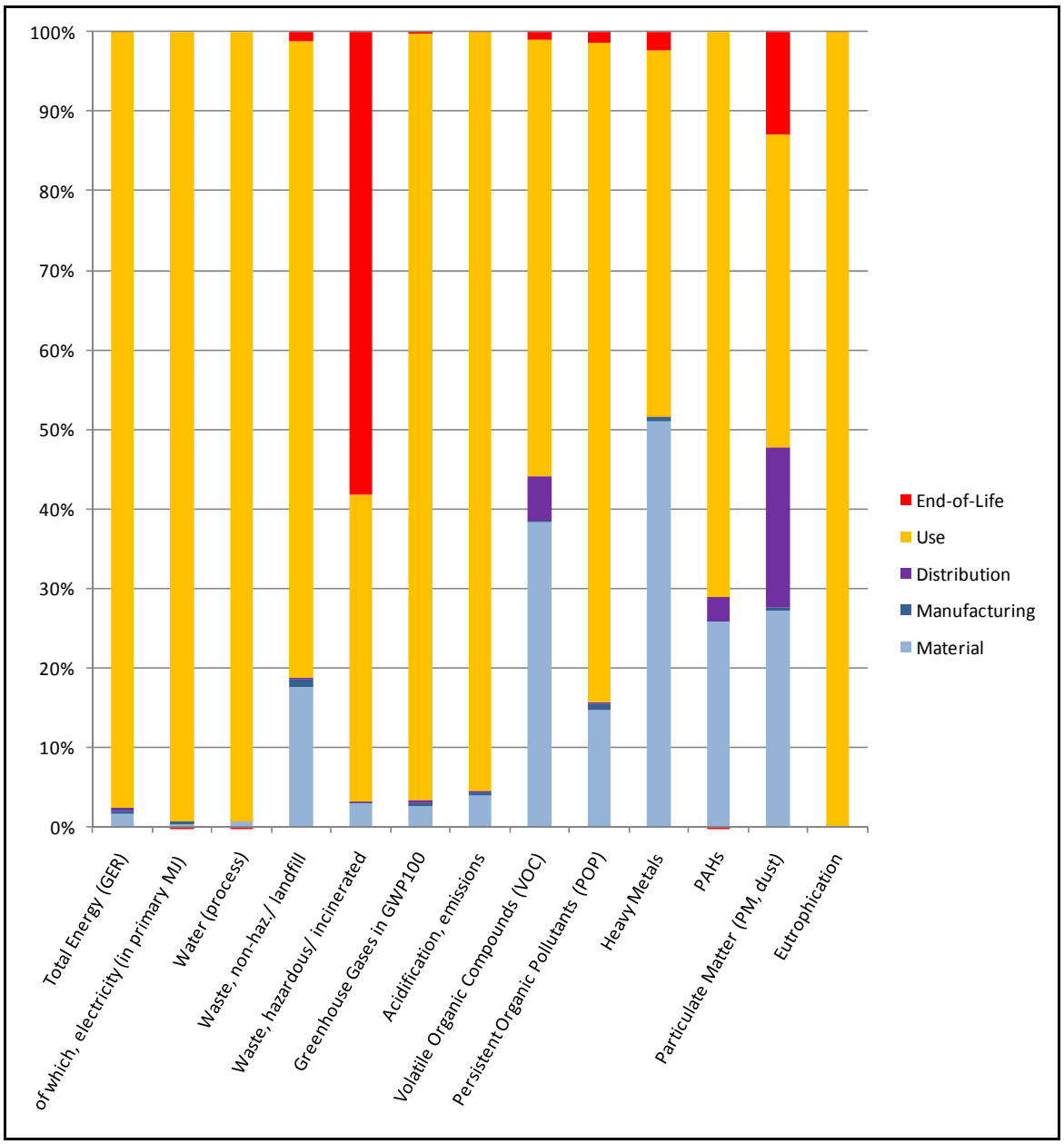


Figure 2 Distribution of environmental impacts of BC 1 per life cycle phase

3.2 Base case 2: Undercounter one-tank

Table 14 shows the environmental impacts of an undercounter one-tank dishwasher over its whole life cycle. The total energy consumption for the whole life cycle of the BC 2 is 497 GJ, of which 443 GJ (i.e. 42.2 MWh_e) electricity.

Table 14 Life Cycle Impact (per unit) of base case 2 – Undercounter one-tank

Nr	Life cycle Impact per product:								Date	Author		
2	Under counter, one tank									BIO		
	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL	
	Resources Use and Emissions		Material	Manuf.	**Total**	**BUTION**		Disposal	Recycl.	**Total**	
	Materials	**unit**									
1	Bulk Plastics	g			**8075**			5653	2423	**8075**	**0**
2	TecPlastics	g			**1500**			1050	450	**1500**	**0**
3	Ferro	g			**54510**			2726	51785	**54510**	**0**
4	Non-ferro	g			**5850**			293	5558	**5850**	**0**
5	Coating	g			**0**			0	0	**0**	**0**
6	Electronics	g			**500**			500	0	**500**	**0**
7	Misc.	g			**8750**			438	8313	**8750**	**0**
	Total weight	g			**79185**			10658	68527	**79185**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	5392	1284	**6676**	**585**	**489932**	740	715	**26**	**497218**
9	of which, electricity (in primary MJ)	MJ	928	766	**1694**	**1**	**441269**	0	11	**-11**	**442954**
10	Water (process)	ltr	4328	11	**4339**	**0**	**477182**	0	7	**-7**	**481514**
11	Water (cooling)	ltr	1410	355	**1765**	**0**	**1176690**	0	58	**-58**	**1178396**
12	Waste, non-haz./ landfill	g	106962	4428	**111389**	**269**	**568526**	4863	41	**4822**	**685007**
13	Waste, hazardous/ incinerated	g	390	0	**390**	**5**	**11281**	6703	6	**6696**	**18373**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	422	72	**494**	**36**	**21399**	55	45	**10**	**21938**
15	Ozone Depletion, emissions	mg R-11 eq.	negligible								
16	Acidification, emissions	g SO2 eq.	3905	309	**4214**	**108**	**126177**	112	62	**51**	**130550**
17	Volatile Organic Compounds (VOC)	g	12	0	**12**	**10**	**192**	2	1	**2**	**216**
18	Persistent Organic Pollutants (POP)	ng i-Teq	475	31	**505**	**2**	**3213**	34	0	**34**	**3753**
19	Heavy Metals	mg Ni eq.	7908	72	**7980**	**14**	**8580**	204	0	**204**	**16777**
	PAHs	mg Ni eq.	331	0	**331**	**24**	**1071**	0	1	**-1**	**1426**
20	Particulate Matter (PM, dust)	g	496	48	**544**	**1641**	**4461**	1007	2	**1005**	**7651**
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	4965	0	**4966**	**0**	**2895**	61	0	**61**	**7921**
22	Eutrophication	g PO4	136	1	**137**	**0**	**80631**	3	0	**3**	**80771**
23	Persistent Organic Pollutants (POP)	ng i-Teq	negligible								

Figure 3 exposes the contribution of each life cycle phase to each impact. Several observations can be made from this analysis:

- Within the production phase, the manufacturing impacts are very small: the maximum contribution is 0.8% in POP emissions, because of the sheetmetal scrap generated

during the manufacturing process. The material extraction and production are responsible for the important contributions of this phase to the quantity of landfilled waste (16%) because of the general metal content, POP (13%) and HM (47%) emissions because of the stainless steel contained in the product and PAH emissions (23%) because of the aluminium parts.

- As expected, the use phase is by far the main contributor to the following impacts: total energy (98.5%) and electricity consumption (99.6%), water for processing (99%), non-hazardous waste (83%), greenhouse gases emissions (97.5%), acidification (97%), POP (86%), PAHs (75%) and eutrophication (99.8%). The water use during the use phase is the main contributor for the water processing impact. The detergent is the source of almost 100% of the eutrophication impact during the use phase, and also makes a slight contribution (around 10%) for waste generation, GWP and POP emissions. The maintenance and repair services are the main reason for the PM emissions because of the travels. For the remaining shares, the electricity consumption is the main source for the impacts, especially total energy and electricity, GWP and acidification.
- The distribution phase is negligible for all impacts except for PM for which it accounts for around 21% of the total emissions, and for VOC emissions (5%). This is due to the product transportation.
- The end-of-life is also negligible for all impacts except for the generation of hazardous waste (36%) and PM (13%). This is due to the high recycling rate (because of the plastics and metals content) which partly counterbalances the negative impacts of incinerating or landfilling the few non recyclable materials. When the red bar is placed below the x-axis on the figure, it means that the end-of-life actually results in a small credit in the impact category considered: in particular, this is the case for energy and electricity consumption.

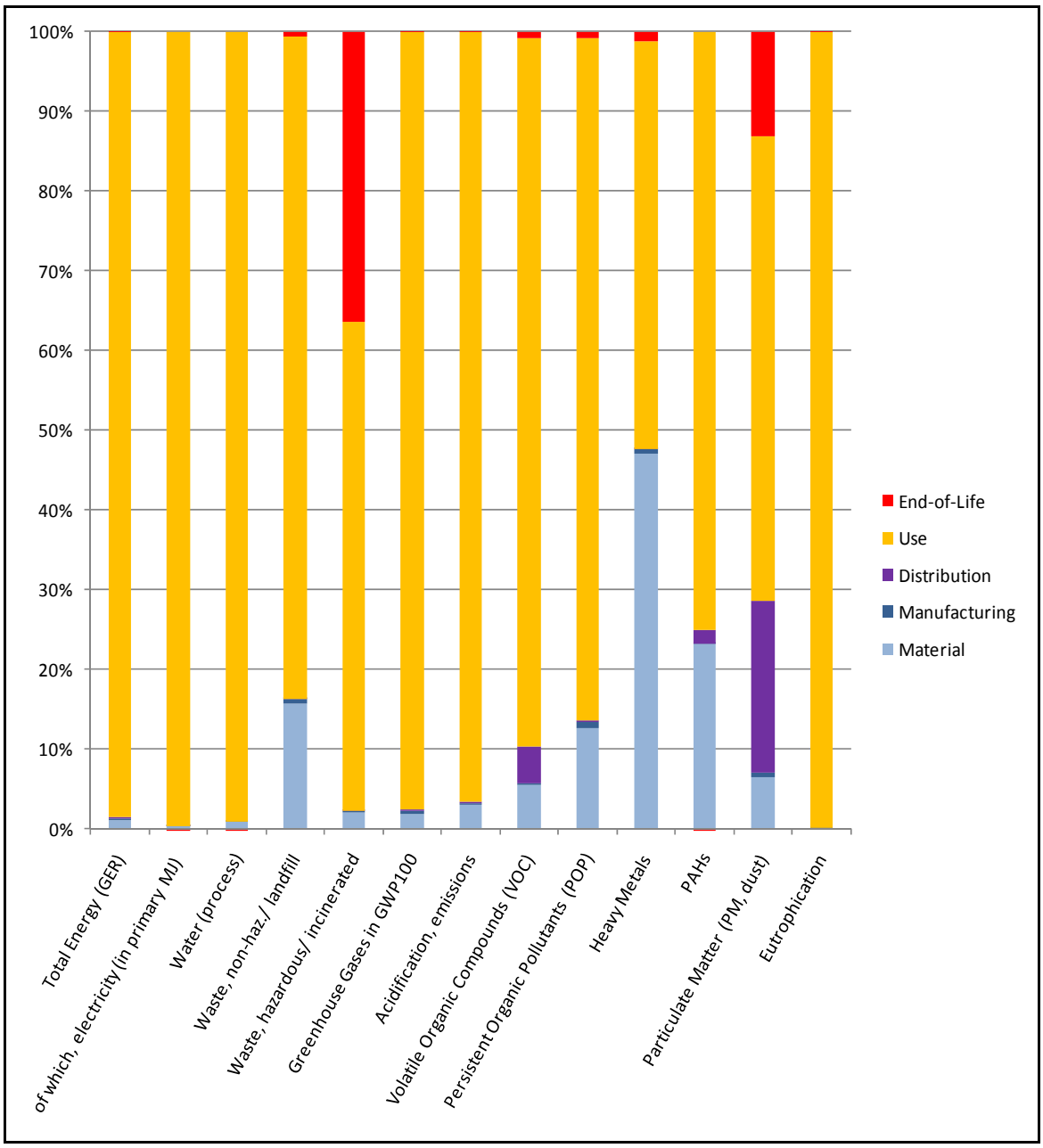


Figure 3 Distribution of environmental impacts of BC 2 per life cycle phase

3.3 Base case 3: Hood-type

Table 15 shows the environmental impacts of a hood-type dishwasher over its whole life cycle. The total energy consumption for the whole life cycle of the BC 3 is 781 GJ, of which 696 GJ (i.e. 66.3 MWh_e) electricity. This BC presents a very close impact profile to base case 2, due to their technical and composition similarities.

Table 15 Life Cycle Impact (per unit) of base case 3 – Hood-type

Nr	Life cycle Impact per product:								Date	Author	
3	Hood type									BIO	
	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	g			**9465**			6626	2840	**9465**	**0**
2	TecPlastics	g			**1800**			1260	540	**1800**	**0**
3	Ferro	g			**98590**			4930	93661	**98590**	**0**
4	Non-ferro	g			**7700**			385	7315	**7700**	**0**
5	Coating	g			**0**			0	0	**0**	**0**
6	Electronics	g			**600**			600	0	**600**	**0**
7	Misc.	g			**17000**			850	16150	**17000**	**0**
	Total weight	g			**135155**			14650	120505	**135155**	**0**
	Other Resources & Waste							see note! debet	credit		
8	Total Energy (GER)	MJ	8786	2058	**10844**	**1195**	**769186**	1014	1005	**9**	**781234**
9	of which, electricity (in primary MJ)	MJ	1449	1227	**2676**	**3**	**693699**	0	12	**-12**	**696365**
10	Water (process)	ltr	7750	18	**7768**	**0**	**741302**	0	8	**-8**	**749062**
11	Water (cooling)	ltr	1892	567	**2459**	**0**	**1849817**	0	69	**-69**	**1852207**
12	Waste, non-haz./ landfill	g	170577	7173	**177750**	**519**	**892728**	8296	48	**8247**	**1079244**
13	Waste, hazardous/ incinerated	g	468	0	**468**	**10**	**17712**	7886	8	**7878**	**26068**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	723	115	**838**	**72**	**33592**	76	66	**10**	**34511**
15	Ozone Depletion, emissions	mg R-11eq.	negligible								
16	Acidification, emissions	g SO2 eq.	6682	496	**7178**	**218**	**198119**	153	88	**65**	**205581**
17	Volatile Organic Compounds (VOC)	g	19	1	**20**	**21**	**300**	3	1	**2**	**344**
18	Persistent Organic Pollutants (POP)	ng i-Teq	828	55	**883**	**3**	**5046**	57	0	**57**	**5989**
19	Heavy Metals	mg Ni eq.	14433	128	**14561**	**26**	**13469**	282	0	**282**	**28338**
	PAHs	mg Ni eq.	417	0	**417**	**48**	**1658**	0	1	**-1**	**2122**
20	Particulate Matter (PM, dust)	g	861	76	**937**	**3521**	**6608**	1372	3	**1369**	**12435**
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	8891	0	**8891**	**1**	**4562**	83	0	**83**	**13536**
22	Eutrophication	g PO4	238	1	**239**	**0**	**125236**	5	0	**4**	**125479**
23	Persistent Organic Pollutants (POP)	ng i-Teq	negligible								

Figure 4 exposes the contribution of each life cycle phase to each impact. Several observations can be made from this analysis:

- Within the production phase, the manufacturing impacts are very small: the maximum contribution is 0.9% in POP emissions, because of the sheet metal scrap generated during the manufacturing process. The material extraction and production are responsible for the important contributions of this phase to the quantity of landfilled waste (16%) because of the general metal content, POP (14%) and HM (51%) emissions because of the stainless steel contained in the product and PAH emissions (20%) because of the aluminium parts.
- As expected, the use phase is by far the main contributor to the following impacts: total energy (98.5%) and electricity consumption (99.6%), water for processing (99.0%), non-hazardous waste (83%), greenhouse gases emissions (97.3%), acidification (96.3%), POP (84%), PAHs (78%) and eutrophication (99.8%). The water use during the use phase is the main contributor for the water processing impact. The detergent is the source of almost 100% of the eutrophication impact during the use phase, and also makes a slight contribution (around 10%) for waste generation, GWP and POP emissions. The maintenance and repair services are the main reason for the PM emissions because of the travels. For the remaining shares, the electricity consumption is the main source for the impacts, especially total energy and electricity, GWP and acidification.
- The distribution phase is negligible for all impacts except for PM for which it accounts for around 28% of the total emissions, and for VOC emissions (6%). This is due to the product transportation.
- The end-of-life is also negligible for all impacts except for the generation of hazardous waste (30%) and PM (11%). This is due to the high recycling rate (because of the plastics and metals content) which partly counterbalances the negative impacts of incinerating or landfilling the few non recyclable materials. When the red bar is placed below the x-axis on the figure, it means that the end-of-life actually results in a small credit in the impact category considered: in particular, this is the case for energy and electricity consumption.

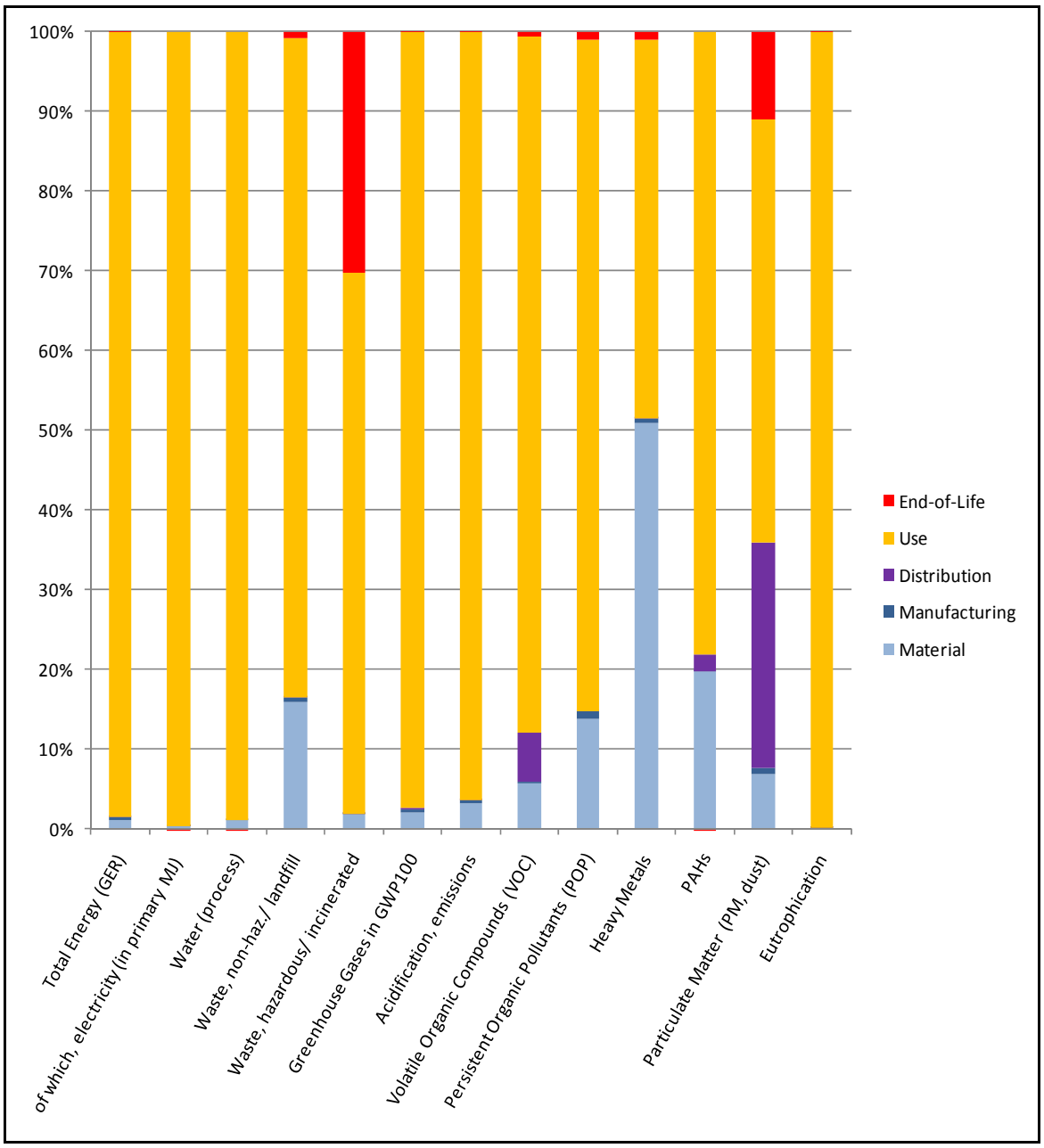


Figure 4 Distribution of environmental impacts of BC 3 per life cycle phase

3.4 Base case 4: Utensil/pot

Table 16 shows the environmental impacts of a utensil/pot dishwasher over its whole life cycle. The total energy consumption for the whole life cycle of the BC 4 is 851 GJ, of which 754 GJ (i.e. 71.8 MWh_e) electricity.

Table 16 Life Cycle Impact (per unit) of base case 4 – Utensil/pot

Nr	Life cycle Impact per product:							Date	Author		
4	Utensil/Pot								BIO		
	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	g			**16000**			11200	4800	**16000**	**0**
2	TecPlastics	g			**4000**			2800	1200	**4000**	**0**
3	Ferro	g			**172000**			8600	163400	**172000**	**0**
4	Non-ferro	g			**12400**			620	11780	**12400**	**0**
5	Coating	g			**0**			0	0	**0**	**0**
6	Electronics	g			**2100**			2100	0	**2100**	**0**
7	Misc.	g			**19500**			975	18525	**19500**	**0**
	Total weight	g			**226000**			26295	199705	**226000**	**0**
								see note!			
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	15858	3617	**19475**	**5549**	**825601**	1753	1657	**96**	**850720**
9	of which, electricity (in primary MJ)	MJ	3150	2157	**5306**	**14**	**748745**	0	22	**-22**	**754044**
10	Water (process)	ltr	14090	32	**14121**	**0**	**768006**	0	15	**-15**	**782113**
11	Water (cooling)	ltr	3310	997	**4306**	**0**	**1996555**	0	122	**-122**	**2000740**
12	Waste, non-haz./ landfill	g	284834	12602	**297436**	**2297**	**958311**	13873	86	**13787**	**1271831**
13	Waste, hazardous/ incinerated	g	1518	1	**1518**	**46**	**19002**	14000	14	**13987**	**34552**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	1316	202	**1518**	**328**	**36084**	131	107	**23**	**37953**
15	Ozone Depletion, emissions	mg R-11eq.	negligible								
16	Acidification, emissions	g SO2 eq.	12000	872	**12872**	**1002**	**212538**	265	144	**121**	**226533**
17	Volatile Organic Compounds (VOC)	g	43	1	**44**	**102**	**334**	6	2	**4**	**484**
18	Persistent Organic Pollutants (POP)	ng i-Teq	1441	96	**1536**	**13**	**5416**	96	0	**96**	**7061**
19	Heavy Metals	mg Ni eq.	25396	224	**25621**	**117**	**14704**	487	0	**487**	**40928**
	PAHs	mg Ni eq.	719	0	**719**	**220**	**1942**	0	1	**-1**	**2881**
20	Particulate Matter (PM, dust)	g	1518	134	**1652**	**16920**	**9840**	2373	4	**2369**	**30781**
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	16005	0	**16006**	**4**	**4987**	144	0	**144**	**21140**
22	Eutrophication	g PO4	412	2	**414**	**0**	**126097**	8	1	**8**	**126518**
23	Persistent Organic Pollutants (POP)	ng i-Teq	negligible								

Figure 5 exposes the contribution of each life cycle phase to each impact. Several observations can be made from this analysis:

- Within the production phase, the manufacturing impacts are very small: the maximum contribution is 1.4% in POP emissions, because of the sheet metal scrap generated during the manufacturing process. The material extraction and production are responsible for the important contributions of this phase to the quantity of landfilled waste (22%) because of the general metal content, POP (20%) and HM (62%) emissions because of the stainless steel contained in the product and PAH emissions (25%) because of the aluminium parts.
- As expected, the use phase is by far the main contributor to the following impacts: total energy (97.0%) and electricity consumption (99.3%), water for processing (98.2%), non-hazardous waste (75%), greenhouse gases emissions (95%), acidification (94%), POP (77%), PAHs (67%) and eutrophication (99.7%). The water use during the use phase is the main contributor for the water processing impact. The detergent is the source of almost 100% of the eutrophication impact during the use phase, and also makes a slight contribution (around 10%) for waste generation, GWP and POP emissions. The maintenance and repair services are the main reason for the PM emissions because of the travels. For the remaining shares, the electricity consumption is the main source for the impacts, especially total energy and electricity, GWP and acidification.
- The distribution phase is negligible for all impacts except for PM for which it accounts for around 55% of the total emissions, and for VOC (21%) and PAHs (8%) emissions. This is due to the product transportation.
- The end-of-life is also negligible for all impacts except for the generation of hazardous waste (40%) and PM (8%). This is due to the high recycling rate (because of the plastics and metals content) which partly counterbalances the negative impacts of incinerating or landfilling the few non recyclable materials. When the red bar is placed below the x-axis on the figure, it means that the end-of-life actually results in a small credit in the impact category considered: in particular, this is the case for energy and electricity consumption.

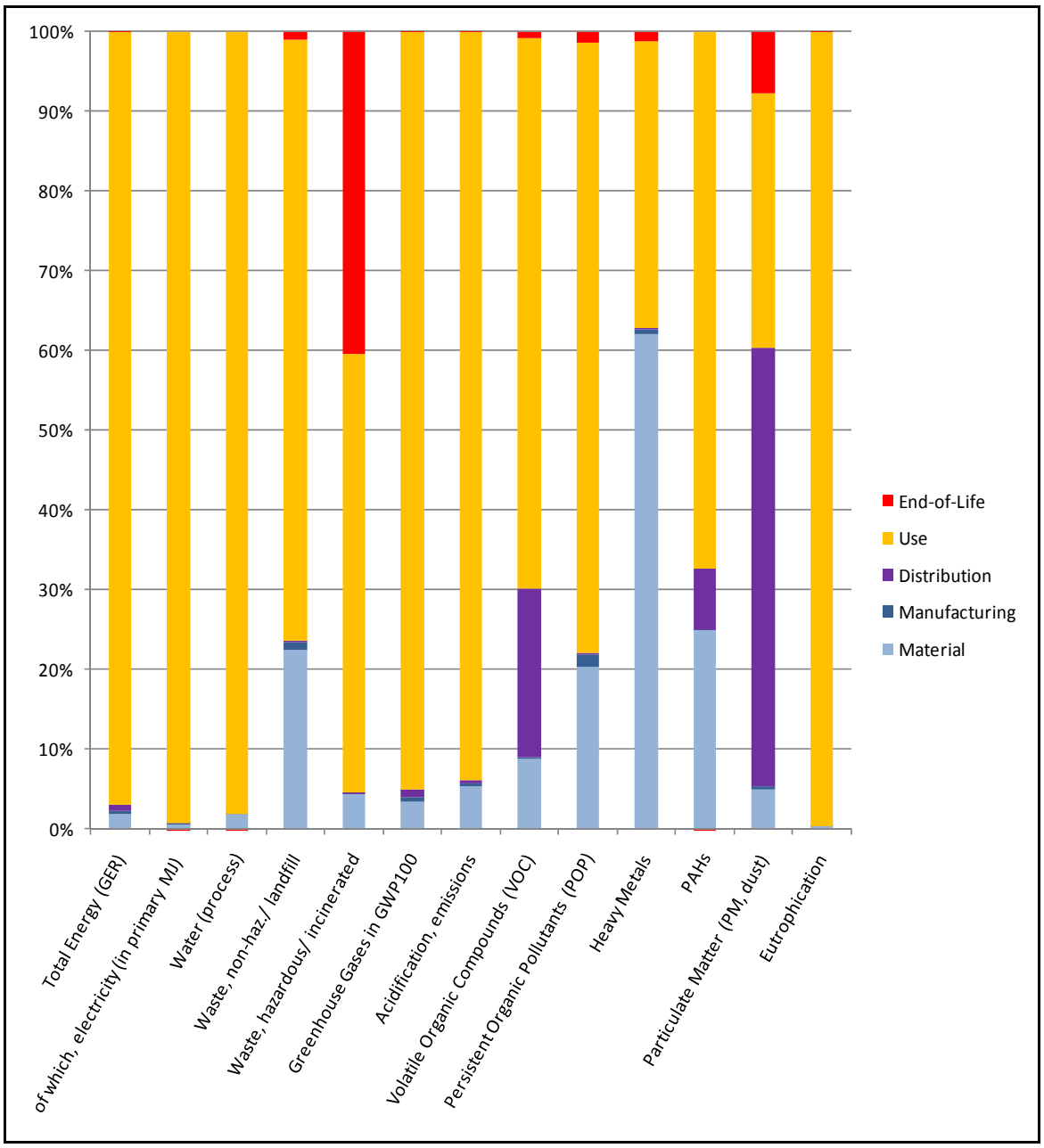


Figure 5 Distribution of environmental impacts of BC 4 per life cycle phase

3.5 Base case 5: Conveyor-type one-tank

Table 17 shows the environmental impacts of a conveyor-type one-tank dishwasher over its whole life cycle. The total energy consumption for the whole life cycle of the BC 5 is 5.19 TJ, of which 4.77 GJ (i.e. 454 MWh_e) electricity.

Table 17 Life Cycle Impact (per unit) of base case 5 – Conveyor-type one-tank

Nr	Life cycle Impact per product:							Date	Author		
5	One-tank conveyor-type								BIO		
	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	g			**99080**			69356	29724	**99080**	**0**
2	TecPlastics	g			**6140**			4298	1842	**6140**	**0**
3	Ferro	g			**670210**			33511	636700	**670210**	**0**
4	Non-ferro	g			**108995**			5450	103545	**108995**	**0**
5	Coating	g			**0**			0	0	**0**	**0**
6	Electronics	g			**9800**			9800	0	**9800**	**0**
7	Misc.	g			**79000**			3950	75050	**79000**	**0**
	Total weight	g			**973225**			126364	846861	**973225**	**0**
	Other Resources & Waste							see note! debet	credit		
8	Total Energy (GER)	MJ	72236	15895	**88131**	**13657**	**5085707**	8487	7817	**669**	**5188164**
9	of which, electricity (in primary MJ)	MJ	13195	9484	**22679**	**35**	**4750805**	0	116	**-116**	**4773403**
10	Water (process)	ltr	55907	140	**56047**	**0**	**3393406**	0	77	**-77**	**3449377**
11	Water (cooling)	ltr	13880	4388	**18268**	**0**	**12668391**	0	642	**-642**	**12686017**
12	Waste, non-haz./ landfill	g	1703048	55062	**1758111**	**5610**	**5910757**	59758	451	**59307**	**7733783**
13	Waste, hazardous/ incinerated	g	6967	2	**6970**	**111**	**117191**	73656	71	**73585**	**197858**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	5627	887	**6514**	**804**	**222034**	632	497	**134**	**229486**
15	Ozone Depletion, emissions	mg R-11eq.	negligible								
16	Acidification, emissions	g SO2 eq.	55258	3829	**59087**	**2462**	**1310126**	1286	673	**613**	**1372288**
17	Volatile Organic Compounds (VOC)	g	167	4	**172**	**253**	**1949**	28	8	**20**	**2394**
18	Persistent Organic Pollutants (POP)	ng i-Teq	6009	397	**6406**	**32**	**33379**	413	0	**413**	**40231**
19	Heavy Metals	mg Ni eq.	100741	930	**101670**	**284**	**88663**	2345	0	**2345**	**192963**
	PAHs	mg Ni eq.	6100	2	**6101**	**542**	**10520**	0	6	**-6**	**17156**
20	Particulate Matter (PM, dust)	g	6441	589	**7031**	**41872**	**35584**	11526	22	**11504**	**95990**
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	65648	0	**65649**	**9**	**31287**	695	0	**695**	**97639**
22	Eutrophication	g PO4	1613	7	**1620**	**0**	**556540**	40	3	**37**	**558197**
23	Persistent Organic Pollutants (POP)	ng i-Teq	negligible								

Figure 6 exposes the contribution of each life cycle phase to each impact. Several observations can be made from this analysis:

- Within the production phase, the manufacturing impacts are very small: the maximum contribution is 1% in POP emissions, because of the sheet metal scrap generated during the manufacturing process. The material extraction and production are responsible for the important contributions of this phase to the quantity of landfilled waste (22%) because of the general metal content, POP (15%) and HM (52%) emissions because of the stainless steel contained in the product and PAH emissions (36%) because of the aluminium parts.
- As expected, the use phase is by far the main contributor to the following impacts: total energy (98%) and electricity consumption (99.5%), water for processing (98.4%), non-hazardous waste (76%), greenhouse gases emissions (97%), acidification (95%), POP (83%), PAHs (61%) and eutrophication (99.7%). The water use during the use phase is the main contributor for the water processing impact. The detergent is the source of almost 100% of the eutrophication impact during the use phase, and also makes a slight contribution (around 7%) for waste generation, GWP and POP emissions. The maintenance and repair services represent “only” 25% of the PM emissions in the use phase (in comparison with previous base cases) because of the travels. For the remaining shares, the electricity consumption is the main source for the impacts, especially total energy and electricity, GWP, acidification and POP emissions.
- The distribution phase is negligible for all impacts except for PM for which it accounts for around 44% of the total emissions, and for VOC (11%) and PAHs (3%) emissions. This is due to the product transportation.
- The end-of-life is also negligible for all impacts except for the generation of hazardous waste (37%) and PM (12%). This is due to the high recycling rate (because of the plastics and metals content) which partly counterbalances the negative impacts of incinerating or landfilling the few non recyclable materials. When the red bar is placed below the x-axis on the figure, it means that the end-of-life actually results in a small credit in the impact category considered: in particular, this is the case for energy and electricity consumption.

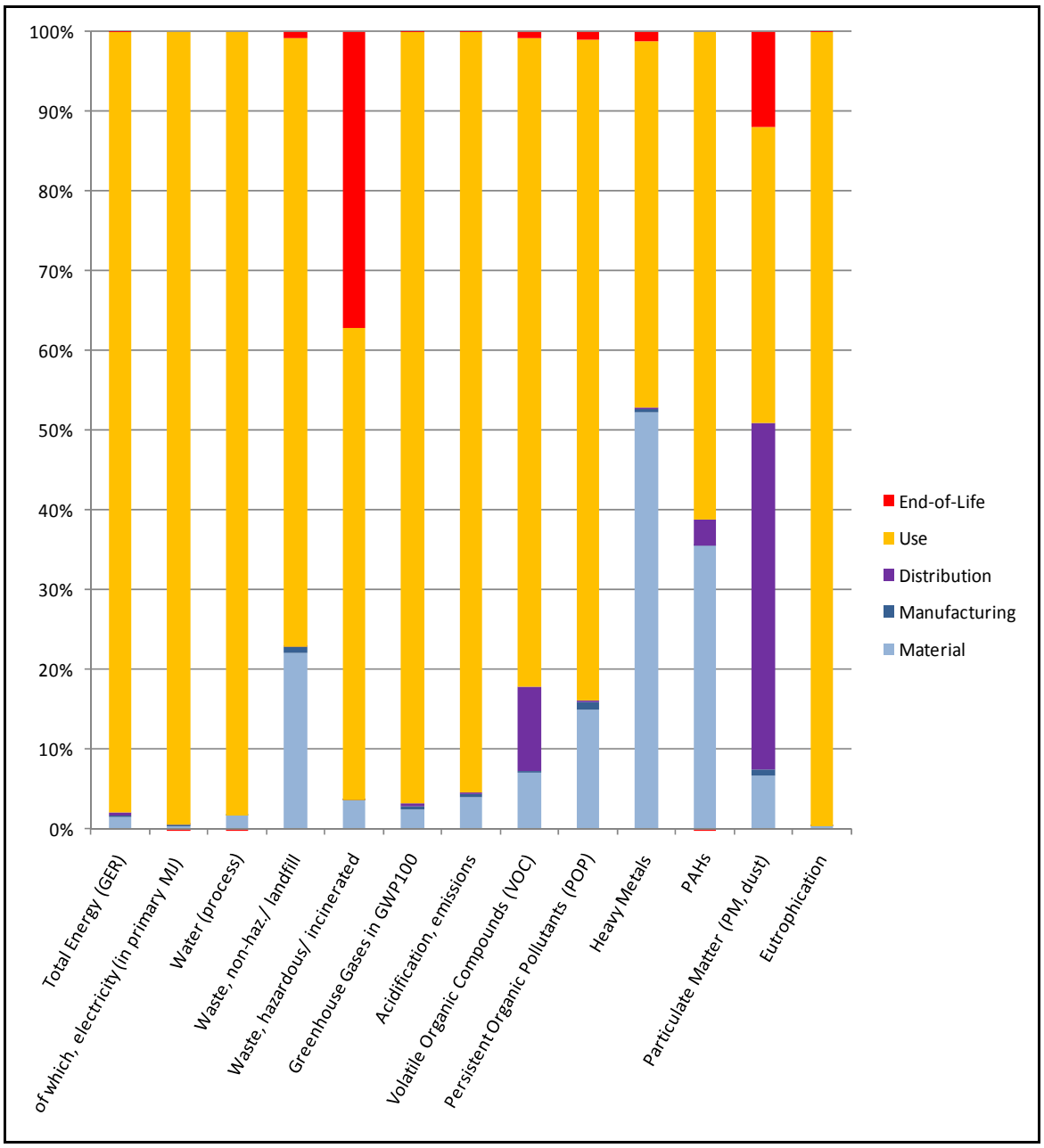


Figure 6 Distribution of environmental impacts of BC 5 per life cycle phase

3.6 Base case 6: Conveyor-type multi-tank

Table 18 shows the environmental impacts of a conveyor-type multi-tank dishwasher over its whole life cycle. The total energy consumption for the whole life cycle of the BC 6 is 19.6 TJ, of which 18.3 TJ (i.e. 1.74 GWh_e) electricity.

Table 18 Life Cycle Impact (per unit) of base case 6 – Conveyor-type multi-tank

Nr	Life cycle Impact per product:							Date	Author		
6	Multi-tank conveyor-type								BIO		
	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	g			**110090**			77063	33027	**110090**	**0**
2	TecPlastics	g			**18660**			13062	5598	**18660**	**0**
3	Ferro	g			**1042440**			52122	990318	**1042440**	**0**
4	Non-ferro	g			**103700**			5185	98515	**103700**	**0**
5	Coating	g			**0**			0	0	**0**	**0**
6	Electronics	g			**15400**			15400	0	**15400**	**0**
7	Misc.	g			**174710**			8736	165975	**174710**	**0**
	Total weight	g			**1465000**			171568	1293433	**1465000**	**0**
	Other Resources & Waste							debet	see note! credit		
8	Total Energy (GER)	MJ	103175	22392	**125567**	**18466**	**19422834**	11321	11047	**274**	**19567140**
9	of which, electricity (in primary MJ)	MJ	20506	13355	**33861**	**47**	**18248215**	1	143	**-142**	**18281981**
10	Water (process)	ltr	86267	197	**86464**	**0**	**12187151**	0	94	**-94**	**12273521**
11	Water (cooling)	ltr	19750	6173	**25924**	**0**	**48661263**	0	785	**-785**	**48686402**
12	Waste, non-haz./ landfill	g	1962298	77932	**2040230**	**7574**	**22531445**	89925	552	**89373**	**24668623**
13	Waste, hazardous/ incinerated	g	10890	3	**10893**	**151**	**447497**	90127	87	**90041**	**548581**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	8280	1250	**9530**	**1087**	**847850**	843	719	**124**	**858591**
15	Ozone Depletion, emissions	mg R-11eq.	negligible								
16	Acidification, emissions	g SO2 eq.	76199	5396	**81595**	**3328**	**5002741**	1711	962	**749**	**5088412**
17	Volatile Organic Compounds (VOC)	g	262	6	**269**	**342**	**7415**	39	12	**26**	**8052**
18	Persistent Organic Pollutants (POP)	ng i-Teq	8986	586	**9573**	**43**	**127356**	621	0	**621**	**137592**
19	Heavy Metals	mg Ni eq.	152879	1374	**154253**	**384**	**335974**	3143	0	**3143**	**493755**
	PAHs	mg Ni eq.	6282	2	**6284**	**732**	**39648**	0	8	**-8**	**46657**
20	Particulate Matter (PM, dust)	g	9431	830	**10261**	**56672**	**129563**	15323	29	**15294**	**211790**
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	97876	1	**97876**	**12**	**118636**	928	0	**928**	**217453**
22	Eutrophication	g PO4	2484	10	**2494**	**0**	**1956057**	53	3	**50**	**1958601**
23	Persistent Organic Pollutants (POP)	ng i-Teq	negligible								

Figure 7 exposes the contribution of each life cycle phase to each impact. Several observations can be made from this analysis:

- Within the production phase, the manufacturing impacts are very small: the maximum contribution is 0.4% in POP emissions, because of the sheet metal scrap generated during the manufacturing process. The material extraction and production are responsible for the contributions of this phase to the quantity of landfilled waste (8%) because of the general metal content, POP (7%) and HM (31%) emissions because of the stainless steel contained in the product and PAH emissions (13%) because of the aluminium parts.
- As expected, the use phase is by far the main contributor to the following impacts: total energy (99.3%) and electricity consumption (99.8%), water for processing (99.3%), non-hazardous waste (91%), greenhouse gases emissions (98.8%), acidification (98.3%), POP (93%), PAHs (85%) and eutrophication (99.9%). The water use during the use phase is the main contributor for the water processing impact. The detergent is the source of almost 100% of the eutrophication impact during the use phase, and also makes a slight contribution (around 7%) for waste generation, GWP and POP emissions. The maintenance and repair services represent “only” 8% of the PM emissions in the use phase (in comparison with previous base cases) because of the travels. For the remaining shares, the electricity consumption is the main source for the impacts, especially total energy and electricity, GWP, acidification and POP emissions.
- The distribution phase is negligible for all impacts except for PM for which it accounts for around 27% of the total emissions and for VOC (4%) emissions. This is due to the product transportation.
- The end-of-life is also negligible for all impacts except for the generation of hazardous waste (16%) and PM (7%). This is due to the high recycling rate (because of the plastics and metals content) which partly counterbalances the negative impacts of incinerating or landfilling the few non recyclable materials. When the red bar is placed below the x-axis on the figure, it means that the end-of-life actually results in a small credit in the impact category considered: in particular, this is the case for energy and electricity consumption.

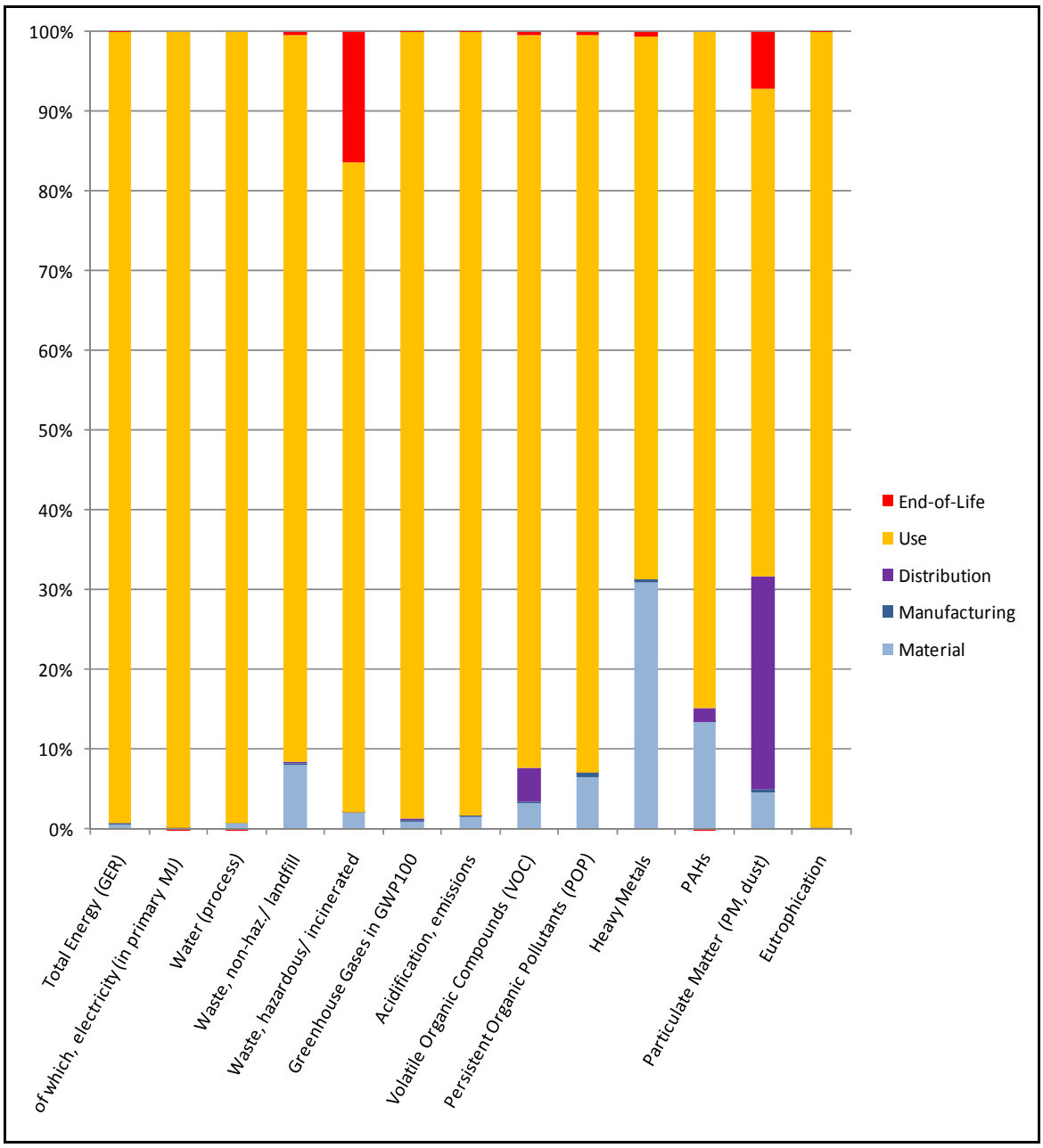


Figure 7 Distribution of environmental impacts of BC 6 per life cycle phase

3.7 Conclusions

The results of the impact assessment are very similar for the six BCs, not in absolute values but in predominance of certain key elements on the environmental impacts:

- The production phase impacts are mostly due to the stainless steel and the aluminium content of the professional dishwashers. The use of these materials however seems necessary so that it is not expected that improvement options enable to lower significantly the impacts due to this life cycle phase.
- The use phase is the main contributing phase for most environmental indicators, especially energy consumption (and electricity consumption, always over 97% of the total impacts), GWP and acidification. The contribution of this phase is mainly due to the amount of electricity needed to run the appliances during the whole lifetime. Besides, the high detergent consumption induces eutrophication impacts and the water consumption obviously results in use of water. Therefore, improvement options enabling energy, water and detergent savings in operation will be the most effective options in reducing the environmental impact of professional dishwashers.
- The distribution is always negligible except for the emissions of particulate matter, which are due to the transportation of the appliances, which is inevitable. Manufacturing lighter machines would reduce this impact but is not considered as a priority option (and manufacturers probably already optimise this aspect as it directly influences their logistic costs).
- The end-of-life mainly contributes significantly to the quantity of hazardous waste generated. However, this indicator is only an intermediate indicator as the consequences of the management of the hazardous waste (often through incineration) are also accounted for in the emissions environmental impacts, where no major contribution of this phase appears. As no harmful compound has been identified in the bill of materials, it is unlikely that any improvement option will reduce the impacts of this phase. On the contrary, the possible implementation of heat pumps (containing refrigerant) in more efficient products may result in additional impacts.

Looking at the results of the Ecodesign preparatory study on domestic washing machines and dishwashers (Lot 14 for DG TREN), the environmental analysis of the base cases shows many similarities. Concerning emissions, the use phase is also the main contributor for greenhouse gases, acidification and VOC. Similarly, the production phase contributes to PAHs and heavy metals emissions and the distribution phase contributes to particulate matter emissions (although the use phase remains the main contributor). Energy consumption and water use are also identified as the most relevant elements in the use phase. The main difference lies in the fact that the contribution of the use phase is globally more important in the case of professional dishwashers, at the expenses of the other phases.

This results from the fact that professional appliances are used more intensively than household appliances.

4 Base case life cycle costs

The result of the procurement process should be the cheapest dishwasher, having the lowest total cost of ownership, taking into account the consumables expenditure and optimised for a given application.

Table 19 exposes the details of the LCC over the lifetime for each base case (see assumed lifetime of base cases in Table 20).[10] Installation costs and end-of-life costs were estimated to be zero in Task 2 and are not displayed in the table.

Table 19 EcoReport outcomes of the LCC calculations of the six base cases

Item	Base case					
	1	2	3	4	5	6
Product price (Euro)	3 200	3 500	4 700	10 500	15 000	45 000
Repair and maintenance costs (Euro)	939	1 296	1 740	3 888	5 162	14 169
Electricity cost (Euro)	1 624	4 881	5 838	6 301	31 846	111 932
Water cost (Euro)	642	992	1 540	1 591	6 335	20 672
Detergent/Rinse aid cost (Euro)	2 450	3 797	5 898	5 938	24 354	78 323
Life Cycle Cost (Euro)	**8 854**	**14 466**	**19 716**	**28 219**	**82 697**	**270 096**

Figure 8 shows the contribution of the product price and the resources and consumables costs for the six base cases LCC.

For BC 1 and BC 4, the product price represents 36-37% of the global LCC. For BC 2 and BC 3, the product price only accounts for 24% and gets an even smaller share for heavy duty appliances (18% for BC 5 and 17% for BC 6). This phenomenon makes sense as the lifetimes are longer, resulting in larger total costs for consumables and resources. Repair and maintenance follow the same evolution as they were estimated through a percentage of the product price. For the resources and consumables shares, the opposite happens: electricity only represent 18% for BC 1 and 22% for BC 4, while it reaches 39% for BC 5 and 41% for BC 6. The detergent share is comprised between 21% and 30% for all base cases and the share for water is less variable (between 6% and 8%). BC 1 is the only base case for which

[10] Annual costs being discounted taking into account the discount rate of 4%.

the detergent costs are significantly more important than the electricity costs (they are similar for BC 3 and BC 4).

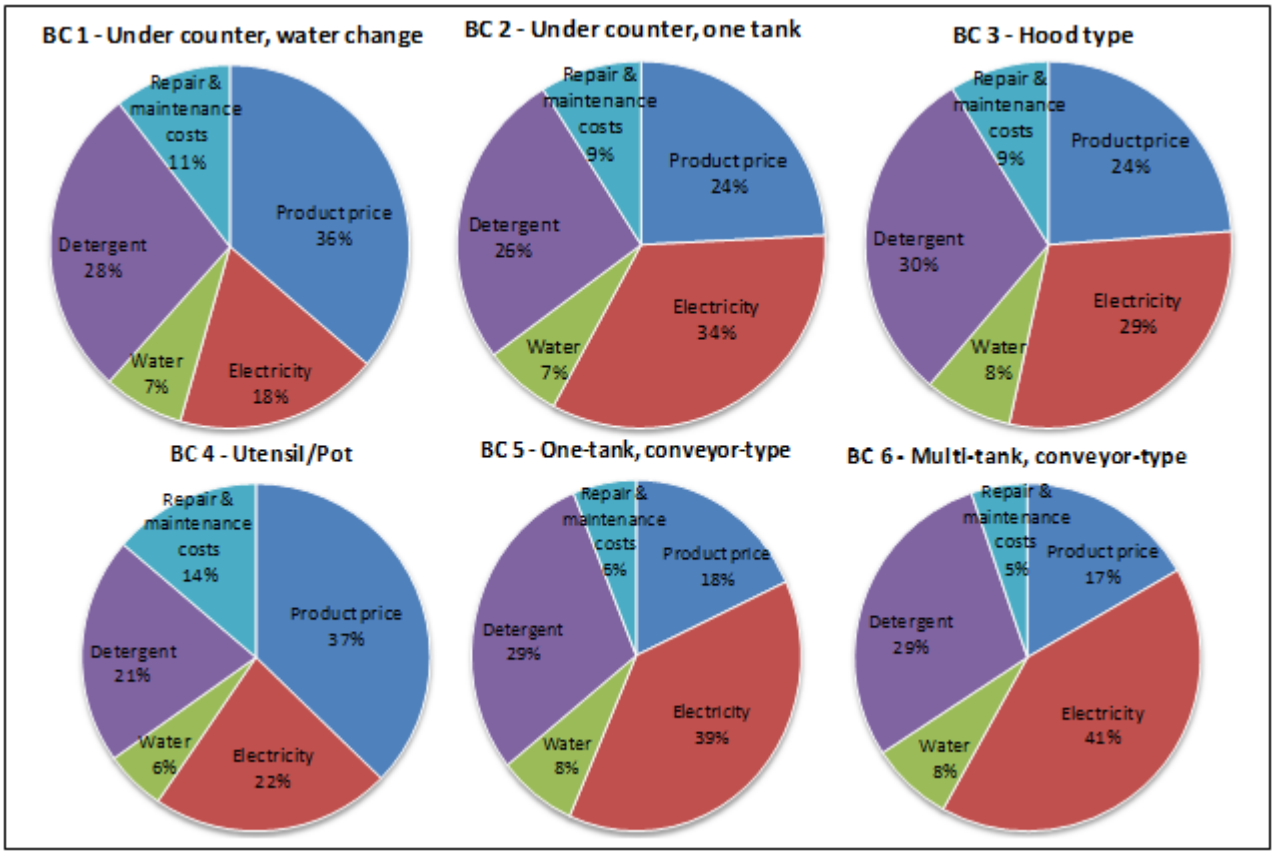


Figure 8 Breakdown of base cases' LCC

5 EU Totals

This section provides the environmental assessment of the base cases at the EU-27 level using stock and market data from Task 2. The total impacts cover:

- The life cycle environmental impact of the new products in 2009 (i.e. impacts of the sales);
- The annual (2009) impact of production, use and disposal of the product group, and the total LCC (i.e. impacts and LCC of the stock).

5.1 Market data

Table 20 displays the market data of the six BCs in EU-27 in 2009.

Table 20 Market and technical data for all base cases in 2009

Base case	Lifetime (years)	Annual sales (units/year)	EU stock (units)
BC 1 Undercounter water-change	12	20 000	207 223
BC 2 Undercounter one-tank	8	138 200	1 012 355
BC 3 Hood-type	8	65 900	482 728
BC 4 Utensil/Pot	8	2 600	19 309
BC 5 One-tank conveyor-type	12	6 600	68 425
BC 6 Multi-tank conveyor-type	17	1 300	18 015

5.2 Life Cycle Environmental Impacts

Table 21 shows the total environmental impacts in 2009 of all professional dishwashers in stock in EU-27, based on the extrapolation of the base cases impacts (all have the same impacts as the base case of their category). Thus, these figures include the production and distribution impacts of the products sold in 2009, the use phase impacts of the stock products being used during 2009 and the end-of-life impacts of the products being discarded that same year.

Table 21 Environmental impacts of the EU-27 stock in 2009 for all base cases

Environmental Impact	Base case						Total
	1	2	3	4	5	6	
Total Energy (GER) (in PJ)	3.4	68.6	51.4	2.3	36.1	26.9	188.6
of which electricity (in TWh)	0.3	5.8	4.4	0.2	3.2	2.4	16.2
Water process (in million m^3)	5.6	66.4	49.3	2.1	24.0	16.9	164.3
Waste, non-hazardous/landfill (in kt)	4.9	94.5	71.0	3.4	53.2	33.8	260.8
Waste, hazardous/ incinerated (in kt)	0.22	2.54	1.72	0.09	1.35	0.75	6.7
Emissions to air							
Greenhouse Gas in GWP100 (in Mt CO_2eq.)	0.15	3.03	2.27	0.10	1.59	1.18	8.3
Acidification, emissions (in kt SO_2eq.)	0.9	18.0	13.5	0.6	9.5	7.0	49.6
Volatile Organic Compounds (VOC) (in kt)	0.003	0.030	0.023	0.001	0.016	0.011	0.1
Persistent Organic Pollutants (POP) (in g i-Teq.)	0.03	0.52	0.39	0.02	0.28	0.19	1.4
Heavy Metals (in ton Ni eq.)	0.14	2.32	1.87	0.11	1.31	0.67	6.4
PAHs (in ton Ni eq.)	0.01	0.20	0.14	0.01	0.12	0.06	0.5
Particulate Matter (PM, dust) (in kt)	0.13	1.06	0.82	0.08	0.65	0.29	3.0
Emissions to water							
Eutrophication (in kt PO_4)	0.97	11.14	8.25	0.34	3.88	2.70	27.3

Summary of environmental impacts of BCs as a percentage of total impact are presented in Figure 9. As the figure shows, undercounter one-tank dishwashers have the greatest impacts within the sector and represent the major share of the total stock. The share of these appliances remains relatively constant, between 35% (for PM) and 41% for eutrophication and water. Hood-type dishwashers, representing 27% of the total stock, also account for a large share of the impacts, between 26% (for PAHs) and 30% for eutrophication and water. Undercounter water-change dishwashers have a very low share for all indicators (always below 4%) despite a share of 11% of the total stock. The low stock of utensil/pot dishwashers and their relatively low capacity explain the negligible share of this base case in the total impacts (less than 1%). Finally, heavy duty appliances (BC 5 and BC 6) represent together around 30-35% of the environmental impacts even if fewer appliances are used in comparison with other types.

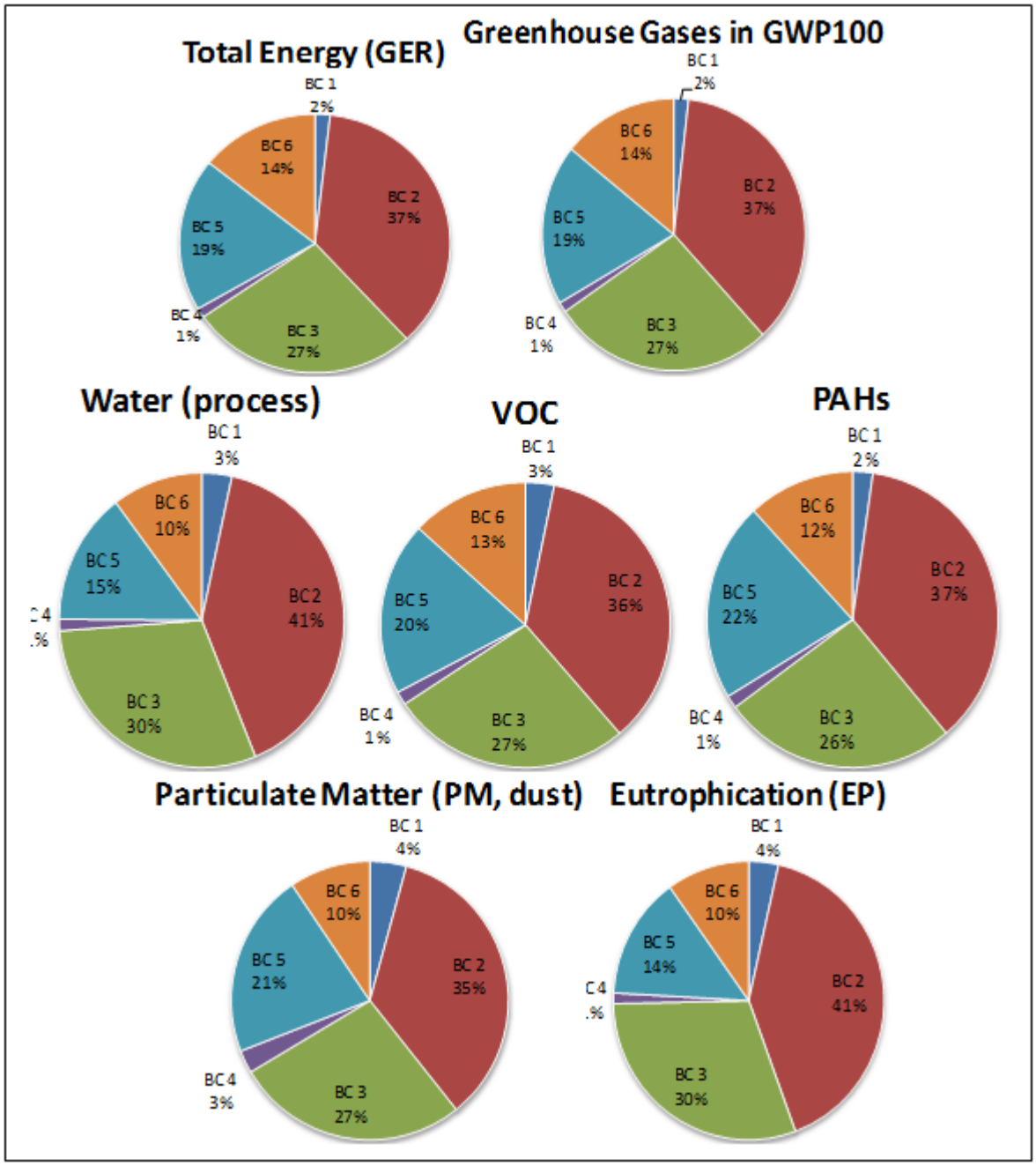


Figure 9 Base cases' share of the environmental impacts of the stock in 2009

Figure 10 focuses on the shares of the electricity consumption. They are similar to other impacts as BC 2 represents 36% of the total electricity consumption of the professional dishwashers stock, BC 3 accounts for 27% of the total and BC 5 and 6 for 34% together. The

total electricity consumption of professional dishwashers is about 16.2 TWh which represents around 0.57% of the EU-27 total electricity consumption.[11]

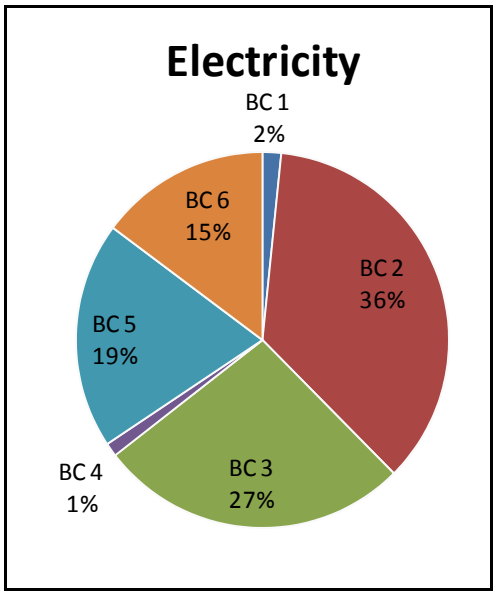


Figure 10 Base cases' share of the electricity consumption of the stock in 2009

No other estimations of the overall impacts of EU professional dishwashers were found in the literature. An American study[12] however estimated the baseline energy use (but other environmental impacts were not assessed). These results are presented in Table 22.

Table 22 Energy consumption of professional dishwashers in the USA, 2008[13]

Category	Primary Energy consumption (TBtu)[14]	Primary Energy consumption (PJ)
Undercounter	5.2	5.5
Conveyor	115.0	121.9
Door type	21.9	23.2
Flight type	18.9	20.0
Total	**161.0**	**170.7**

11 Source Eurostat: EU27 electricity consumption in 2007 = 244 million toe = 2 837 TWh.

12 Navigant Consulting (2009), *Energy Savings Potential and RD&D Opportunities for Commercial Building Appliances*, for US Department of Energy.

13 Navigant Consulting (2009), *Energy Savings Potential and RD&D Opportunities for Commercial Building Appliances*, for US Department of Energy.

14 Conversion factor: 1 Btu = 1060 kJ

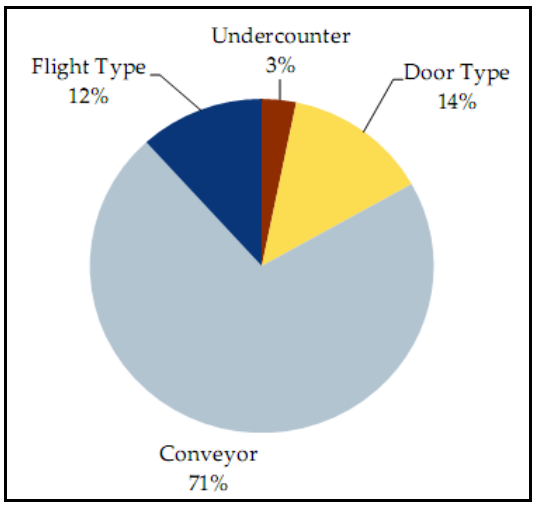


Figure 11 Professional Dishwashers Primary Energy Consumption by Washer Type, in the USA, 2008 [13]

These results are in accordance: while the EU-27 (with a population of around 500 million inhabitants and a GDP of $ 16 447 259[15]) has an annual primary energy consumption of 234.0 PJ for professional dishwashers, the US (with a population of 310 million inhabitants and a GDP of $ 14 256 275[15]), has an annual consumption of 170.7 PJ for the same sector.

However, important differences can be seen on Figure 11, as conveyor dishwashers are expected to represent 71% of the total consumption in the US, while only 36% in EU-27. Undercounter dishwashers also have a much smaller share in the US than in the EU (3% vs. 37%). This difference may come from the specificities of the market structure as it seems that the sales of conveyor-type dishwashers represent a more important share of the total sales in the US than in the EU-27.

5.3 Life Cycle Costs

Regarding the total consumer expenditure in 2009 related to the six BCs, about 36% of the total costs are due to electricity consumption, 8% to water consumption and 27% to detergent consumption while product prices represent 21% of this total. The distribution per base case is given in Figure 12 and details on consumer expenditure are presented in Table 23.

[15] International Monetary Fund, 2009

Table 23 Total Annual Consumer expenditure in EU-27 in 2009

Environmental Impact	Base case						Total
	1	2	3	4	5	6	
EU-27 sales (in thousand units)	20	138.2	65.9	2.6	6.6	1.3	234.6
Share of the EU-27 sales	8.5%	58.9%	28.1%	1.1%	2.8%	0.6%	100%
Product Price (in million Euro)	64	484	310	27	99	59	1 042
Electricity (in million Euro)	36	800	456	20	283	215	1 811
Water (in million Euro)	14	163	120	5	56	40	398
Detergent (in million Euro)	54	571	423	17	178	116	1 358
Repair and maintenance costs (in million Euro)	21	195	125	11	38	21	410
Total (in million Euro)	189	2 212	1 434	80	654	451	5 020

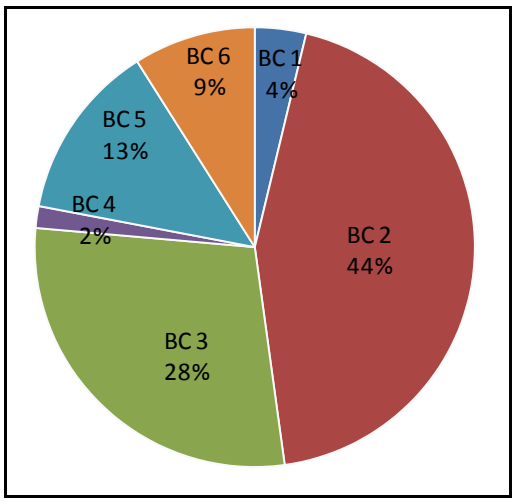


Figure 12 Base cases' share of the total consumer expenditure in 2009

The contributions to the total consumer expenditure are slightly different from the ones to the environmental impacts. Total consumer expenditure in 2009 related to undercounter one-tank dishwashers represents 44% of the total. Hood-types are the next highest with 28% and third come conveyor-type appliances accounting for 13% (one-tank) and 9% (multi-tank) of the total consumer expenditure. Total consumer expenditure does not take into account possible benefits received for materials at disposal.

6 EU-27 total system impact

During operation, professional dishwashers produce heat which is transferred to the water first and partially to the dishes afterwards. This heat (and residual moisture) can then be transferred to the room if the machine has no specific heat recovery option implemented. The environmental impacts of this heat transfer can be positive as well as negative, depending on several parameters:

- The climate: If the room needs to be heated, the dishwasher will complement the heating system. On the contrary, if the room needs to be cooled (it is usually the case for kitchens with warm and humid atmosphere), operating a dishwasher will require additional energy consumption from the ventilation/air conditioning system. A dishwasher with a heat recovery system or a heat pump will reduce the energy consumption of the dishwasher itself on the one hand, and also spares the extra work needed from the ventilation system in comparison with a basic dishwasher on the other hand.
- The energy source of the dishwasher and of the heating system: electricity needs to be produced from a primary energy, generally with low efficiency. If the dishwasher only uses electricity as energy source, the central heating system will be much more efficient and heating the room indirectly thanks to the dishwasher will reduce the global efficiency of the heating process.

Due to huge differences between Member States and appliances, no global heat transfer can be estimated at EU level with reliability.

The infrastructure of the building where the dishwasher is installed has also an influence on the possible options to reduce the energy consumption of the system. The base cases are all considered with only cold water supply and 100% electric heating. However, the implementation of warm water supply (see Task 7) or the use of another energy source (e.g. gas which, however, is not very common for professional dishwashers) normally enable to reduce the use of primary energy (and lower many environmental impacts) even if it does not reduce the final energy needed at the level of the machine: the heat required and contained in the water remains the same.

7 Conclusions

The environmental impacts assessment carried out with the EcoReport tool for each base case shows that the use phase is by far the most impacting stage of the life cycle in terms of energy consumption, water consumption, greenhouse gases emissions and eutrophication. Therefore, the analysis of the improvement potential in Task 7 will mainly focus on technologies that reduce the electricity, water and detergent consumption during the use phase.

Because of their large amount of appliances in total stock, the undercounter one-tank dishwashers are responsible for about 40% of the overall impacts due to professional dishwashers in EU. They also represent 44% of the annual consumer expenditure as their range of price is very wide. Hood-type dishwashers and conveyor-type dishwashers also significantly contribute to the total environmental impacts and expenditure while undercounter water-change and utensil/pot dishwashers account for minor shares.

Task 6 will examine the improvement options of professional dishwashers considered as best available technologies, in an attempt to improve upon the base cases. Based on the life cycle analysis made in this task, these options mainly focus on the reduction of energy, water and detergent consumption of the dishwashers during the use phase.

8 Annex

8.1 Detailed bills of materials of the six base cases

Bill of material of Base case 1

Pos nr	MATERIALS Extraction & Production Description of component	Weight in g	Category Click &select	Material or Process select Category first !
1	Stainless Steel	24560.0	3-Ferro	**25-Stainless 18/8 coil**
2	Steel Sheet galvanized	403.0	3-Ferro	**21-St sheet galv.**
3	Cast Iron	2303.0	3-Ferro	**23-Cast iron**
4	Polypropylene (PP)	4980.0	1-BlkPlastics	**4-PP**
5	Polyamid (PA)	399.0	2-TecPlastics	**11-PA 6**
6	Polymethylmetacrylate (PMMA)	6.0	2-TecPlastics	**13-PMMA**
7	Acrylonitrile Butadiene Styrene (ABS)	7510	1-BlkPlastics	**10-ABS**
8	Plystyrene (PS)	512.0	1-BlkPlastics	**5-PS**
9	Styropor expandable polystyrene (EPS)	40.0	1-BlkPlastics	**6-EPS**
10	Polybutylene Terephthalate (PBT)	35.0		
11	Polyvinylchlorid (PVC)	403.0	1-BlkPlastics	**8-PVC**
12	EPDM-rubber	524.0	1-BlkPlastics	**1-LDPE**
13	POM	230.0	1-BlkPlastics	**2-HDPE**
14	PE	187.0	1-BlkPlastics	**2-HDPE**
15	Plastics others	268.0		
16	Aluminium	273.0	4-Non-ferro	**26-Al sheet/extrusion**
17	Cu wire	1006.0	4-Non-ferro	**29-Cu wire**
18	CuZn38 cast	23.0	4-Non-ferro	**31-CuZn38 cast**
19	Chromium	710		
20	Bitumen	6089.0	7-Misc.	**55-Bitumen**
21	Concrete	1263.0	7-Misc.	**58-Concrete**
22	Cotton	452.0		
23	Epoxy	609.0	2-TecPlastics	**14-Epoxy**
24	Wood	2034.0	7-Misc.	**56-Cardboard**
25	others (Paper)	285.0	7-Misc.	**57-Office paper**
26	Electronics (control)	448.0	6-Electronics	**98-controller board**
27	Packaging (EPS)	724.0	1-BlkPlastics	**6-EPS**
28	Packaging (PE foil)	172.0	1-BlkPlastics	**2-HDPE**
29	Packaging (Wood)	10110	7-Misc.	**56-Cardboard**
30	Packaging (cardboard)	635.0	7-Misc.	**56-Cardboard**

Bill of material of Base case 2

Pos nr	MATERIALS Extraction & Production Description of component	Weight in g	Category Click &select	Material or Process select Category first !
1	Stainless steel	49760.0	3-Ferro	**25-Stainless 18/8 coil**
2	Polypropylene (PP)	4565.0	1-BlkPlastics	**4-PP**
3	Polyamide (PA)	500.0	2-TecPlastics	**11-PA 6**
4	Epoxy	1000.0	2-TecPlastics	**14-Epoxy**
5	Acrylonitrile Butadiene Styrene (ABS)	70.0	1-BlkPlastics	**10-ABS**
6	Pumps (copper)	2500.0	4-Non-ferro	**30-Cu tube/sheet**
7	Pumps (stack of sheets)	2500.0	3-Ferro	**22-St tube/profile**
8	Pumps (stainless steel wave)	2250.0	3-Ferro	**25-Stainless 18/8 coil**
9	Pumps (Al)	2250.0	4-Non-ferro	**26-Al sheet/extrusion**
10	Cable (copper)	1100.0	4-Non-ferro	**29-Cu wire**
11	Cable sheath (PVC)	600.0	1-BlkPlastics	**8-PVC**
12	Cable sheath (silicone, EDPM)	300.0	1-BlkPlastics	**1-LDPE**
13	Electronics (control)	500.0	6-Electronics	**98-controller board**
14	Gaskets (EDPM)	2040.0	1-BlkPlastics	**1-LDPE**
15				
16	Packaging (polystyrene)	500.0	1-BlkPlastics	**5-PS**
17	Packaging (wood)	6000.0	7-Misc.	**56-Cardboard**
18	Packaging (cardboard)	2750.0	7-Misc.	**56-Cardboard**

Bill of material of Base case 3

Pos nr	MATERIALS Extraction & Production Description of component	Weight in g	Category Click &select	Material or Process select Category first !
1	Stainless steel	93090.0	3-Ferrous	**25-Stainless 18/8 coil**
2	Polypropylene (PP)	4310.0	1-BlkPlastics	**4-PP**
3	Polyamide (PA)	1000.0	2-TecPlastics	**11-PA 6**
4	Epoxy	800.0	2-TecPlastics	**14-Epoxy**
5	Acrylonitrile Butadiene Styrene (ABS)	70.0	1-BlkPlastics	**10-ABS**
6	Pumps (copper)	3000.0	4-Non-ferrous	**30-Cu tube/sheet**
7	Pumps (stack of sheets)	3000.0	3-Ferrous	**22-St tube/profile**
8	Pumps (stainless steel wave)	2500.0	3-Ferrous	**25-Stainless 18/8 coil**
9	Pumps (Al)	3000.0	4-Non-ferrous	**26-Al sheet/extrusion**
10	Cable (copper)	1700.0	4-Non-ferrous	**29-Cu wire**
11	Cable sheath (PVC)	1000.0	1-BlkPlastics	**8-PVC**
12	Cable sheath (silicone, EDPM)	500.0	1-BlkPlastics	**1-LDPE**
13	Electronics (control)	600.0	6-Electronics	**98-controller board**
14	Gaskets (EDPM)	3085.0	1-BlkPlastics	**1-LDPE**
15				
16	Packaging (polystyrene)	500.0	1-BlkPlastics	**5-PS**
17	Packaging (wood)	12250.0	7-Misc.	**56-Cardboard**
18	Packaging (cardboard)	4750.0	7-Misc.	**56-Cardboard**

Bill of material of Base case 4

Pos nr	MATERIALS Extraction & Production Description of component	Weight in g	Category Click &select	Material or Process select Category first !
1	Stainless steel	165000.0	3-Ferrous	**25-Stainless 18/8 coil**
2	Polypropylene (PP)	3000.0	1-BlkPlastics	**4-PP**
3	Polyamide (PA)	4000.0	2-TecPlastics	**11-PA 6**
4	Epoxy	0.0	2-TecPlastics	**14-Epoxy**
5	Ethylene Propylene Dien M-class rubber (EPDM)	4000.0	1-BlkPlastics	**1-LDPE**
6	Acrylonitrile Butadiene Styrene (ABS)	0.0	1-BlkPlastics	**10-ABS**
7	Pumps (copper)	5000.0	4-Non-ferrous	**30-Cu tube/sheet**
8	Pumps (stack of sheets)	4000.0	3-Ferrous	**22-St tube/profile**
9	Pumps (stainless steel wave)	3000.0	3-Ferrous	**25-Stainless 18/8 coil**
10	Pumps (Al)	5000.0	4-Non-ferrous	**26-Al sheet/extrusion**
11	Cable (copper)	2400.0	4-Non-ferrous	**29-Cu wire**
12	Cable sheath (PVC)	1400.0	1-BlkPlastics	**8-PVC**
13	Cable sheath (silicone, EDPM)	1100.0	1-BlkPlastics	**1-LDPE**
14	Electronics (control)	2100.0	6-Electronics	**98-controller board**
15	Gaskets, etc. (EDPM)	6000.0	1-BlkPlastics	**1-LDPE**
16				
17	Packaging (polystyrene)	500.0	1-BlkPlastics	**5-PS**
18	Packaging (wood)	16000.0	7-Misc.	**56-Cardboard**
19	Packaging (cardboard)	3500.0	7-Misc.	**56-Cardboard**

Bill of material of Base case 5

Pos nr	MATERIALS Extraction & Production Description of component	Weight in g	Category Click &select	Material or Process select Category first !
1	Stainless steel	642250.0	3-Ferrous	**25-Stainless 18/8 coil**
2	Polypropylene (PP)	55500.0	1-BlkPlastics	**4-PP**
3	Polyamide (PA)	6140.0	2-TecPlastics	**11-PA 6**
4	Polyvinyl chloride (PVC)	4600.0	1-BlkPlastics	**8-PVC**
5	Polystyrene (PS)	4430.0	1-BlkPlastics	**5-PS**
6	Acrylonitrile Butadiene Styrene (ABS)	5000.0	1-BlkPlastics	**10-ABS**
7	Pumps (copper)	16825.0	4-Non-ferrous	**30-Cu tube/sheet**
8	Pumps (stack of sheets)	15625.0	3-Ferrous	**22-St tube/profile**
9	Pumps (stainless steel wave)	12335.0	3-Ferrous	**25-Stainless 18/8 coil**
10	Pumps (Al)	17470.0	4-Non-ferrous	**26-Al sheet/extrusion**
11	Condenser (AL)	4720.0	4-Non-ferrous	**26-Al sheet/extrusion**
12	Condenser (Cu)	7080.0	4-Non-ferrous	**30-Cu tube/sheet**
13	Ventilator, fan (AL)	17440.0	4-Non-ferrous	**26-Al sheet/extrusion**
14	Ventilator, fan (Cu)	10160.0	4-Non-ferrous	**30-Cu tube/sheet**
15	Drive motor (AL)	4000.0	4-Non-ferrous	**26-Al sheet/extrusion**
16	Drive motor (Cu)	5000.0	4-Non-ferrous	**30-Cu tube/sheet**
17	Cable (copper)	16300.0	4-Non-ferrous	**29-Cu wire**
18	Cable sheath (PVC)	8640.0	1-BlkPlastics	**8-PVC**
19	Cable sheath (silicone, EDPM)	5170.0	1-BlkPlastics	**1-LDPE**
20	Electric contactor (copper)	10000.0	4-Non-ferrous	**29-Cu wire**
21	Electronics (control)	9800.0	6-Electronics	**98-controller board**
22	Gaskets (EDPM)	12800.0	1-BlkPlastics	**1-LDPE**
23				
24	Packaging (polystyrene)	2940.0	1-BlkPlastics	**5-PS**
25	Packaging (wood)	63500.0	7-Misc.	**56-Cardboard**
26	Packaging (cardboard)	15500.0	7-Misc.	**56-Cardboard**

Bill of material of Base case 6

Pos nr	MATERIALS Extraction & Production Description of component	Weight in g	Category Click &select	Material or Process select Category first !
1	Stainless steel	980000.0	3-Ferrous	**25-Stainless 18/8 coil**
2	Polypropylene (PP)	58000.0	1-BlkPlastics	**4-PP**
3	Polyamide (PA)	18660.0	2-TecPlastics	**11-PA 6**
4	Epoxy	0.0	2-TecPlastics	**14-Epoxy**
5	Ethylene Propylene Dien M-class rubber (EPDM)	12000.0	1-BlkPlastics	**1-LDPE**
6	Acrylonitrile Butadiene Styrene (ABS)	0.0	1-BlkPlastics	**10-ABS**
7	Pumps (copper)	39020.0	4-Non-ferrous	**30-Cu tube/sheet**
8	Pumps (stack of sheets)	37070.0	3-Ferrous	**22-St tube/profile**
9	Pumps (stainless steel wave)	25370.0	3-Ferrous	**25-Stainless 18/8 coil**
10	Pumps (Al)	44880.0	4-Non-ferrous	**26-Al sheet/extrusion**
11	Cable (copper)	19800.0	4-Non-ferrous	**29-Cu wire**
12	Cable sheath (PVC)	11440.0	1-BlkPlastics	**8-PVC**
13	Cable sheath (silicone, EDPM)	8360.0	1-BlkPlastics	**1-LDPE**
14	Electronics (control)	15400.0	6-Electronics	**98-controller board**
15	Gaskets, etc. (EDPM)	15000.0	1-BlkPlastics	**1-LDPE**
16				
17	Packaging (polystyrene)	5290.0	1-BlkPlastics	**5-PS**
18	Packaging (wood)	141180.0	7-Misc.	**56-Cardboard**
19	Packaging (cardboard)	33530.0	7-Misc.	**56-Cardboard**

8.2 Stakeholder feedback to draft versions of Task 5

Please note that the feedback refers to prior draft versions of Task 5 report; thus the indicated numerations of chapters, tables, figures or pages might have changed.

Feedback		Comment
JRC IPTS		
	In general the Draft Task 5 of the Professional Dishwashers Report makes a good impression. It is very well structured, transparent and clearly presented in line with the MEEUP methodology. We consider that significant improvements on the environmental assessment of the base cases are feasible if the study could reach a greater level of detail (i.e. it could be more precise, and/or could contain a longer components/substance list in the EcoReport in order to capture the differences among the base cases). Moreover, we would like to emphasise a significant aspect in the calculation of the overall environmental performance of the EU product group stock in which correction factors are used. These corrections result in higher absolute values. Neither the decision of using correction factors is substantiated nor is the determination of them evidence-based. These values are highly relevant when implementing measures are considered. In particular, following the consultant approach, products which have average environmental performance seem compared to the stock as environmental sound solutions. This calculation should be made and presented in a different form ensuring transparency and being evidence based.	Thank you for your valuable comments. See reply below
	In Draft Task 5, the environmental impact results of the six product base cases as elaborated in the EcoReport tool do not seem to have significant differences in terms of predominance of certain elements (see Section 5.2.7 Conclusions, page 33). The analysis ends up focusing mainly on the energy and consumables during the use phase. We consider that such results indicate that the analysis needs to go into greater detail so that the product's ecodesign differences can be captured. At this point it should also be emphasised that such outcomes unveil restrictions of the EcoReport tool.	Indeed limitations of the EcoReport (especially for the material database) are estimated to be partly responsible for this similarity between the six base cases analysis. However, the base cases are not fundamentally different from a technical point of view and the fact that the hot spots are the same does not seem unexpected for the project team.
	The assumptions made for the product group end-of-life phase with incineration and recycling rates of 100 % for plastics and metals respectively are considered overestimated. A rate of landfill disposal should be presented.	Considered in revision, see reply below
	In the computation of the overall environmental assessment of the product group, EU stock correction factors regarding the performance of new and older products are used. The use of these correction factors results in higher overall environmental impact values of the total product group. The relevance of these values directly affects the calculation of the environmental savings potential when implementing measures are determined and allows appliances with average environmental performances to seem like environmentally-sound solutions. This calculation should be clarified and substantiated.	See reply below

Feedback		Comment
Section 5.1.2 page 8	Specific materials of product components were not available in the database of the EcoReport tool. Therefore, a few materials were approximated by using other materials of the database whereas others were ignored. In order to substantiate the approximations made, it is considered supportive to provide and illustrate the similarities of the life cycle environmental performance of these material pairs. This could be possible by using available LCA databases and respective LCIA methods. Moreover, the environmental performance of the materials that were not approximated (in this case, it was chromium, cotton and polybutylene terephtalate (PBT)) should also be provided and compared with the environmental performance of other components investigated. This is necessary in order to further substantiate any decision regarding their exclusion from the investigation. The components' share of the total weight of the dishwasher should not be the only reason substantiating their exclusion. If high environmental relevance of these components is confirmed, then a dataset could be added as new entry in the database of the EcoReport.	Preliminary environmental analyses have been added to the report to complement such assumptions. Besides, the project team would like to add that it is estimated more relevant (when the material is not of outstanding importance in the BOM) to make assumptions on closest materials available in the EcoReport database, rather than add "homemade" impacts for a new category in EcoReport (problem of consistency between different datasets).
Section 5.1.4.1	The number of kilometres travelled for maintenance and repair of one machine over its product lifetime is time-dependent. Thus, the assumption made of 1000 km should be transformed in x km/year in order to better time dependant real life conditions.	Considered in revision due to new stakeholder input at final stakeholder meeting
Section 5.1.5	After the product use, the metal parts of professional dishwashers are assumed to have recycling rates of 100 %. Respectively the incineration rates of the plastic parts were also assumed to reach 100 %. Both values are not considered realistic. These rates need refinement which would additionally take into account the geographical variation among the Member States (please see also the comments above).	The text has been corrected: the intended meaning of the sentence was that 100% of the recovered metals and plastics are recycled or incinerated. Post WEEE and post ROHS conditions are assumed within MEEuP and the assumed default value of non-recovered products in a post-WEEE scenario is 5%. In particular, the standard recycling rate for metals and TV glass is set at 95%, assumption under which the recycling benefits of metals (defined with MEEuP) are valid. The same rate will be considered for the recovery of all types of material (5% of the BOM goes to landfill).
Section 5.1.5	Professional dishwashers with pumps for heat recovery are not considered within the base cases with the justification that they are BAT appliances. These kinds of dishwashers are indeed considered to be BAT; nevertheless, this does not necessarily exclude them from being taken into account in the base case. The base case is defined as a conscious abstraction of reality which should represent an average product in the market. Therefore, as long as dishwashers with heat recovery pumps have a significant market share, then they should be included in the base cases.	Description of the market according to this option was tentatively made in draft Task 2 but the lack of data (according to manufacturers, such records do not exist) has led the team to consider the base case as a basic product, with the option of heat pump being entirely BAT. Reflection of the market during the course of Task 6

Feedback		Comment
		has supported this assumption: heat pumps are usually not yet applied in smaller DW categories due to lower profitability. With high-throughput machines of categories 5 and 6, the profitability is better, but still pumps for heat recovery are usually offered only as optional, not as standard equipment. Therefore, they do not have a significant market share and it is justified that they are not included into the base cases.
Section 5.1.6 (Point 3)	According to the consultant, the professional dishwasher's environmental efficiency differs largely when new products and older ones are compared. As the environmental assessment is based on 'base cases currently sold in the market' the consultant proposes the use of correction factors in order to avoid underestimation of the overall environmental assessment of the product group stock. This decision needs to be justified in more detail. Moreover, if these correction factors are considered necessary then their determination should rely on scientific evidence and not on simply assumptions and/or estimations of stakeholders. The graphical presentation of the lines of environmental performance of the product stock over time (past and future) as calculated with and without correction would clarify the importance of this issue (e.g. on the y axis the environmental performance values and on the x axis the years). We would like to draw attention to the fact that with the implementation of these correction factors, the overall environmental performance of the product stock seems to be higher compared with the calculation without correction. This could directly affect the phase of implementing measures proposal because with the current calculation, significant environmental savings can also be allocated to products which are of average performance. This takes place because the environmental performance is compared with the performance of the product group stock which is 'corrected' thus with higher absolute values.	This is not an initiative from the team but a required input of the EcoReport tool: Overall Improvement Ratio (Stock vs. New), Use Phase. It is indeed expected to take into account the fact that in the current stock, the products are less efficient than the currently sold products. For all product categories, this input was estimated from data presented in Task 2, as specified in the text and reminded in the table.
Section 5.1.4.1	Reference should be provided on the values given in Table 9 'Overall improvements ratios for all base cases'.	Added in revision.
Section 5.2.7	In the conclusion chapter, a discussion on the similarities and differences between domestic and professional dishwashers should be added.	Added in revision.
Section 5.4.2	It is considered necessary to identify the environmental hot spots of each base case and their respective contribution to the overall life cycle product performance. For instance one hot spot is electricity consumption which is responsible for base case 1 for x % of eutrophication potential and y % of VOC, etc. Furthermore, another hot spot is material A as it contributes respectively to y % of the total overall value of heavy metals, etc. That way it would be easier to identify the focus areas of BAT and implementing measures.	The project team believes that this is what is currently presented in sections 3.1 to 3.6 3.7 summarises these hot spots.

Feedback		Comment
Hobart		
Section 2.4.4	**Travelling effort for maintenance and repair:** 1000 km over the product lifetime seems to be not applicable for all six categories. The effort for maintenance and repair is more or less related to the complexity of the particular machine. There is also a relation based on the usage of a particular machine (i.e. cycles per day, operating hours per day, care handling etc.). Thus, lower category machines need less maintenance and repair than upper categories and consequently accordant kilometres. Note: Data for different categories are not available.	Considered in revision due to new stakeholder input at final stakeholder meeting
Granuldisk		
5.1.4.2	The water consumption in pre-soak and pre-wash prior to the washing in the machine is not included in Table 5. For Base Case 4 Utensil/Pot washers, this consumption can't be neglected since it's much higher than the water consumption in the machine (5 to 8 times higher). For utensil- and pot-washers using granule technology this consumption will be avoided! Granule technology = A mechanical cleaning process where plastic granules and water are blasting the pots and pans clean without using pre-soaking and scrubbing. Water consumption in pre-soak/-wash process MUST be included at least in BC4.	Please refer to the discussion in Task 6 (BAT) for this point: In order to give incentive to reduce the overall water consumption of dishwashing, the inclusion of the whole process from dirty to clean (including the pre-soak and pre-cleaning phase) would be rather desirable for all dishwasher categories, with special focus on utensil / pot dishwashers. However, the water consumption for pre-cleaning is strongly dependent on the specific user behaviour and cannot be influenced by the technology of the dishwashing machine itself. Further, there is no standard measurement method and thus no reliable data to record the average consumption through external pre-cleaning of the wash ware for the different dishwasher categories. Finally, as we already excluded all manually process steps outside the dishwashing machines from the scope of this study as stated in Task 1, we didn't include the consumption of the pre-soak / pre-cleaning phase into the calculation of base cases at all.
5.1.4.3	As 30 % of the total detergent consumption is used in the pre-wash process it's necessary to include this in the total detergent consumption. For utensil- and pot-washers using granule technology this consumption will be avoided as no pre-soak or pre-wash is needed. Granule technology = A mechanical cleaning process where plastic granules and water are blasting the pots and pans clean without using pre-soaking and scrubbing. Detergent consumption in pre-soak/-wash process MUST be included at least in BC4.	
5.1.4.1	Hot water is used for pre-soak and pre-wash. The energy for heating this water is not included either! For utensil- and pot-washers using granule technology this consumption will be avoided as no pre-soak or pre-wash is needed. Granule technology = A mechanical cleaning process where plastic granules and water are blasting the pots and pans clean without using pre-soaking and scrubbing	

Preparatory Studies for Eco-design Requirements of Energy-using Products

Lot 24: Professional Washing Machines, Dryers and Dishwashers

Tender No. TREN/D3/91-2007

February 2011

Final Report, Part: Dishwashers

Task 6: Technical Analysis
Best Available Technologies (BAT)

Öko-Institut e.V.
Institute for Applied Ecology, Germany
Ina Rüdenauer
Markus Blepp
Eva Brommer
Carl-Otto Gensch
Kathrin Graulich

BIO Intelligence Service, France
Shailendra Mudgal
Raul Cervantes
Thibault Faninger
Lorcan Lyons

Büro Ö-Quadrat, Germany
Dieter Seifried

Öko-Institut e.V.
Freiburg Head Office
P.O. Box 17 71
79017 Freiburg, Germany
Street Address
Merzhauser Str. 173
79100 Freiburg, Germany
Tel. +49 (0) 761 – 4 52 95-0
Fax +49 (0) 761 – 4 52 95-88

Darmstadt Office
Rheinstr. 95
64295 Darmstadt, Germany
Tel. +49 (0) 6151 – 81 91-0
Fax +49 (0) 6151 – 81 91-33

Berlin Office
Schicklerstr. 5-7
10179 Berlin, Germany
Tel. +49 (0) 30 – 40 50 85-0
Fax +49 (0) 30 – 40 50 85-388

www.oeko.de

For reasons of better readability, two Task 6 reports were prepared.

The report at hand covers ***professional dishwashers***.

The Task 6 report on *professional washing machines and dryers* is published separately.

For the benefit of the environment, this document has been optimised for **double-sided printing**.

Part: Professional Dishwashers

Table of Contents – Task 6: Technical Analysis Best Available Technologies (BAT)

List of tables IV

List of figures V

1 Introduction 1

1.1 Objective of Task 6 1

1.2 Methodology and assessment of data quality 1

2 Main areas of environmental improvement potentials 2

3 Best available technologies at component and product level 5

3.1 Reducing the overall water consumption 5

3.1.1 Description of the design options 5

3.1.1.1 M 1.1 Optimised water-rinsing systems 5

3.1.1.2 M 1.2 Steam rinsing 7

3.1.1.3 M 1.3 Optimised filter systems 8

3.1.1.4 M 1.4 Automatic load adjustment systems 10

3.1.1.5 M 1.5 Auxiliary rinsing processes 11

3.1.1.6 M 1.6 Granule technology 12

3.1.2 Material composition 14

3.2 Reducing energy losses through exhaust air and dishes 14

3.2.1 Description of the design options 15

3.2.1.1 M 2.1 Heat recovery from exhaust air 15

3.2.1.2 M 2.2 Alternative temperature profile 22

3.2.1.3 M 2.3 Reuse of the heat from drying dishes through active drying zone 23

3.2.2 Material composition 25

3.3 Reducing energy losses through waste water 26

3.3.1 Description of the design options 26

3.3.1.1 M 3.1 Heat recovery from waste water 26

3.3.2 Material composition 28

3.4 Other improvement options 28

3.4.1 Description of the design options 28

3.4.1.1 M 4.1 Insulation of wash tanks or the dishwashing machine 28

3.4.1.2 M 4.2 High-efficiency pumps and motors 29

3.4.1.3	M 4.3 Self-cleaning machine	30
3.4.1.4	M 4.4 Alarms	31
3.4.1.5	M 4.5 Customer-specific adjustment of the dishwashing process through electronic control of the whole process	32
3.4.1.6	M 4.6 Documentation of the dishwashing process and the dishwashing parameters	33
3.4.1.7	M 4.7 Sensor systems to control the dishwashing process	34
3.4.1.8	M 4.8 Optimised tank volume	34
3.4.1.9	Effects of lower washing temperatures on composition of detergents	35
3.4.2	Material composition	38
3.5	**Possible implementation and combinations**	**39**
3.6	**Best available products on the market**	**40**
4	**Best existing product technology outside the EU**	**41**
5	**Annex**	**43**
5.1	**Working paper “Task 6” for stakeholders**	**43**
5.2	**Stakeholder feedback to draft versions of Task 6**	**43**

List of tables

Table 1	Differences in material composition through implementation of the design option described	14
Table 2	Differences in material composition through implementation of the design option described	25
Table 3	Differences in material composition through implementation of the design option described	28
Table 4	Tank volume and temperature of a best available product	35
Table 5	Advantages and disadvantages of different chemical sanitizers	37
Table 6	Technologies built into the best available products on the market (feedback from manufacturers)	40

List of figures

Figure 1	Heat losses from different professional dishwashers	3
Figure 2	Development of the water consumption of hood-type dishwashers from the manufacturer Winterhalter	6
Figure 3	A micro-thin water film from four sides optimises the distribution of water	6
Figure 4	Additional water nozzles at the corner of a hood-type dishwasher	7
Figure 5	Cyclone filters system	9
Figure 6	Automatic water regulation to minimum level on detection of empty compartments	10
Figure 7	Inside of a triple-rinse chamber	12
Figure 8	Principle of granule based utensil / pot dishwasher technology (category 4)	13
Figure 9	Heat exchanger of a flight-type dishwasher	15
Figure 10	Heat recovery from exhaust air through a heat exchanger	16
Figure 11	Energy balance of a hood-type dishwasher	17
Figure 12	Heat recovery from exhaust air through a heat exchanger and heat pump	18
Figure 13	Heat recovery from exhaust air through a heat exchanger and heat pump	19
Figure 14	Heat recovery from exhaust air and from kitchen air through a heat exchanger and heat pump	20
Figure 15	Energy savings through a counter-flow heat exchanger and different methods of heat pump integration.	21
Figure 16	Energy Management – the hot zone is embedded in colder zones	23
Figure 17	Air flow concept	25
Figure 18	Heat recovery from exhaust air and waste water	26
Figure 19	Possible program types of an undercounter dishwasher	32

1 Introduction

1.1 Objective of Task 6

Task 6 entails a technical analysis not of current products on the market but on currently available technology, expected to be introduced at product level within 2–3 years. It provides part of the input for the identification of part of the improvement potential (Task 7), i.e. the part that relates especially to the best available technology. Therefore, objective of Task 6 is to describe the principal design options for improving the efficiency and environmental performance of professional dishwashers.

1.2 Methodology and assessment of data quality

In Section 2, we start the technical analysis of best available technologies with a short repetition of the general energy flows and losses of professional dishwashers using examples of different dishwasher types (for details, cf. Task 4). This analysis provides an initial insight into the environmentally most important areas and improvement potentials.

In Section 3, several design options at component or product level leading to a reduction in water and energy demand during the use phase are described. In order to assess possible trade-offs through additional environmental impacts in the production, distribution or end-of-life phase, for each design option the differences in material composition between a standard product and a product with integrated design option(s) were analysed. Further, we provide a rough estimation of the proportion of the respective BAT options already being implemented. These best available technologies in the areas identified for improvement as well as indicative quantitative data were derived from manufacturers' brochures supplemented by personal communication with and input from manufacturers based on a working paper.

Further, we describe which combinations of different best available technologies are possible and which design options are actually applicable to the different dishwasher types (as many, but not all of the listed improvement options can be used within every dishwasher category). After these more general analyses of several possible design options, we asked manufacturers to describe the components of currently best available products on the market for each dishwasher category.

Finally, in Section 4 state-of-the-art of best existing product technology outside the EU are presented.

Important note: Assessment of data quality throughout Task 6 report

It is important to note that all information with regard to the saving potential of improvement options should be seen in the following context:

- There are currently no European applicable standard measurement methods for quantifying the energy and water consumption of professional dishwashers, and there are likewise no standards requiring manufacturers to define the measurement procedure for potential savings (see Task 1).
- Energy and water savings depend on many different factors such as: ambient air temperature, inlet water temperature, temperature and humidity of exhaust air, temperature of waste water, type of machine and, last but not least, the reference case to which savings are compared.
- Quantification based on information from independent side is not possible as there is no scientific literature about the results of BAT and the potential saving impacts of improvement options in the professional dishwashing sector published.
- Within the study we also tried to collect usage data from different categories of end-users (e.g. large canteens). But it was not possible to get data which enable us to quantify the impact of BAT on water- and energy-savings.
- Manufacturers assess their innovative systems in different ways to their competitors.
- The figures in sales brochures are usually used for marketing purposes and therefore might over-estimate the actual savings.
- Quantitative data provided by manufacturers with regard to the savings potentials are only rough estimations.
- Due to the above reasons, estimations and quantitative data of the different manufacturers diverge considerably.
- The data presented in the Task report at hand are average values of the responses.

2 Main areas of environmental improvement potentials

Based on obtainable data with regard to the energy flows of different types of professional dishwashers (cf. Task 4), the following illustration summarises the shares of heat losses and main areas of environmental improvement potentials respectively.

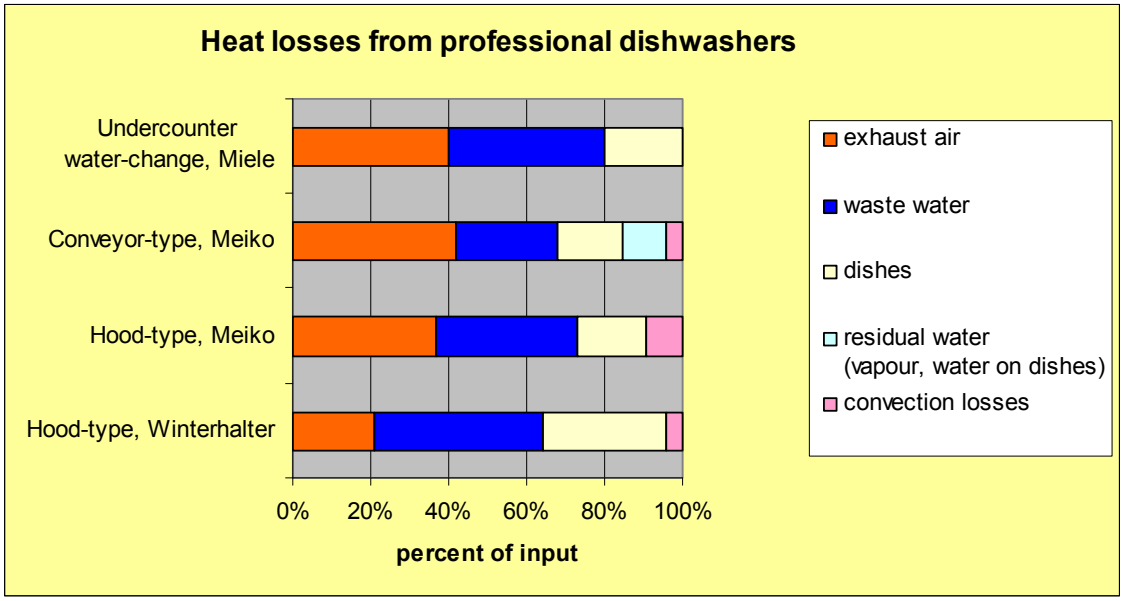


Figure 1 Heat losses from different professional dishwashers

Although data vary between the different categories and sources, Figure 1 generally shows that the most important losses occur in the following areas:

- Exhaust air,
- Waste water,
- Hot, clean dishes.

Approximately 90% of the energy losses can be allocated to these three areas. Consequently, the greatest improvement potential is in these areas. Typically, the losses through exhaust air and waste water are in the same range and totally represent about two thirds of the losses.

Of course, the magnitude of the losses is related to the overall input volume of water and energy. If the input (shown in the illustration as 100%) can be reduced through water-saving measures – without reducing the cleaning performance of the dishwasher – this subsequently leads to energy savings and reduced consumption of detergent and rinse aid[1]. Systematic work on achieving more efficient professional dishwashers will consequently also focus on reducing the overall water consumption. The according measures will be analysed in Section 3.1.

Another option to increase the efficiency of dishwashers can be realised by recovering the heat from either the exhaust air, waste water and/or the cleaned dishes. However, recovering

[1] Within Lot 24 it was assumed that the concentration of detergent in the dishwashing process and the concentration of rinse aid in the rinse-process will be constant (see Task 3).

heat from waste water is limited because it has to have a minimum outflow temperature.[2] Possible design options are described in Sections 3.2 and 3.3.

Besides reducing the overall water consumption and recovering heat, in Section 3.4 we analyse and discuss further improvement options which might be able to reduce the energy and water consumption of professional dishwashers.

There are no specific options listed with regard to the reduction of detergents. From the perspective of dishwashing operators, a sole reduction of the detergent consumption is not reasonable as optimal *concentration* of the detergent is needed to reach the desired cleaning result. The detergent concentration depends on the overall amount of water used for the cleaning process. Thus, the detergent consumption is correlated to the water consumption, and the consumption of detergents will decrease if the overall water consumption can be reduced (see Section 3.1 for design options on reduced water consumption).

Further, according to A.I.S.E[3], there are some market developments promoting a reduced consumption of detergents (cf. also Task 2):

- Suppliers of detergents for professional applications place emphasis on the improvement of formulae and avoidance of components with a high environmental impact. To keep the use of raw materials in a dishwashing process to a minimum, a great variety of products if offered, which makes it possible to narrow down the components of a product to the exact requirements. The mix can be tailored to fit the customer's needs, thus avoiding chemical waste and unnecessary disposal into the environment.
- Products are more and more concentrated and the promotion of powder systems (currently the majority of the market uses liquid detergents) means that more concentrated products with less water can be delivered to the customers.
- First products are entering the market in which the rinse aid function is build into the main wash detergent. Besides simplicity, this offers product, packaging and transport savings to the customer.

The description of improvement options is structured according to the following categories:

- Reducing the overall water consumption (resulting in detergent and rinse aid savings),
- Reducing energy losses through exhaust air and dishes,
- Reducing energy losses through waste water,
- Other improvement options, and
- Improvement options outside EU.

---

2 Waste water contains a high amount of grease and fats that may solidify if too much heat is extracted from the waste water; this material can build up in drainage pipes and cause severe problems for operation.

3 International Association for Soaps, Detergents and Maintenance Products

3 Best available technologies at component and product level

3.1 Reducing the overall water consumption

In dishwasher category 1 (water-change system), fresh water that has to be heated is used for each step of the dishwashing process. Consequently, any design option to reduce the water consumption in the wash and final-rinse phases would lead to a corresponding reduction of energy and thus also a reduction of detergent and rinse aid consumption.

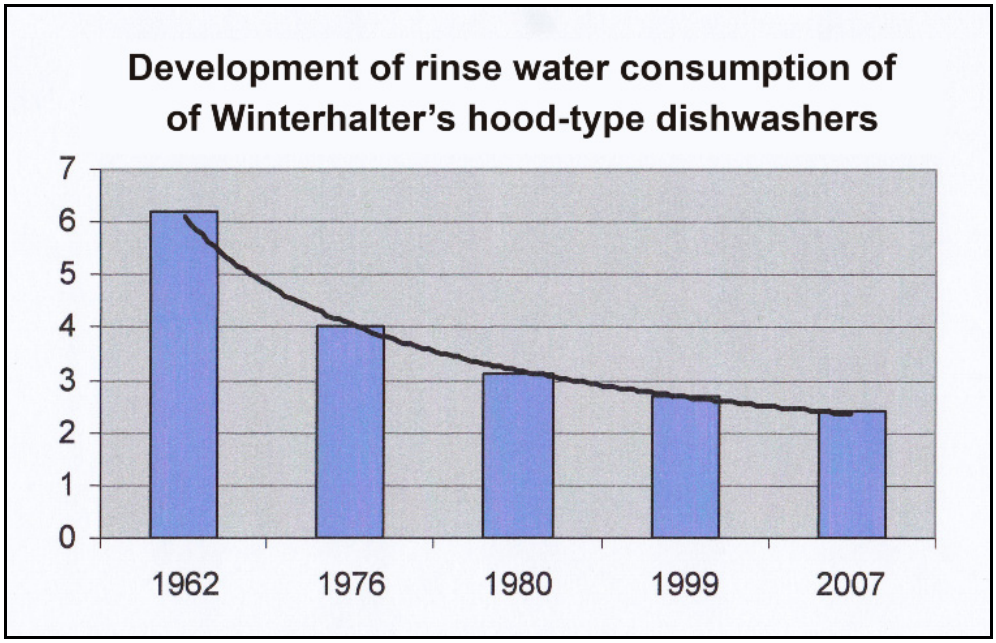
In all other dishwasher categories based on a tank system, rinse water is used to regenerate the detergent solution circulated in the wash tanks. The greater the amount of rinse water used the more water has to be heated up to the temperature of the rinsing process. Therefore, almost any measure which reduces this water consumption will also lead to a reduction in energy consumption.

Calculative, a reduction of 20% in water use (for example from 2.5 litres to 2 litres per cycle) will lead to a reduction in energy consumption of around 0.8 kWh per hour (basis: 30 cycles per hour and a temperature difference of 45°C).

3.1.1 Description of the design options

3.1.1.1 M 1.1 Optimised water-rinsing systems

Optimised water-rinsing systems have special precision nozzles that disperse rinse water like a curtain and form a thin film of water on items of wash ware. The more precisely the water is steered towards the dishes the less water is needed. Water consumption could be reduced in previous decades; e.g. pass-through dishwashers that once used more than 6 litres per cycle currently use only about 2.5 litres per cycle or even less (see Figure 2).



(Source: Winterhalter)

Figure 2 Development of the water consumption of hood-type dishwashers from the manufacturer Winterhalter

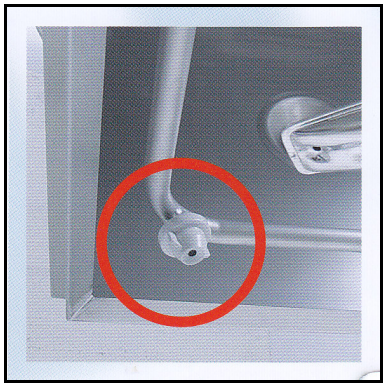
In addition to the conventional top-down and bottom-up rinsing system, some conveyor-type dishwashers (category 5 and 6) also rinse wash ware with lateral rinsing systems (see Figure 3) which, according to manufacturers, enables even more effective removal of soil and detergent. For instance, one manufacturer claims that his fresh-water rinse system reduces the water consumption up to 50%. However, as the reference case is not described and could be based on a rather low efficient appliance, the value does not help to quantify possible savings compared to an average model.



(Source: Winterhalter)

Figure 3 A micro-thin water film from four sides optimises the distribution of water

In the case of a hood-type dishwasher from another manufacturer, additional sprayers have been installed at every corner of the dishwashing machine so as to achieve uniform rinsing of all wash ware (see Figure 4). Newly designed racks shall optimise the water flow from below the rack, thus leading to improved washing and rinsing results.



(Source: Meiko)

Figure 4 Additional water nozzles at the corner of a hood-type dishwasher

Another manufacturer uses a system with reverse spray arms in order to achieve improved cleaning results for hood-type dishwashers.

In general, optimised water-rinsing systems are an important measure for reducing the water consumption of all categories of professional dishwashers. However, differing from the above stated reduction potentials of individual machines, manufacturers estimate the average reduction potential of water savings to be around 10%. For other manufacturers it is very difficult to quantify individual design options like spray arms as the system has to be seen as a whole – the pump rating, water consumption, spray arms, etc. Further, comparing reductions of water consumption cannot be undertaken without taking the hygienic and optical dishwashing result into account as well.

The overall reduction potential is dependent on the water-rinsing system of the specific machine and the improvement options that can be installed. In most up-to-date machines, the water-saving potential seems to be already exhausted; only lower-end dishwashers on the market might still achieve water savings by implementing unexploited improvement options.

As it is not possible to identify any specific reduction potential for water and energy consumption in the different categories, we didn't further analyse this improvement option under cost-benefit aspects.

3.1.1.2 M 1.2 Steam rinsing

For this process, detergent is first rinsed off with water. The ensuing steam rinse completely fills the washing chamber with steam which then forms a very thin film on the wash ware and removes residual alkalinity. "Steam reaches every part of the wash ware, and spray shadows

are avoided. The self-drying effect of the wash ware is further enhanced by the increased temperature penetration into the wash ware."[4]

For the steam-heating process, a small quantity of water (relative to the traditional process) is heated up to 85°C and only a fraction of the rinsing water (approximately 100 ml) is heated up to 100°C; overall, less water is needed for steam rinsing compared to water rinsing.

The steam rinsing system was first introduced in a category 2 dishwasher (undercounter, one-tank). For instance, one manufacturer claims that the rinse program uses 1.4 litres of water followed by an additional steam rinse of only 0.1 litres, leading to a final rinse-water consumption of 1.5 litres per cycle[5]. Compared to machines with water rinsing, this represents a saving of up to 55 percent in water as well as up to 70 percent in rinse aid.[6]

The use of steam rinsing in categories 3 to 6 is more difficult because the additional pressure of the steam has to be kept in the machine. This is currently not possible for the categories 5 and 6 (because of the open entrance and exit of these machines). For categories 3 and 4 it is possible in principle but the washing chamber would have to be sealed very well.

Steam rinsing is effective regarding reducing water consumption. However, the rinse performance has to be taken into account as water has its advantages regarding rinsing off debris and residues of chemicals. The energy required for the generation of steam by heating water up to 100°C reduces the energy savings gained from decreased water consumption. Some manufacturers doubt that energy savings can be achieved with steam-rinsing systems at all. .

3.1.1.3 M 1.3 Optimised filter systems

Another possibility to reduce the amount of rinse water is to improve the filter system of the dishwashing machines. As more soil can be removed from the water during the dishwashing process, less water is needed for the final rinsing.

Two possible options are described here:

- Centrifugal systems (cyclone filter)
- Integrated pre-scouring system.

The **centrifugal system** (see Figure 5) works in the following way: suspended soil in the wash water passes through a small unit which causes a vortex effect, separating out suspended matter in the water. Some manufacturers use this technique in undercounter and hood-type dishwashers. For category 2 and 3 dishwashers, the improvement potential by the means of a cyclone filter applying the centrifugal principle is estimated by manufacturers to be 40 up to 70%.

---

4 Source: Hobart; http://www.hobart-export.com/wExport_en/news/news_records/488060762.php (21.7.2010)

5 http://www.premax.de/en/media/prospekte/web_PR-599-K-e_FP.pdf (11.8.2010)

6 http://www.hobart-export.com/wExport_en/news/news_records/488060762.php (11.8.2010), the "standard machine" is not specified however.

Another manufacturer has also used a vortex-action filtering system on larger conveyor-type machines of category 5 and 6.

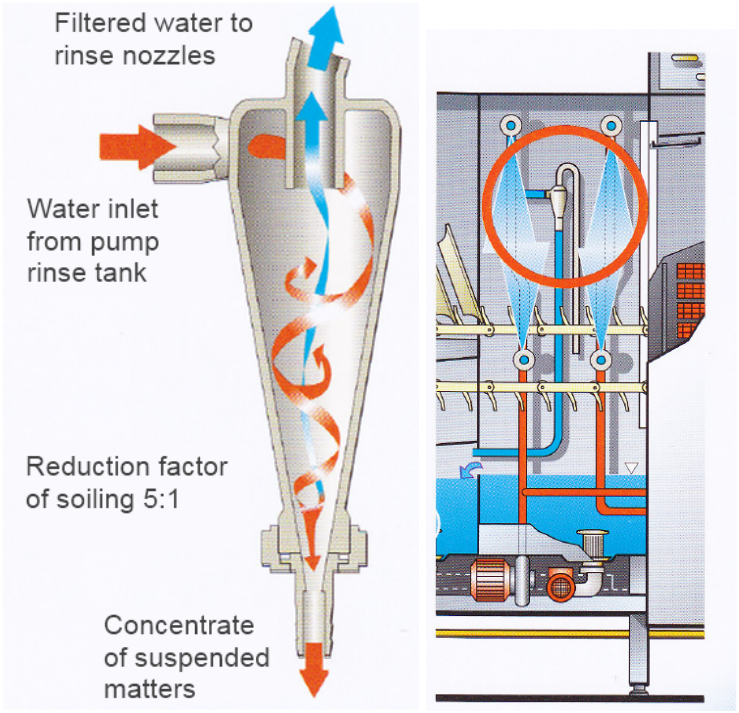


Figure 5 Cyclone filters system

Another possibility used in conveyor-type dishwashers (categories 5 and 6) is the installation of an **integrated pre-scouring system** with intermittent rinsing with fresh water from the 'pumped final-rinse zone'. The water from this process is filtrated via two cyclones. With this system, it is possible to rinse away food particles from dishes even before they reach the main wash tanks and final-rinse zone (see also M 1.5). According to one manufacturer, such a system could result in a reduction of up to 20% in fresh-water use.

In principle, it can be stated that in all dishwasher categories (apart from category 1 which is based on a water-change system), advanced filter systems are already available on the market. In these cases, there will be no significant water savings by improving advanced to the best filter systems. However, also machines with more primitive filter systems are offered on the market. These filter systems might be sufficient if the machine are used less frequently (e.g. 10 times a day) and the accumulation of dirt in the tanks is limited.

On the basis of those primitive filter systems (which are not assumed to be the base case) the possible water-saving potential by installing advanced filtering systems might be 10% to 20% of the total water use..

3.1.1.4 M 1.4 Automatic load adjustment systems

Partial load of dishwashing machines causes additional energy, water, and detergent consumption (cf. Task 3).[7] To adjust the water and thus the energy consumption automatically to the actual load of dishwashers, sensor technologies can be implemented in dishwashers.

For conveyor-type dishwashers (categories 5 and 6), the systems detect the amount of wash ware as well as empty conveyor-belt sections and then adjust water consumption accordingly.[8] It should be noted that only the final rinsing process will be adapted to the load.

Figure 6 shows the adaptation of fresh-water rinsing to empty conveyor-belt sections.

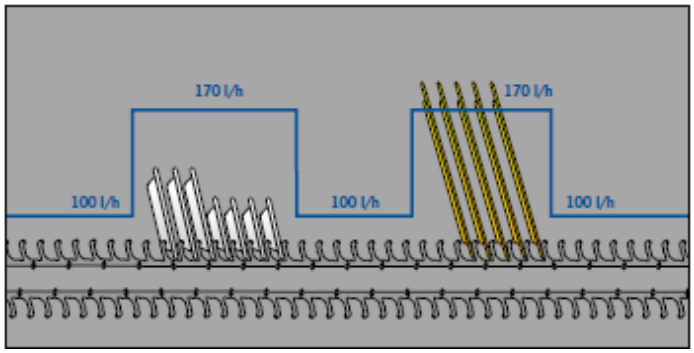


Figure 6 Automatic water regulation to minimum level on detection of empty compartments[8]

Some manufacturers offer conveyor-type dishwashers with an automatic system that works in a different way. A photocell activates the dishwasher when the incoming items are recognised, and the final rinse does not start until the load reaches the final-rinse zone. If no extra items are loaded, the machine stops automatically. The machine restarts once the photocell is reactivated.[9] Although this system works in a similar way, the effect may depend on the special design and programming of the systems. Consequently, a similar configuration may be programmed differently (e.g. timing of the deactivation of the washing zone) and will result in a different impact on energy and water savings.

On the other hand, automatic load-adjustment systems might also have disadvantages: in case the machine is stopped the vapour in the machine might collapse and the water would be drained away. This even results in additional water and energy consumption after the stop. Further, the washing process might be disturbed during the reactivating phase, resulting in a poor washing result.

---

7 On average, the real-life workload – depending on the dishwasher category – is assumed to be 60 to 80% (75% for conveyor-belt dishwashers), resulting in additional consumption (energy: 7.5 to 15%, water and detergent: 10 to 30%; cf. Task 3)

8 See e.g. http://www.hobart-export.com/wExport_global/p_warewashing/documents/literatures/flight-type/web_PR-705-K-e_SENSOTRONIC.pdf

9 http://viewer.zmags.com/publication/0e45a329#/0e45a329/8

Until now, technology for adjusting water consumption to the machine load technology has only been used in conveyor-type dishwashers (categories 5 and 6). In case of category 1 dishwashers, sensors could detect if the machine is only loaded half-full (i.e. only upper or only lower basket). For cleaning half load, the water reduction could possibly be 20%, thus it is not as effective as washing at full load. Dishwashers from categories 2 to 4 have not incorporated any automatic load adjustment systems. In principle this would be possible, but it would be very complex and expensive as it is only possible with a special matrix system which can recognise the position of the wash ware and which routes the water directly to these places.

The water and energy savings of the automatic load adjustment system strongly depend on the use of the dishwashing machine.[10] If the conveyor belt is loaded to full capacity, there will be no savings. In practice, however, empty spaces or gaps between the dishes or baskets can hardly be avoided. Rinsing those empty spaces or even frequently interrupted dishwashing processes have a huge effect on the consumption.

As there is no survey about the average load and no scientific report about the saving results in relation to the partial load for the different dishwasher categories we didn't further analyse this improvement option under cost-benefit aspects.

3.1.1.5 M 1.5 Auxiliary rinsing processes

For conveyor-type dishwashers (category 5 and 6), lower fresh-water consumption can be reached through a two or three-step rinsing zone. The rinsing process is divided into a pre-rinse or intermediate rinse in which the rinse water is circulated via a small tank, and a fresh-water rinse without circulation. For instance, one company uses a triple rinse system, which consists of a pre-rinse nozzle, a re-circulated rinse and a fresh-water final rinse. The pre-rinse nozzle is positioned before the pumped rinse. It rinses off most detergent from the wash ware before entering the rinse zone. The water is directed back into the wash tank, minimising detergent addition into the re-circulating rinse water.[11]

[10] For the base case calculations within this report, we assumed that conveyor-type dishwashers are running continuously during the dishwashing periods. There might be differences if e.g. rack type dishwashers are used discontinuously. In a dishwashing process which is frequently interrupted, an automatic load adjustment system might have higher savings results. However, there is currently no information on typical user behaviour and consumption data with regard to discontinuous operation. Thus, within Task 4 (recommendations on mandates) we suggest consideration of real-life use conditions (inter alia partial load) when developing a new standard on consumption and performance measurement.

[11] http://www.hobart-export.com/wExport_global/p_warewashing/documents/literatures/flight-type/web_FTN_PR-600-e.pdf



(Source: Hobart)

Figure 7 Inside of a triple-rinse chamber

An auxiliary rinse with recycled water from the tank helps reducing the water consumption for the final fresh-water rinse. For this reason, less water has to be heated up to the high rinsing temperature, thus resulting in reduced energy consumption. One manufacturer states that with an auxiliary rinse system it is possible to lower the water consumption for the final fresh-water rinse from approximately 400 litres per hour to 180 litres per hour.

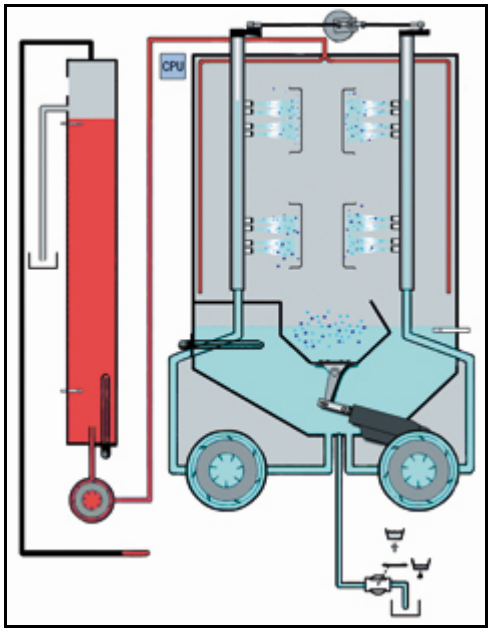
The auxiliary rinsing (with an additional tank) is used almost exclusively for conveyor-type dishwashers with more than one tank. Only one company is using the system for a hood-type dishwasher (category 3).[12] For category 1 dishwashers (water-change system), it is not applicable. The system is used in most of the high-end products but there are also multi-tank conveyor-type machines on the EU market which still do not make use of the advantages of an auxiliary rinse system.

3.1.1.6 M 1.6 Granule technology

For utensil/pot dishwashers (category 4), granule technology is applicable. It is a mechanical cleaning process where plastic granules and water are blasting the pots and pans clean without using pre-soaking and scrubbing. Even hard burnt-in pots and pans or dried-in soil is cleaned by the granules without soaking or scrubbing outside the machines.

Figure 8 shows the cleaning process of granule machines. The main characteristics of an exemplary granulate dishwasher have already been described in Task 4 (Technical Analysis Existing Products).

[12] http://www.wexiodisk.co.uk/Products/SingleTankDishwashingMachines/WD9/tabid/70/Default.aspx. Unfortunately, we did not get any data to provide a cost-benefit ratio of this improvement option for base case 3.



(Source: Granuldisk)

Figure 8 Principle of granule based utensil / pot dishwasher technology (category 4)

According to the manufacturer's feedback, through this process, which is used by more than 10 000 end-users, the following consumption values can be saved compared to conventional technology used in utensil / pot dishwashers:

- Water consumption: up to 70%
- Detergent consumption: up to 60%
- Energy consumption: up to 60%

This effect mainly is based on water savings in the external pre-cleaning phase prior to the cleaning within the dishwashing machine. According to the manufacturer's feedback, the water consumption in the external pre-cleaning phase is with around 8 litres hot water per item 5 to 8 times higher compared to the water consumption within the machine. For utensil / pot dishwashers using granule technology this consumption would be avoided.

In order to give incentive to reduce the overall water consumption of dishwashing, the inclusion of the whole process from dirty to clean (including the pre-soak and pre-cleaning phase) would be rather desirable for all dishwasher categories with special focus on utensil / pot dishwashers. However, the water consumption for pre-cleaning is strongly dependent on the specific user behaviour and cannot be influenced by the technology of the dishwashing machine itself. Further, there is no standard measurement method and thus no reliable data to record the average consumption through external pre-cleaning of the wash ware for the dishwasher categories. Finally, as we already excluded the manually process steps outside the dishwashing machines from the scope of this study in Task 1, we didn't further analyse the granule technology under cost-benefit aspects in the following tasks.

3.1.2 Material composition

The improvement options M 1.1 to M 1.6 described above lead to a reduction in water and energy demand during the use phase. In order to analyse possible trade-offs through additional environmental impacts in the production, distribution or end-of-life phase, differences in material composition between a basic product and a product with integrated design options were investigated (see the following table).

Table 1 Differences in material composition through implementation of the design option described

Design Option / Material category	M 1.1 Optimised water rinsing systems	M 1.2 Steam rinsing	M 1.3 Optimised filter systems	M 1.4 Automatic load adjustment systems	M 1.5 Auxiliary rinsing processes	M 1.6 Granule technology
	[g]					
Bulk plastics						
PP			+500		+500	
Ferrous metals						
stainless steel		+10 000	+500		+10 000	
Non-ferrous metals						
copper wire		+1 000	+1 500		+1 500	
Al diecast			+500		+500	
Electronics		+100	+100	+100	+100	

Note: empty fields = not applicable or no response by manufacturers

3.2 Reducing energy losses through exhaust air and dishes

As mentioned in Section 2, roughly two thirds of heat losses occur through exhaust air and waste water. Approximately another third leaves the dishwashing process through the hot dishes. One improvement option might be to lower the overall process temperature of the cleaning process as this would reduce the losses of exhaust air, waste water and the wasted heat from dishes as well. However, the overall cleaning and hygienic performance has to be taken into account. This reduces the possibility of lowering process temperatures.

Another alternative to reduce the energy consumption is a process management that leads to lower heat-output flows or through the recovery of heat from these flows. The different design options for heat recovery from exhaust air and dishes are described in the following sections. Generally, for undercounter water-change dishwashers (category 1) the volume of (heated) air within the machine is relatively low compared to the other categories; thus for this dishwasher type it is difficult to achieve significant improvements.

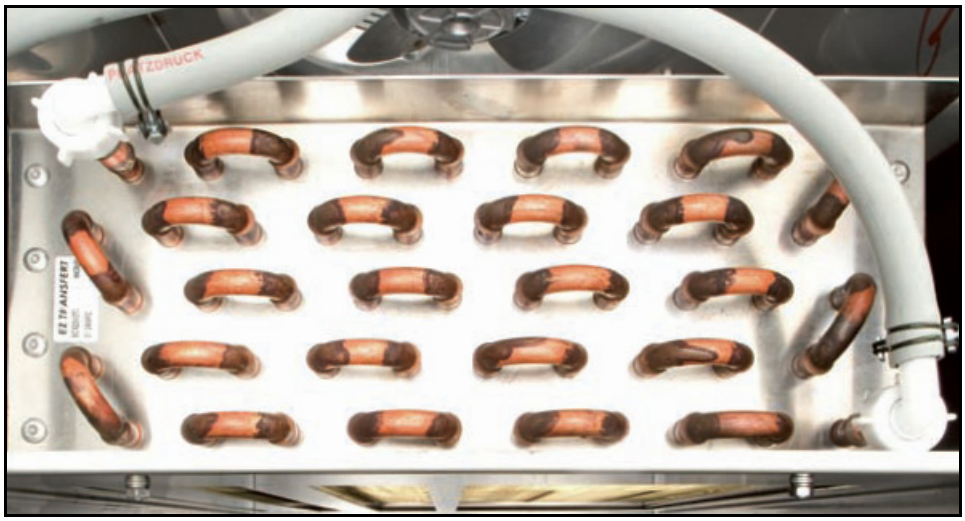
3.2.1 Description of the design options

3.2.1.1 M 2.1 Heat recovery from exhaust air

M 2.1.1 Heat recovery through a heat exchanger

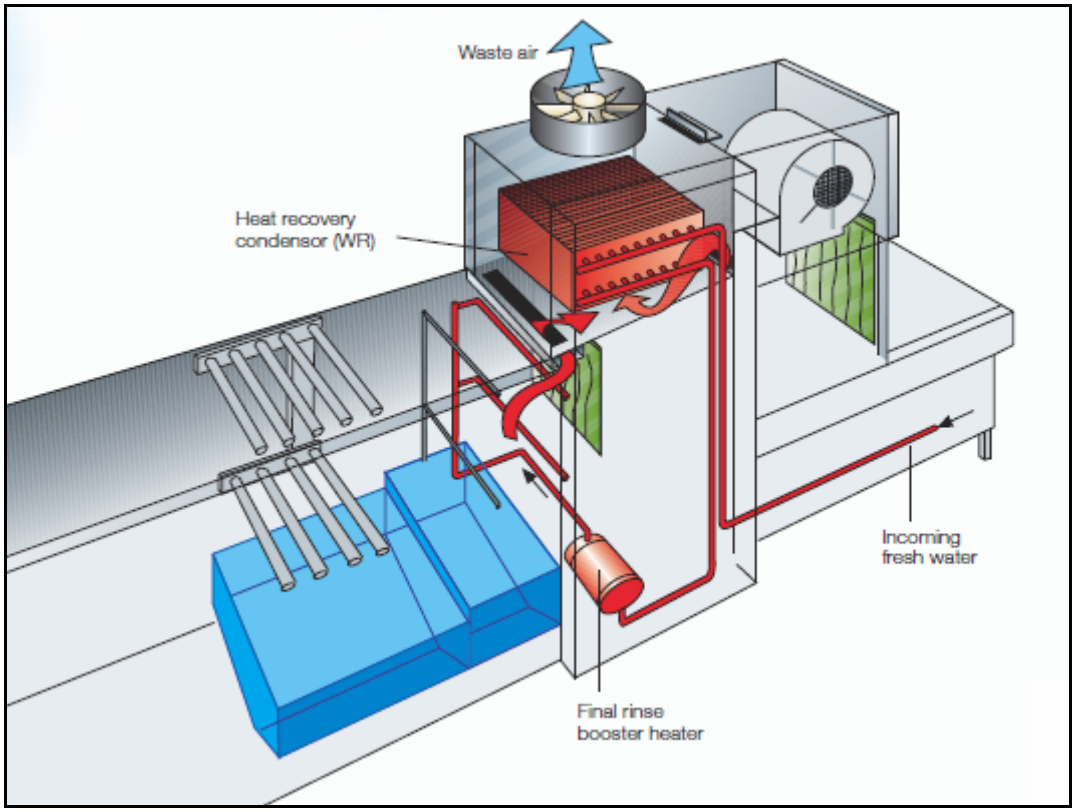
The heat from the exhaust air can be used to preheat the incoming water of the machine through a counter-flow heat exchanger. The exhaust air, which still has a remarkable energy content (35°C and 68% of humidity) is cooled down and dried before it is expelled. Using the heat gained from this process, the incoming water can be preheated to around 40°C.

The following illustration shows a heat exchanger.



(Source: Hobart)

Figure 9 Heat exchanger of a flight-type dishwasher



(Source: Meiko)

Figure 10 Heat recovery from exhaust air through a heat exchanger

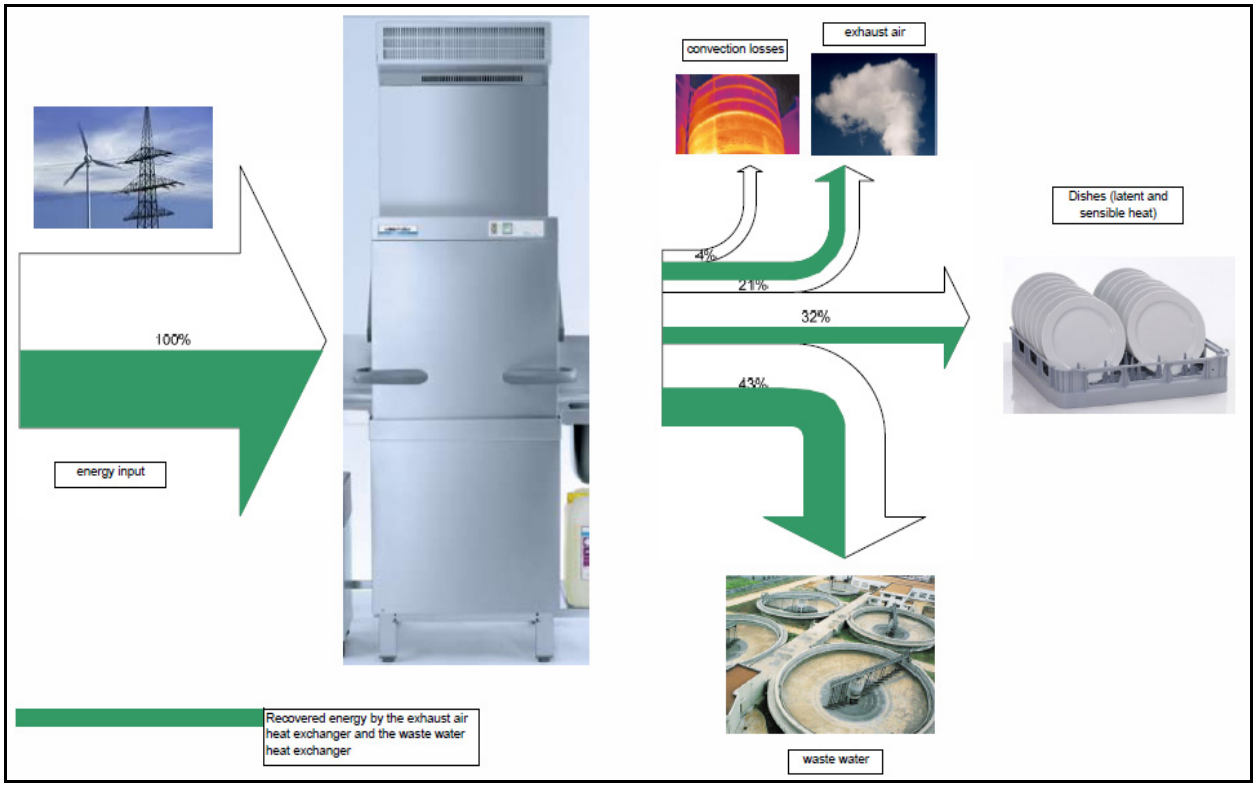
Figure 10 above shows the working principle of an exhaust-air heat exchanger. The warm and humid air is ventilated through the heat recovery condenser. There, the heat is taken over by the incoming fresh water flowing in pipes through the air stream. The preheated water will then also be heated up through the final-rinse booster heater.

A good counter-flow heat exchanger can achieve an efficiency of approximately 90%, which means that 90% of the temperature difference between outgoing and incoming fluid can be used to heat up the incoming water. According to manufacturers, the temperature difference between the exhaust air and the hot water outflow of the heat exchanger will be about 5°C, while in older models the temperature difference may be up to 20°C.

By using a heat exchanger, more than half the losses of energy from the exhaust air can be recovered. Manufacturers stated that energy savings of 15% to 25% are possible related to the overall energy demand of a reference product without heat exchanger. An additional advantage of the heat recovery process is that the outgoing (exhaust) air will be cooled down and thus includes less humidity.

In the figure below, showing again the principal heat losses, the exemplified hood-type dishwasher is equipped with a heat exchanger to reduce the heat losses from exhaust air and an additional heat exchanger to reduce the heat losses from waste water. By these measures,

the overall energy consumption can be reduced about 40% percent. The illustration also shows that the absolute amount of energy which can be saved is dependent on the total water consumption and energy input.



(Source: Winterhalter)

Figure 11 Energy balance of a hood-type dishwasher

M 2.1.2 Heat recovery through a heat pump

With the addition of a heat pump, the energy remaining in exhaust air can be used more efficient than with a counter-flow heat exchanger alone.

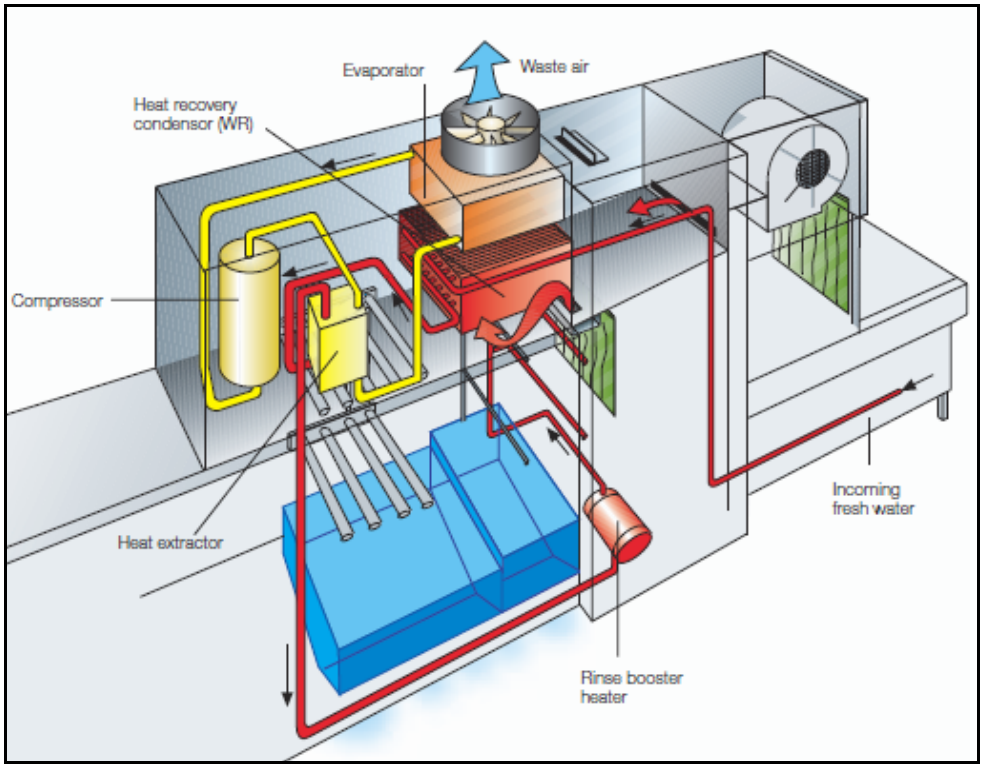
A heat pump is an electric device with both heating and cooling capabilities. It extracts heat from one medium (for example exhaust air) at a lower temperature and transfers it to another (for example rinse water) at a higher temperature, thereby cooling the former and warming the latter. Thus, the energy gained – which is transformed to a higher temperature level – can be used to heat up the wash tank and the rinsing water.

The following three examples show different ways in which heat pumps can be used in dishwashers (see also Figure 12 to Figure 14).

a) The heat pump (yellow circuit) initially recovers the heat from the exhaust air, which leaves the heat exchanger (heat recovery condenser) at a temperature of about 35°. The exhaust air is then cooled down further by the heat exchanger of the heat pump (in

the illustration: evaporator). After passing this heat on to a gas medium, the heat pump mechanism compresses the gas medium in the compressor in order to increase its temperature. Following this compression pumping process, the heat pump transfers heat to the cold incoming fresh water (red pipes), while the now condensed cooled medium cycles back to recover more heat from the exhaust air. In this manner, incoming fresh water for the fresh-water rinse can be preheated to about 60 to 70°C, thereby saving initial water heating energy.

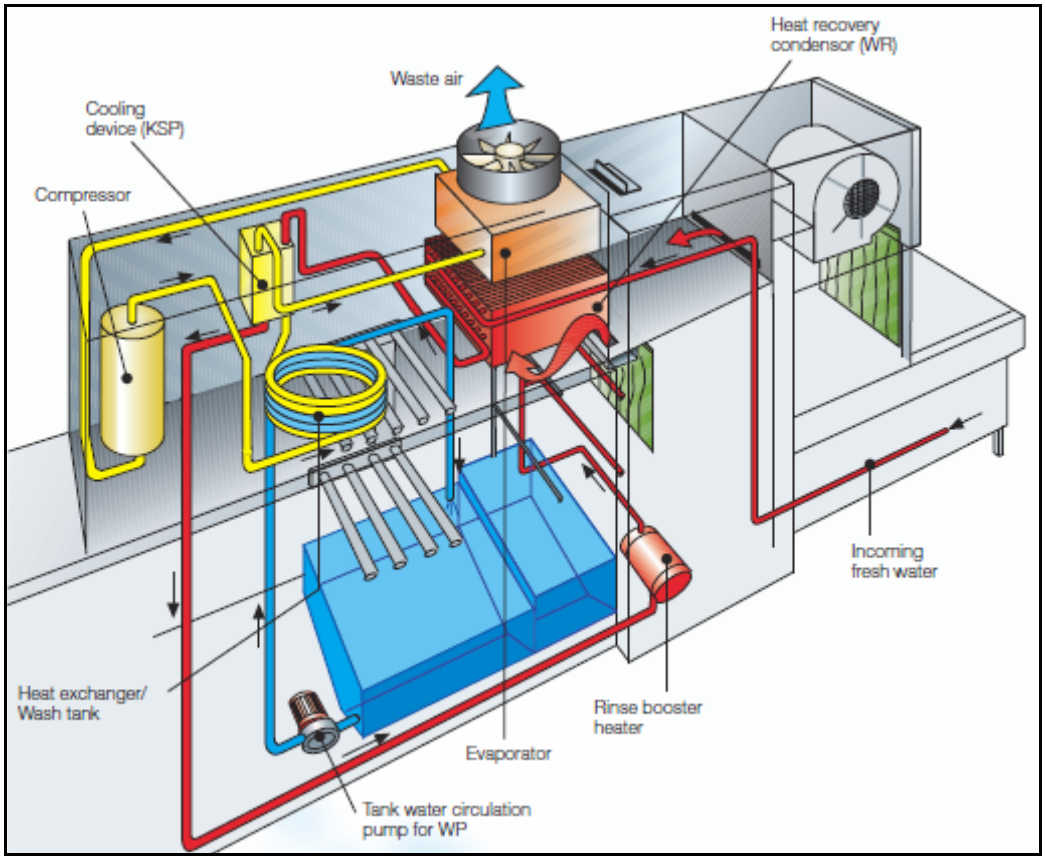
An additional advantage of the heat-pump process is that the outgoing (exhaust) air will be cooled down to 18-22°C. This results on the one hand in improved ambient conditions in the kitchen or in additional savings. On the other hand, under certain conditions, the air from the dishwashing process can be released to the room and reduce cooling requirements for the kitchen or operating facility.



(Source: Meiko)

Figure 12 Heat recovery from exhaust air through a heat exchanger and heat pump

b) The second possibility is similar to the first, however the heat from the heat pump (yellow circuit) is used to pre-heat the detergent solution in the *wash tanks* (blue pipes) in addition to heating the rinse water (red pipes). The advantage of this arrangement is that a larger part of the energy from the exhaust air can be reused, which saves additional heating energy.

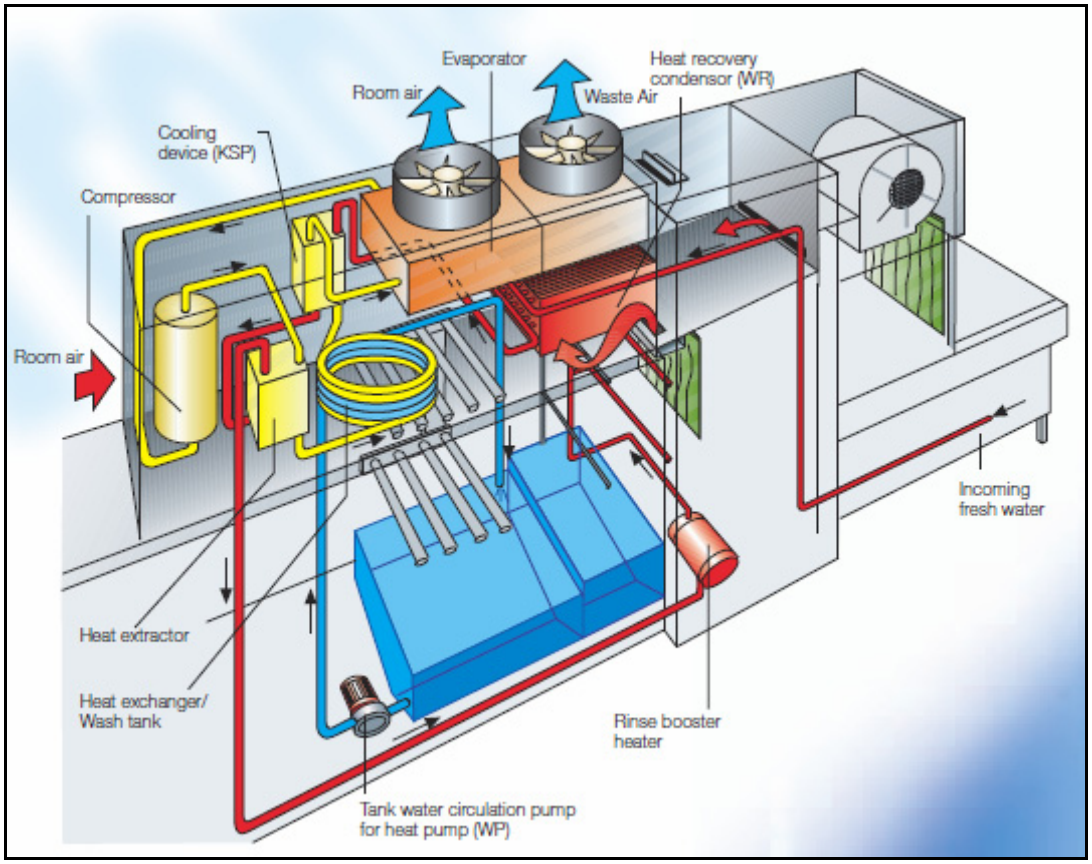


(Source: Meiko)

Figure 13 Heat recovery from exhaust air through a heat exchanger and heat pump

c) In the third case, not only the exhaust air from the dishwashing process is used for the heat pump, but also the air of the room. The advantage of this arrangement is an additional heat gain and further climatisation of the kitchen. In the example below, the total heat requirement of the dishwashing machine can be reduced by 62% (cf. stage 4 in figure 14).[13]

[13] Meiko: B-Tronic, K-Tronic, Heat recovery: a system with high benefits



(Source: Meiko)

Figure 14 Heat recovery from exhaust air and from kitchen air through a heat exchanger and heat pump

Figure 15 below shows the energy savings (green) in relation to the total heat demand for the four different heat recovery options described above. The installation of a counter-flow heat exchanger (design option M 2.1.1) saves about 27% of the heat required for the dishwashing process (i.e. only the heating energy, not the total energy of the dishwashing process including energy for pumps, transport belt and electronics).

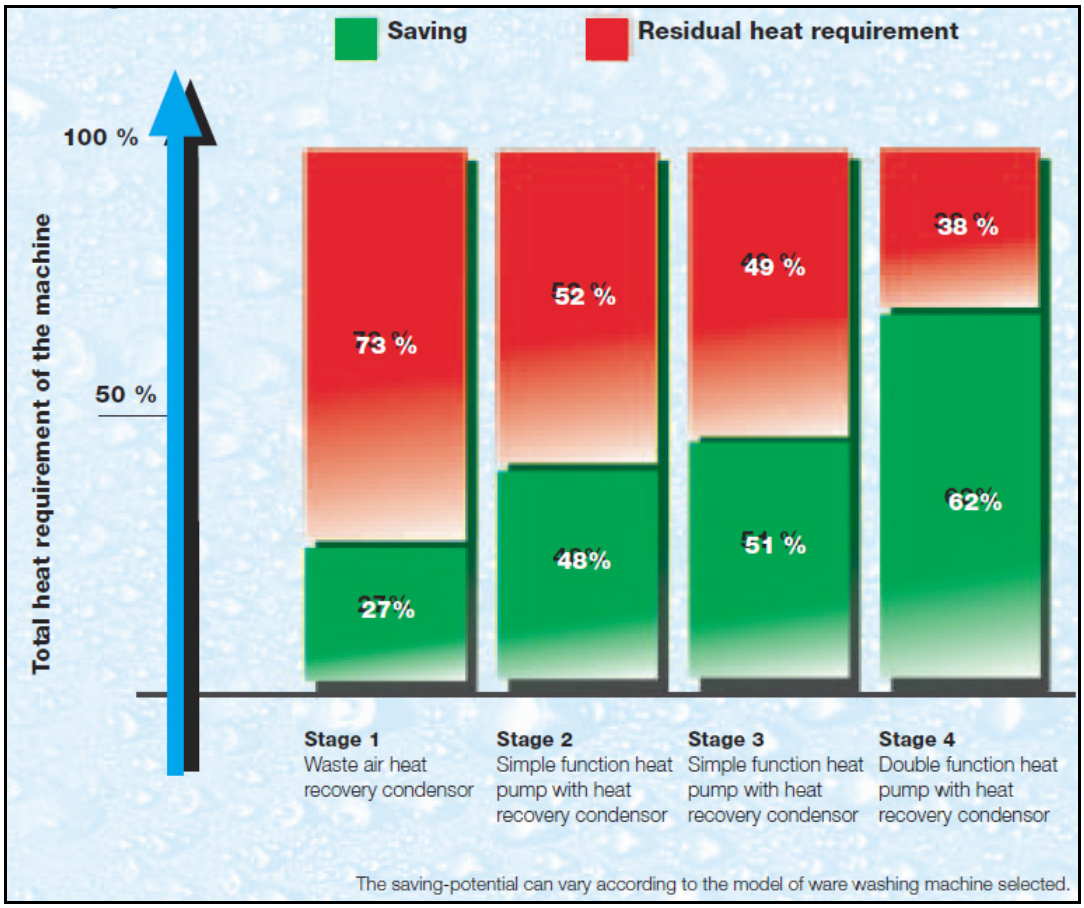
In stage 2 (design option M 2.1.2a) a heat pump is added to enhance the heat recovery process. Preheating of the rinse water increases the heat savings to 48%. If the heat pump is used to preheat both rinse water and wash tanks (stage 3, design option M 2.1.2b), the savings increase to 51%. Finally, if the heat pump system utilises warm air from the kitchen (in addition to hot exhaust air from the dishwasher), savings can reach 62% (stage 4, design option M 2.1.2c).

However, these potential savings depend on the assumed base case under consideration[14] as well as on the specific conditions in situ. Especially for stage 4 the possibility to install this

[14] The base case for categories 5 and 6 are assumed to be 75% partial workload, while the dishwashers are operated in a *continuous* process. For discontinuous operation (which has not been analysed within this study

technology is depending on the type and total energy consumption of the dishwasher and the local infrastructure (available space and ventilation).

The savings results are depending on the specific conditions (fresh-water temperature, air temperature in- and outside, air volume, and humidity of the exhaust air).



(Source: Meiko)

Figure 15 Energy savings through a counter-flow heat exchanger and different methods of heat pump integration.

According to manufacturers' information, more than 75% of multi-tank conveyor-type dishwashers (category 6), are already equipped with a heat exchanger; within multi-tank conveyor-types (category 5) just over the half of the dishwashers already use this technology; heat pumps are usually offered as optional/additional equipment.

due to a lack of data), the situation would be different. As exhaust heat pumps will suffer if they are switched on and off frequently, the dishwashing operators might not turn them off e.g. in a discontinuous operation. Thus, the rinse process will continue although there is no wash ware in the rinsing sector, resulting even in additional consumption values.

It should also be pointed out that the possibilities described above are only appropriate for cold-water inlets and cannot be used in combination with warm water supply of the rinse water. The decision whether to use a heat exchanger, a heat pump or none of these options also depends on the ambient conditions in the establishment where the dishwasher is used: if there is already a central heat recovery system installed, it might be more cost-effective to use the central system to recover heat from the exhaust air of the dishwasher.

Four other aspects should be mentioned:

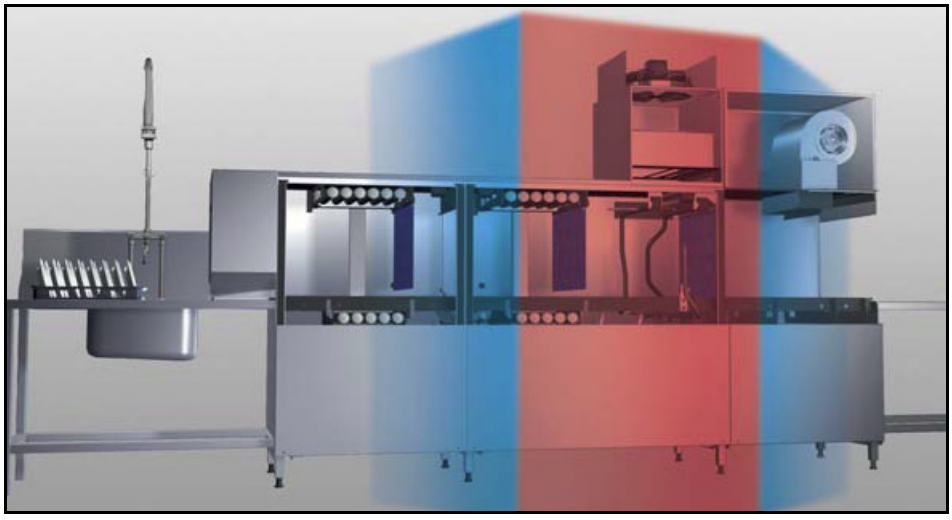
- Commercially available heat pumps have a limited temperature level with regard to the medium after the compressor. Furthermore, since the overall water consumption is already low in high-efficiency dishwashers, the capacity for transferring recovered heat to incoming fresh water is correspondingly reduced. The effect of these two factors is that not all of the heat recovered may be used and returned to the washing circle.
- Double-step heat pumps could be used to increase the temperature of the supply line to a higher temperature level (more than 90°C), but they require a lot of space and create additional costs. Further, the additional saving potential is very limited (see previous bullet point).
- Heat pumps need an annual inspection to establish whether or not the refrigerant is leaking; thus it will cause additional maintenance costs.
- Due to a lack of space it is more difficult to integrate heat pumps into smaller under-counter dishwashers[15].

3.2.1.2 M 2.2 Alternative temperature profile

In particular in the case of conveyor-type dishwashers, heat losses in the loading and unloading areas may be reduced by concentrating the heat-intensive processes in the mid section of the machine (see Figure 16). The high-temperature wash zone is embedded between the pre-wash and the fresh-water rinse zones which are supposed to act as a temperature barrier.[16] The temperature equalisation takes place within the machine and energy losses are reduced.

[15] As one manufacturer stated

[16] Hobart, Flight-Type Dishwasher Premax FTP



(Source: Hobart)

Figure 16 Energy Management – the hot zone is embedded in colder zones

The temperature barrier between the zones may also be enhanced by the use of specially designed thermal-layered curtains hung in the loading and unloading areas. One manufacturer claims that thermal-layered curtains reduce temperatures in the loading and unloading areas by 2 to 3 degrees.[17]

In addition to the effect described, the temperature in the washing zone is slightly increased (from typically 55°C to 65°C) while the rinse temperature is slightly lowered (from typically 85°C to 75°C). The energy-saving potential of this system is estimated by the manufacturer to be 10 to 15%. In contrast, other manufacturers question whether this innovation leads to quantifiable and reproducible energy savings at all. Additionally, there are doubts that the hygienic result can be achieved in every case because the rinsing temperature is lower than in the traditional system.

While the spatial embedding of the wash zone is only applicable for conveyor-type dishwashers (categories 5 and 6), an alternative temperature profile of the wash and rinse process could also be used for dishwashers of categories 1 to 4 in principle. However, there is no information available with regard to the possible savings potential of this design option, thus we didn't further analyse this improvement option under cost-benefit aspects.

3.2.1.3 M 2.3 Reuse of the heat from drying dishes through active drying zone

The heat stored in the dishes or other wash ware is substantial but it can only partly be used and regained without disturbing the drying process. It seems difficult to achieve a high efficiency of this system (low savings potential accompanied by comparably high investment).

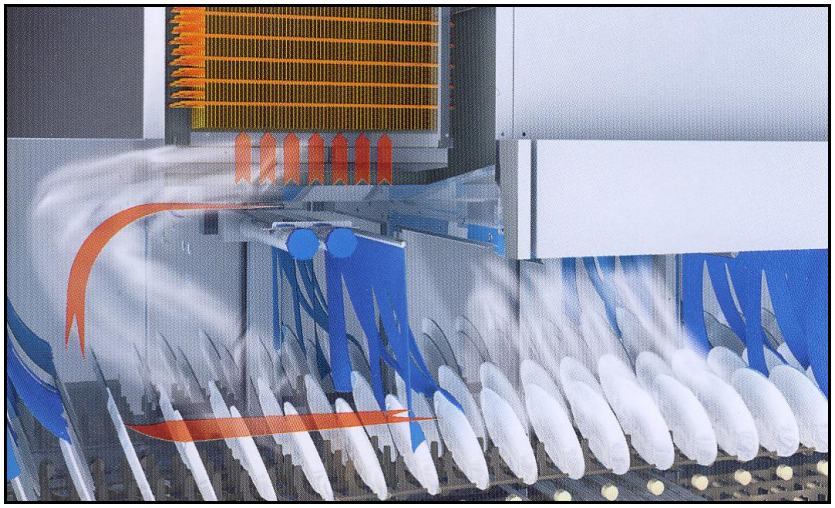
[17] Hobart. Hobart CLe Warewashers. 17 August 2010. Retrieved from: https://feg.hobartcorp.com/resourcecenter/Marketing%20Literature/F40077%20%2806-08%29%20broCLeWareWash.pdf

For example, heat losses through china could be reduced by using dishes with less weight or heat capacity and through heat recovery from the outgoing china. However, the reduction of weight or heat capacity might be limited as this affects the drying performance (if the dishes contain less heat, the remaining water might not evaporate completely).

For category 2 and 3 dishwashers, the heat stored within the hot and humid air and the dishes can be reused during the drying process. Dry air from outside the dishwasher can be ventilated through the machine to accelerate the drying process and the hot dishes will transfer heat to the incoming air stream. This heat can then be transferred via a heat exchanger and/or concentrated with a heat pump in order to preheat the rinsing water or wash tanks (similar to improvement options M 2.1.1 and M 2.1.2).

As for conveyor-belt dishwashers, one manufacturer is advertising a fresh-air drying zone. In this case, the drying process is supported by a blower and an air heating system. To reduce the humidity in the drying zone to 10%, fresh dry air from the kitchen is drawn into the drying chamber. The humid and hot air is then directed through the machine and gives its heat to the washing process. At the entrance to the machine, the air is drawn into the exhaust system by a ventilator. Usually, the residual heat of the exhaust air will be recovered through a heat exchanger or a heat pump (see options M 2.1.1 and M 2.1.2).

Another concept makes use of heat recovery through an active drying zone: heat is extracted from dishes by an incoming air flow; at the same time, warm air from the machine's fresh-rinse zone is directed through the colder areas of the machine (against the transport direction of the belt) and then transfers the residual heat to a heat exchanger situated near the entrance to the dishwasher. The advantage of this arrangement is a smaller heat loss throughout the whole machine. In some cases, the effect of this technique is that no additional, active drying (additional heat) of the dishes is necessary. Proponents of this system claim that the directional air flow (from the clean to the dirty sectors) also helps to avoid contamination of clean dishes. The manufacturer estimates the overall energy savings for conveyor-type (category 6) dishwashers to be up to 30%.



(Source: Meiko)

Figure 17 Air flow concept

3.2.2 Material composition

Table 2 Differences in material composition through implementation of the design option described

Design Option / Material category*	M 2.1.1	M 2.1.2	M 2.2	M 2.3
	Heat recovery of exhaust air through heat exchanger	Heat recovery of exhaust air through heat pump[18]	Alternative temperature profile	Reuse of heat from hot dishes through active drying zone
	[g]			
Bulk plastics				
PP		+500	+500	+500
Ferrous metals (stainless steel, steel sheet, steel tube/profile, cast iron, ferrite)				
stainless steel	+5 000	+35 000	+10 000	+5 000
Non-ferrous metals				
copper	+5 000	+55 000		+6 500
Al diecast				+500
Electronics		+500		+100
Misc.				
refrigerant[19]		+2 500		

Note: empty fields = not applicable or no response by manufacturers

[18] Note: Although the addition of a heat pump increases the volume and weight significantly, it is expected that the influence of this on the overall environmental impacts will be negligible (cf. Section 3.4.2 and Task 7).

[19] Note: About 5% of the refrigerant will get lost during the life cycle of the dishwashing machine. (Source: E-mail from Miele, 22.12.2010)

3.3 Reducing energy losses through waste water

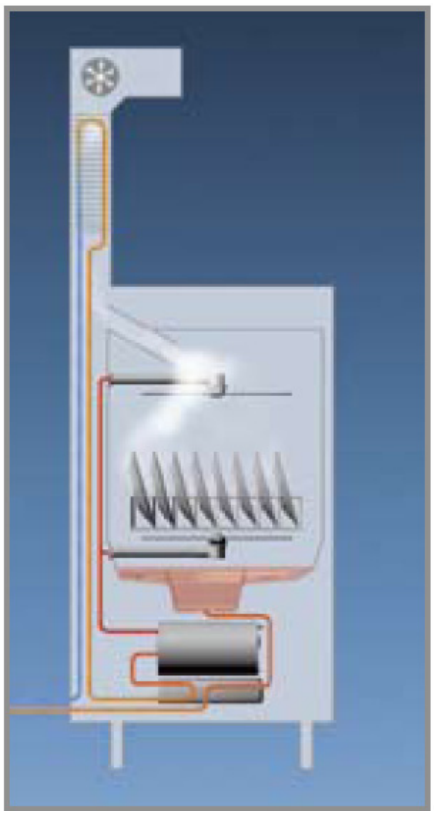
As described in Section 2, a large share of energy is lost through waste water leaving the dishwasher, which usually has a higher temperature than the inlet water. Heat from waste water can either be reduced through reduced rinsing-water consumption on the one hand, or through heat recovery from the waste water.

3.3.1 Description of the design options

3.3.1.1 M 3.1 Heat recovery from waste water

M 3.1.1 Heat recovery through heat exchanger

There are only a few companies recovering the heat from waste water of the dishwashing process. For example, one company offers a hood-type dishwasher with a combination of heat recovery from the exhaust air and heat recovery from the waste water.



(Source: Winterhalter)

Figure 18 Heat recovery from exhaust air and waste water

Since drainage water usually includes significant amounts of grease, removing heat from the water can lead to the dissolved grease solidifying in the piping downstream of the heat exchanger and thus creating a maintenance problem. For this reason, fresh water is first

warmed up by the exhaust air (blue to orange pipes in Figure 18) and, in a second step, the warm water is further heated by the heat exchanger of the waste water (orange to red pipes in Figure 18). Using this concept, it is possible to ensure that the temperature of the waste water will not drop to a temperature of below 40°C.

With heat recovery from exhaust air (cf. M 2.1.1), the energy savings would be about 20% to 25%. By using a heat exchanger for the waste water, additionally 10% of the total energy consumption might be saved. In total, about 30 to 35% of the energy might be saved compared to a reference machine.

M 3.1.2 Heat recovery through heat pump

Using a heat pump, the residual energy of waste water can be used more efficiently than with a counter-flow heat exchanger alone. Specifically, the combined use of a heat pump and heat exchanger enables the wash tank and/or rinsing water to be heated to a higher temperature compared to using only a heat exchanger. However, currently no machine was found on the market that incorporates this feature, thus we didn't further analyse this improvement option under cost-benefit aspects.

The reason for this is the maintenance problem resulting from solidifying fats and grease in the drainage pipes – this occurs when too much heat is recovered from waste water. A second reason is that it is difficult to reuse the energy from the heat pump because the temperature level is not high enough to heat the fresh rinsing water to the required temperature (usually 85°C).

On the other hand, if heat is already recovered from exhaust air (cf. M 2.1) – which is easier to manage and has the additional advantage of dehumidifying and cooling down the exhaust air – the additional heat that can usefully be recovered from the waste water of the dishwashing process is limited.

3.3.2 Material composition

Table 3 Differences in material composition through implementation of the design option described

Design Option / Material category*	M 3.1.1 Heat recovery of waste water through heat exchanger	M 3.1.2 Heat recovery of waste water through heat pump[20]
	[g]	
Bulk plastics		
PP		+500
Ferrous metals		
stainless steel	+10 000	+45 000
Non-ferrous metals		
copper		+35 000
Electronics		+500
Misc.		
refrigerant[21]		+2 500

Note: empty fields = not applicable or no response by manufacturers

3.4 Other improvement options

Finally, there are some further design options that might reduce the energy consumption or energy losses during the dishwashing process.

3.4.1 Description of the design options

3.4.1.1 M 4.1 Insulation of wash tanks or the dishwashing machine

The energy balances of different professional dishwashers show that convection losses are about 4 to 9 percent of the total heat losses (see Section 2).

The wash tank or the whole dishwashing machine (in category 5 and 6 the washing and rinse zone) can be insulated to reduce heat losses in the operating mode as well as in the ready-to-use mode. The insulation options include the insulation of:

- Doors,
- Pipes to external heat sources,
- Tanks,

[20] Note: Although the addition of a heat pump increases the volume and weight significantly, it is expected that the influence of this on the overall environmental impacts will be negligible (cf. Section 3.4.2 and Task 7).

[21] Note: About 5% of the refrigerant will get lost during the life cycle of the dishwashing machine. (Source: E-mail from Miele, 22.12.2010)

- Walls (double walls can provide additional insulation),
- Bottom of the machine, and
- Screens (thermal-layered screens in loading and unloading zones).

Due to safety reasons, all walls and doors that can come into contact with the operator of the machine usually have a double skin with air insulation or foamed plastic between these layers (PVC, polystyrene, polyurethane etc.) to prevent excessive temperatures on these parts. The other components of the dishwashing machine such as tanks, motors, boilers and screens are usually not insulated with the exception of some multi-tank conveyor-type dishwashers (category 6).

For example, one manufacturer equips all machines with a closed bottom (via steel panel), which means that they have a layer of air insulation between the tanks and the outside of the machine. According to manufacturers' feedback approximately 1% energy could be saved by improved insulation compared to today's performance.

Undercounter water-change dishwashers (category 1) already have a double skin design. For hood-type dishwashers (category 3), another method for retaining heat is to insulate the hood with a double-walled design. Additionally, the hood of the machine can be sealed in such a way that steam cannot escape through the hood-lifting mechanism. In this way, the steam from previous cycles can be used for the next washing cycle. The energy savings of this system are estimated to be 3 kWh per hour.

3.4.1.2 M 4.2 High-efficiency pumps and motors

The efficiency of the whole hydraulic system (motors, pumps and pipes) can be optimised. Nevertheless, account should be taken of the fact that the heat losses of motors or other aggregates will heat up the machine, thus replacing a certain amount of energy needed to heat the wash tanks, and therefore not lost completely. In cases where the machines are equipped with a bottom panel, nearly all the energy losses of motor and pumps would be useful for heating up the tanks. Vice versa, if these losses would be smaller due to more efficient motors and pumps, the dishwasher would need more energy for heating up the process.

The European Commission has recently taken steps to further regulate the energy performance of electric motors and pumps; however, these standards currently do not apply to dishwashers. For instance, the EU Directive No. 640/2009/EC specifies energy efficiency standards and requirements for motors and pumps based on testing methods and limits in IEC 60034-2-1:2007 and IEC 60034-30:2008. However, the motors of professional dishwashers fall outside the scope of this Directive for several reasons:

- The Directive applies to motors with an output of between 0.75 and 375 kW. Smaller motors for as e.g. in undercounter dishwashers are not covered by this regulation.

- The Directive does not apply to motors completely integrated into a product (for example gear, pump, fan or compressor) and whose energy performance cannot be tested independently from the product.

Consultation with stakeholders has revealed that dishwasher manufacturers typically do not produce pump motors in-house, and they are primarily concerned with sourcing/selecting long-lasting and durable motors and pumps for their systems; energy efficiency is not a primary consideration.

Larger motors (above 0.75 kW) built into professional dishwashers are standard motors provided by suppliers that also produce EuP-conform motors. It is also to be expected that dishwasher motors will become more efficient, even though their improvement is not required under the Directive.

Attention should preferably be given to optimising the entire hydraulic system, including the pumps, in order to enhance the energy saving potential. Despite the potential for improvement outlined above, the energy savings from optimised hydraulic systems would be quite small. For instance, if the efficiency of the hydraulic system can be raised by 10% (which was the opinion of two manufacturers), savings of approximately 10 to 15% could be achieved in the electricity required to power the motor. In this case, the total savings from motors and pumps would be about 1 to 1.5% as only roughly 10% of the total energy consumption of a professional dishwasher is caused by pumps and motors (90% is needed for heating purposes).

3.4.1.3 M 4.3 Self-cleaning machine

Usually, dishwashing machines have to be cleaned regularly. In many cases, this will be done manually (the whole machine being hosed down with a water jet from the mains). However, there are some machines using a self-cleaning process. Two methods of self-cleaning can be distinguished:

- With the first type of automatic cleaning, the machine cleans itself after switch-off. For example, such operating principle was found in a hood-type dishwasher (category 3). After entering the self-clean mode by touching a button, the machine automatically cleans the interior and then switches off. Additionally, an integrated drain pump removes any remaining dirty water from the machine, eliminating both deposits and odours.[22] The automatic cleaning at the end of the day is a useful and water-saving feature, because the machine is cleaned with the residual water of the wash tank and the rinsing boiler.
- Another self-cleaning process involves the machine automatically cleaning itself after a certain water quality limit has been exceeded. For example, some machines have a

[22] Winterhalter. Winterhalter GS 500 Series. 16 August 2010. Retrieved from: http://www.winterhalter.co.uk/uploads/tx_whboxes/GS_500__e_D_04.pdf

sediment sensor that “monitors the dishwater quality and if necessary initiates step-by-step regeneration”.[23] In theory, this method could lead to savings in energy and water consumption because the system can avoid additional dishwashing which would be necessary if poor water quality leads to inadequate cleaning performance. In practice, however, this situation would be very seldom. In most cases, even if the cleaning result may be insufficient, the dishes or utensils are not cleaned a second time. This means that the automatic detection of the water quality would not create any energy or water savings but would only improve the cleaning result.

For undercounter water-change dishwashers (category 1), this design option is not applicable as BAT as they basically clean themselves after each cycle.

As the reference cleaning of the machine is based on a manual process which is strongly dependent on the user behaviour and which is not within the scope of this study (cf. Task 3), we didn’t further analyse this improvement option under cost-benefit aspects.

3.4.1.4 M 4.4 Alarms

Alarms, signals and prompts (visual and acoustic, via beeps, flashing lights or signals) can be an effective way of indicating the machine's status to operators and service personnel. Alarms can save water and energy by ensuring that proper levels of detergent/rinse aid are maintained within the machine, thus reducing the probability of unsatisfactory cleaning results and repeated dishwashing cycles.

In conveyor-type dishwashers (categories 5 and 6), alarms are most commonly integrated into the control panel's functionality, which, in turn, is connected to sensors throughout the machine. Alarms may indicate incorrect levels of tank temperature, water/detergent/rinse aid levels, malfunction (dosing-pumps, jams, ware blocking spray fields) or if the efficiency of the heat-exchanger unit goes down below a certain level (i.e. the time to clean the unit). Some machines automatically shut down or stop the wash cycle depending on the error/alarm triggered. This step reduces the likelihood of repeat washes due to unsatisfactory cleaning results or damage to the machine.

Some of these features are used in category 1 to 4 dishwashers. In some conveyor-type dishwashers the dosing and alarm systems are outsourced to other companies such as detergent suppliers.

The saving potential from alarm systems is hard to measure. The difficult task is to define a base case or rather whether alarm systems would actually reduce the number of washes presumably associated with inadequate cleaning results (for instance, if the detergent or rinse aid runs out). Stakeholders indicated that, in practice, dishes and utensils will usually not be washed a second time even if the cleaning result is poor. Therefore, it is likely that

[23] Winterhalter. Winterhalter undercounter dishwashing machines UC Series. 16 August 2010. Retrieved from: http://www.winterhalter.co.uk/uploads/tx_whboxes/UC-Broschuere-GB_23.pdf

alarm systems will not create any energy or water savings; however, they may help improve the overall cleaning results. Due to the unclear situation with regard to the overall improvement potential we didn't further analyse this option under cost-benefit aspects.

3.4.1.5 M 4.5 Customer-specific adjustment of the dishwashing process through electronic control of the whole process

Customer-specific adjustment of dishwashing parameters can lead to more appropriate dishwashing results and energy performance for different customer requirements. A number of manufacturers offer the possibility of accessing pre-programmed settings that adjust water temperature, cycle time and jet pressure depending on the wash ware and soiling conditions (see Figure 19).

Moreover, by providing a simple intuitive interface with access to programmable washing cycles, service operators can optimise dishwashing according to the type of wash ware and/ or the soiling level. For instance, one manufacturer provides an undercounter dishwasher that allows adjustment of the dishwashing cycle according to the requirements of the customer. For example, the machine requires a special detergent for some programs that operate at a reduced temperature. Another machine offers a similar feature through three selectable pump power levels that are appropriate for different wash ware.



(Source: Winterhalter)

Figure 19 Possible program types of an undercounter dishwasher

Programs are usually optimized by the manufacturer. Customised programs have advantages and disadvantages: on the one hand, the specialised programs could save water and energy if the dishwashing process is correctly adapted to the needs of the customers. However, it should be ensured that these adjustments cannot be carried out by the customer himself but only by the manufacturer's specialists to ensure a clean and hygienic result for every dishwashing process. When customers deviate from those programs, it might lead to a higher consumption of water and energy.

One manufacturer criticises that most applications are “standard” applications which could be handled with “standard” configurations. However, an optimisation of the dishwashing programs for every special application and customer is not feasible.

So far, energy, water and detergent savings achievable with customised programs cannot be quantified, thus we didn’t further analyse this option under cost-benefit aspects.

3.4.1.6 M 4.6 Documentation of the dishwashing process and the dishwashing parameters

Machines with the ability to document the dishwashing process and its parameters have a small data storage device which saves the presetting data (temperature, power of the pump etc.) and the data of every dishwashing cycle. It is normally integrated into the control panel. Data and dishwashing parameters are often password (or PIN) protected, which allows management or service personnel greater control over the machine’s operating parameters. Some manufacturers allow different levels of authorisation or access to their devices; in the case of one manufacturer the menu includes three options:

1. Operating Menu: allows the user to turn the machine on and off, and to select from a set of programmable cycles; provides basic information, e.g. temperature alterations
2. Chef Menu (PIN-protected): allows the head of the dishwashing section to access information that may be relevant for management, such as operating or hygiene data.
3. Service Menu (PIN-protected): allows an authorized user (service personnel, manufacturer of the machine) to change the machine’s settings.

Some other parameters that may be documented include: time between servicing visits, device malfunctions (jams, blocked spray fields), water quality and dishwasher capacity.

The advantage of having different access levels is that service personnel can reconstruct which changes have been carried out in order to investigate the reasons for possible poor dishwashing results. On the one hand, this could be the basis for optimising the dishwashing process and, on the other hand, it can avoid unwanted intervention by the user in the dishwashing programs.

There are several options for linking documentation and monitoring systems with relevant diagnostic tools and dishwasher repair or service companies. A standard data-logging system would store information within a data-storage unit located inside the dishwasher. More recent data-logging techniques enable dishwashers to communicate operational information with customers’ personal computers or PDA devices through wire or wireless connections.[24] With the help of software provided by the manufacturer, these systems can support logging, display and diagnosis system status in real time. In some cases, dishwashers may support

[24] Meiko. K-Tonic function description. 16 August 2010. Retrieved from: http://www.meiko.info/Produkte,45,106,en,Function_description&showID=105

direct communication with service companies, which can reduce processing time for service calls and reduce shut-down times.[25]

The documentation and information systems could help the kitchen manager to control the work of the operators and if necessary influence their behaviour. The customer at least gains indication on certain improvement potentials. But there is no experience how many customers use the information for this reason. Another advantage is that, in the long run, manufacturers can optimise the dishwashing process and machines based on the data obtained from the machines. In both cases there will be an additional saving potential but it cannot yet be quantified as it very much depends on the specific user behaviour,[26] thus we didn't further analyse this option under cost-benefit aspects.

3.4.1.7 M 4.7 Sensor systems to control the dishwashing process

Sensor systems can detect whether the soil is dissolved and whether the hygienic result achieved is sufficient. Thus the dishwashing cycles can automatically be shortened, e.g. a diffusion sensor might help to reduce water consumption by omitting a pre-wash step in case of lower initial soiling of the dishes.

Soil measurement in the wash liquid is possible using a turbidity sensor; however, this has not yet been widely integrated into dishwasher products currently on the market. Using soil measurement sensors, the duration of the wash cycle could be influenced and the quantity of regeneration water optimised. For instance, sensors could initiate total refilling of the tanks or even of one specific tank. Similarly to previous improvement options, the impact of such a system cannot be quantified. Savings could be achieved by prevention of a second run but in practice real savings depend on customer behaviour. Two manufacturers stated that a second run for dishes is rather unusual. In most cases, the results of the dishwashing process are accepted even if the results might be improved. The potential savings also depend on the initial soiling of the wash ware.

Due to the unclear situation with regard to the overall improvement potential we didn't further analyse this option under cost-benefit aspects.

3.4.1.8 M 4.8 Optimised tank volume

The consumption of professional dishwashers is classified into

- Energy and water consumption in operating mode,
- Energy consumption in left-on / ready-to-use mode, and
- Energy and water consumption for initial filling and heating of the wash tanks.

---

[25] Meiko. FV 40.2. 16 August 2010. Retrieved from: http://www.meiko.info/index.php?scriptlet=Meiko/Web/ProductsBrowser&pID=10&pdID=200531

[26] One manufacturer quantified the savings to be between 0 to 20%, strongly depending on user behaviour with and without such a documentation system.

The consumption for initial filling and heating of the wash tanks depends on the volume and temperature difference between inlet water and wash tank temperature.

While two manufacturers state that the tank volume will not be a relevant factor in achieving a best available product, another manufacturer claims that the tank volume could be optimised to reduce energy losses and has specified how a best available product deviates from a standard product as shown in Task 3.

However, due to missing data with regard to the overall improvement potential we didn't further analyse this option under cost-benefit aspects.

Table 4 Tank volume and temperature of a best available product

Dishwasher category	Standard product (cf. Task 3)		Best available product	
	Volume of wash tank(s) (assumed average)	Operating temperature of wash tanks (assumed average)	Volume of wash tank(s)	Operating temperature of wash tanks
No 1 Undercounter water-change	not applicable	not applicable	not applicable	not applicable
No 2 Undercounter one-tank	15 litres	60°C	13 litres	60°C
No 3 Hood-type	40 litres	60°C	20 litres	60°C
No 4 Utensil/Pot dishwashers	100 litres	60°C	80 litres	60°C
No 5 One-tank conveyor-type	120 litres	60°C	120 litres	60°C
No 6 Multi-tank conveyor-type	230 litres	40°C pre-wash 60°C wash tank	230 litres	60°C

3.4.1.9 Effects of lower washing temperatures on composition of detergents

Currently in Europe the hygienic requirements during the dishwashing process are met by thermal means (as outlined e.g. in the DIN standards on food hygiene, cf. Task 1). In this case no special disinfecting agents are needed in the detergents or rinse agents. By reducing the dishwashing temperatures the detergent solution would not have to be heated up so much, thus being a possibility to reduce the overall energy demand of dishwashers.

According to the so-called "Sinner's circle" (see Task 3), there are four main factors influencing the cleaning process: Temperature, chemistry (detergency), time and mechanics. Only when these four factors match it is possible to achieve satisfying (dish-) washing results and to fulfil the requested hygiene conditions. If one parameter is reduced, other factors must be increased to compensate.

Thus, if the washing temperature (= energy consumption) is reduced, either the contact time with the detergent needs to be prolonged or the decontamination and disinfection perform-

ance of the detergent needs to be enhanced. In this context, the hygiene requirements given in DIN 10510 to 10512 are considered obligatory: by reducing the operational temperature within dishwashing machines, a thermal disinfection of the wash ware is not given anymore. Consequently, the use of chemical disinfection components is required to achieve the requested decontamination performance of $5\log_{10}$ stages for 90% of the wash ware.

For better understanding, in the following the differences between cleaning and sanitizing are described[27]:

- Cleaning is the process of removing food and other types of soil from a surface, such as a dish, glass, or cutting board. Cleaning is done with a cleaning agent that removes food, soil, or other substances.
- Sanitizing refers to the reduction of micro organisms to levels considered safe from a public health viewpoint.[28] It is done using heat, radiation, or chemicals. Heat and chemicals are commonly used as a method for sanitizing; radiation rarely is. The item to be sanitized must first be washed properly before it can be properly sanitized. Some chemical sanitizers, such as chlorine and iodine, react with food and soil and so will be less effective on a surface that has not been properly cleaned.

Generally, there are two possibilities for sanitizing.[27]

Thermal sanitizing

The thermal sanitizing involves the use of hot water, hot air or steam for a specified temperature and contact time.

- Hot water is the most common method used. The time required is determined by the temperature of the water. According to DIN 10510 and 10512, the final rinse must be 80 to 85°C (cf. Task 1). Cleaned items must be exposed to these temperatures for a certain time. Hot-water sanitization is a slow process which requires come-up and cool-down time; can have high energy costs.
- The use of steam as a sanitizing process has limited application. It is generally more expensive compared to alternatives, and it is difficult to regulate and monitor contact temperature and time.

---

27 Schmidt, R. H. (2009): Basic Elements of Equipment Cleaning and Sanitizing in Food Processing and Handling Operations. FS14, Series of the Food Science and Human Nutrition Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. http://edis.ifas.ufl.edu/fs077

28 The official definition (Association of Official Analytical Chemists) of sanitizing for food product contact surfaces is a process which reduces the contamination level by 99.999% (5 logs) in 30 sec. For comparison: **Sterilizing** refers to the statistical destruction and removal of all living organisms. **Disinfecting** refers to inanimate objects and the destruction of all vegetative cells (not spores).

Chemical sanitizing

An extreme form of shift to lower dishwashing temperatures (and consequently lower energy consumption) is the so called chemical sanitising which is more widely used in the USA. Chemical sanitizing machines often wash at much lower temperatures, but not lower than 49°C. Rinse water temperature in these machines should be between 24 and 49°C for the sanitizer to be effective. Here, the lower water temperatures during the final rinse are compensated by the use of an approved chemical sanitizer at a specified concentration and contact time. Chemicals that are approved sanitizers are chlorine, iodine, and quaternary ammonium. Table 5 gives an overview of the advantages and disadvantages of the different chemical sanitizers.[29]

Table 5 Advantages and disadvantages of different chemical sanitizers

Chemical	Concentration	Contact Time	Advantage	Disadvantage
Chlorine	50 ppm in water between 24 and 38°C	7 seconds	Effective on a wide variety of bacteria; highly effective; not affected by hard water; generally inexpensive	Corrosive, irritating to the skin, effectiveness decreases with increasing pH of solution; deteriorates during storage and when exposed to light; dissipates rapidly; loses activity in the presence of organic matter
Iodine	12.5-25 ppm in water that is at least 24°C	30 seconds	Forms brown colour that indicates strength; not affected by hard water; less irritating to the skin than is chlorine; and activity not lost rapidly in the presence of organic matter	Effectiveness decreases greatly with an increase in pH (most active at pH 3.0; very low acting at pH 7.0); should not be used in water that is at 49°C or hotter; and might discolour equipment and surfaces
Quaternary Ammonium Compounds	Up to 200 ppm in water that is at least 24°C	30 seconds	Nontoxic, odourless, colourless, noncorrosive, non-irritating; stable to heat and relatively stable in the presence of organic matter; active over a wide pH range	Slow destruction of some microorganisms; not compatible with some detergents and hard water

In Europe, chemical sanitizing as practiced in the US is available, but not widely accepted due to the high environmental impact of the heavy use of aggressive chemical detergents as well as due to the following disadvantages:

- Chemical decontamination is hard to measure with sensors. It is therefore more difficult to guarantee a certain washing result and hygienic performance.

[29] Source: http://chinesefoodsafety.com/sections/pdf/section11b_clean.pdf

- Bleaching agents like sodium hypochlorite have only limited storability before loosing their full performance. It therefore might be that disinfectants are used that are not fully active anymore.
- Remainders of sodium hypochlorite on the wash ware can cause nuisances of odour or taste.
- Additional entries of chlorine-containing detergents could affect microorganisms in sewage plants and could have other harmful effects, e.g. the development of toxic organic chlorine compounds cannot be excluded.
- The drying efficiency might be problematic (poor drying results).

Some manufacturers, however, indeed seem to plan introducing low temperature dishwashing programmes, which are supposed to meet the hygienic requirements according to DIN standards and which are marketed with a compatible detergent. As outlined above some disinfecting component will be included in the detergent. However, the kind of disinfectant and amount is not known. As the whole composition of these detergents is not accessible it is not possible to quantify the environmental effects. An appropriate indicator would be the critical dilution volume which can be used to quantify the aquatic toxicity of chemicals.[30]

3.4.2 Material composition

Manufacturers did not state any change in material composition with regard to the improvement options presented in the above sections. The additional input has to be seen mainly in know-how and some electronics.

In general, the additional material consumption of the options described does not play a significant role due to the following reasons:

- The input of all material has only a minor influence on the energy-consumption and the total environmental impact. Within Task 4 Report we analysed that the environmental impact resulting from the manufacture (including material), distribution and disposal of the devices is negligible compared to that during the use period: For example the global warming potential (GWP) caused by the use phase accounts for 97% to 99% of the total GWP over the lifetime of professional dishwashers.
- The material with the highest influence is stainless steel for the containment and frame of the dishwashing machine (50 to 80% depending on category). Even if stainless steal would be substituted through another material with no (!) environmental impact, the influence on total environmental impact over lifetime of the dishwashing machine would be lower than 2%. But there is no alternative for stainless steel for now.

[30] Source: 2003/31/EC: Commission Decision of 29 November 2002 establishing revised ecological criteria for the award of the Community eco-label to detergents for dishwashers and amending Decision 1999/427/EC

- Due to the missing standard measurement method and reliable results from independent analysis the range of incertitude of the consumption data is essentially higher than the influence of all materials.
- There might be a possibility to reduce the energy-consumption of the dishwashing process by changing the material of the dishes with a lower heat capacity. However, this would have impacts on the drying process, the cleaning results and would also affect user preferences. As the material design of dishes is isolated from the design options of the machinery, this option is out of scope of this study.

3.5 Possible implementation and combinations

Implementation possibilities: From a technical point of view, i.e. not taking into account economic feasibility, in principle nearly all improvement options could be implemented in every dishwasher category. Nevertheless, the following practical restrictions apply:

- M 1.2: Steam rinsing is currently only applied to undercounter one-tank dishwashers (category 2) of one manufacturer. In principle, it could also be implemented in other automatic-program devices (categories 3 and 4). However, it is not possible to implement it in conveyor-type dishwashers (category 5 and 6) as these appliances have an open entry and exit area and thus the steam would escape from the rinse zone into the surrounding area.
- M 1.4: Automatic load-recognition systems are currently only offered for conveyor-type dishwashers (categories 5 and 6). Such systems could also be implemented in automatic-program devices, but would require a special matrix system which can recognise the position of the wash ware and route the water directly to these places.
- M 1.5: Multi-zone rinsing is, by definition, restricted to machines with different cleaning zones, which means that this system would be restricted to category 5 and 6 dishwashers. If an additional rinsing zone with pump rinsing is implemented, an additional tank is necessary. This means that in case an additional rinsing zone would be added to a one-tank conveyor-type (category 5) this machine would, by definition, belong to category 6. On the other hand, however, it is also a question of definition. Automatic-program devices do not have different cleaning zones. But they could also have a second tank for pump rinsing. Thus an auxiliary rinse could also be performed within dishwasher categories 2 to 4. This system is only used by the Swedish manufacturer Wexiödisk for a hood-type dishwasher. For category 1 dishwashers, this design option is not applicable.
- M 2.3: The special air-flow concept combined with heat recovery (see chapter 3.2) is applied to conveyor-type dishwashers (categories 5 or 6) and cannot be implemented in other categories.

Combination possibilities: In principle it is possible to combine nearly all kinds of options in one dishwasher except for the following restrictions:

- Heat pumps and heat exchangers cannot be combined with a warm water supply for the purpose of recovering energy from exhaust air and waste water as a certain temperature difference between outgoing and incoming water is required.
- The implementation of some improvement options requires space. For instance, in the case of undercounter machines, it would be difficult to integrate a heat pump due to the compact nature of these dishwashers. For the same reason, it would be even more difficult to install both a heat pump for the exhaust air and a heat exchanger for the waste water.
- It does not make much sense to install a heat pump for waste water when, on the one hand, a heat pump for the exhaust air may already be recovering most of the heat required for the dishwashing process and, on the other hand, the heat recovery from the exhaust air is more efficient than waste-water heat recovery because:
  - more heat can be gained from exhaust air than from waste water,
  - the humidity and temperature of the ambient air can be reduced, and
  - heat extracted from exhaust air will not cause grease to build up inside drainage pipes (as is the case with waste-water heat recovery if too much heat is extracted from the water).

3.6 Best available products on the market

In Sections 3.1 to 3.4 we provided a more general technical description of a broader spectrum of possible design options and a first estimated quantification of the improvement potentials by manufacturers. In Section 3.5 we narrowed the spectrum due to certain constraints with regard to implementation and combination possibilities. For this section, we asked manufacturers to specify those components or technologies being currently implemented in best available products on the market. From this inquiry, an impression of the most important design options and combinations thereof for each dishwasher category shall be derived.

Table 6 Technologies built into the best available products on the market (feedback from manufacturers)

Dishwasher category	Company 1	Company 2	Company 3
No 1 Undercounter water-change	--	--	--
No 2 Undercounter one-tank	Filter system and heat recovery from exhaust air	Optimised spray arms for washing and rinsing, filter system, exhaust air heat recovery,	Exhaust air heat recovery, optimised spray arms, double skin
No 3 Hood-type			

Dishwasher category	Company 1	Company 2	Company 3
No 4 Utensil/Pot dishwashers		drain heat recovery	
No 5 Conveyor-type one-tank	Filter system, reversed air flow and heat recovery from exhaust air	Optimised spray arms for washing and rinsing, side nozzles, exhaust air heat recovery	Optimised spray arms, intelligent air flow, multi-zone rinsing, exhaust air heat recovery with heat pump, double skin
No 6 Conveyor-type multi-tank			

Naturally, the best available products currently on the market have not implemented all possible design options as the marginal savings are decreasing and therefore additional investments do not pay off. Nevertheless, from a sole technological point of view, it would of course be possible to implement most options in professional dishwashers.

In this case, if *all* available BAT components were used, the additional energy saving potential compared to the best available products as presented in Table 6 could be 2 to 5% according to two manufacturers. The water-saving potential was estimated to be 0 to 5% compared to the current BAT products. However, these figures were not differentiated according to the different categories.

4 Best existing product technology outside the EU

According to stakeholders' feedback 30 to 40% of the US market washes with chemicals (chemical sanitizing, cf. Section 3.4.1.9). However, due to perceived inferior washing and drying results and the further described disadvantages, this approach has limited acceptance in the EU market.

In general, it was stated by all manufacturers that the most advanced dishwashing technologies and the most efficient dishwashing machines are produced in the European Union. Even the American dishwashing industry seems to be far behind Europe, as American dishwashers use more energy and water than European products. This is due to the fact, that on the US market sanitizing treatment of dishes is commonly applied (hot water sanitizing and chemical sanitizing respectively, cf. Section 3.4.1.9). These machines and processes generally require higher (sanitizing) temperatures compared to the (cleaning) temperatures of dishwashers in Europe. Thus, also the thresholds of the US ENERGY STAR label are not particularly ambitious compared to the performance of the European dishwashers. ENERGY STAR differentiates high and low temperature efficiency requirements for each hot water and chemical sanitizing machinery (see Task 1).

No further improvement options for professional dishwashers from outside EU are known.

5 Annex

5.1 Working paper "Task 6" for stakeholders

This paper is provided separately (EuP_Lot24_Dish_T6_Annex_Workingpaper.pdf).

5.2 Stakeholder feedback to draft versions of Task 6

Please note that the feedback refers to draft versions of Task 6 report; thus, the indicated numerations of chapters, tables, figures or pages might have changed.

Feedback		Comment
Granuldisk		
6.2.1	**Reducing the overall water consumption** The huge water consumption in pre-soak and pre-wash must be included in BC 4 in order to give incentive to reduce the overall water consumption. The whole process from dirty to clean must be covered.	Included in the text (cf. 3.1.1.6); In order to give incentive to reduce the overall water consumption of dishwashing, the inclusion of the whole process from dirty to clean (including the pre-soak and pre-cleaning phase) would be rather desirable for all dishwasher categories with special focus on utensil / pot dishwashers. However, the water consumption for pre-cleaning is strongly dependent on the specific user behaviour and cannot be influenced by the technology of the dishwashing machine itself. Further, there is no standard measurement method and thus no reliable data to record the average consumption through external pre-cleaning of the wash ware for the dishwasher categories. Finally, as we already excluded the manually process steps outside the dishwashing machines from the scope of this study in Task 1, we didn't further analyse the granule technology under cost-benefit aspects in the following tasks.
6.2	**Improvement options** A chapter describing utensil- and pot-washers using granule technology must be included. Granule technology = A mechanical cleaning process where plastic granules and water are blasting the pots and pans clean without using pre-soaking and scrubbing. This technology is today used by more than 10 000 end-users! M 1.6 Granule pot- and pan-washing machines. A mechanical cleaning process where	Considered in revision.

Feedback		Comment
	plastic granules and water are blasting the pots and pans clean without using pre-soaking and scrubbing. Through this process we can save: • Up to 70% in water consumption • Up to 60% in detergent consumption • Up to 60% in energy consumption • Up to 50% in man hours Even hard burnt-in pots and pans or dried-in soil is efficiently cleaned without any soaking or scrubbing outside the machines. The granules are taking over the hard job. Figure x (enclosed in the e-mail) shows the cleaning process of granule pot and pan-washing machines.	
JRC IPTS		
General comment to Task 6	With regard to Draft Task 6: 'Technical analysis of best available techniques' we consider that amendments on the quantification of the environmental savings potentials of BAT would improve the outcome of this task. This is important in order to ensure reliability on the forthcoming policy support issues (in Task 7 and 8).	This comment refers to the prior version of Task 6. In the revised Task 6 version of the draft final report published on 8 November 2010 this chapter has been improved essentially.
General comment to Task 6	The investigation of the BAT while broad remains rather qualitative. Based on the outcomes of Task 5 on the environmental assessment of the product base cases, the analyses of the BAT are mainly restricted to energy and water efficiency in the use phase. However, quantification of the technological improvements is not considered sufficient as it is solely left on stakeholders' estimations. From our point of view, a systematic approach using specific technical parameters which would eventually enable the quantification of the overall energy and water savings due to the application of BAT should be provided.	Within the study we also tried to collect usage data from different categories of end-users (e.g. large canteens). But it was not possible to get data which enable us to quantify the impact of BAT on water- and energy-savings. Regarding the consumption data we have to accentuate that there is no standard measurement method existing to quantify the consumption of energy and water for the dishwashing machines. Quantification based on information from independent side is also not possible as there is no scientific literature about the results of BAT in the professional dishwashing sector published.

Feedback		Comment
6.2.4 (page 38)	In this section it is stated that the changes of technological features in professional dishwashers 'has to been seen mainly in know-how and some electronics'. This could be true on this particular point however we would like to emphasise that one of the objectives of the current preparatory study is to provide the evidence for any consideration of material substitution which could result in environmental savings. As mentioned in the general comments above, the environmental investigation seems to be on a level that does not allow this issue to be captured. A greater level of detail in the analysis would provide the necessary information to unveil this aspect.	We did not put emphasis in the consideration of material substitution due to the following reasons: A) The input of all material has only a minor influence on the energy-consumption and the total environmental impact. Within Task 4 Report we analysed that the environmental impact resulting from the manufacture (including material), distribution and disposal of the devices is negligible compared to that during the use period: For example the global warming potential (GWP) caused by the use phase accounts for 97% to 99% of the total GWP over the lifetime of professional dishwashers. B) The material with the highest influence is stainless steel for the containment and frame of the dishwashing machine (50 to 80% depending on category). If stainless steal would be substituted through another material with no (!) environmental impact, the influence on total environmental impact over lifetime of the dishwashing machine would be lower than 2%. But there is no alternative for stainless steel for now. C) Due to the missing standard measurement method and reliable results from independent analysis the range of incertitude of the consumption data is essential higher than the influence of all materials. D) There might be a possibility to reduce the energy consumption of the dishwashing process by changing the material of the dishes with a lower heat capacity. However, this would have impacts on the drying process, the cleaning results and would also affect user preferences. As the material design of dishes is isolated from the design options of the machinery, this option is out of scope of this study.
6.5	The analysis of appliances implementing best available technologies is extensive. However precise quantitative features and technical performance parameters (which would result later in environmental savings calculations) of BAT are lacking or scarcely presented. Moreover, the option of applying on the same device one or more than one BAT is not evaluated. We consider it necessary that in this re-	The comment refers to the prior version of Task 6. In the revised Task 6 version of the draft final report published on 8 November 2010, the chapter has been improved essentially. We included the impact and costs of five improvement options. In the final report, however, this section has been moved to Task 7 to be coherent with the MEEuP methodology.

Feedback		Comment
	spect, the analysis of BAT should be further elaborated. A systematic approach which would allow for quantification and evaluation of the presented best available techniques should be applied and presented.	
6.5.2	Formatting error	Considered in revision.
CECED Italia		
General considerations	As a general comment on cold water machines we deem that any consideration on these particular kinds of products should be specifically assessed. These machines have a huge environmental impact due to the heavy use of aggressive chemical detergents. In other words, energy consumption for cold water and warm water appliances cannot be compared without considering the notable environmental impact differences.	Note: Be aware of the differences between dishwashers with cold and/or warm water supply (cf. Task 3) and the use of low dishwashing temperatures (chemical sanitising). Chemical sanitising has been presented in detail in Section 3.4.1.9. However, due to the portrayed disadvantages, this approach has limited acceptance in the EU market and thus has not been further analysed as BAT.
3.4.1.10	Chemical sanitizing: We would like to highlight that the US situation for chemical sanitizing is completely different from EU considering a totally different standard scenario (NFS for US). In Europe it could not be accepted this approach due to the high environmental impact of the heavy use of aggressive chemical detergents. Moreover, there could also be several problems in drying performance.	Included in revision.
Wexiödisk		
6.2.1, M 1.4 Automatic load adjustment system, page 15.	I find the estimated savings of water, energy and chemicals by far to low when it comes to "Automatic load adjustment systems" on BC 5 and BC 6. Enclose you will find a pdf document describing a test that was done together with a customer. Even though the test is rather old it clearly shows the impact the way of controlling the machine has. The machines in the test are one manufactured by Wexiödisk and branded Metos and the other one is from a competitor. What one shall have in mind is that the machine from the competitor has a	The section has been detailed accordingly; pointing out that the base cases were assumed to run continuously; discontinuous operation would lead to higher improvement potentials with regard to automatic load adjustment systems; however, for the purposes of the study, discontinuous operation could not be taken as basis as it strongly depends on user behaviour and could not be quantified. However, in Task 4 (recommendations on mandates) we ask for real-life usage (inter alia partial load / discontinuous operation) to be included in the development on a new performance standard.

Feedback		Comment
	very accurate control system with autotimer for the wash tank as well as the rinse tank. Meaning the zones does not start when there is no item in them. And for your information the control it has (had) was and is much more accurate than the one Hobart, Meiko and Winterhalter has today. In the technical data you can see that the rinse water flow rate was 20% higher on our machine. What even out the figure partly is that the machine was equipped with drying zones, without them the difference in percentage would be even bigger. Another thing worth to mention is that the place is the worst case for this type of tests, meaning that one wash rather intensively during a period of a couple of hours. I will tell you that we haven't done anything to make the test look better for us. Meaning nothing has been manipulated and the figures are correct. The disadvantages described in the text regarding collapsed vapour, additional water and energy consumption and poor washing result is by far exaggerated and does not exist, except in marketing material from the competitors not having this system.	
"Auxiliary rinsing"	Second thing is that I don't understand why you has excluded is the "Auxiliary rinsing" on BC 3 in Task 7. On hood type machines with this system we have the same rinse result with 1/3 of the rinse water volume compared with one without this system. The rinse result is not only tested with fenoftaline (meaning controlling if any chemicals are left on the rinsed items) it is also heavily tested with food soils such as mashed potatoes etc. 1/3 of the water consumption in the rinse does not only mean water savings but also huge savings in energy as well as chemicals. When calculat-	We didn’t exclude "Auxiliary rinsing" on BC 3. In Task 6 we wrote: “The auxiliary rinsing (with an additional tank) is used almost exclusively for conveyor-type dishwashers with more than one tank. Only one company is using the system for a hood-type dishwasher (category 3). For category 1 dishwashers, it is not applicable.“ We could not provide a cost-benefit ratio for the base case 3 because we didn’t get any data from the sole company who is producing this hood-type dishwasher.

Feedback		Comment
	ing overall consumption meaning standby consumption (ready-to-use mode) and continuous operation there is a 50% reduction of chemicals, water and energy.	
M 2.1.2 Exhaust air heat pump	Due to the way of working one want to minimize the on and of mode as much as possible to extend the lifetime of the exhaust air heat pump units. The result of this is that one doesn't turn of the rinse water when it's not needed. Just to give you one example: If one wash one basket in the state of the art model Premax with heat pump from Hobart the rinse water will be on for a length of 2 to 3 baskets, meaning 100% to 200% of the water will be used to just rinse empty spaces. And what this lead to is rather obvious when looking in the test from the Espoo school. In my opinion the figures for BC 5 and BC 6 should not be 100% but instead 120 to 130%.	It is correct that exhaust heat pump units will suffer if they are switched on and off frequently. In consequence the rinse process will continue for some time, even if there is no wash ware in the rinsing sector. As we describe above, the base case for category 5 (and 6) was assumed to be a *continuous* washing process with a workload of 75%. Under these terms and conditions no additional water consumption will occur.
M 4.4 Alarms	We have an alarm in our tunnel rack machines that goes on when the efficiency of the heat recovery unit goes down below a certain level. Meaning when it's time to clean the unit. This in my opinion does save some energy.	The described alarm system of your company makes sense and it will save some energy. Dishwashers from some other companies use a self-cleaning process of the heat-exchanger which will be activated after every working-day. The saving potential of the systems are dependent on the soiling of the dishes and other factors. As far as we know there is no scientific report or qualified measurements about the saving potential of such kind of alarm systems.
Overall comment	You had a note in one of the previous tasks regarding the difference in consumption stated in the brochures compared to real life operations. The hunt for lower consumption has lead to an increasing gap between those two figures. Overall has this made the machines more sensitive to cope with food soil. I have done a "simple" simulation of what could happen (see pdf-file enclose) in different scenario. One can see that just after 11 wash cycles the concentration of dirt in the water in simulation 2 is more than 100% higher	The mentioned graph is showing a plausible result. We agree that theoretically we should include the pre-treatment of the wash ware into the whole dishwashing-process to judge the efficiency of the whole process. But this is not possible because the pre-treatment process is strongly dependent on the behaviour of the service people, of the soiling of dishes, the existing infrastructure and other factors. Additionally there is no survey about water and energy consumption of the pre-treatment process in the EU on one side and the interrelation between pre-treatment of the washware, the use of the dishwashing machine (program selection) and the washing-results of the dishwashing machines on the other

Feedback		Comment
	than simulation 1. Meaning when the rinse cycle starts the ware are twice as dirty in simulation 2 but the rinse has 29% less amount of water to cope with this, compared to simulation 1. As you can see the tank volume of simulation 2 is the same as the BAT Hood type machine shown in table 4, task 6. This has increased the demand for pre-washing the ware before it enters the machine. The measurement we have done shows that the consumption for pre-treatment in a typical hood type installation is between 3 to 6 litres/basket of 40 to 50°C heated water. Not an insignificant amount of cost in the whole washing process.	side. In this EuP-study we had to compare the efficiency of different dishwasher categories and to analyse the improvement potential of the dishwashers under ideal and typical use. An according explanation has been added to Task 6 (Section 3.1.1.6) and Task 3 (real-life user behaviour, influence of external process steps)

Preparatory Studies for Eco-design Requirements of Energy-using Products

Lot 24: Professional Washing Machines, Dryers and Dishwashers

Tender No. TREN/D3/91-2007

January 2011

Final Report, Part: Dishwashers

Task 7: Improvement Potential

Öko-Institut e.V.
Institute for Applied Ecology, Germany
Ina Rüdenauer
Markus Blepp
Eva Brommer
Carl-Otto Gensch
Kathrin Graulich

BIO Intelligence Service, France
Shailendra Mudgal
Raul Cervantes
Thibault Faninger
Lorcan Lyons

Büro Ö-Quadrat, Germany
Dieter Seifried

Öko-Institut e.V.
Freiburg Head Office
P.O. Box 17 71
79017 Freiburg, Germany
Street Address
Merzhauser Str. 173
79100 Freiburg, Germany
Tel. +49 (0) 761 – 4 52 95-0
Fax +49 (0) 761 – 4 52 95-88

Darmstadt Office
Rheinstr. 95
64295 Darmstadt, Germany
Tel. +49 (0) 6151 – 81 91-0
Fax +49 (0) 6151 – 81 91-33

Berlin Office
Schicklerstr. 5-7
10179 Berlin, Germany
Tel. +49 (0) 30 – 40 50 85-0
Fax +49 (0) 30 – 40 50 85-388

www.oeko.de

For reasons of better readability, two Task 7 reports were prepared.

The report at hand covers ***professional dishwashers***.

The Task 7 report on *professional washing machines and dryers* is published separately.

For the benefit of the environment, this document has been optimised for **double-sided printing**.

Part: Professional Dishwashers

Table of Contents – Task 7: Improvement Potential

List of figures IV

List of tables V

1 Introduction 1
1.1 Objective of Task 7 1
1.2 Methodology and assessment of data quality 1

2 Design options 2
2.1 Description of individual design options 3
2.1.1 Bill of materials 4
2.1.2 Volume 5
2.1.3 Energy consumption 6
2.1.4 Water and detergent consumption 9
2.1.5 Prices and costs 10
2.2 Combination of design options: Best Available products 11
2.3 Warm water input option 12

3 Impacts analysis 15
3.1 Base case 1: Undercounter water-change 15
3.2 Base case 2: Undercounter one-tank 18
3.3 Base case 3: Hood-type dishwashers 21
3.4 Base case 4: Utensil/pot dishwashers 24
3.5 Base case 5: Conveyor-type one-tank 27
3.6 Base case 6: Conveyor-type multi-tank 30

4 Costs analysis 33
4.1 Base case 1: Undercounter water-change 33
4.2 Base case 2: Undercounter one-tank 34
4.3 Base case 3: Hood-type dishwashers 35
4.4 Base case 4: Utensil/pot dishwashers 37
4.5 Base case 5: Conveyor-type one-tank 39
4.6 Base case 6: Conveyor-type multi-tank 41

5 Analysis of LLCC and BAT 43
5.1 Base case 1: Undercounter water-change 44
5.2 Base case 2: Undercounter one-tank 46
5.3 Base case 3: Hood-type dishwashers 48
5.4 Base case 4: Utensil/pot dishwashers 50

5.5 Base case 5: Conveyor-type one-tank 52
5.6 Base case 6: Conveyor-type multi-tank 54
6 Long-term targets (BNAT) and systems analysis 56
7 Conclusion 57
8 Annex 59
8.1 Enquiry for stakeholders 59
8.2 Stakeholder feedback to draft versions of Task 7 66

List of figures

Figure 3-1 Energy consumption by improvement option for base case 1 17
Figure 3-2 Improvement potential by improvement option for base case 1 17
Figure 3-3 Energy consumption by improvement option for base case 2 20
Figure 3-4 Improvement potential by improvement option for base case 2 20
Figure 3-5 Energy consumption by improvement option for base case 3 23
Figure 3-6 Improvement potential by improvement option for base case 3 23
Figure 3-7 Energy consumption by improvement option for base case 4 26
Figure 3-8 Improvement potential by improvement option for base case 4 26
Figure 3-9 Energy consumption by improvement option for base case 5 29
Figure 3-10 Improvement potential by improvement option for base case 5 29
Figure 3-11 Energy consumption by improvement option for base case 6 32
Figure 3-12 Improvement potential by improvement option for base case 6 32
Figure 4-1 Life cycle costs breakdown by improvement option for base case 1 34
Figure 4-2 Life cycle costs breakdown by improvement option for base case 2 35
Figure 4-3 Life cycle costs breakdown by improvement option for base case 3 37
Figure 4-4 Life cycle costs breakdown by improvement option for base case 4 39
Figure 4-5 Life cycle costs breakdown by improvement option for base case 5 41
Figure 4-6 Life cycle costs breakdown by improvement option for base case 6 43
Figure 5-1 Economic and environmental analysis for base case 1 45
Figure 5-2 Economic and environmental analysis for base case 2 47
Figure 5-3 Economic and environmental analysis for base case 3 49
Figure 5-4 Economic and environmental analysis for base case 4 51
Figure 5-5 Economic and environmental analysis for base case 5 53
Figure 5-6 Economic and environmental analysis for base case 6 55

List of tables

Table 2-1	Capacities, prices and consumption values of bases cases	4
Table 2-2	Material composition of the design options	5
Table 2-3	Relative volume by improvement option in comparison with the base case	6
Table 2-4	Estimated energy savings potential by improvement option for base case 1 (undercounter water-change)	7
Table 2-5	Estimated energy savings potential by improvement option for base case 2 (undercounter one-tank)	7
Table 2-6	Estimated energy savings potential by improvement option for base case 3 (hood-type)	8
Table 2-7	Estimated energy savings potential by improvement option for base case 4 (utensil/pot)	8
Table 2-8	Estimated energy savings potential by improvement option for base case 5 (conveyor-type one-tank)	9
Table 2-9	Estimated energy savings potential by improvement option for base case 6 (conveyor-type multi-tank)	9
Table 2-10	Relative water and detergent consumption by improvement option, in comparison with the base case	10
Table 2-11	Purchase prices (and repair costs) by improvement option in comparison with the base case	10
Table 2-12	Description of the BA products, by base case	11
Table 2-13	Evolution of the volume, energy and water consumption and of the purchase price for BA products	12
Table 2-14	Warm water consumption and heat power inputs	14
Table 3-1	Environmental impacts by improvement option for base case 1	16
Table 3-2	Environmental impacts by improvement option for base case 2	19
Table 3-3	Environmental impacts by improvement option for base case 3	22
Table 3-4	Environmental impacts by improvement option for base case 4	25
Table 3-5	Environmental impacts by improvement option for base case 5	28
Table 3-6	Environmental impacts by improvement option for base case 6	31
Table 4-1	Life cycle costs by improvement option for base case 1	33
Table 4-2	Life cycle costs by improvement option for base case 2	35
Table 4-3	Life cycle costs by improvement option for base case 3	36
Table 4-4	Life cycle costs by improvement option for base case 4	38
Table 4-5	Life cycle costs by improvement option for base case 5	40
Table 4-6	Life cycle costs by improvement option for base case 6	42

1 Introduction

1.1 Objective of Task 7

The objective of Task 7 is to assess the environmental and economic impacts of the base cases (BC) with the improvement options identified in Task 6. Impacts include the monetary consequences in terms of Life Cycle Cost (LCC) for the user, environmental costs and benefits, economic and social impacts. The solution with the Least Life Cycle Cost (LLCC) and the Best Available Technology (BAT) will be highlighted. The available design options are investigated by assessing the environmental impact and LCC of each against the base case using the MEEuP EcoReport, as in Task 5.

The assessment of LCC is relevant to indicate how design solutions might affect total user expenditure over the total product lifetime (purchase, operating and end-of-life costs). The gap between the LLCC option and the BAT one indicates the remaining room for product-differentiation (competition), in cases where the LLCC option is set as a minimum target. The BAT represents a short- to medium-term target, for which promotional measures would probably be more appropriate than restrictions. The Best Not yet Available Technology (BNAT) gives an idea of long-term possibilities and helps to define the exact scope and definition of any possible measures.

1.2 Methodology and assessment of data quality

Based on the currently applied BAT design options, the general constraints with regard to implementation and combination possibilities, and the infeasibility to quantify the improvement potential of most of the options (see Task 6), six design options were chosen for further proceedings.

For these selected design options, manufacturers were asked to quantify the concrete saving potential and price differences compared to the base case products as defined in Tasks 3, 4 and 5. The inquiry was sent out to seven manufacturers (see Annex). The following tables in section 2 present the aggregated and averaged results of four filled in questionnaires.

Important note: Assessment of data quality throughout Task 6 report

It is important to note that all information with regard to the saving potential of improvement options should be seen in the following context:

- There are no standard measurement methods for quantifying the energy and water consumption of professional dishwashers, and there are likewise no standards requiring manufacturers to define the measurement procedure for potential savings (see Task 1).

- Energy and water savings depend on many different factors such as: ambient air temperature, inlet water temperature, temperature and humidity of exhaust air, temperature of waste water, type of machine and, last but not least, the reference case to which savings are compared.
- Quantification based on information from independent side is not possible as there is no scientific literature about the results of BAT and the potential saving impacts of improvement options in the professional dishwashing sector published.
- Within the study we also tried to collect usage data from different categories of end-users (e.g. large canteens). But it was not possible to get data which enable us to quantify the impact of BAT on water- and energy-savings.
- Manufacturers assess their innovative systems in different ways to their competitors.
- The figures in sales brochures are usually used for marketing purposes and therefore might over-estimate the actual savings.
- Quantitative data provided by manufacturers with regard to the savings potentials are only rough estimations.
- Due to the above reasons, estimations and quantitative data of the different manufacturers diverge considerably.
- The data presented in the Task report at hand are average values of the responses.

2 Design options

The Technical Analysis of BAT (see Task 6) identified and described individual design options for environmental improvement according to the usual criteria:

- The design option(s) should not change significantly the functionality or performance parameters compared to the base case.
- The design option(s) should have a significant potential for improvement regarding at least one of the following eco-design parameters without deteriorating others: consumption of energy, water and other resources, use of hazardous substances, emissions to air, water or soil, weight and volume of the product, use of recycled material, quantity and nature of consumables needed for proper use and maintenance, ease of reuse and recycling, extension of lifetime or amount of waste generated.
- The design option(s) should not entail excessive costs. Redesign, testing, investment and/or production costs should be investigated, taking into account economies of scale, sector-specific margins and market structure, and the time required for market penetration of the new design option(s) and replacement of the existing products. Assessment of the costs includes an estimation of possible price increase due to

implementation of the design option either by looking at product prices on the market and/or by applying a production cost model with sector-specific margins.

In the following section, the influence of the implementation of the improvement options on base case products is assessed in more detail.

2.1 Description of individual design options

The improvement options that will be analysed in this task are (all options do not necessarily apply to all base cases):

- **M 1.5 Auxiliary rinsing** (see 3.1.1.5 in Task 6): for conveyor-type dishwashers, lower fresh-water consumption can be achieved thanks to a two or three-step rinsing zone.
- **M 2.1.1 Exhaust air heat exchanger** (see 3.2.1.1 in Task 6): the heat from the exhaust air can be used to preheat the incoming water of the machine through a counter-flow exchanger.
- **M 2.1.2 Exhaust air heat pump** (see 3.2.1.1 in Task 6): thanks to a heat pump, an electric device with cooling and heating capabilities, the energy contained in the exhaust air can be recovered more efficiently than with a heat exchanger.
- **M 3.1.1 Waste water heat exchanger** (see 3.3.1.1 in Task 6): the process is the same as for an exhaust air heat exchanger except that the heat is extracted from the waste water.
- **M 4.1 Insulation**, closed bottom (see 3.4.1.1 in Task 6): the wash tank and other parts of the dishwasher can be thermally insulated to reduce convection losses in the operating and ready-to-use modes.
- **M 4.2 High efficiency pumps and motors** (see 3.4.1.2 in Task 6): the efficiency of the whole hydraulic system (including pumps, motors and pipes) can be optimised, thus reducing energy losses.

- Along with these six individual design options, one overall combination of design options will be added for each base case. This option will be labelled **Best Available (BA) product** (see section 2.2).
- Finally, the **warm water supply** will also be studied, in comparison with the base case, but in an indicative way only (see section 2.3). This option will not be identified as the LLCC or BAT option as its implementation highly depends on the available building infrastructure.

The following subsections will summarise the changes in an improved product that would result from the implementation of the various single design options in each base case.

The parameters of the analysis that are kept constant are the same which were used for the base case analysis (see Task 5). Table 2-1 first summarizes the capacities, prices and

consumption values of the base cases as defined in Tasks 3, 4 and 5. These values represent the 100% baseline for the assessment of the design options as provided in the following subsections.

Table 2-1 Capacities, prices and consumption values of bases cases

Parameters	Base case					
	1	2	3	4	5	6
	Under-counter water-change	Under-counter one-tank	Hood-type	Utensil/ Pot	Conveyor-type one-tank	Conveyor-type multi-tank
Capacity (dishes/hour)	200	550	860	20 cycles/hour	1 750	3 600
Purchase price (Euro)	3 200	3 500	4 700	10 500	15 000	45 000
Continuous operation						
Specific energy consumption (kWh/100 dishes)	4.3	1.6	1.7	0.5 (per cycle)	2.0	2.0
Specific water consumption (l/100 dishes)	80	16	16	5.2 (per cycle)	13	12
Standby consumption (kWh/hour)						
Left-on mode (BC 1), ready-to-use-mode (BC 2-6)	0.01	0.25	0.35	1.00	0.80	2.00

2.1.1 Bill of materials

The implementation of improvement options can involve the addition of components to enhance product performance (e.g. heat pump). These components increase the quantity of raw materials required to manufacture the product, the weight and volume, as well as the quantity of materials discarded at the end-of-life of the dishwasher. Table 2-2 lists the additional materials required for each improvement option considered.

Table 2-2 Material composition of the design options

Materials	Additional bill of materials due to the improvement options (g)					
	M 2.1.1 Exhaust air heat exchanger	**M 2.1.2 Exhaust air heat pump**	**M 3.1.1 Waste water heat exchanger**	**M 4.1 Insulation, closed bottom**	**M 4.2 High efficient pumps and motors**	**M 1.5 Auxiliary rinsing**
Stainless steel	+ 5 000	+ 35 000	+ 10 000	n.a.	n.a.	+ 10 000
Copper sheet/tube	+ 5 000	+ 55 000				
Copper wire						+ 1 500
Aluminium diecast						+ 500
Polypropylene		+ 500				+ 500
Electronics		+ 500				+ 100
Refrigerant R-134a		+ 2500				

(Sources: Task 6, Tables 1, 2, and 3, and section 3.4.2)
Note: empty fields = not applicable or no response by manufacturers

The option M 2.1.2 (exhaust air heat pump) results in the presence of refrigerant in the product bill of materials. According to manufacturers, the refrigerant R-134a is commonly used in dishwashers' heat pumps and is thus the type of refrigerant used as an input in EcoReport. This refrigerant has a negligible ozone depletion potential and a 100-year Global Warming Potential of 1 430.[1]

Stakeholders[2] mentioned that the percentage of refrigerant lost during the life cycle of the product was comprised between 5% and 15%. In practice, it is common that a limited number of machines (newly installed ones) lose the total amount of refrigerant due to a defect, which increases significantly the loss rate of the stock. One or several partial refill(s) of the refrigerant can be done over the lifetime. Therefore, the fugitive and dumped refrigerant percentage will be set at 10% over the whole lifecycle in EcoReport.

2.1.2 Volume

It was assumed that the density of the complete product remains the same. Thus the change in volume of the packaged product between the base case and the product with the improvement option is the same as the change in mass. These values were calculated from the bills of materials (see Table 2-2 and Task 5) and are shown in Table 2-3. Given the results of Task 5, this input has a very low influence on the final outcomes of the environmental analysis, and no influence at all on the economic analysis.

1 IPCC Fourth Assessment Report (AR4), 2007

2 Feedback from Miele and GDF-Suez

Table 2-3 Relative volume by improvement option in comparison with the base case

	M 2.1.1 Exhaust air heat exchanger	M 2.1.2 Exhaust air heat pump	M 3.1.1 Waste water heat exchanger	M 4.1 Insulation, closed bottom	M 4.2 High efficiency pumps and motors	M 1.5 Auxiliary rinsing
BC 1 Undercounter water-change	120%	-	-	100%	100%	-
BC 2 Undercounter one-tank	113%	218%	113%	100%	100%	-
BC 3 Hood-type	107%	169%	107%	100%	100%	-
BC 4 Utensil/pot	104%	141%	104%	100%	100%	-
BC 5 Conveyor-type one-tank	101%	109%	101%	100%	100%	101%
BC 6 Conveyor-type multi-tank	101%	106%	101%	100%	100%	101%

'-' means that the option cannot be implemented in the product category considered

2.1.3 Energy consumption

The following tables (Table 2-4 to Table 2-9) show the energy performance improvement enabled by the single design options, both for continuous operation and for the left-on/ready-to-use mode and calculate the overall energy performance improvement by taking into account the annual energy consumption breakdown presented in Task 4.

Manufacturers' aggregated and averaged estimations on the evolution of energy consumption are provided assuming the values of the base cases represent 100% each. As can be seen, the main differences occur in the energy consumption during the operating mode. The energy demand in the ready-to-use mode mainly influenced through improved insulation and a reduction in vaporisation losses of the wash tanks (M 4.1), only accounts for a minor part of the overall energy demand, leading only to limited overall saving potential.

Table 2-4 Estimated energy savings potential by improvement option for base case 1 (undercounter water-change)

	Annual energy consumption of the base case (kWh)	Relative consumption by improvement option, in comparison with the base case 1					
		M 2.1.1 Exhaust air heat exchanger	**M 2.1.2 Exhaust air heat pump**	**M 3.1.1 Waste water heat exchanger**	**M 4.2 High efficiency pumps & motors**	**M 4.1 Insulation, closed bottom**	**M 1.5 Auxiliary rinsing**
Continuous operation	1 249	97%	not consi-dered[3]	not consi-dered[4]	97%	98%	-
Standby consumption (Left-on mode)	5	100%	-	-	100%	100%	-
Overall energy consumption	1 254	**97%**	-	-	**97%**	**98%**	-

(Source: Manufacturers answers through questionnaire)

Table 2-5 Estimated energy savings potential by improvement option for base case 2 (undercounter one-tank)

	Annual energy consumption of the base case (kWh)	Relative consumption by improvement option, in comparison with the base case 2					
		M 2.1.1 Exhaust air heat exchanger	**M 2.1.2 Exhaust air heat pump**	**M 3.1.1 Waste water heat exchanger**	**M 4.2 High efficiency pumps & motors**	**M 4.1 Insula-tion, closed bottom**	**M 1.5 Auxiliary rinsing**
Continuous operation	4 391	90%	90%	90%	92%	100%	-
Initial filling	236	-	-	-	-	-	-
Standby consumption (Ready-to-use mode)	626	100%	100%	100%	100%	99%	-
Overall energy consumption[5]	5 253	**91.6%**	**91.6%**	**91.6%**	**93.3%**	**99.9%**	-

(Source: Manufacturers answers through questionnaire)

[3] Actually, the technical realisation within the available space seems not possible. Further, heat pumps in a temperature range of about 90°C seem to be not realisable with commercially available compressors.

[4] This design option is within the available space not realisable.

[5] Composed of continuous operation, standby consumption and initial filling (not displayed in the table)

Table 2-6 Estimated energy savings potential by improvement option for base case 3 (hood-type)

	Annual energy consumption of the base case (kWh)	Relative consumption by improvement option, in comparison with the base case 3					
		M 2.1.1 Exhaust air heat exchanger	**M 2.1.2 Exhaust air heat pump**	**M 3.1.1 Waste water heat exchanger**	**M 4.2 High efficiency pumps & motors**	**M 4.1 Insula-tion, closed bottom**	**M 1.5 Auxiliary rinsing**
Continuous operation	6 845	88%	90%	85%	92%	100%	-
Initial filling	629	-	-	-	-	-	-
Standby consumption (Ready-to-use mode)	784	100%	100%	100%	100%	99%	-
Overall energy consumption[5]	8 258	**90.1%**	**91.7%**	**87.6%**	**93.4%**	**99.9%**	-

(Source: Manufacturers answers through questionnaire)

Table 2-7 Estimated energy savings potential by improvement option for base case 4 (utensil/pot)

	Annual energy consumption of the base case (kWh)	Relative consumption by improvement option, in comparison with the base case 4					
		M 2.1.1 Exhaust air heat exchanger	**M 2.1.2 Exhaust air heat pump**	**M 3.1.1 Waste water heat exchanger**	**M 4.2 High efficiency pumps & motors**	**M 4.1 Insula-tion, closed bottom**	**M 1.5 Auxiliary rinsing**
Continuous operation	5 423	85%	90%	85%	92%	100%	-
Initial filling	1 257	-	-	-	-	-	-
Standby consumption (Ready-to-use mode)	2 233	100%	100%	100%	100%	99%	-
Overall energy consumption[5]	8 913	**90.9%**	**93.9%**	**90.9%**	**95.1%**	**99.7%**	-

(Source: Manufacturers answers through questionnaire)

Table 2-8 Estimated energy savings potential by improvement option for base case 5 (conveyor-type one-tank)

	Annual energy consumption of the base case (kWh)	Relative consumption by improvement option, in comparison with the base case 5					
		M 2.1.1 Exhaust air heat exchanger	**M 2.1.2 Exhaust air heat pump**	**M 3.1.1 Waste water heat exchanger**	**M 4.2 High efficiency pumps & motors**	**M 4.1 Insula-tion, closed bottom**	**M 1.5 Auxiliary rinsing**
Continuous operation	34 259	80%	78%	85%	93%	100%	88%
Initial filling	1 728	-	-	-	-	-	-
Standby consumption (Ready-to-use mode)	1 716	100%	100%	100%	100%	98%	100%
Overall energy consumption[5]	37 703	**81.8%**	**80.0%**	**86.4%**	**93.6%**	**99.9%**	**89.1%**

(Source: Manufacturers answers through questionnaire)

Table 2-9 Estimated energy savings potential by improvement option for base case 6 (conveyor-type multi-tank)

	Annual energy consumption of the base case (kWh)	Relative consumption by improvement option, in comparison with the base case 6					
		M 2.1.1 Exhaust air heat exchanger	**M 2.1.2 Exhaust air heat pump**	**M 3.1.1 Waste water heat exchanger**	**M 4.2 High efficiency pumps & motors**	**M 4.1 Insula-tion, closed bottom**	**M 1.5 Auxiliary rinsing**
Continuous operation	94 624	82%	75%	85%	88%	100%	88%
Initial filling	3 975	-	-	-	-	-	-
Standby consumption (Ready-to-use mode)	3 630	100%	100%	100%	100%	98%	99%
Overall energy consumption[5]	102 229	**83.3%**	**76.9%**	**86.1%**	**88.9%**	**99.9%**	**88.9%**

(Source: Manufacturers answers through questionnaire)

2.1.4 Water and detergent consumption

Assuming the detergent concentration is kept constant whatever quantity of water is required during the dishwashing operation, the change in detergent consumption is the same to the change in water consumption when implementing improvement options (in terms of percentage). In Table 2-10, manufacturers' aggregated and averaged estimations on the evolution of the water consumption are provided, assuming the values of the base cases represent 100% each.

Table 2-10 Relative water and detergent consumption by improvement option, in comparison with the base case[6]

	M 2.1.1 Exhaust air heat exchanger	M 2.1.2 Exhaust air heat pump	M 3.1.1 Waste water heat exchanger	M 4.2 High efficient pumps and motors	M 4.1 Insulation, closed bottom	M 1.5 Auxiliary rinsing
BC 1 Undercounter water-change	100%	-	-	95%	100%	-
BC 2 Undercounter one-tank	100%	100%	100%	93%	100%	-
BC 3 Hood-type	100%	100%	100%	93%	100%	-
BC 4 Utensil/Pot	100%	100%	100%	93%	100%	-
BC 5 Conveyor-type one-tank	100%	100%	100%	90%	100%	88%
BC 6 Conveyor-type multi-tank	100%	100%	100%	85%	100%	88%

2.1.5 Prices and costs

The changes in purchase prices are shown in Table 2-11. The maintenance and repair costs of improved products are assumed to represent the same share of the purchase price as for the base cases: 37.5% for BC 1 and 44% for all other BCs (see Task 2). As a result, they change in the same way as purchase prices. Manufacturers' aggregated and averaged estimations on the evolution of the prices are provided assuming the values of the base cases represent 100% each.

Table 2-11 Purchase prices (and repair costs) by improvement option in comparison with the base case[7]

	M 2.1.1 Exhaust air heat exchanger	M 2.1.2 Exhaust air heat pump	M 3.1.1 Waste water heat exchanger	M 4.2 High efficient pumps + motors	M 4.1 Insulation, closed bottom	M 1.5 Auxiliary rinsing
BC 1 Undercounter water-change	105%	-	-	108%	103%	-
BC 2 Undercounter one-tank	118%	200%	115%	113%	103%	-
BC 3 Hood-type	120%	200%	118%	115%	103%	-
BC 4 Utensil/Pot	117%	160%	109%	110%	101%	-
BC 5 Conveyor-type one-tank	115%	160%	120%	110%	108%	113%
BC 6 Conveyor-type multi-tank	108%	132%	115%	115%	106%	113%

6 Source: Manufacturers answers through questionnaire

7 Source: Manufacturers answers through questionnaire

2.2 Combination of design options: Best Available products

Most of the improvement options presented can be implemented at the same time in a single product but the marginal savings decrease with the number of options implemented.

The objective of this section was to find out the lowest, technically achievable energy and water consumption in the six categories by using all available and technically feasible improvement options and best available technology components. Because carrying out a thorough analysis of the marginal savings for each combination of improvement options would not be realistic and because the data obtained through the Tasks 6-7 questionnaire was not substantially completed by all manufacturers, only the overall combination of improvement options for each BC is presented in this task (the sum of all options, not all possible combinations). This corresponds to the best available product (BA product) on the market and the results are based on existing products produced by manufacturers. The individual design options that are implemented in the BA product for each BC are presented in Table 2-12.

Table 2-12 Description of the BA products, by base case[8,9]

	M 2.1.1 Exhaust air heat exchanger	**M 2.1.2 Exhaust air heat pump**	**M 3.1.1 Waste water heat exchanger**	**M 4.2 High efficient pumps + motors**	**M 4.1 Insulation, closed bottom**	**M 1.5 Auxiliary rinsing**
BC 1 Undercounter water-change[10]	Yes	-	-	Yes	Yes	-
BC 2 Undercounter one-tank	Yes	-	Yes	Yes	Yes	-
BC 3 Hood-type	Yes	-	Yes	Yes	Yes	-
BC 4 Utensil/Pot	Yes	-	Yes	Yes	Yes	-
BC 5 Conveyor-type one-tank	Yes	Yes	(Yes)	Yes	Yes	Yes
BC 6 Conveyor-type multi-tank	Yes	Yes	(Yes)	Yes	Yes	Yes

The bills of materials of these BA products are directly derived from Table 2-2, by adding the indicated components to the composition of the corresponding base case.

[8] Source: Manufacturers answers through questionnaire

[9] This is an “average” Bill of Materials for the product as the best available products of different manufacturers do not necessarily implement the same technical improvement features. Given the low importance of the production phase in the overall environmental impacts, this approximation is estimated reasonable.

[10] The measures “exhaust air heat pump” and “waste water heat exchanger” have not been considered under BC 1 because of the restricted available space of this machine type.

The energy consumption and price evolutions in comparison with the base cases were obtained from manufacturers' information and are summarised in Table 2-13.

Table 2-13 Evolution of the volume, energy and water consumption and of the purchase price for BA products

	BA product of					
	BC 1	**BC 2**	**BC 3**	**BC 4**	**BC 5**	**BC 6**
Volume	**120%**	**125%**	**115%**	**109%**	**113%**	**109%**
Continuous operation	92%	86%	79%	78%	68%	60%
Standby consumption (Left-on/Ready-to-use mode)	100%	99.3%	99.3%	99.3%	98.7%	98.7%
Overall energy consumption	**92.0%**	**88.2%**	**82.5%**	**86.4%**	**70.9%**	**62.9%**
Overall water consumption	**95%**	**95%**	**95%**	**95%**	**85%**	**75%**
Purchase price (and repair and maintenance costs)	**116%**	**160%**	**177%**	**151%**	**181%**	**168%**

(Source: Manufacturers answers through questionnaire. The change in volume was assessed from the change in mass in the Bills of Materials. The overall energy consumption is a balanced average of the continuous and standby operation modes, like in section 2.1.3.)

2.3 Warm water input option

In Task 3, the fact that warm water can be used as a direct input to professional dishwashers is described. This can be considered as a sort of improvement option because the process of external water heating is normally more efficient when done at the building level than with electric resistance inside the appliance: the final energy required by the machine is exactly the same but the efficiency of the heating process is higher if warm water is used and the operating costs may be different depending on the source of primary energy (gas, wood, etc.). However, this alternative depends on the infrastructure available to the dishwasher's owner and it might not be possible to implement it in every situation. Furthermore, the objective of the European Commission is not to impose one or several type(s) of energy source to the end users. **Therefore, the option will be analysed from the environmental and economic perspectives like the other improvement options, but will however not be identified as the LLCC or BAT option when scoring best.**

From a technical point of view, the machine is considered to be exactly the same product as the base case (the number of inlet valves does not impose the use of cold or warm water): same bill of materials, same volume, same (final) energy, water and detergent consumption, same purchase price and repair and maintenance costs. The only two differences reside in the breakdown of the energy consumption, where a certain percentage will be brought to the

system in the form of 'heat' via warm water (instead of electricity), and in the operating energy costs due to indirect primary energy consumption to heat the water externally.

To calculate the heat contained in the warm water consumed annually (see Table 2-14), the cold water temperature was assessed at 15°C and the warm water temperature at 60°C. The heat capacity of water considered is 4.19 kJ/(kg.K). The annual power input due to warm water is the direct result of the multiplication of the annual quantity of warm water consumed by the heat capacity of water and the temperature gap (45°C in this case).

The calculation of primary energy consumption necessary for the initial heating of the warm water is done automatically and taken into account in the environmental and economic analysis in EcoReport. The most common central heating boiler was estimated to be a gas boiler (non-condensing) with an efficiency of 90%.[11,12]

In the life cycle assessment, the production, distribution and end-of-life impacts of the boiler are not taken into account in the environmental impacts (only direct emissions and energy use are accounted for). First, these impacts are expected to be negligible in comparison with the impacts of the primary energy consumed during the use phase of the boiler. Besides, it would be very tricky to estimate what the percentage of the boiler operation dedicated to the dishwasher warm water is, on average in the EU-27. This share can indeed be very variable depending on the building considered. Boilers were already considered in an eco-design preparatory study (Lot 1 for DG ENER, eco-design requirements are expected to be defined in 2011 for this product category), as well as central heating products (Lot 21 for DG ENER).

Regarding the costs, it could be argued that the use of the external boiler generates additional installation, purchase and maintenance costs. However, it is believed that the investment for a central heating gas boiler would not be made just in order to supply a commercial dishwasher with warm water. The most common case is that the customer benefits from the infrastructure available and goes for a 100% electric product if it is not. As a result, the costs for the external boiler are already allocated to other processes and would exist anyway. Costs that could have possibly been taken into account in the analysis are the installation costs for the specific connection and pipes from the boiler to the dishwasher. However, given that the analysis of the warm water supply option will not be considered as BAT or LLCC option, this level of detail was not estimated necessary.

[11] Efficiency values in EcoReport relate to net calorific value (lower heating value).

[12] Feedback from GDF-Suez.

Table 2-14 Warm water consumption and heat power inputs[13]

	Annual quantity of warm water consumed (m^3) Description of the technical characteristics of the machine	**Annual heat power input due to warm water (kWh)[14]**	**Total annual energy consumption[15] (kWh)**
BC 1 Undercounter water-change	12.96 Machine with two valves, using cold and warm water in continuous operation **Assumption:** 50% of the water input is warm water and the remaining share is cold water.	679	1 254
BC 2 Undercounter one-tank	55.82 Machine with one single valve using only warm water (for initial filling and final rinse)	2 926	5 253
BC 3 Hood-type	86.65 Machine with one single valve using only warm water (for initial filling and final rinse)	4 542	8 258
BC 4 Utensil/pot	89.52 Machine with one single valve using only warm water (for initial filling and final rinse)	4 692	8 913
BC 5 Conveyor-type one-tank	33.00 Machine with two or more valves using warm water for the initial filling and cold water for the final rinse	1 730	37 703
BC 6 Conveyor-type multi-tank	75.90 Machine with two or more valves using warm water for the initial filling and cold water for the final rinse	3 978	102 229

Due to the lack of data and the minor importance of alternative heating processes possible within the dishwashers (low pressure steam and hot water heating, see Table 13 in Task 3), the analysis of such appliances has not been done in this context. The environmental and economic results for this alternative internal heating option are however expected to be similar to the ones that will be presented for the warm water supply option, as these two options rely on the same principle: replace some share of the electricity consumption with a more efficient heating process based on gas water heating.

[13] Source: Tasks 4 and 5 and own calculations

[14] Additional heat input in comparison with the base case situation, where only cold water is supplied. These figures result from direct calculations.

[15] This energy consumption is exactly the same as the total annual energy consumption of the base cases (see Task 5)

3 Impacts analysis

The aim of this sub-task is to quantify the environmental benefits and impacts of the improvement options. All relevant design improvements are investigated to see how the option affects the output values of the EcoReport. It is likely that the impact assessment will reveal trade-offs between some impact categories for a given option. For example, an option with less greenhouse gas emissions might result in increased non-renewable material consumption or waste generation. An appropriate weighting of the different impact categories is not easy to establish, and this matter merits further discussion with the European Commission and experts.

3.1 Base case 1: Undercounter water-change

The results of the environmental analysis of the improvement options for BC 1 are seen below. Excluding the warm water supply option, the BA product provides the greatest improvement for most of the impacts (up to 8% improvement in electricity consumption and water cooling) (Table 3-1). Then comes option M 4.2 (high efficient pumps and motors), reducing the electricity consumption by 3% and the eutrophication potential by 5%.

Regarding option M 2.1.1, its implementation is detrimental for many environmental indicators (e.g. +37% for non hazardous waste generation, +13% for heavy metals emissions in air, +2% for POP, +3% for PAHs and +5% PM emissions), which tends to show that the addition of material required for this option is not counterbalanced by the energy savings that it enables during the use phase.

Table 3-1 Environmental impacts by improvement option for base case 1

life-cycle indicators per unit	unit	Base Case 1	M 2.1.1 Exhaust air heat exchanger	M 4.2 High efficient pumps + motors	M 4.1 Insulation, closed bottom	BA product	Warm Water
Other resources and waste							
Total Energy (GER)	GJ	196.5	192.9	190.1	193.4	183.3	145.8
	% change with BC	0%	-2%	-3%	-2%	-7%	-26%
of which, electricity	primary GJ	159.1	154.4	154.3	155.9	146.6	73.5
	MWh	15.1	14.7	14.7	14.8	14.0	7.0
	% change with BC	0%	-3%	-3%	-2%	-8%	-54%
Water (process)	kL	324.6	324.7	308.7	324.4	308.6	318.9
	% change with BC	0%	0%	-5%	0%	-5%	-2%
Water (cooling)	kL	422.7	410.2	410.1	414.3	389.2	194.6
	% change with BC	0%	-3%	-3%	-2%	-8%	-54%
Waste, non-haz./ landfill	kg	277.3	378.8	269.9	273.6	367.8	178.1
	% change with BC	0%	37%	-3%	-1%	33%	-36%
Waste, hazardous/ incinerated	kg	11.4	11.3	11.3	11.4	11.1	9.5
	% change with BC	0%	-1%	-1%	-1%	-3%	-17%
Emissions (Air)							
Greenhouse Gases in GWP100	t CO2 eq.	8.7	8.6	8.4	8.6	8.1	6.9
	% change with BC	0%	-2%	-3%	-2%	-6%	-21%
Acidification, emissions	kg SO2 eq.	51.8	52.4	50.1	51.0	49.9	30.3
	% change with BC	0%	1%	-3%	-2%	-4%	-41%
Volatile Organic Compounds (VOC)	kg	0.1	0.1	0.1	0.1	0.1	0.1
	% change with BC	0%	1%	-2%	-1%	-2%	-5%
Persistent Organic Pollutants (POP)	µg i-Teq	1.5	1.5	1.5	1.5	1.5	1.0
	% change with BC	0%	2%	-3%	-1%	-2%	-37%
Heavy Metals	g Ni eq.	7.4	8.4	7.3	7.4	8.2	6.0
	% change with BC	0%	13%	-1%	-1%	11%	-20%
PAHs	g Ni eq.	0.7	0.7	0.7	0.7	0.7	0.5
	% change with BC	0%	3%	-2%	-1%	0%	-25%
Particulate Matter (PM, dust)	kg	6.8	7.1	6.8	6.8	7.1	6.3
	% change with BC	0%	5%	-1%	0%	4%	-7%
Emissions (Water)							
Heavy Metals	g Hg/20	3.5	4.4	3.5	3.5	4.4	3.0
	% change with BC	0%	25%	-1%	-1%	24%	-16%
Eutrophication	kg PO4	56.0	56.1	53.2	56.0	53.3	56.0
	% change with BC	0%	0%	-5%	0%	-5%	0%

Figure 3-1 shows the primary energy and electricity consumption (with the percentage of the primary energy that it represents) over the life cycle. For all improvement options excluding warm water supply, the share of electricity remains approximately the same (80-81% of the total primary energy) because of the important electricity consumption during the use phase. A significant difference can be observed for the “warm water”, where electricity represents only 50% of the total primary energy, due to the fact that a share of the energy heating the water comes from the external heating system (gas boiler in our model).

Figure 3-2 shows the evolution of some environmental indicators (GWP, acidification, PAHs and Eutrophication) for each design option.

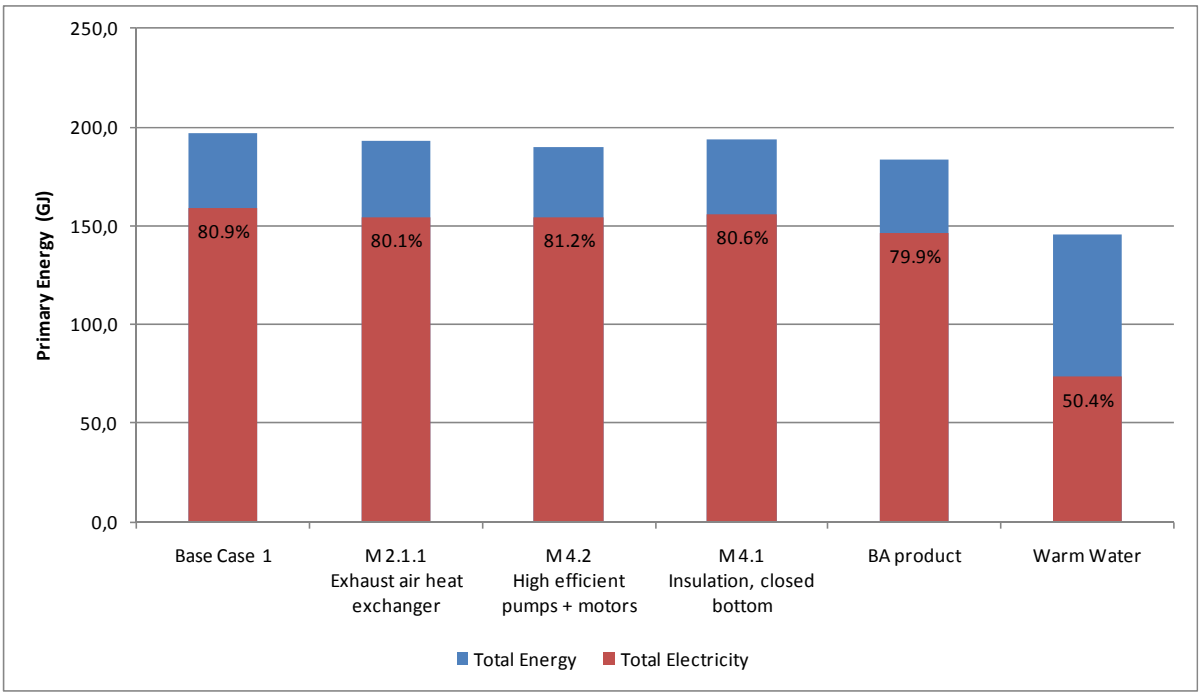


Figure 3-1 Energy consumption by improvement option for base case 1

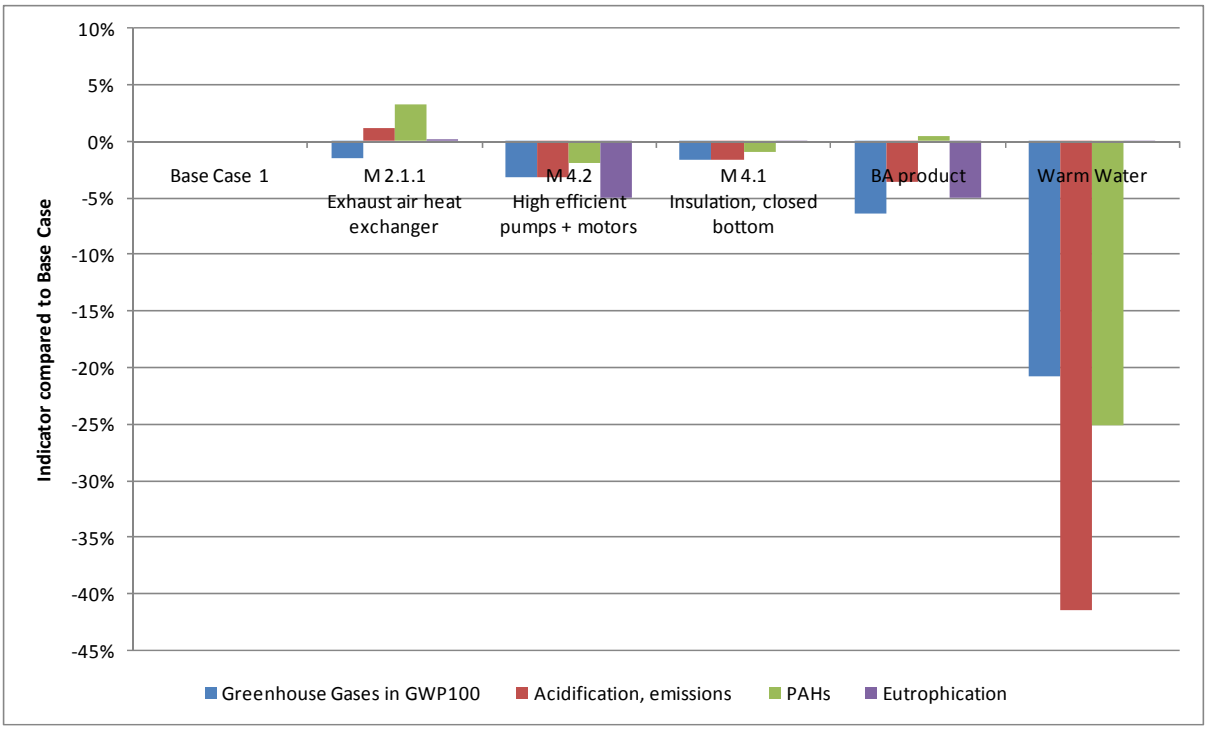


Figure 3-2 Improvement potential by improvement option for base case 1

3.2 Base case 2: Undercounter one-tank

The results of the environmental analysis of the improvement options for BC 2 are seen below. The BA product provides the greatest improvement for most of the impacts (up to 12% improvement in electricity consumption and water cooling) (Table 3-2), when warm water supply is not considered as a suitable option. Then come the single options M 2.1.1, M 3.1.1 and M 4.2 which have a similar overall influence on the environmental impacts. The option M 2.1.2 is detrimental for several environmental indicators (+66% for non-hazardous waste, +18% for PAHs, +20% for POP) despite reducing the electricity consumption by 8%. The option M 4.1 Insulation has a negligible influence on the environmental performance of the dishwasher.

Figure 3-3 shows the primary energy and electricity consumption (with the percentage of the primary energy that it represents) over the life cycle. A significant difference can be observed for the breakdown of “warm water”. For other design options, the share of electricity remains approximately the same. Figure 3-4 shows the evolution of some environmental indicators for each design option. In particular, only option 4.2 and the BA product reduce the eutrophication potential, as these are the only options reducing the water consumption (and thus the detergent consumption as well).

Table 3-2 Environmental impacts by improvement option for base case 2

life-cycle indicators per unit	unit	Base Case 2	M 2.1.1 Exhaust air heat exchanger	M 2.1.2 Exhaust air heat pump	M 3.1.1 Waste water heat exchanger	M 4.2 High efficient pumps + motors	M 4.1 Insulation, closed bottom	BA product	Warm Water
Other resources and waste									
Total Energy (GER)	GJ	497.2	461.2	468.1	461.2	464.3	496.7	444.5	351.6
	% change with BC	0%	-7%	-6%	-7%	-7%	0%	-11%	-29%
of which, electricity	primary GJ	443.0	406.2	407.6	406.3	413.4	442.4	391.3	197.2
	MWh	42.2	38.7	38.8	38.7	39.4	42.1	37.3	18.8
	% change with BC	0%	-8%	-8%	-8%	-7%	0%	-12%	-55%
Water (process)	kL	481.5	479.4	482.0	479.8	448.2	481.5	456.8	465.1
	% change with BC	0%	0%	0%	0%	-7%	0%	-5%	-3%
Water (cooling)	kL	1 178.4	1 080.1	1 080.8	1 080.2	1 099.7	1 177.0	1 039.9	523.0
	% change with BC	0%	-8%	-8%	-8%	-7%	0%	-12%	-56%
Waste, non-haz./ landfill	kg	685.0	689.0	1 134.7	653.6	646.9	684.4	680.0	400.0
	% change with BC	0%	1%	66%	-5%	-6%	0%	-1%	-42%
Waste, hazardous/ incinerated	kg	18.4	17.5	18.2	17.5	17.6	18.4	17.1	12.7
	% change with BC	0%	-5%	-1%	-5%	-4%	0%	-7%	-31%
Emissions (Air)									
Greenhouse Gases in GWP100	t CO2 eq.	21.9	20.4	21.2	20.4	20.5	21.9	19.7	16.8
	% change with BC	0%	-7%	-3%	-7%	-7%	0%	-10%	-24%
Acidification, emissions	kg SO2 eq.	130.6	121.7	127.2	121.7	122.1	130.4	117.8	68.9
	% change with BC	0%	-7%	-3%	-7%	-6%	0%	-10%	-47%
Volatile Organic Compounds (VOC)	kg	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	% change with BC	0%	-5%	4%	-5%	-6%	0%	-7%	-9%
Persistent Organic Pollutants (POP)	µg i-Teq	3.8	3.6	4.4	3.6	3.5	3.7	3.6	2.1
	% change with BC	0%	-4%	18%	-4%	-6%	0%	-4%	-43%
Heavy Metals	g Ni eq.	16.8	17.1	23.5	17.7	16.2	16.8	18.3	12.6
	% change with BC	0%	2%	40%	5%	-3%	0%	9%	-25%
PAHs	g Ni eq.	1.4	1.4	1.7	1.4	1.4	1.4	1.4	0.9
	% change with BC	0%	-3%	20%	-5%	-5%	0%	-5%	-34%
Particulate Matter (PM, dust)	kg	7.7	7.8	10.3	7.8	7.5	7.6	8.0	6.3
	% change with BC	0%	1%	34%	2%	-2%	0%	4%	-17%
Emissions (Water)									
Heavy Metals	g Hg/20	7.9	8.3	13.0	8.6	7.7	7.9	9.1	6.3
	% change with BC	0%	5%	64%	8%	-2%	0%	15%	-20%
Eutrophication	kg PO4	80.8	80.8	80.9	80.8	75.1	80.8	76.8	80.8
	% change with BC	0%	0%	0%	0%	-7%	0%	-5%	0%

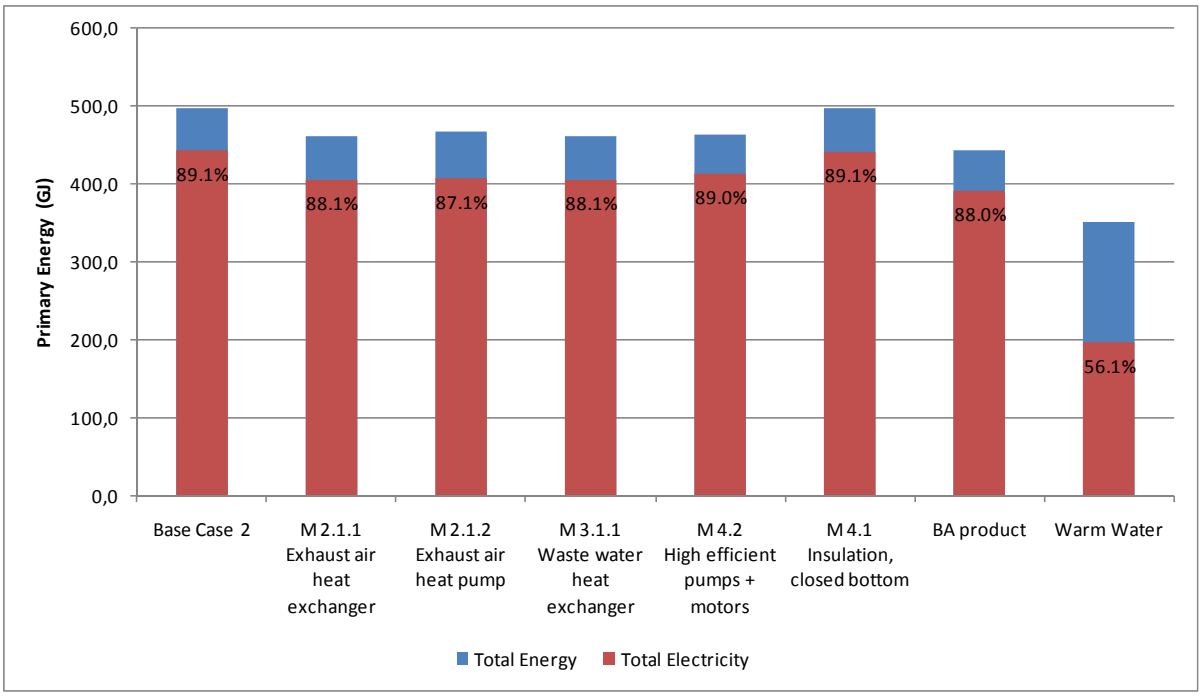


Figure 3-3 Energy consumption by improvement option for base case 2

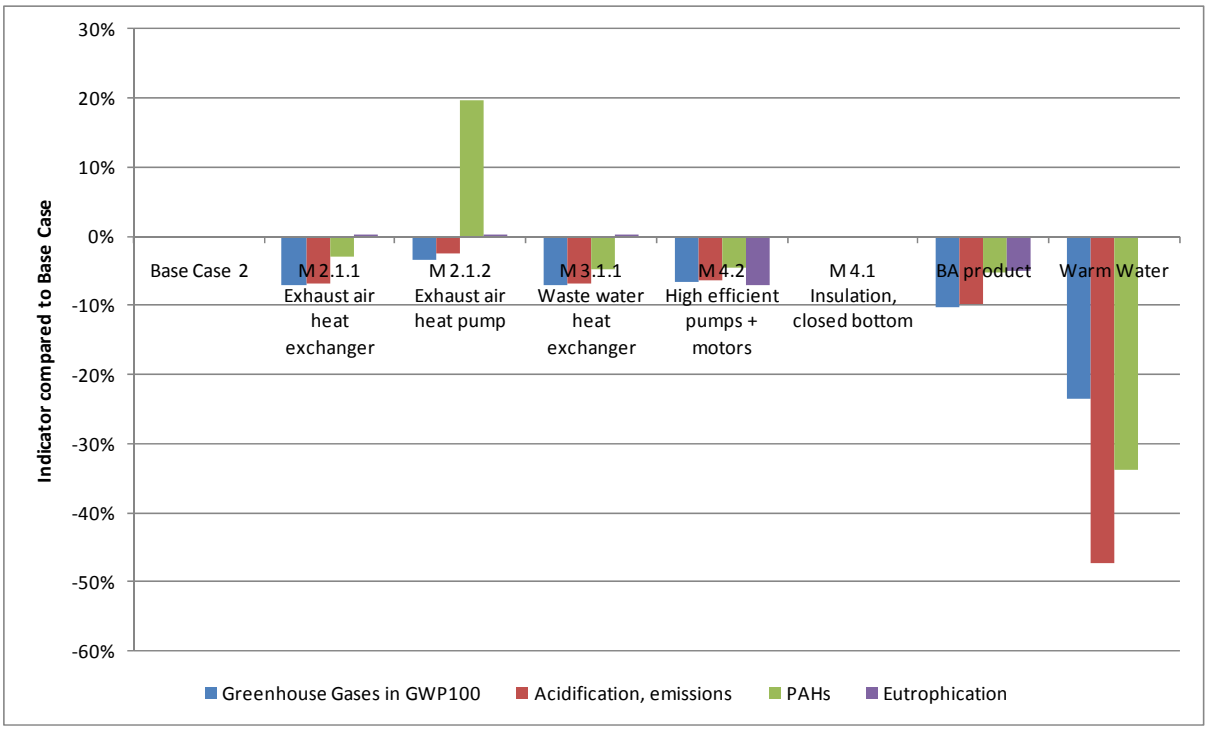


Figure 3-4 Improvement potential by improvement option for base case 2

3.3 Base case 3: Hood-type dishwashers

The results of the environmental analysis of the improvement options for BC 3 are seen below. The BA product provides the greatest improvement for most of the impacts (up to 17% improvement in electricity consumption and water cooling) (Table 3-3), when warm water supply is not considered as a suitable option. Then comes option M 3.1.1 Waste water heat exchanger, reducing the electricity consumption by 12% and the PAHs and POP emissions by 8%. Again, the option M 2.1.2 Exhaust air heat pump is detrimental for several environmental indicators.

Figure 3-5 shows the primary energy and electricity consumption (with the percentage of the primary energy that it represents) over the life cycle. A significant difference can be observed for the “warm water supply”. For other design options, the share of electricity remains approximately the same (88-89%). Figure 3-6 shows the evolution of some environmental indicators for each design option, showing in particular that the heat pump increases the PAHs emissions in comparison with BC 3.

Table 3-3 Environmental impacts by improvement option for base case 3

life-cycle indicators per unit	unit	Base Case 3	M 2.1.1 Exhaust air heat exchanger	M 2.1.2 Exhaust air heat pump	M 3.1.1 Waste water heat exchanger	M 4.2 High efficient pumps + motors	M 4.1 Insulation, closed bottom	BA product	Warm Water
Other resources and waste									
Total Energy (GER)	**GJ**	781.2	713.1	731.6	695.9	730.0	780.6	658.0	555.2
	% change with BC	0%	-9%	-6%	-11%	-7%	0%	-16%	-29%
of which, electricity	**primary GJ**	696.4	627.5	640.4	610.3	650.4	695.7	575.5	314.8
	MWh	66.3	59.8	61.0	58.1	61.9	66.3	54.8	30.0
	% change with BC	0%	-10%	-8%	-12%	-7%	0%	-17%	-55%
Water (process)	**kL**	749.1	744.8	748.2	744.1	697.3	749.0	707.4	723.6
	% change with BC	0%	-1%	0%	-1%	-7%	0%	-6%	-3%
Water (cooling)	**kL**	1 852.2	1 668.3	1 699.6	1 622.3	1 729.5	1 850.5	1 529.2	834.8
	% change with BC	0%	-10%	-8%	-12%	-7%	0%	-17%	-55%
Waste, non-haz./ landfill	**kg**	1 079.2	1 046.0	1 505.1	990.6	1 019.8	1 078.5	992.4	636.9
	% change with BC	0%	-3%	39%	-8%	-6%	0%	-8%	-41%
Waste, hazardous/ incinerated	**kg**	26.1	24.5	25.4	24.1	24.9	26.1	23.2	17.3
	% change with BC	0%	-6%	-2%	-8%	-5%	0%	-11%	-34%
Emissions (Air)									
Greenhouse Gases in GWP100	**t CO2 eq.**	34.5	31.6	32.9	30.8	32.3	34.5	29.2	26.5
	% change with BC	0%	-9%	-5%	-11%	-6%	0%	-15%	-23%
Acidification, emissions	**kg SO2 eq.**	205.6	188.5	197.0	184.0	192.4	205.4	174.7	109.8
	% change with BC	0%	-8%	-4%	-11%	-6%	0%	-15%	-47%
Volatile Organic Compounds (VOC)	**kg**	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	% change with BC	0%	-7%	1%	-9%	-6%	0%	-12%	-9%
Persistent Organic Pollutants (POP)	**µg i-Teq**	6.0	5.6	6.5	5.5	5.7	6.0	5.4	3.5
	% change with BC	0%	-6%	9%	-8%	-6%	0%	-11%	-42%
Heavy Metals	**g Ni eq.**	28.3	28.1	34.7	28.4	27.5	28.3	28.7	21.8
	% change with BC	0%	-1%	22%	0%	-3%	0%	1%	-23%
PAHs	**g Ni eq.**	2.1	2.0	2.4	2.0	2.0	2.1	1.9	1.4
	% change with BC	0%	-5%	12%	-8%	-5%	0%	-10%	-35%
Particulate Matter (PM, dust)	**kg**	12.4	12.4	15.4	12.4	12.2	12.4	12.5	10.4
	% change with BC	0%	0%	24%	-1%	-2%	0%	0%	-17%
Emissions (Water)									
Heavy Metals	**g Hg/20**	13.5	13.7	18.5	13.9	13.2	13.5	14.3	11.1
	% change with BC	0%	1%	37%	2%	-2%	0%	5%	-18%
Eutrophication	**kg PO4**	125.5	125.5	125.6	125.5	116.7	125.5	119.3	125.5
	% change with BC	0%	0%	0%	0%	-7%	0%	-5%	0%

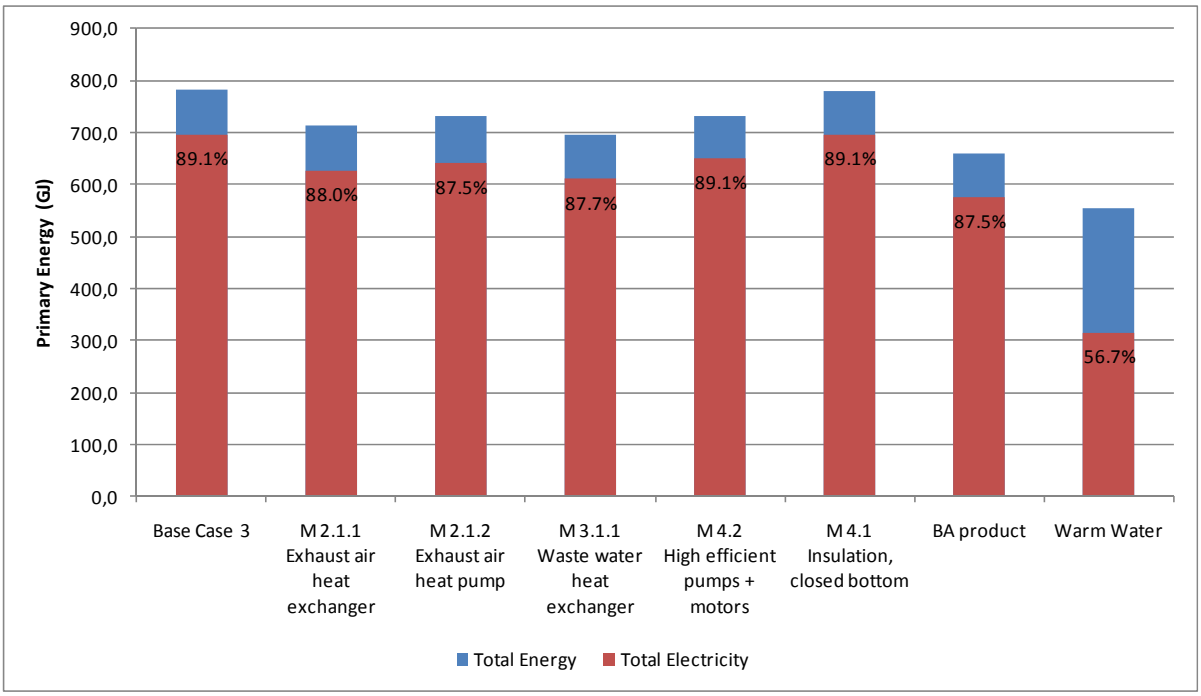


Figure 3-5 Energy consumption by improvement option for base case 3

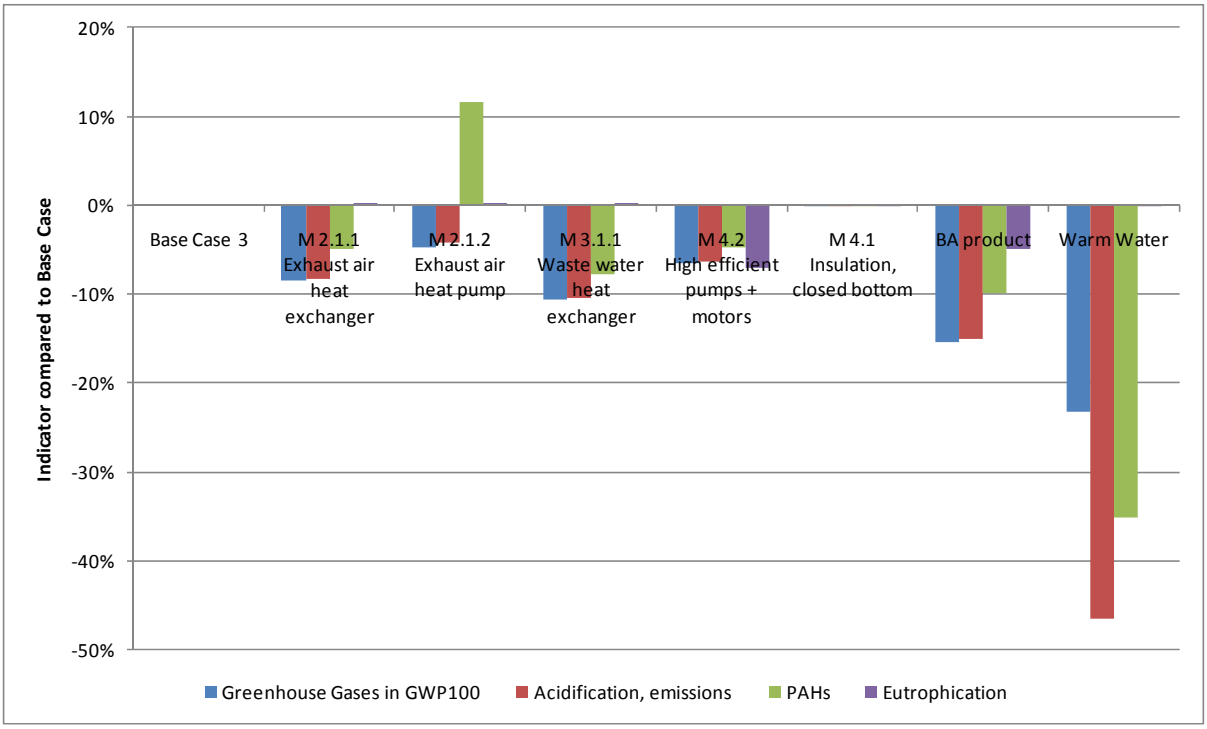


Figure 3-6 Improvement potential by improvement option for base case 3

3.4 Base case 4: Utensil/pot dishwashers

The results of the environmental analysis of the improvement options for BC 4 are seen below. The BA product provides the greatest improvement for most of the impacts (up to 13% improvement in electricity consumption) (Table 3-4), when warm water supply is not considered as a suitable option. Then come the single improvement options M 2.1.1 Exhaust air heat exchanger and M 3.1.1 Waste water heat exchanger with approximately the same environmental results. Again, the option M 2.1.2 Heat pump is detrimental for several environmental indicators.

Figure 3-7 shows the primary energy and electricity consumption (with the percentage of the primary energy that it represents) over the life cycle. A significant difference can be observed for the “warm water” supply but for other design options, the share of electricity remains approximately the same (87-88%). Figure 3-8 shows changes in environmental indicators for each design option.

Table 3-4 Environmental impacts by improvement option for base case 4

life-cycle indicators per unit	unit	Base Case 4	M 2.1.1 Exhaust air heat exchanger	M 2.1.2 Exhaust air heat pump	M 3.1.1 Waste water heat exchanger	M 4.2 High efficient pumps + motors	M 4.1 Insulation, closed bottom	BA product	Warm Water
Other resources and waste									
Total Energy (GER)	GJ	850.7	783.4	814.6	783.4	809.0	848.8	747.5	617.3
	% change with BC	0%	-8%	-4%	-8%	-5%	0%	-12%	-27%
of which, electricity	primary GJ	754.0	685.9	710.0	685.9	717.6	752.2	652.9	359.9
	MWh	71.8	65.3	67.6	65.3	68.3	71.6	62.2	34.3
	% change with BC	0%	-9%	-6%	-9%	-5%	0%	-13%	-52%
Water (process)	kL	782.1	777.9	782.0	778.3	729.4	782.0	740.6	755.8
	% change with BC	0%	-1%	0%	0%	-7%	0%	-5%	-3%
Water (cooling)	kL	2 000.7	1 818.6	1 880.0	1 818.7	1 903.6	1 995.7	1 730.2	949.7
	% change with BC	0%	-9%	-6%	-9%	-5%	0%	-14%	-53%
Waste, non-haz./ landfill	kg	1 271.8	1 239.4	1 712.1	1 204.0	1 223.5	1 269.7	1 207.9	814.9
	% change with BC	0%	-3%	35%	-5%	-4%	0%	-5%	-36%
Waste, hazardous/ incinerated	kg	34.6	33.0	34.2	33.0	33.6	34.5	32.1	25.5
	% change with BC	0%	-5%	-1%	-5%	-3%	0%	-7%	-26%
Emissions (Air)									
Greenhouse Gases in GWP100	t CO2 eq.	38.0	35.0	36.9	35.1	36.1	37.9	33.5	29.6
	% change with BC	0%	-8%	-3%	-8%	-5%	0%	-12%	-22%
Acidification, emissions	kg SO2 eq.	226.5	209.6	221.3	209.6	215.8	226.1	200.7	127.6
	% change with BC	0%	-7%	-2%	-7%	-5%	0%	-11%	-44%
Volatile Organic Compounds (VOC)	kg	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	% change with BC	0%	-4%	7%	-4%	-3%	0%	-6%	-6%
Persistent Organic Pollutants (POP)	µg i-Teq	7.1	6.7	7.7	6.7	6.8	7.0	6.6	4.5
	% change with BC	0%	-5%	9%	-5%	-4%	0%	-7%	-37%
Heavy Metals	g Ni eq.	40.9	40.7	47.5	41.3	40.2	40.9	41.6	34.2
	% change with BC	0%	-1%	16%	1%	-2%	0%	2%	-17%
PAHs	g Ni eq.	2.9	2.8	3.2	2.8	2.8	2.9	2.7	2.1
	% change with BC	0%	-3%	11%	-4%	-3%	0%	-6%	-27%
Particulate Matter (PM, dust)	kg	30.8	31.3	38.4	31.3	30.6	30.8	31.9	28.7
	% change with BC	0%	2%	25%	2%	-1%	0%	4%	-7%
Emissions (Water)									
Heavy Metals	g Hg/20	21.1	21.3	26.2	21.6	20.9	21.1	22.0	18.6
	% change with BC	0%	1%	24%	2%	-1%	0%	4%	-12%
Eutrophication	kg PO4	126.5	126.5	126.6	126.5	117.7	126.5	120.2	126.5
	% change with BC	0%	0%	0%	0%	-7%	0%	-5%	0%

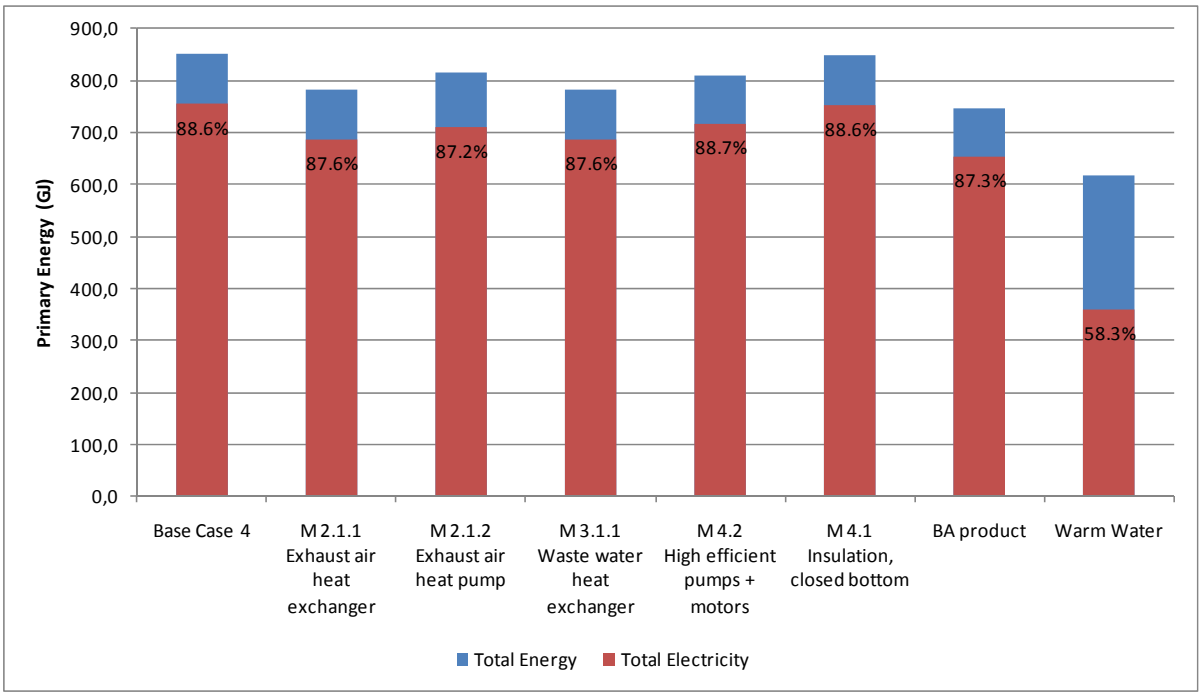


Figure 3-7 Energy consumption by improvement option for base case 4

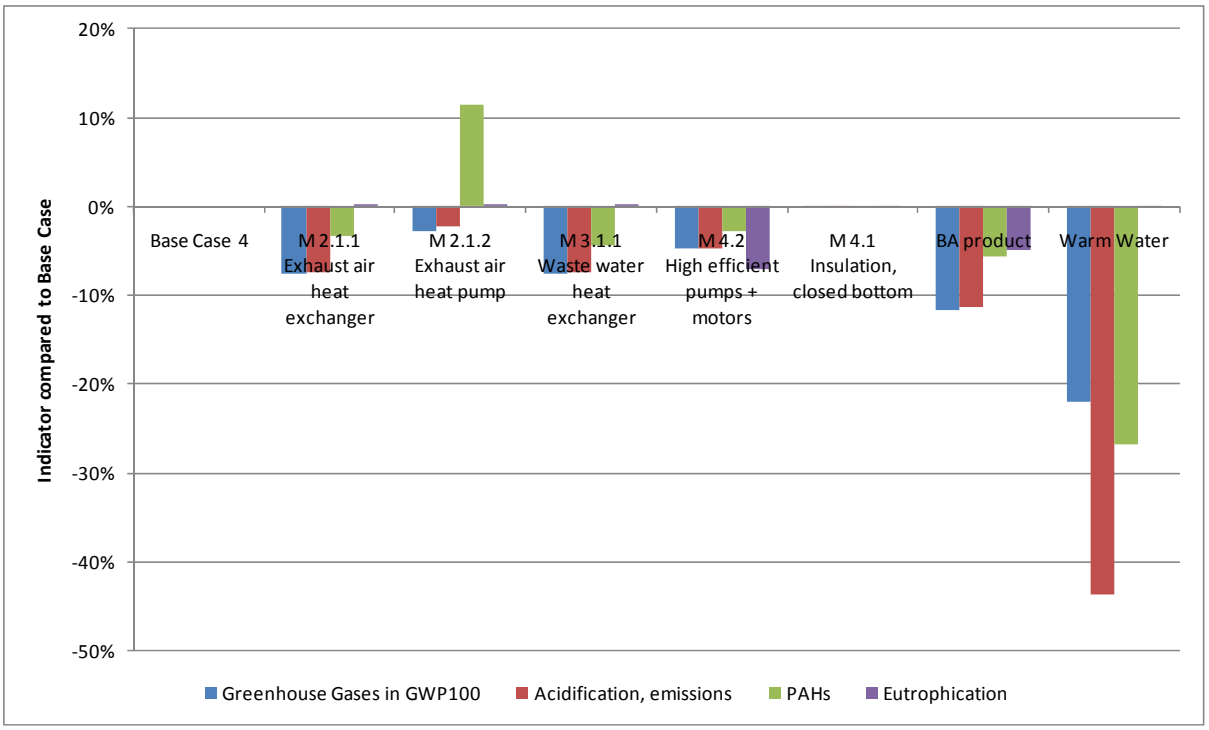


Figure 3-8 Improvement potential by improvement option for base case 4

3.5 Base case 5: Conveyor-type one-tank

The results of the environmental analysis of the improvement options for base case 5 are shown below. The “BA product” provides the greatest improvement for most of the impacts (up to 29% improvement in electricity consumption and water cooling) (Table 3-5), even when warm water is considered as a suitable option. The “warm water” is by far not as beneficial as it was for the previous base cases and the implementation of the heat pump (M 2.1.2) is now reducing substantially all the environmental impacts. For this product category, the base case is scoring worst for every environmental indicator considered.

Figure 3-9 shows the primary energy and electricity consumption (with the percentage of the primary energy that it represents) over the life cycle. Important differences can be observed in terms of energy consumption between the design options but the share of electricity is always around 90-92% of the total primary energy consumed. Figure 3-10 shows the evolution of some environmental indicators for each design option. In particular, we notice that the GWP, acidification and PAHs emission indicators are correlated to the energy efficiency while the eutrophication is linked to the water efficiency (options M 1.5, M 4.2 and BA product).

Table 3-5 Environmental impacts by improvement option for base case 5

life-cycle indicators per unit	unit	Base Case 5	M 2.1.1 Exhaust air heat exchanger	M 2.1.2 Exhaust air heat pump	M 3.1.1 Waste water heat exchanger	M 4.2 High efficient pumps + motors	M 4.1 Insulation, closed bottom	M 1.5 Auxiliary rinsing	BA product	Warm Water
Other resources and waste										
Total Energy (GER)	GJ	5 188.2	4 325.7	4 246.9	4 541.6	4 852.8	5 183.8	4 631.7	3 765.8	5 059.0
	% change with BC	0%	-17%	-18%	-12%	-6%	0%	-11%	-27%	-2%
of which, electricity	primary GJ	4 773.4	3 910.2	3 825.2	4 126.1	4 471.2	4 769.1	4 255.7	3 391.4	4 555.4
	MWh	454.6	372.4	364.3	393.0	425.8	454.2	405.3	323.0	433.8
	% change with BC	0%	-18%	-20%	-14%	-6%	0%	-11%	-29%	-5%
Water (process)	kL	3 449.4	3 392.2	3 389.0	3 407.0	3 121.6	3 449.1	3 046.5	2 900.6	3 434.8
	% change with BC	0%	-2%	-2%	-1%	-10%	0%	-12%	-16%	0%
Water (cooling)	kL	12 686.0	10 383.9	10 154.4	10 959.5	11 880.2	12 674.5	11 304.9	8 996.1	12 104.7
	% change with BC	0%	-18%	-20%	-14%	-6%	0%	-11%	-29%	-5%
Waste, non-haz./ landfill	kg	7 733.8	6 779.6	7 125.4	6 994.4	7 344.9	7 728.8	7 131.1	6 666.1	7 481.0
	% change with BC	0%	-12%	-8%	-10%	-5%	0%	-8%	-14%	-3%
Waste, hazardous/ incinerated	kg	197.9	178.0	176.7	182.9	190.1	197.8	185.4	165.9	192.8
	% change with BC	0%	-10%	-11%	-8%	-4%	0%	-6%	-16%	-3%
Emissions (Air)										
Greenhouse Gases in GWP100	t CO2 eq.	229.5	191.9	188.9	201.3	214.9	229.3	205.2	168.1	224.9
	% change with BC	0%	-16%	-18%	-12%	-6%	0%	-11%	-27%	-2%
Acidification, emissions	kg SO2 eq.	1 372.3	1 150.6	1 134.1	1 206.2	1 285.9	1 371.2	1 229.7	1 011.7	1 317.6
	% change with BC	0%	-16%	-17%	-12%	-6%	0%	-10%	-26%	-4%
Volatile Organic Compounds (VOC)	kg	2.4	2.1	2.1	2.2	2.3	2.4	2.2	1.9	2.4
	% change with BC	0%	-13%	-14%	-10%	-5%	0%	-9%	-21%	-1%
Persistent Organic Pollutants (POP)	µg i-Teq	40.2	34.7	34.9	36.1	38.0	40.2	36.7	32.1	38.8
	% change with BC	0%	-14%	-13%	-10%	-5%	0%	-9%	-20%	-4%
Heavy Metals	g Ni eq.	193.0	179.1	184.0	183.4	187.2	192.9	185.0	179.8	189.2
	% change with BC	0%	-7%	-5%	-5%	-3%	0%	-4%	-7%	-2%
PAHs	g Ni eq.	17.2	15.5	15.7	15.9	16.5	17.1	16.1	14.8	16.7
	% change with BC	0%	-10%	-9%	-7%	-4%	0%	-6%	-14%	-2%
Particulate Matter (PM, dust)	kg	96.0	91.8	95.7	93.0	94.1	96.0	93.7	94.8	94.8
	% change with BC	0%	-4%	0%	-3%	-2%	0%	-2%	-1%	-1%
Emissions (Water)										
Heavy Metals	g Hg/20	97.6	92.7	96.9	94.3	95.7	97.6	95.4	96.6	96.2
	% change with BC	0%	-5%	-1%	-3%	-2%	0%	-2%	-1%	-1%
Eutrophication	kg PO4	558.2	558.2	558.3	558.2	502.6	558.2	491.4	474.8	558.2
	% change with BC	0%	0%	0%	0%	-10%	0%	-12%	-15%	0%

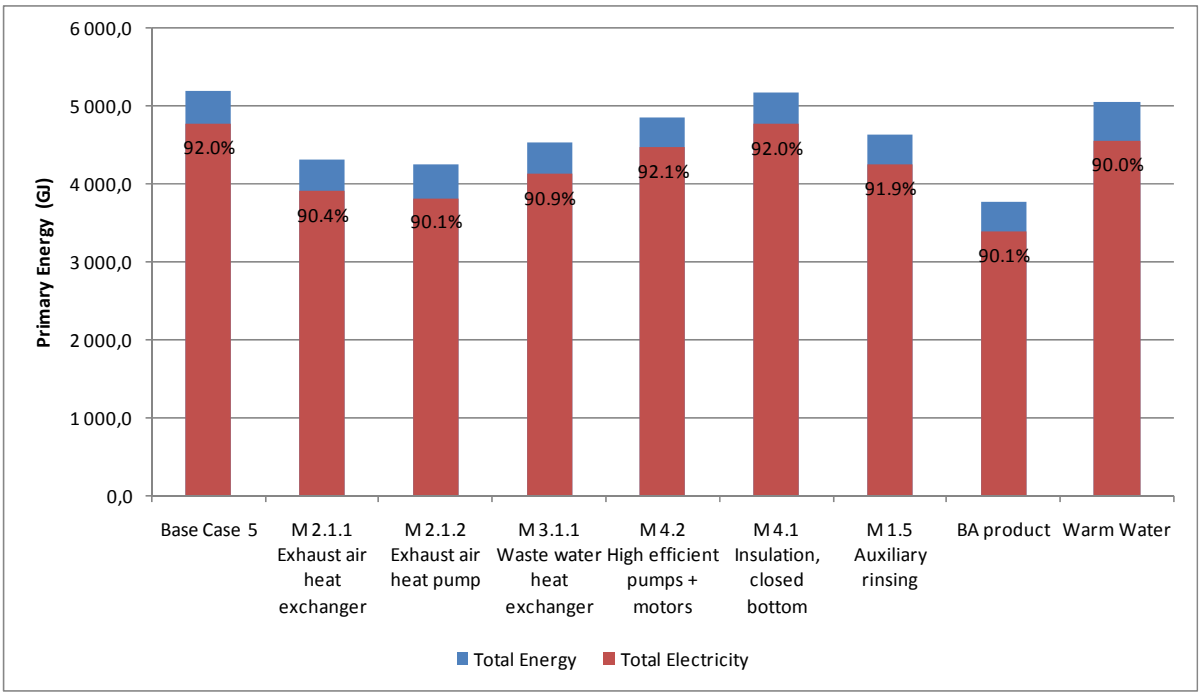


Figure 3-9 Energy consumption by improvement option for base case 5

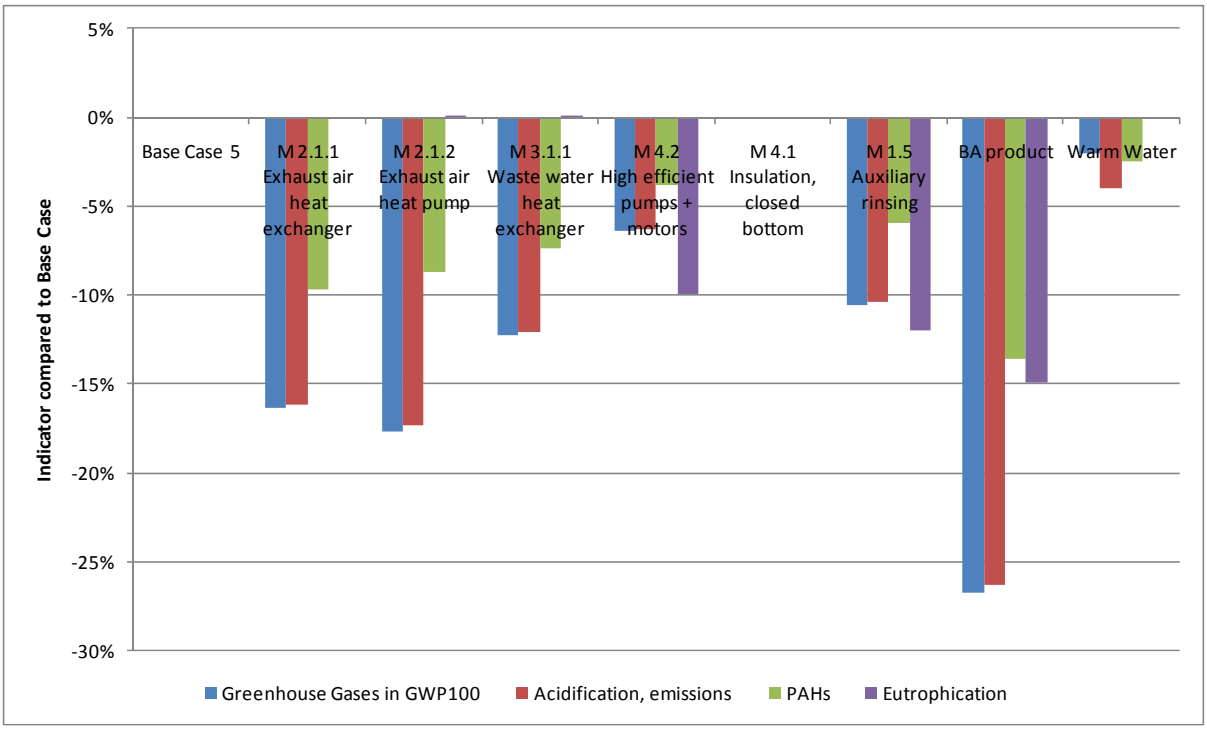


Figure 3-10 Improvement potential by improvement option for base case 5

3.6 Base case 6: Conveyor-type multi-tank

The results of the environmental analysis of the improvement options for BC 6 are seen below. The BA product provides the greatest improvement for most of the impacts (up to 37% improvement in electricity consumption and water cooling) (Table 3-6), even when warm water is considered as a suitable option. Similarly to base case 5, the “warm water” is by far not as beneficial as it was for the base cases 1 to 4 and the implementation of the heat pump (M 2.1.2) is also reducing substantially all the environmental impacts. The base case is scoring worst for every environmental indicator considered.

Figure 3-11 shows the primary energy and electricity consumption (with the percentage of the primary energy that it represents) over the life cycle. Important differences can be observed in terms of energy consumption between the design options. Figure 3-12 shows the evolution of some environmental indicators for each design option.

Table 3-6 Environmental impacts by improvement option for base case 6

life-cycle indicators per unit	unit	Base Case 6	M 2.1.1 Exhaust air heat exchanger	M 2.1.2 Exhaust air heat pump	M 3.1.1 Waste water heat exchanger	M 4.2 High efficient pumps + motors	M 4.1 Insulation, closed bottom	M 1.5 Auxiliary rinsing	BA product	Warm Water
Other resources and waste										
Total Energy (GER)	**GJ**	19 567.1	16 527.7	15 352.8	17 034.5	17 365.2	19 554.2	17 395.1	12 522.1	19 146.5
	% change with BC	0%	-16%	-22%	-13%	-11%	0%	-11%	-36%	-2%
of which, electricity	**primary GJ**	18 282.0	15 241.9	14 060.9	15 748.6	16 255.1	18 269.0	16 248.9	11 519.5	17 571.9
	MWh	1 741.1	1 451.6	1 339.1	1 499.9	1 548.1	1 739.9	1 547.5	1 097.1	1 673.5
	% change with BC	0%	-17%	-23%	-14%	-11%	0%	-11%	-37%	-4%
Water (process)	**kL**	12 273.5	12 071.2	11 995.0	12 105.4	10 492.9	12 272.7	10 822.4	9 085.0	12 226.2
	% change with BC	0%	-2%	-2%	-1%	-15%	0%	-12%	-26%	0%
Water (cooling)	**kL**	48 686.4	40 579.1	37 426.9	41 930.4	43 281.5	48 651.8	43 264.4	30 648.7	46 792.9
	% change with BC	0%	-17%	-23%	-14%	-11%	0%	-11%	-37%	-4%
Waste, non-haz./ landfill	**kg**	24 668.6	21 190.4	20 265.4	21 742.4	22 115.6	24 653.6	22 192.7	17 081.9	23 845.3
	% change with BC	0%	-14%	-18%	-12%	-10%	0%	-10%	-31%	-3%
Waste, hazardous/ incinerated	**kg**	548.6	478.5	452.0	490.2	497.8	548.3	498.9	387.1	532.2
	% change with BC	0%	-13%	-18%	-11%	-9%	0%	-9%	-29%	-3%
Emissions (Air)										
Greenhouse Gases in GWP100	**t CO2 eq.**	858.6	726.0	675.2	748.1	762.5	858.0	763.8	551.8	843.6
	% change with BC	0%	-15%	-21%	-13%	-11%	0%	-11%	-36%	-2%
Acidification, emissions	**kg SO2 eq.**	5 088.4	4 306.2	4 007.4	4 436.6	4 521.1	5 085.1	4 529.7	3 279.6	4 910.2
	% change with BC	0%	-15%	-21%	-13%	-11%	0%	-11%	-36%	-4%
Volatile Organic Compounds (VOC)	**kg**	8.1	6.9	6.5	7.1	7.2	8.0	7.2	5.4	8.0
	% change with BC	0%	-14%	-19%	-12%	-10%	0%	-10%	-32%	-1%
Persistent Organic Pollutants (POP)	**µg i-Teq**	137.6	117.8	110.9	121.1	123.2	137.5	123.4	92.6	132.9
	% change with BC	0%	-14%	-19%	-12%	-10%	0%	-10%	-33%	-3%
Heavy Metals	**g Ni eq.**	493.8	442.5	428.7	451.8	456.0	493.5	458.1	384.1	481.6
	% change with BC	0%	-10%	-13%	-8%	-8%	0%	-7%	-22%	-2%
PAHs	**g Ni eq.**	46.7	40.7	38.7	41.7	42.3	46.6	42.4	33.2	45.3
	% change with BC	0%	-13%	-17%	-11%	-9%	0%	-9%	-29%	-3%
Particulate Matter (PM, dust)	**kg**	211.8	195.6	193.0	198.4	199.7	211.7	200.5	179.1	208.0
	% change with BC	0%	-8%	-9%	-6%	-6%	0%	-5%	-15%	-2%
Emissions (Water)										
Heavy Metals	**g Hg/20**	217.5	198.5	195.6	202.0	204.4	217.4	205.4	181.8	212.9
	% change with BC	0%	-9%	-10%	-7%	-6%	0%	-6%	-16%	-2%
Eutrophication	**kg PO4**	1 958.6	1 958.5	1 958.6	1 958.5	1 665.2	1 958.6	1 723.9	1 469.7	1 958.6
	% change with BC	0%	0%	0%	0%	-15%	0%	-12%	-25%	0%

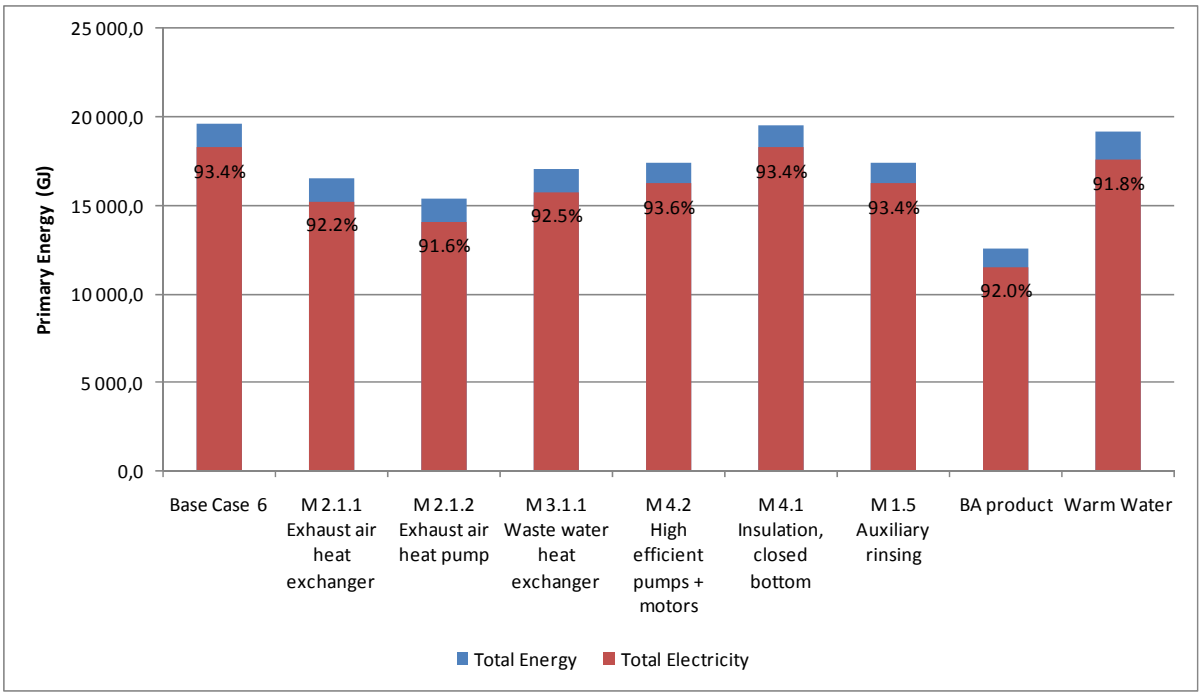


Figure 3-11 Energy consumption by improvement option for base case 6

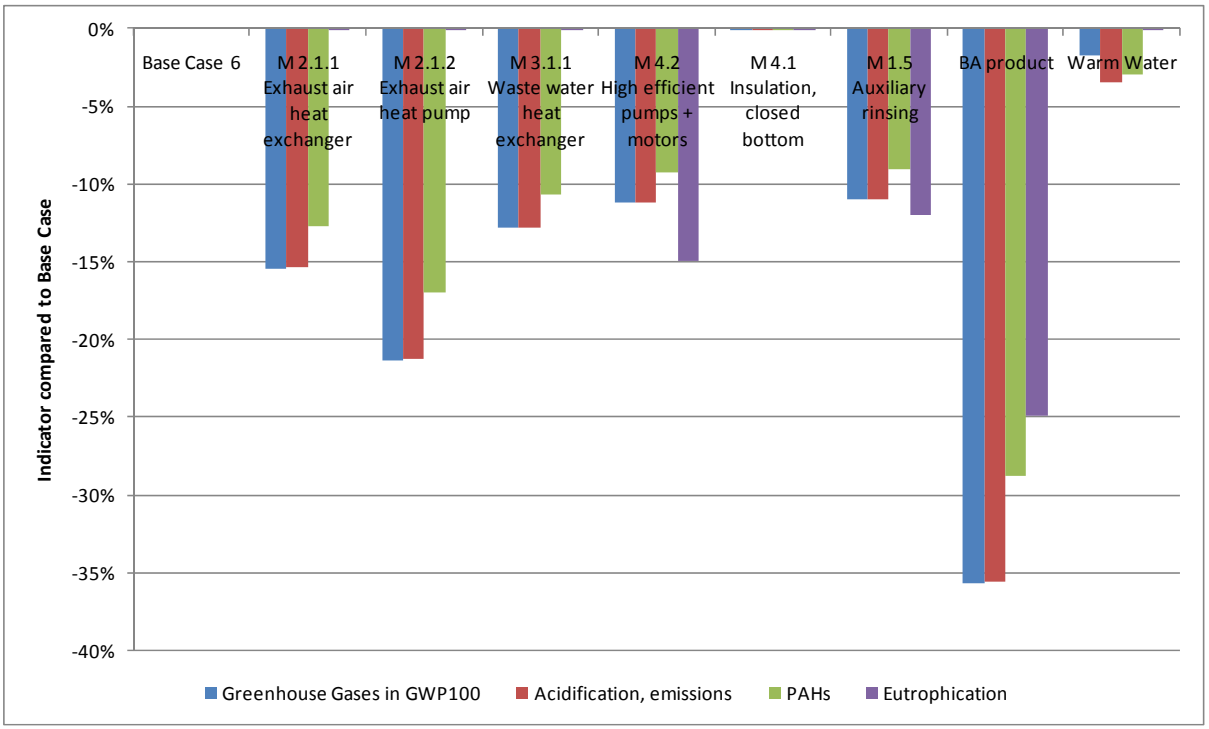


Figure 3-12 Improvement potential by improvement option for base case 6

4 Costs analysis

The aim of this sub-task is to assess the LCC of each of the design options (and their combination) considered. In doing so, the quantification will cover both the purchase prices and the operating expenses by consumers, as in Task 5.

The approach chosen, and deemed to be the most relevant for the type of options selected, is to consider the marginal costs due to the improvement options. The extent to which the various costs are expected to change from the LCC established for the base cases in Task 5 is analysed. This approach is relevant here because the options considered constitute more an evolution or additional features than a complete technological revolution of the products.

4.1 Base case 1: Undercounter water-change

The three individual improvement options analysed would result in an increase in the purchase price of BC 1, meaning that the BA product would result in an increase of 16% (Table 4-1). On the other hand, electricity costs are only slightly reduced (8% for the BA product) and do not overbalance the higher purchase price, resulting in LCC increases (1-2% for individual improvement options, or 4% for the BA product).

As previously assumed, the warm water supply does not affect the purchase price. LCC of the warm water option is 7% lower than the base case and electricity costs are reduced significantly, though the option does imply gas costs.

Table 4-1 Life cycle costs by improvement option for base case 1

life-cycle indicators per unit	unit	Base Case 1	M 2.1.1 Exhaust air heat exchanger	M 4.2 High efficient pumps + motors	M 4.1 Insulation, closed bottom	BA product	Warm Water
Economic indicators							
Purchase price	€	3 200	3 360	3 456	3 296	3 712	3 200
	% change with BC	0%	5%	8%	3%	16%	0%
Electricity costs	€	1 624	1 576	1 576	1 592	1 495	745
	% change with BC	0%	-3%	-3%	-2%	-8%	-54%
Water and detergent costs	€	3 092	3 092	2 937	3 092	2 937	3 092
	% change with BC	0%	0%	-5%	0%	-5%	0%
Maintenance and repair costs	€	939	985	1 014	967	1 089	939
	% change with BC	0%	5%	8%	3%	16%	0%
Gas costs	€	0	0	0	0	0	286
	% change with BC	-	-	-	-	-	-
Life-cycle cost	€	8 854	9 013	8 982	8 946	9 232	8 261
	% change with BC	0%	2%	1%	1%	4%	-7%

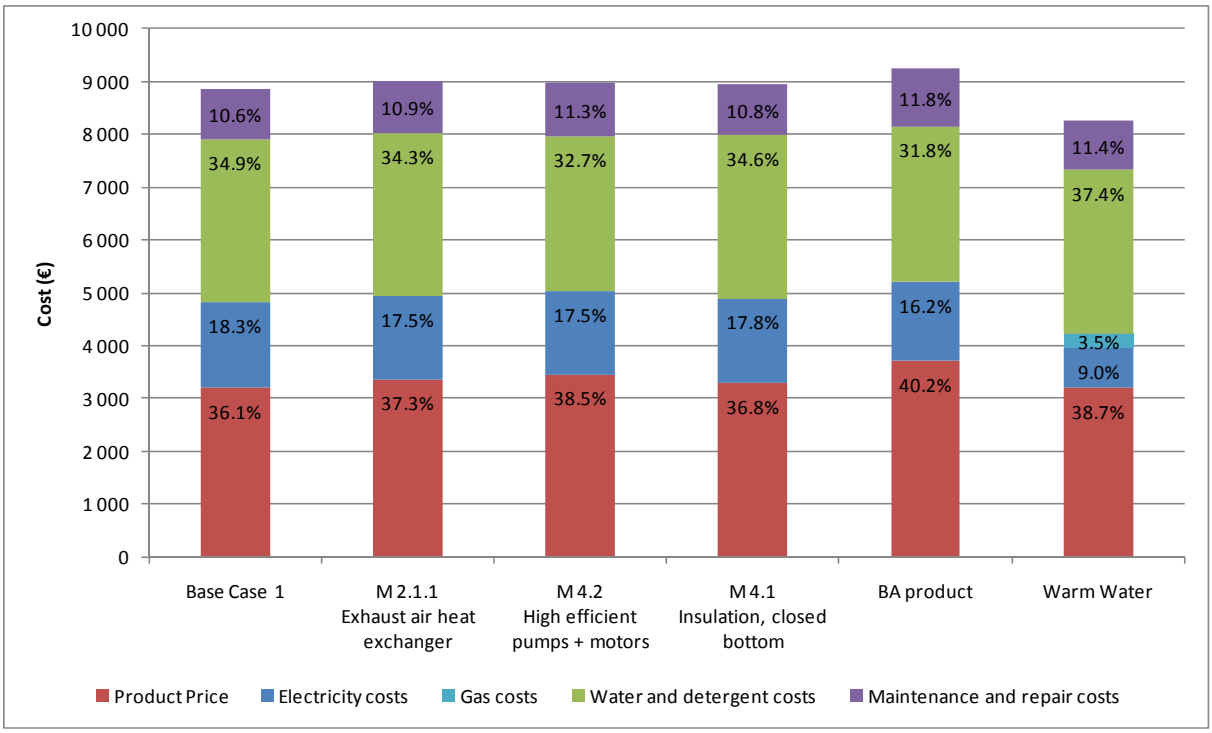


Figure 4-1 Life cycle costs breakdown by improvement option for base case 1

4.2 Base case 2: Undercounter one-tank

For BC 2, the exhaust air heat pump option would double the purchase price to 7 000 Euro and increase LCC by 30%. Implementation of high efficiency pumps and motors would slightly reduce the LCC and increase the purchase price by 13%.

Again the warm water supply option results in an important decrease of the LCC of 13%. As for the other base cases it reduces electricity costs but implies additional gas costs, of 884 Euro this time.

Table 4-2 Life cycle costs by improvement option for base case 2

life-cycle indicators per unit	unit	Base Case 2	M 2.1.1 Exhaust air heat exchanger	M 2.1.2 Exhaust air heat pump	M 3.1.1 Waste water heat exchanger	M 4.2 High efficient pumps + motors	M 4.1 Insulation, closed bottom	BA product	Warm Water
Economic indicators									
Purchase price	€	3 500	4 130	7 000	4 025	3 955	3 605	5 600	3 500
	% change with BC	0%	18%	100%	15%	13%	3%	60%	0%
Electricity costs	€	4 881	4 473	4 473	4 473	4 554	4 875	4 305	2 162
	% change with BC	0%	-8%	-8%	-8%	-7%	0%	-12%	-56%
Water and detergent costs	€	4 789	4 789	4 789	4 789	4 454	4 789	4 550	4 789
	% change with BC	0%	0%	0%	0%	-7%	0%	-5%	0%
Maintenance and repair costs	€	1 296	1 529	2 592	1 490	1 465	1 335	2 074	1 296
	% change with BC	0%	18%	100%	15%	13%	3%	60%	0%
Gas costs	€	0	0	0	0	0	0	0	884
	% change with BC	-	-	-	-	-	-	-	-
Life-cycle cost	€	14 466	14 922	18 854	14 778	14 428	14 604	16 529	12 632
	% change with BC	0%	3%	30%	2%	0%	1%	14%	-13%

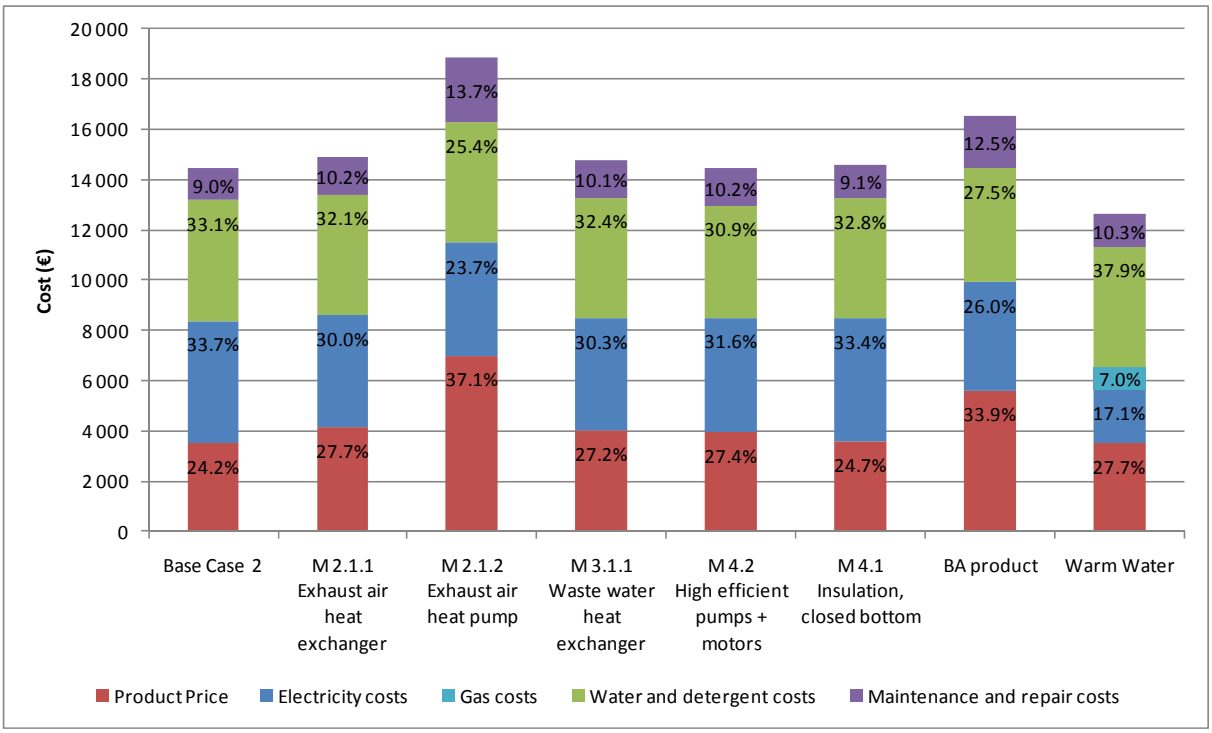


Figure 4-2 Life cycle costs breakdown by improvement option for base case 2

4.3 Base case 3: Hood-type dishwashers

For hood-type dishwashers, again the exhaust air heat pump option doubles the purchase price and increases LCC by a similar percentage (30%). And again, high efficiency pumps and motors would leave the LCC almost unchanged (by reducing water and detergent costs by 7%) and increase the purchase price, by 15%. Here, the warm water option reduces LCC by 10%, with gas costs of 1 226 Euro.

Table 4-3 Life cycle costs by improvement option for base case 3

life-cycle indicators per unit	unit	Base Case 3	M 2.1.1 Exhaust air heat exchanger	M 2.1.2 Exhaust air heat pump	M 3.1.1 Waste water heat exchanger	M 4.2 High efficient pumps + motors	M 4.1 Insulation, closed bottom	BA product	Warm Water
Economic indicators									
Purchase price	**€**	4 700	5 640	9 400	5 546	5 405	4 841	8 319	4 700
	% change with BC	0%	20%	100%	18%	15%	3%	77%	0%
Electricity costs	**€**	5 838	5 257	5 354	5 112	5 451	5 832	4 818	2 627
	% change with BC	0%	-10%	-8%	-12%	-7%	0%	-17%	-55%
Water and detergent costs	**€**	7 438	7 438	7 438	7 438	6 917	7 438	7 066	7 438
	% change with BC	0%	0%	0%	0%	-7%	0%	-5%	0%
Maintenance and repair costs	**€**	1 740	2 088	3 481	2 054	2 001	1 793	3 081	1 740
	% change with BC	0%	20%	100%	18%	15%	3%	77%	0%
Gas costs	**€**	0	0	0	0	0	0	0	1 226
	% change with BC	-	-	-	-	-	-	-	-
Life-cycle cost	**€**	19 716	20 424	25 673	20 150	19 775	19 904	23 283	17 731
	% change with BC	0%	4%	30%	2%	0%	1%	18%	-10%

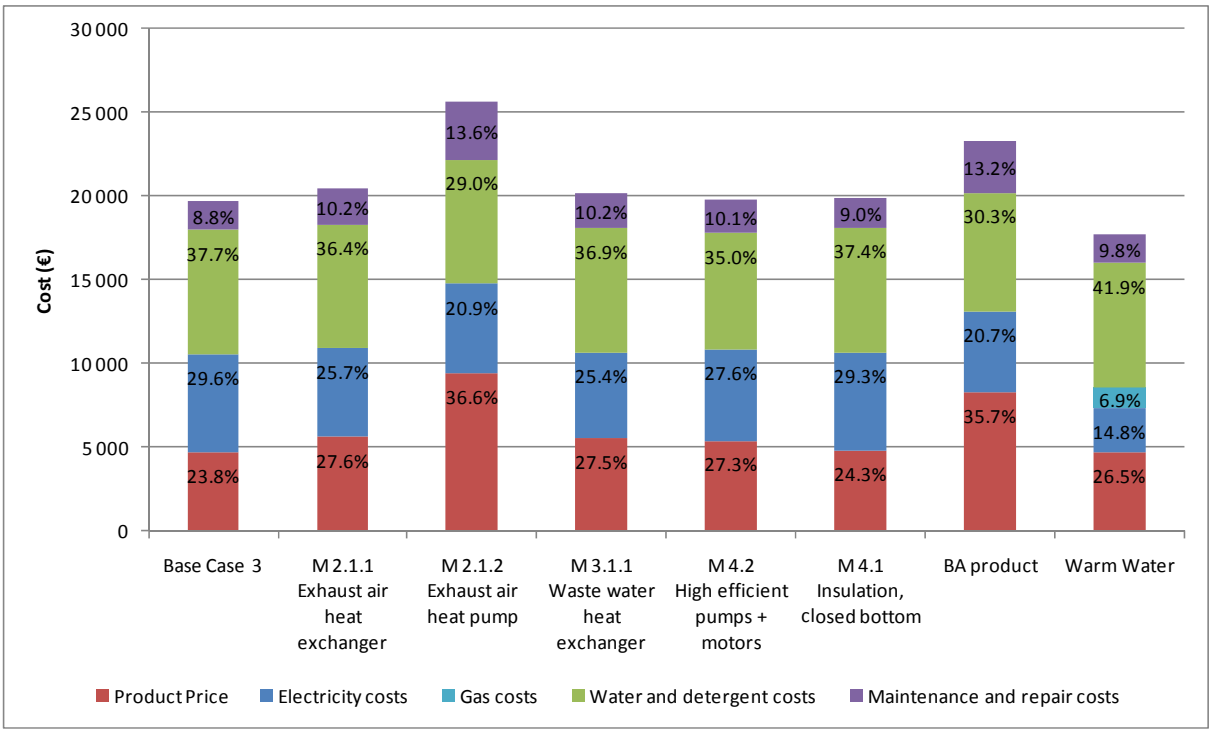


Figure 4-3 Life cycle costs breakdown by improvement option for base case 3

4.4 Base case 4: Utensil/pot dishwashers

The BA product in base case 4 costs 77% more to purchase, and is 35% more expensive on a life cycle basis. The insulation option has a negligible effect on costs. Otherwise, the trends are similar to the previous base cases.

Over the lifecycle of the dishwasher, the warm water supply results in monetary savings of 7% compared to the base case LCC.

Table 4-4 Life cycle costs by improvement option for base case 4

life-cycle indicators per unit	unit	Base Case 4	M 2.1.1 Exhaust air heat exchanger	M 2.1.2 Exhaust air heat pump	M 3.1.1 Waste water heat exchanger	M 4.2 High efficient pumps + motors	M 4.1 Insulation, closed bottom	BA product	Warm Water
Economic indicators									
Purchase price	€	10 500	12 285	16 800	11 445	11 550	10 605	18 585	10 500
	% change with BC	0%	17%	60%	9%	10%	1%	77%	0%
Electricity costs	€	6 301	5 726	5 918	5 726	5 994	6 285	5 446	2 984
	% change with BC	0%	-9%	-6%	-9%	-5%	0%	-14%	-53%
Water and detergent costs	€	7 529	7 529	7 529	7 529	7 002	7 529	7 153	7 529
	% change with BC	0%	0%	0%	0%	-7%	0%	-5%	0%
Maintenance and repair costs	€	3 888	4 549	6 221	4 238	4 277	3 927	6 882	3 888
	% change with BC	0%	17%	60%	9%	10%	1%	77%	0%
Gas costs	€	0	0	0	0	0	0	0	1 266
	% change with BC	-	-	-	-	-	-	-	-
Life-cycle cost	€	28 219	30 089	36 468	28 938	28 824	28 347	38 066	26 168
	% change with BC	0%	7%	29%	3%	2%	0%	35%	-7%

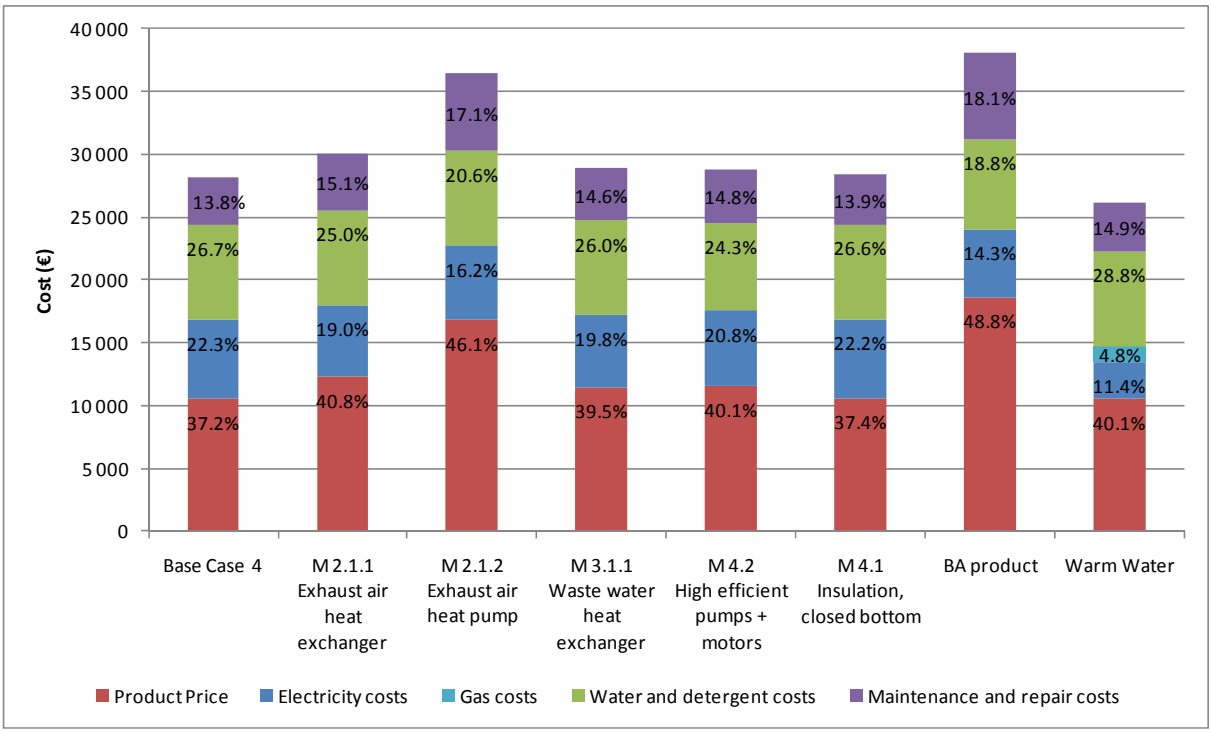


Figure 4-4 Life cycle costs breakdown by improvement option for base case 4

4.5 Base case 5: Conveyor-type one-tank

For conveyor-type one-tanks, the warm water option only reduces electricity costs by 5%, and LCC by 1%. In this case, the option M 1.5 Auxiliary rinsing is the most beneficial option from a LCC point of view –5%), but an exhaust air heat exchanger or high efficiency pumps and motors would also reduce LCC for a relatively small increase in purchase price.

Table 4-5 Life cycle costs by improvement option for base case 5

life-cycle indicators per unit	unit	Base Case 5	M 2.1.1 Exhaust air heat exchanger	M 2.1.2 Exhaust air heat pump	M 3.1.1 Waste water heat exchanger	M 4.2 High efficient pumps + motors	M 4.1 Insulation, closed bottom	M 1.5 Auxiliary rinsing	BA product	Warm Water
Economic indicators										
Purchase price	€	15 000	17 250	24 000	18 000	16 500	16 200	16 950	27 150	15 000
	% change with BC	0%	15%	60%	20%	10%	8%	13%	81%	0%
Electricity costs	€	31 846	26 059	25 480	27 506	29 820	31 817	28 374	22 567	30 385
	% change with BC	0%	-18%	-20%	-14%	-6%	0%	-11%	-29%	-5%
Water and detergent costs	€	30 689	30 689	30 689	30 689	27 620	30 689	27 007	26 086	30 689
	% change with BC	0%	0%	0%	0%	-10%	0%	-12%	-15%	0%
Maintenance and repair costs	€	5 162	5 936	8 259	6 194	5 678	5 575	5 833	9 343	5 162
	% change with BC	0%	15%	60%	20%	10%	8%	13%	81%	0%
Gas costs	€	0	0	0	0	0	0	0	0	571
	% change with BC	-	-	-	-	-	-	-	-	-
Life-cycle cost	€	82 697	79 934	88 428	82 389	79 619	84 281	78 163	85 146	81 807
	% change with BC	0%	-3%	7%	0%	-4%	2%	-5%	3%	-1%

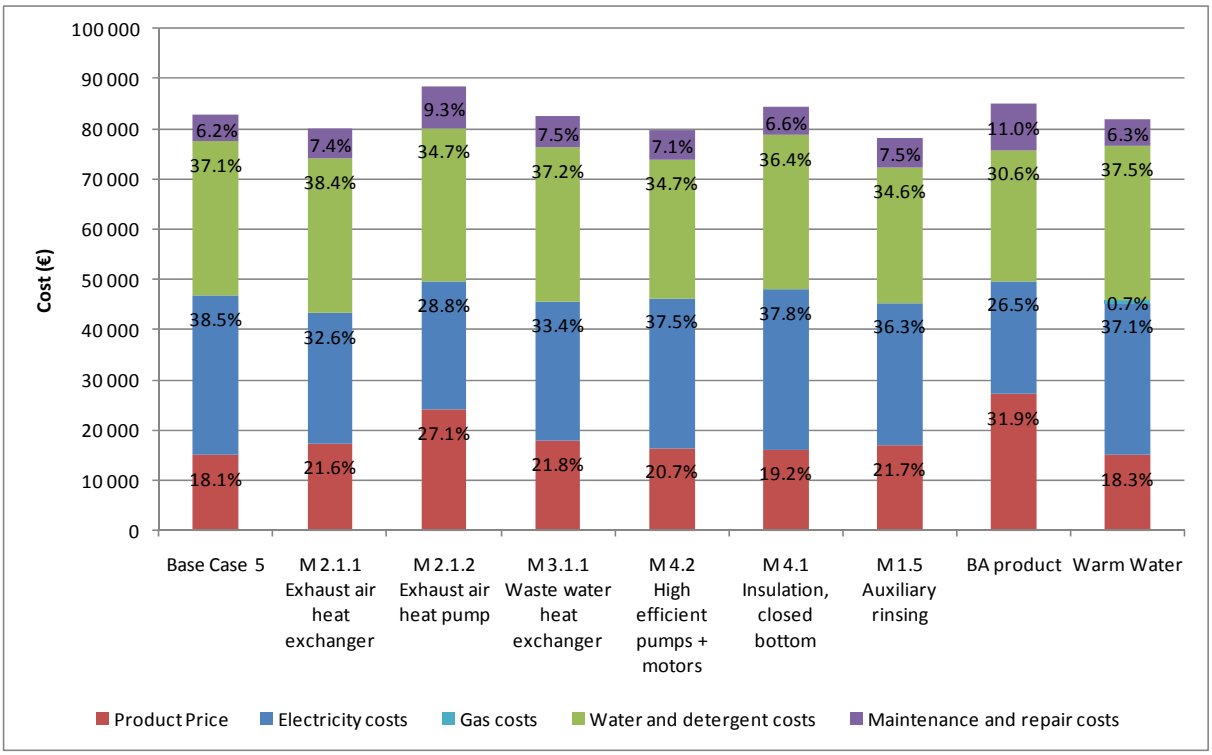


Figure 4-5 Life cycle costs breakdown by improvement option for base case 5

4.6 Base case 6: Conveyor-type multi-tank

Finally, for conveyor-type multi-tank machines, the BA product increases the purchase price by 68% but results in economic savings over the lifetime. All single improvement options reduce the LCC with the exception of M 4.1 Insulation, which would only increase LCC by 1%. Warm water has only a negligible effect.

Table 4-6 Life cycle costs by improvement option for base case 6

life-cycle indicators per unit	unit	Base Case 6	M 2.1.1 Exhaust air heat exchanger	M 2.1.2 Exhaust air heat pump	M 3.1.1 Waste water heat exchanger	M 4.2 High efficient pumps + motors	M 4.1 Insulation, closed bottom	M 1.5 Auxiliary rinsing	BA product	Warm Water
Economic indicators										
Purchase price	€	45 000	48 600	59 400	51 750	51 750	47 700	50 850	75 600	45 000
	% change with BC	0%	8%	32%	15%	15%	6%	13%	68%	0%
Electricity costs	€	111 932	93 283	86 030	96 391	99 499	111 852	99 459	70 438	107 576
	% change with BC	0%	-17%	-23%	-14%	-11%	0%	-11%	-37%	-4%
Water and detergent costs	€	98 995	98 995	98 995	98 995	84 146	98 995	87 115	74 246	98 995
	% change with BC	0%	0%	0%	0%	-15%	0%	-12%	-25%	0%
Maintenance and repair costs	€	14 169	15 303	18 704	16 295	16 295	15 020	16 011	23 805	14 169
	% change with BC	0%	8%	32%	15%	15%	6%	13%	68%	0%
Gas costs	€	0	0	0	0	0	0	0	0	1 703
	% change with BC	-	-	-	-	-	-	-	-	-
Life-cycle cost	€	270 096	256 180	263 129	263 430	251 689	273 566	253 436	244 089	267 443
	% change with BC	0%	-5%	-3%	-2%	-7%	1%	-6%	-10%	-1%

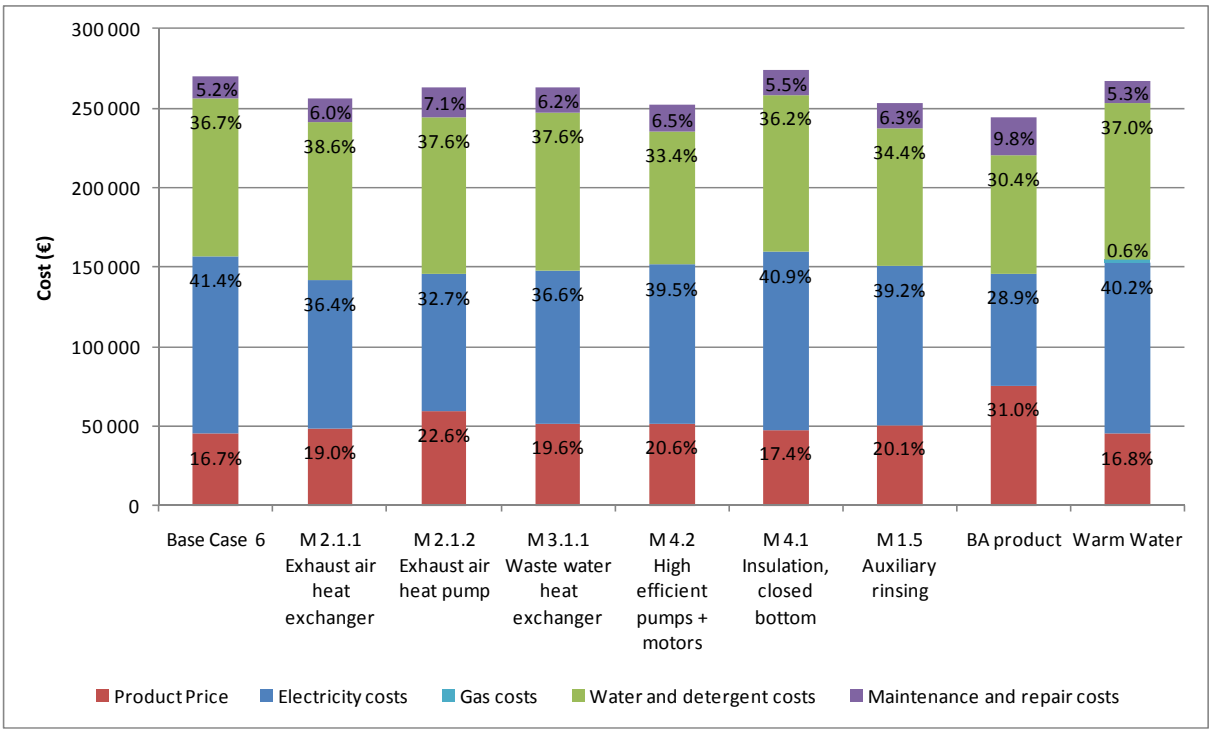


Figure 4-6 Life cycle costs breakdown by improvement option for base case 6

5 Analysis of LLCC and BAT

In this sub-task we will combine environmental impacts and costs. The objective is to identify, amongst the options analysed, the Least Life Cycle Cost (LLCC) option and the Best Available Technology (BAT). This task will include:

- Ranking the identified design options by LCC (e.g. option 1, option 2, option 3)
- Considering the possible trade-offs (positive or negative side effects of the envisaged options/individual design measures);
- Estimating the accumulative improvement and cost effects of implementing the ranked options simultaneously (e.g. option 1, option 1+2, option 1+2+3, etc.), also taking into account 'rebound' side effects of the individual design measures;
- Ranking the cumulative design options, drawing an LCC-curve (Y1-axis = Energy consumption, Y2-axis = LCC, X-axis = options) and identifying the Least Life Cycle Cost (LLCC) point and the BAT point. The improvement potential resulting from the ranking will be discussed, such as the appropriateness of setting minimum requirements at the LLCC point, to use the environmental performance of the BAT point or benchmarks set in other countries as a benchmark or if manufacturers will make use of this ranking to evaluate alternative design solutions and the achieved environmental performance of the product.

The figures in the following subsection show on the one hand the total primary energy consumed over the whole life cycle of the products and the life cycle costs on the other hand. Primary energy was chosen here as the most important and representative environmental indicator, given the importance of the use phase and the electricity consumption during this phase:

- Although implementing the design options often increases the quantity of waste generated (mostly non-hazardous in the case of professional dishwashers), this impact category is directly related to the quantity of material that is contained in the product and the major environmental impacts that are due to this waste management (e.g. incineration) are also accounted for in other emissions impact categories. Thus, this category gives an interesting indicator but should not be considered as a priority. Besides, the implementation of some features (heat pumps, heat exchangers, etc.) requires the manufacture of additional materials resulting in higher PAH (especially aluminium), POP and heavy metal emissions (especially stainless steel). However, because of the high recycling rates of the metals, it is estimated that the higher emissions they may cause are not of primary importance in these life cycle assessments.
- Acidification is another important environmental indicator and an overview of the environmental results tables shows that its evolution is very similar (almost the same) as that of Global Warming Potential. Primary energy consumption is estimated to be representative and in line with these two indicators.
- Eutrophication is almost entirely due to detergent consumption, which in this study is linked to water consumption (based on the assumption that the detergent concentration is constant). Given the large amount of water consumed during the use phase, this environmental indicator is also considered important.

As explained earlier, the warm water supply option will not be identified as the LLCC or BAT option if scoring best from the environmental or economic point of view.

5.1 Base case 1: Undercounter water-change

Figure 5-1 shows that the LLCC for BC1 is actually the base case product. Option M 4.1 Insulation comes second, before the individual design options M 4.2, and then M 2.1.1. The BA product is last from an economic point of view: the implementation of all design options does not seem beneficial over the lifetime of the dishwasher.

The BA product is the BAT option (taking primary energy as the reference indicator, as specified earlier). The option M 4.2 ‘High efficient motor and pumps’ scores second, just ahead of M 2.1.1 and M 4.1. The base case logically has the highest primary energy consumption.

Besides, the warm water supply is clearly worth being implemented whenever possible as it is the option having the least life cycle cost and the lowest primary energy consumption of all actual improvement options.

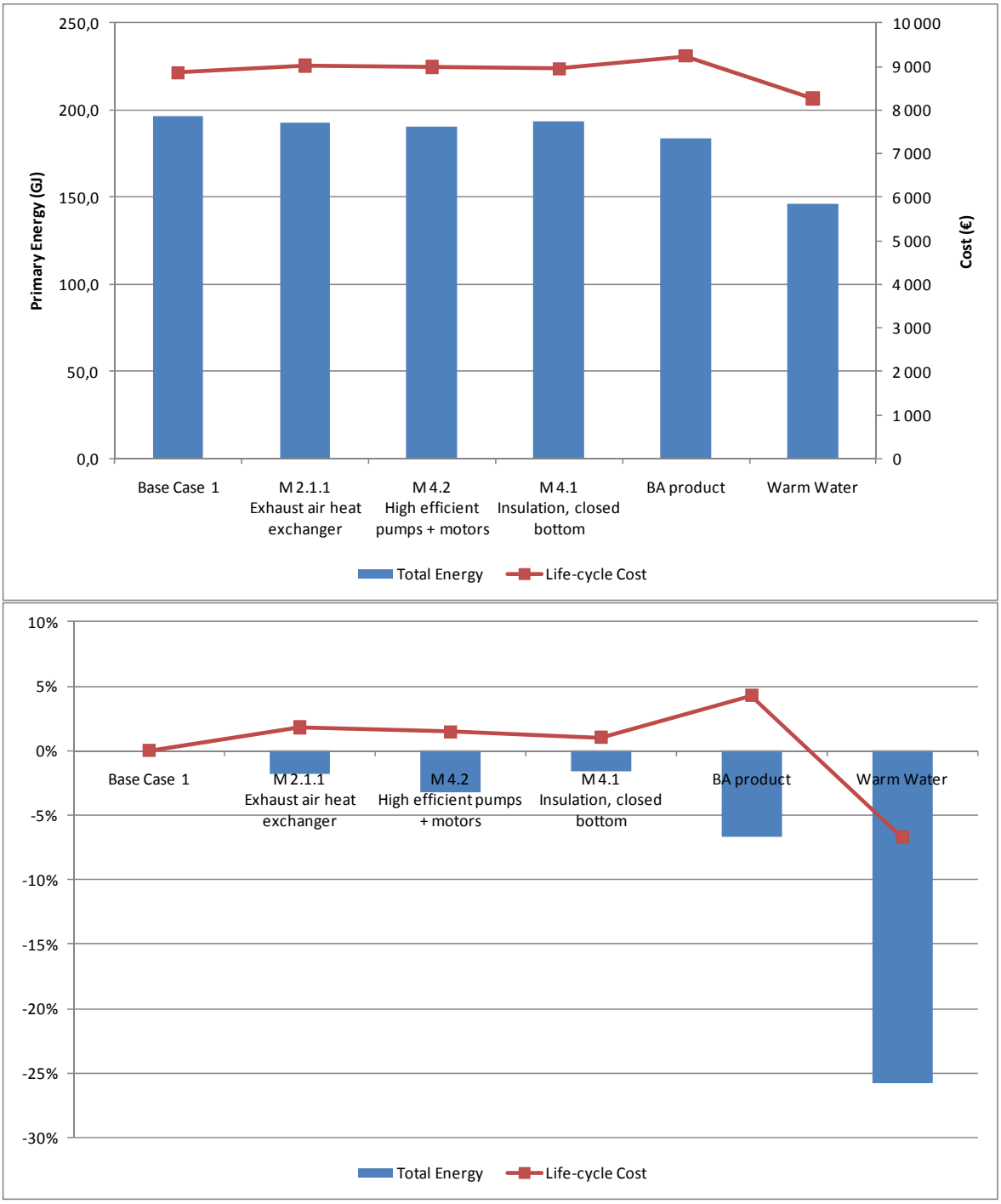


Figure 5-1 Economic and environmental analysis for base case 1

5.2 Base case 2: Undercounter one-tank

Figure 5-2 shows that the LLCC for BC2 is the single option M 4.2 High efficient pumps and motors. The base case comes second, very close to the following single design options: M 4.1, M 3.1.1, M 2.1.1. Then comes the BA product and last is the exhaust air heat pump (M 2.1.2).

Regarding primary energy consumption, the BA product is the BAT option. Options M 2.1.1 Exhaust air heat exchanger and M 3.1.1 Waste water heat exchanger score second, just in front of the individual design options M 4.2 High efficient pumps and motors and M 2.1.2 Heat pump (M 4.1 better insulation almost makes no difference in comparison with the base case). The base case logically has the highest primary energy consumption.

Regarding the combined environmental and economic analysis, warm water is clearly worth being implemented as it scores better than the base case both environmentally and economically (it is a virtual BAT and LLCC option). Other single design options could be considered (M 4.2, M 3.1.1, M 2.1.1) as improving the environmental footprint without (major) additional investment. Again, the BA product is not beneficial from an economic point of view.

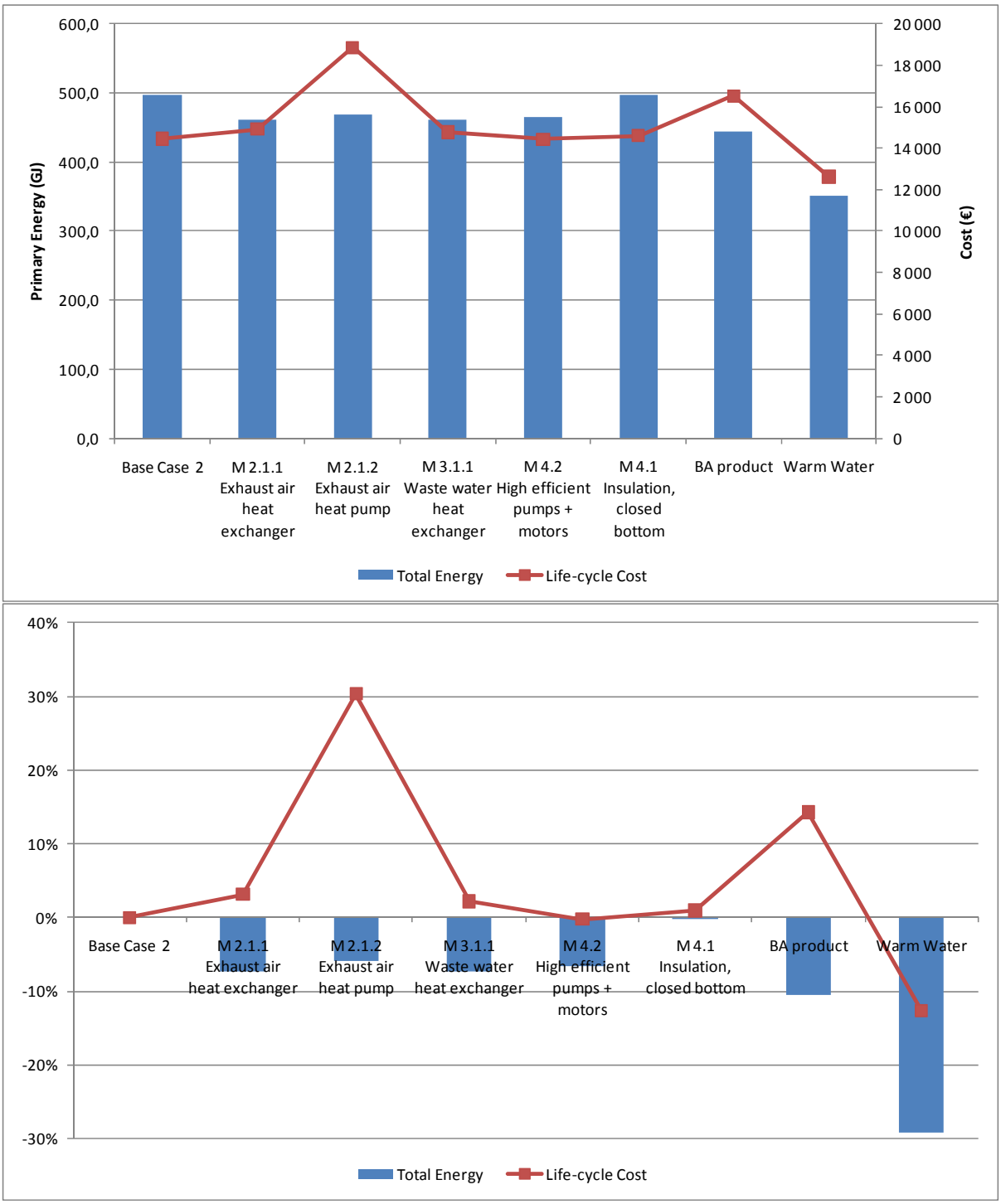


Figure 5-2 Economic and environmental analysis for base case 2

5.3 Base case 3: Hood-type dishwashers

Figure 5-3 shows that the LLCC for BC3 is the base case product, very close to the following single design options: M 4.2, M 4.1, M 3.1.1, M 2.1.1. Then comes the BA product and last is the exhaust air heat pump (M 2.1.2). This profile is very similar to the BC 2 analysis.

Regarding the primary energy consumption, the BA product is the BAT option. It scores just in front of the individual design options (M 3.1.1, then M 2.1.1, M 4.2, M 2.1.2, and lastly M 4.1). The base case logically has the highest primary energy consumption.

Regarding the combined environmental and economic analysis, warm water is clearly worth implementing as it scores better than the base case both environmentally and economically (it is again a virtual LLCC and BAT option). Other single design options could be considered (M 4.2, M 3.1.1, M 2.1.1) as improving the environmental footprint without major additional investment. Again, the BA product is not beneficial from the economic point of view but the reduction in primary energy it achieves is nonetheless important.

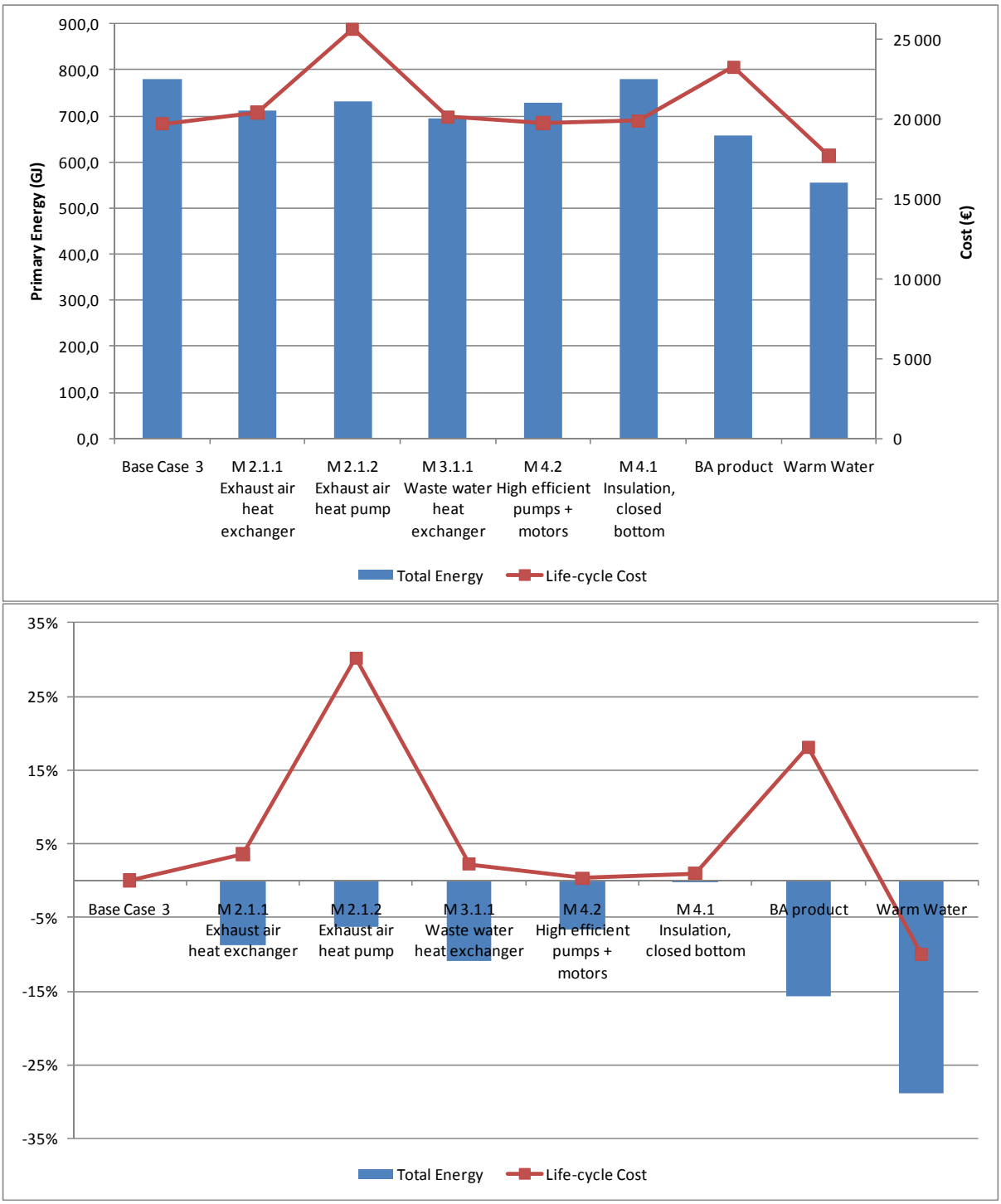


Figure 5-3 Economic and environmental analysis for base case 3

5.4 Base case 4: Utensil/pot dishwashers

Figure 5-4 shows that the LLCC for BC4 is the base case product. The following single design options have close but slightly larger LCC: M 4.1, M 4.2, M 3.1.1, M 2.1.1. Then comes the exhaust air heat pump option (M 2.1.2) with a much higher LCC (+30%), and last is the BA product.

Regarding primary energy consumption, the BA product represents the BAT option. The waste water or exhaust air heat exchangers (M 3.1.1 and M 2.1.1) score second, just in front of the remaining individual design options (M 4.2, M 2.1.2, and lastly M 4.1 which induces a limited improvement). The base case logically has the highest primary energy consumption.

Regarding the combined environmental and economic analysis, the warm water supply is clearly worth being implemented as it scores better than the base case both environmentally and economically (it is a virtual LLCC and BAT option). Other single design options could be considered (M 3.1.1, M 4.2 or even M 2.1.1) as improving the environmental footprint without major additional investment. The BA product and the exhaust air heat pump are not beneficial from the economic point of view because their LCC are much higher than the base case LCC: the operating expenses of the use phase do not counterbalance the initial investment in the product price.

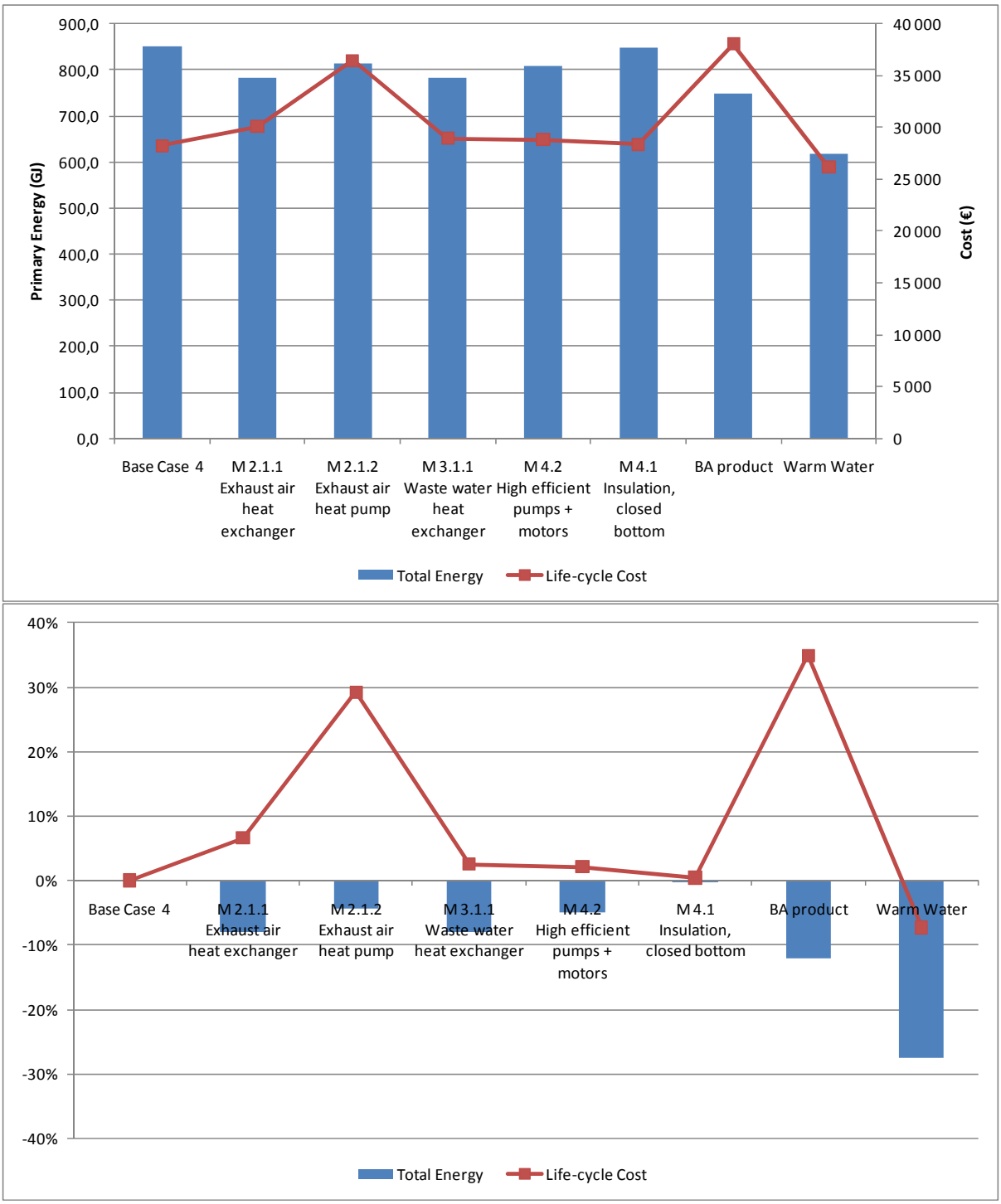


Figure 5-4 Economic and environmental analysis for base case 4

5.5 Base case 5: Conveyor-type one-tank

Significant changes appear for BC5 in comparison with the four previous base cases (see Figure 5-5). The LLCC for BC5 is not the base case product anymore, but the auxiliary rinsing option (M 1.5). Then come the other single improvement options: M 4.2 High efficient pumps and motors, M 2.1.1 Exhaust air heat exchanger, and M 3.1.1 Waste water heat exchanger, which are less expensive on a whole life cycle basis than the base case. M 4.1, the BA product and M 2.1.2 Heat pump have, on the other hand, higher LCCs.

The BA product is again the BAT option. The heat pump (M 2.1.2) scores second, ahead of the other individual design options. The base case unsurprisingly has the highest primary energy consumption.

Regarding the combined environmental and economic analysis, some options are clearly worth implementing as they score better than the base case both environmentally and economically: M 2.1.1 Exhaust air heat exchanger, M 1.5 Auxiliary rinsing, M 3.1.1 Waste water heat exchanger, M 4.2 High efficient pumps and motors. Despite the important decreases in energy consumption, the BA product and the exhaust air heat pump are still not beneficial from an economic point of view, but their LCCs are quite close to the base case LCC (respectively +3% and +7%).

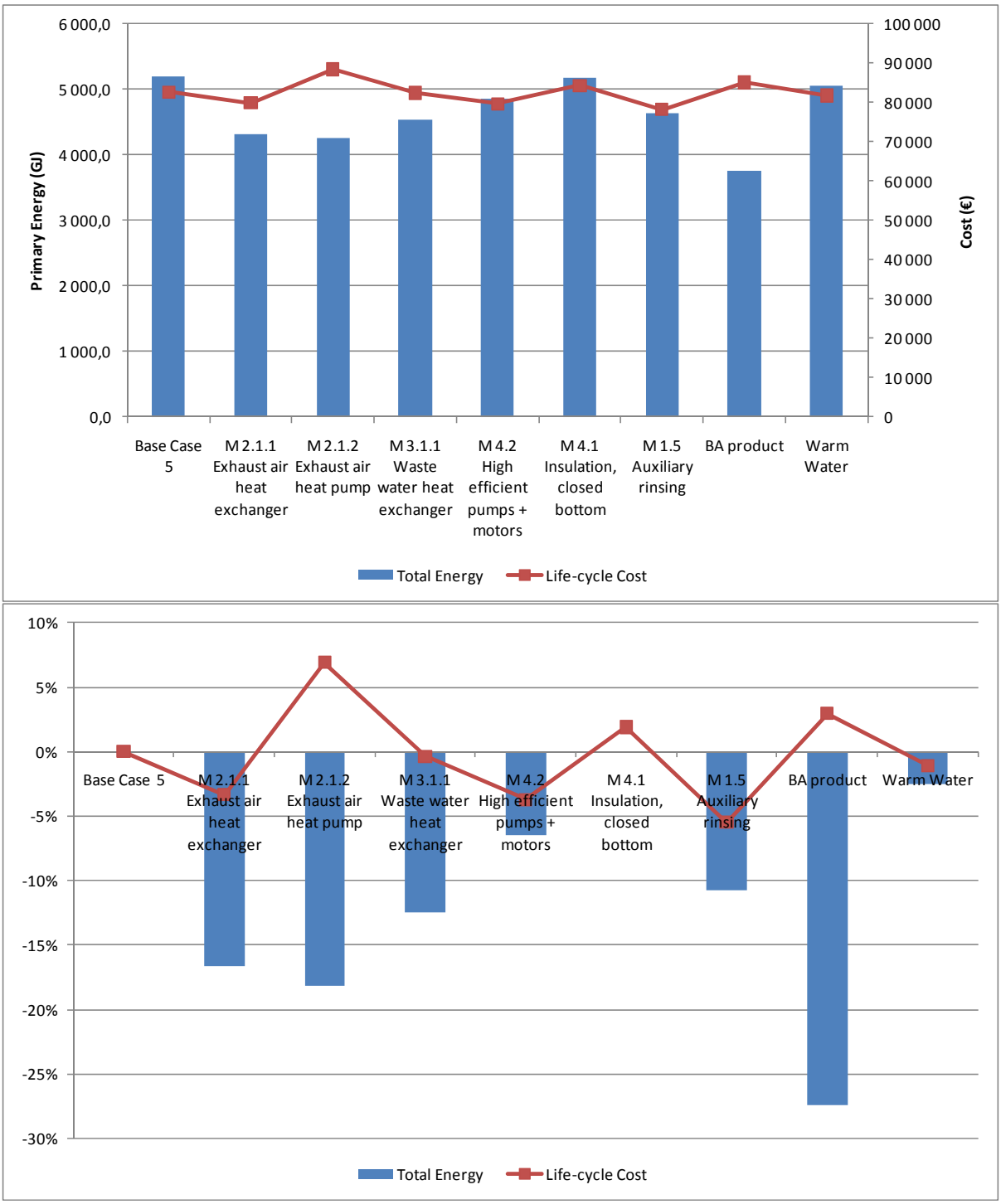


Figure 5-5 Economic and environmental analysis for base case 5

5.6 Base case 6: Conveyor-type multi-tank

The LLCC for BC 6 is the BA product (see Figure 5-6). Then come the following single improvement options: M 4.2 High efficient motors and pumps, M 1.5 Auxiliary rinsing, M 2.1.1 Exhaust air heat exchanger, M 2.1.2 Heat pump and M 3.1.1 Waste water heat exchanger. Warm water is also slightly beneficial economically and better insulation (M 4.1) is the only option for which this is not the case.

Regarding the primary energy consumption, the BA product is also the BAT option. The heat pump (M 2.1.2) scores second, ahead of the other individual design options. The reduction in primary energy consumption due to warm water and M 4.1 is very low. The base case logically has the highest primary energy consumption.

Regarding the combined environmental and economic analysis, the situation is very different: for the first time, the BA product and the heat pump have lower LCCs than the base cases and are certainly worth implementing. The BA product is even the LLCC and the BAT option. All other options, except M 4.1 (higher LCC), also appear environmentally and economically beneficial.

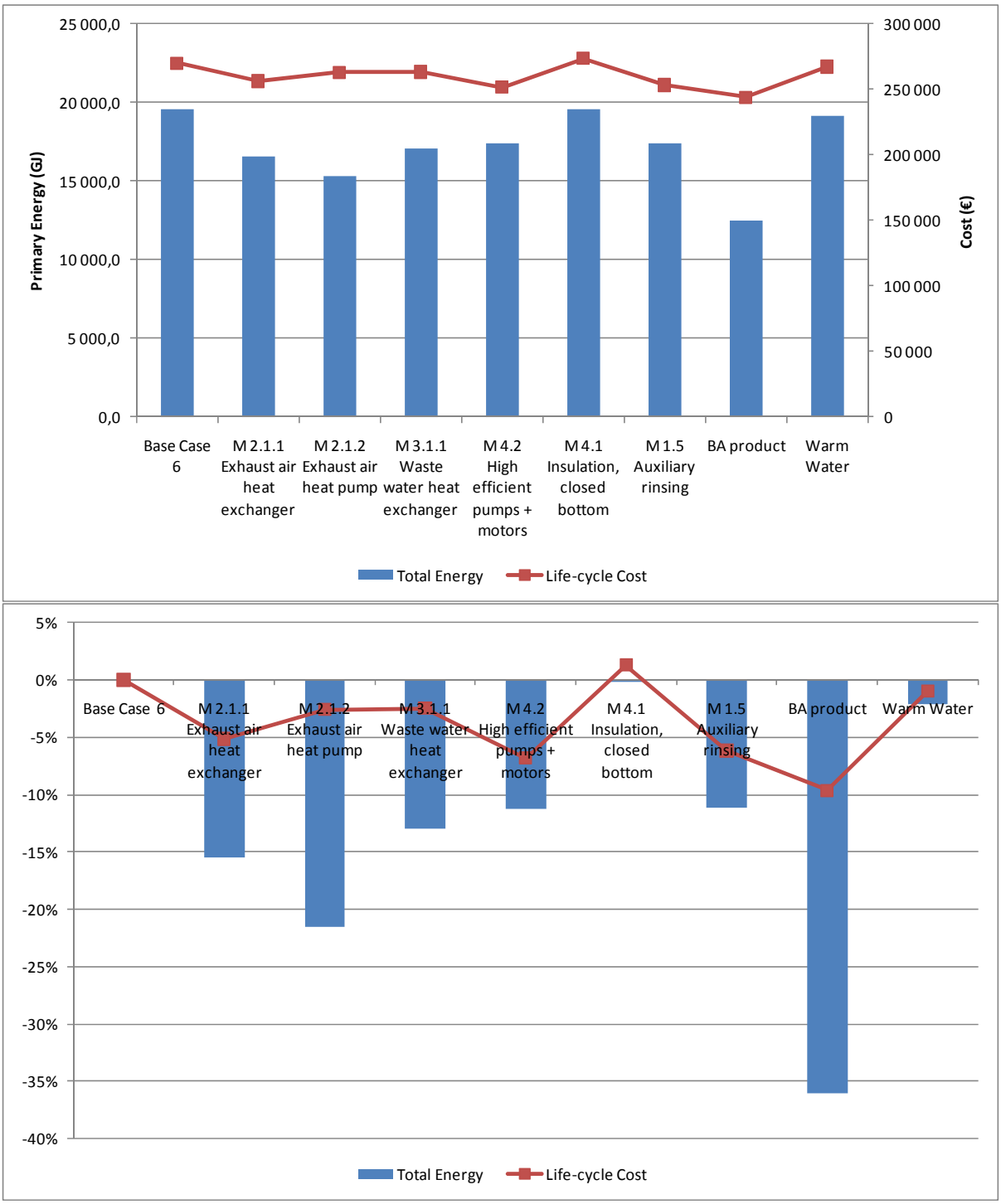


Figure 5-6 Economic and environmental analysis for base case 6

6 Long-term targets (BNAT) and systems analysis

Not all possible improvement options were considered in the preceding sections. Some are still prohibitively expensive or not yet widely available. Such options can be described as BNAT and considered long-term targets. The term BNAT indicates long-term possibilities and helps to define the exact scope and nature of any potential eco-design measures.

Predicting the technological status over such a long period (a horizon of 2020/2025) in a very innovative sector is not possible with a high level of accuracy. Technology roadmaps tend to have a time horizon of 10-12 years at most, describing mid-term targets but often without specifying which particular technologies will be used to achieve those targets.

Some BNAT options are likely to become less costly to manufacturers in coming years, and would thus become applicable to products on the market. Some improvement options or available technologies mentioned by manufacturers that have not yet been applied to professional dishwashers are:

- latent heat storage (through phase-change materials),
- thermo-chemical heat storage (e.g. similar to the zeolite technology introduced as BAT in dishwashers for domestic use in 2010),[16]
- heat pipe,
- detergent re-use (water treatment of waste water and detergent recovery),
- microwave technology (water heating through microwave),
- peltier technology (electric heat pump),
- high-temperature heat pumps capable of reaching a temperature that can heat up the final rinse to 85°C.

None of the technologies was mentioned to be introduced within the next two or three years. Further, the savings potential of these technologies could not be quantified by the manufacturers.

[16] The dishwashers feature a special container of zeolite, a mineral with the ability to store moisture and energy. It dries the dishes after the cleaning cycle by absorbing the moisture from the air in the dishwasher's interior. During the next cleaning cycle, the zeolite is heated up and the moisture released so that it is ready for the next drying cycle. Zeolite speeds up the drying process, so that the dishwashers need 20 percent less electricity than the most energy efficient household dishwashers to date. However, the regeneration (heating up) of the zeolite currently needs 25 minutes; as for professional dishwashers the whole cleaning cycle is considerably shorter, zeolite technology is not applicable to date in professional DW. According to manufacturer's feedback, a reduction of the regeneration time of zeolite is not possible for the present state of technology. Theoretically the technology could be applied in category 1 to 4 dishwashers that are not so frequently used. For category 5 and 6 dishwashers the technology could only be used to transfer the heat from the wash tanks from one to another day.

At market level, Task 2 identified that environmental awareness is increasing; consumers also have economic motivation to reduce energy and water use. These trends drive changes in use patterns and machine sales over time.

However, a full discussion of these issues is not yet possible. Because the professional dishwasher sector is very competitive, manufacturers are reluctant to disclose information about research and development activities.

7 Conclusion

As a conclusion, Task 7 makes the environmental and economic comparison of the improvement options introduced in Task 6 and quantified thanks to a questionnaire, with the base case assessment done in Task 5.

For base cases 1 to 4, it appears that the improvement options, despite introducing some environmental benefits (e.g. electricity savings), do not seem economical over the lifetime of the dishwashers. The savings during the use phase (less energy and water costs) are not sufficient to counterbalance the higher investment for the purchase price. Some options have nevertheless Life Cycle Costs that are very close to the base results and could be implemented in case of financial incentives.

However; for base cases 5 and 6, which are larger appliances, several options appear as beneficial in the LCC analysis: auxiliary rinsing, exhaust air heat exchanger, high efficient pumps and motors or exhaust air heat pump (for base case 6). In parallel, these options enable to achieve important energy savings because of the high use rate of these heavy-duty machines.

The results of this analysis are highly dependent on the inputs and a sensitivity analysis in Task 8 will complement the current results to highlight the influence of the most important parameters of the study on the environmental and financial outcomes.

8 Annex

8.1 Enquiry for stakeholders

"Saving potential and additional costs of single improvement options"

Guidance

The objective of the enquiry is to obtain the concrete saving potential and price differences between standard products (as defined in Task 3 and 4) and these products including the mentioned design options to reduce water and energy consumption.
As we are aware that filling this enquiry may represent a substantial amount of work, please fill in XYZ first if your time and resources are not sufficient to fill in the whole spreadsheet.

This enquiry contains information request on all the base-cases. Please provide information for as many as you can, depending on the products manufactured by your company.

None of the information you will provide will be published as such. The data will be aggregated and averaged to be representative of the EU market. If you wish, a Non-Disclosure Agreement can be signed between Büro Ö-Quadrat/Oeko-Institut and your company.

Definition of the base-cases:
BC 1: Under-counter water-change dishwashers (capacity: 200 dishes/hour)
BC 2: Under-counter one-tank dishwashers (capacity: 550 dishes/hour)
BC 3: Pass-through (hood-type) dishwashers (capacity: 860 dishes/hour)
BC 4: Utensil/Pot dishwashers (capacity: 0.42 m2, 20 cycles/hour)
BC 5: One-tank conveyor-dishwashers (capacity: 1750 dishes/hour)
BC 6: Multi-tank conveyor-dishwashers (with one pump pre wash zone, one cleaning zone and one f
capacity: 3600 dishes/hour)

Please contact Dieter Seifried, Kathrin Graulich or Eva Brommer in case of any question at:

seifried@oe2.de
k.graulich@oeko.de
e.brommer@oeko.de

Saving potential and additional costs of single improvement options

Introduction

From previous enquiries the following design options were identified as options where the saving potential can be quantified at all and which therefore need to be analysed in more detail:
option 1: exhaust air heat exchanger
option 2: exhaust air heat pump
option 3: waste water heat exchanger
option 4: high efficienc hydraulic system and motors
option 5: Insulation of dishwasher, closed bottom
option 6: auxiliary rinsing system

Please indicate in the following tables what would be the saving potential of each option and the additional costs of a product with such a feature compared to a standard product without this feature. The reference values of the bas case products as defined in tasks 2, 3 and 4 are listed in the first table.

It is possible to give minimum values (e.g. at least 20% higher purchase price) or ranges (e.g. energy saving between 5 and 15%). Any information is highly appreciated.

Please don't fill in the grey shaded cells.

I. Reference values of standard product (see task 2 and 3 reports)

	Base Cases					
	BC 1	BC 2	BC 3	BC 4	BC 5	BC 6
	Under-counter water-change	Under-counter one-tank	Pass-through (hood-type)	Utensil/Pot	One-tank conveyor-type	Multi-tank conveyor-type
Reference price	3.200 €	3.500 €	4.700 €	10.500 €	15.000 €	45.000 €
Continuous operation						
Specific energy consumption (kWh/100 dishes)	4,3	1,6	1,7	0,5 (per cycle)	2	2
Specific water consumption (l/100 dishes)	80	16	16	5,2 (per cycle)	13	12
Standby consumption						
Left-on mode (BC 1), ready-to-use-mode (BC 2-6) (kWh/h)	0,01	0,25	0,35	1,00	0,80	2,00
Do you agree with the reference values? (yes/no)						
If no, please provide reference values that you would suggest:						

II. Saving potential

In the following section, please provide information on the evolution of the prices, energy and water consumption within the tables, in %, assuming the values of the base-case represent 100% each (for instance, multi-tank conveyor-type dishwasher with an exhaust air heat pump has a price of 115% of the reference price of the base-case). If you have suggested other values for the base-cases than the ones given above (corresponding to those of Task 2 and 3 reports), please give this evolution based on your suggested values.
The green cells correspond to the base-cases dishwashers.
Please do not fill in the grey cells.

		Improvement options					
Base Case 1 Under-counter water-change		Option 1: Exhaust air heat exchanger	Option 2: Exhaust air heat pump	Option 3: Waste water heat exchanger	Option 4: High efficient hydraulic system + motors	Option 5: Insulation, closed bottom	Option 6: Auxiliary rinsing
Purchase price	100%						
Continuous operation							
Specific energy consumption (kWh/100 dishes)	100%						
Specific water consumption (l/100 dishes)	100%						
Standby consumption							
Left-on mode (BC 1), ready-to-use-mode (BC 2-6) (kWh/h)	100%						

		Improvement options					
Base Case 2 Under-counter one-tank		Option 1: Exhaust air heat exchanger	Option 2: Exhaust air heat pump	Option 3: Waste water heat exchanger	Option 4: High efficient hydraulic system + motors	Option 5: Insulation, closed bottom	Option 6: Auxiliary rinsing
Purchase price	100%						
Continuous operation							
Specific energy consumption (kWh/100 dishes)	100%						
Specific water consumption (l/100 dishes)	100%						
Standby consumption							
Left-on mode (BC 1), ready-to-use-mode (BC 2-6) (kWh/h)	100%						

Base Case 3 Pass-through (hood-type)		Improvement options					
		Option 1: Exhaust air heat exchanger	Option 2: Exhaust air heat pump	Option 3: Waste water heat exchanger	Option 4: High efficient hydraulic system + motors	Option 5: Insulation, closed bottom	Option 6: Auxiliary rinsing
Purchase price	100%						
Continuous operation							
Specific energy consumption (kWh/100 dishes)	100%						
Specific water consumption (l/100 dishes)	100%						
Standby consumption							
Left-on mode (BC 1), ready-to-use-mode (BC 2-6) (kWh/h)	100%						

Base Case 4 Utensil/Pot		Improvement options					
		Option 1: Exhaust air heat exchanger	Option 2: Exhaust air heat pump	Option 3: Waste water heat exchanger	Option 4: High efficient hydraulic system + motors	Option 5: Insulation, closed bottom	Option 6: Auxiliary rinsing
Purchase price	100%						
Continuous operation							
Specific energy consumption (kWh/100 dishes)	100%						
Specific water consumption (l/100 dishes)	100%						
Standby consumption							
Left-on mode (BC 1), ready-to-use-mode (BC 2-6) (kWh/h)	100%						

Base Case 5 One-tank conveyor-type		Improvement options					
		Option 1: Exhaust air heat exchanger	Option 2: Exhaust air heat pump	Option 3: Waste water heat exchanger	Option 4: High efficient hydraulic system + motors	Option 5: Insulation, closed bottom	Option 6: Auxiliary rinsing
Purchase price	100%						
Continuous operation							
Specific energy consumption (kWh/100 dishes)	100%						
Specific water consumption (l/100 dishes)	100%						
Standby consumption							
Left-on mode (BC 1), ready-to-use-mode (BC 2-6) (kWh/h)	100%						

Base Case 6 Multi-tank conveyor-type		Improvement options					
		Option 1: Exhaust air heat exchanger	Option 2: Exhaust air heat pump	Option 3: Waste water heat exchanger	Option 4: High efficient hydraulic system + motors	Option 5: Insulation, closed bottom	Option 6: Auxiliary rinsing
Purchase price	100%						
Continuous operation							
Specific energy consumption (kWh/100 dishes)	100%						
Specific water consumption (l/100 dishes)	100%						
Standby consumption							
Left-on mode (BC 1), ready-to-use-mode (BC 2-6) (kWh/h)	100%						

Combination of quantifiable design options

Introduction

The following table shows that in principle all options can technically be combined. Please comment on the table if you do not agree with the assumption.

Please indicate in the second table, which options influence the energy / water saving potential of each other, if options are combined. Please quantify this influence if possible. For instance, the saving potential of an exhaust air heat pump is 10%, that of a waste water heat exchanger 10%, when installed as single option. If both options are built into one dishwasher the overall saving potential might be only 15%.

Finally please indicate in the third table the saving potential of products including all mentioned improvement options. The reference values shown in the "savings_and_costs" spreadsheet are considered as "100%" for each Base Case. If for example Base Case 2 (under-counter one-tank dishwasher) contains all possible improvement options then the energy consumption during operation might be 60%. You are also invited to include any comments (last line).

Please don't fill in the grey shaded cells.

I. Combinations of improvement options

Design option	Exhaust air heat exchanger	Exhaust air heat pump	Waste water heat exchanger	High efficient hydraulic systems and motors	insulation, closed bottom	Auxiliary rinsing system
Exhaust air heat exchanger	-					
Exhaust air heat pump	x	-				
Waste water heat exchanger	(x)	(x)	-			
High efficient hydraulic systems and motors	x	x	x	-		
Insulation, closed bottom	x	x	x	x	-	
Auxiliary rinsing system	x	x	x	x	x	-
Your comments						

x = possible combination
(x) combination limited

II. Influence of combination on saving potential

Design option	Exhaust air heat exchanger	Exhaust air heat pump	Waste water heat exchanger	High efficient hydraulic systems and motors	insulation, closed bottom	Auxiliary rinsing system
Exhaust air heat exchanger	-					
Exhaust air heat pump		-				
Waste water heat exchanger			-			
High efficient hydraulic systems and motors				-		
Insulation, closed bottom					-	
Auxiliary rinsing system						-

III. Relative purchase price and consumption of dishwashers with all improvement options

		Product including all possible improvement options					
		BC 1	BC 2	BC 3	BC 4	BC 5	BC 6
	Base Case value	Under-counter water-change	Under-counter one-tank	Pass-through (hood-type)	Utensil/Pot	One-tank conveyor-type	Multi-tank conveyor-type
Purchase price	100%						
Continuous operation							
Specific energy consumption (kWh/100 dishes)	100%						
Specific water consumption (l/100 dishes)	100%						
Standby consumption							
Left-on mode (BC 1), ready-to-use-mode (BC 2-6) (kWh/h)	100%						
Your comments							

8.2 Stakeholder feedback to draft versions of Task 7

Please note that the feedback refers to draft versions of Task 7 report; thus, the indicated numerations of chapters, tables, figures or pages might have changed.

Feedback		Comment
Hobart		
Section 4.5 and 4.6	The LCC values for machines with exhaust heat recovery and exhaust heat pump seem to be unrealistically high in relation to the base case.	The project team was also surprised by these preliminary results. This comment was discussed during the final stakeholder meeting and cost information on heat pumps has been double checked.
CECED Italia		
Section 2.3	We have several doubts that warm water input should be considered as an improvement option and included in the LLCC analysis. It is not clear how the cost of this option is evaluated in the LLCC analysis; in fact as it is written in Task 3 "the overall environmental and economic advantage of the connection to warm water supply strongly depends on the type of water heating outside the appliance and other infrastructural parameters, like length of the stub water line". Moreover in our opinion other costs should be taken into account as the maintenance of the heating system, the actions undertaken to prevent legionella and, most relevant, costs for the system installation where possible ("this additional improvement option depends on the infrastructure available to the dishwasher's owner and it might not be possible to implement it in every situation ")	Modified: the warm water supply has been excluded from the formal BAT and LLCC analysis
2.3	We do not have any specific data to present on boiler and external infrastructure but we would like to remark that the situation presented in the study in our opinion is a marginal situation that cannot be considered as representative of general conditions.	It is mentioned in the report (tasks 7 and 8) that this warm water input option should not be considered as a typical option
	We have some doubts on average lifetime data used in task 7 that seem to be not coherent with data used in lot 2. Is it correct?	This was checked but no error was found.
JRC IPTS		
	With regard to Part 2 entitled 'Professional Dishwashers', the report structure of the Draft Task 7: 'Improvement Potential' is generally in line with MEEUP methodology as applied in other DG ENER preparatory studies. However, we would like to draw attention to the fact that the part of the report regarding the identification of BAT options which are subject of the investigation in the improvement potential calculation has been shifted from Draft Task 7 to Draft Task 6. This shift is not justified. Despite the fact that this shift is less important if one studies the whole document, we consider it better to follow the MEEUP methodology as applied in all other preparatory studies as this eases the cross-checking of horizontal issues and enhances readability for policymakers.	Has been corrected in the final version of the report

Feedback		Comment
	In general the Draft Task 7 report gives a good impression. It is well structured and clearly presented. However, in some points, we consider that the draft report could be improved. In general, we consider that the study though consistent and transparent does not reach a significant level of detail. In the previous Draft Task 6 the analysis of the BAT products was kept on a rather generic level (please see also our comments on Draft Task 6 report) and now in Draft Task 7 the followed improvement potentials seem to be –inevitably– based strongly on stakeholder estimations (e.g. Table 3–11 of Draft Task 7 are based on stakeholders' rough estimations as presented in Draft Task 6). We consider that instead of a rather perfunctory approach, a more in depth investigation is needed and is appropriate for achieving the set goals of the Preparatory Study.	Thank you. The analysis made in Task 7 is indeed based mostly on parameters presented in Task 6. The data limitations regarding the BAT options were already presented in the responses to the comments on Task 6.
	In that respect we refer as an example to the relevant study regarding domestic appliances, in particular domestic dishwashers found in the respective documents of the finalised Preparatory Study of Lot 14 'Domestic Washing Machines and Dishwashers'. In this case technical parameters and models (e.g. the method for calculating the energy efficiency index, the cleaning efficiency index and the drying efficiency index) were determined and developed. The implementing measures on household dishwashers later used these models for the determination of benchmarks (please see also Regulation (EU) No 1016/2010). There are undeniable differences between domestic and professional dishwashers. However, there are many similarities between these two product groups and we consider a more precise determination of the technical parameters to still be feasible. This would allow the investigation of the improvement potential to be more precise and reliable.	The main difference between household and professional appliances is that there are much more variations in the programmes and types of machines available. Manufacturers insist that they should be the ones developing a harmonised testing methodology, and this work will begin in January 2011 within CENELEC working groups.
	Furthermore, it appears to be very helpful to handle the two product groups, domestic and professional dishwashers in more consistent and fair way especially when implementing measures are proposed and undertaken. Demanding precise eco-design goals for domestic devices via the implementing measurements whereas leaving the professional devices with rather roughly determined options does not seem to be a coherent approach.	We understand and agree with this point but the lack of standards/ harmonised test method is the reason why proposing specific eco-design goals does not seem feasible yet, but remains an objective for the next 2-3 years.
	Furthermore we would like to draw attention to a specific point regarding the investigation of one improvement option. In particular, in Section 2.3 'Warm water Input' of Draft Task 7 the improvement option of using warm water as input in the dishwasher is investigated. This option, based on the presented findings in Section 3.1-3.4 shows the highest environmental improvement in 4 out of 6 investigated product base cases. Thus, it gains special importance for the study. However, some important assumptions undertaken in the calculation of this option are not presented clearly and/or need to be further substantiated. In particular, it is not clear if in this improvement option in the assessment of the environmental performance of the dishwashers the product system is expanded. If it is expanded, does it include additionally the life cycle of the gas boiler (which is used for warming the water) and the consumption of gas? Are the emissions during the use phase of the gas boiler as well as the ones associated with the other life cycle stages included in the environmental assessment? How are the system boundaries of the two compared product systems, base case and improvement option set? Are they comparable? These are questions which should be clearly answered. If comparability of the options is not ensured, then instead of environmental savings a shift from environmental burdens between the two product systems can be	See answer below.

Feedback		Comment
	expected (e.g. from product life cycle of dishwashers to product life cycle of gas boilers).	
	Moreover, the assumption that water is warmed using a gas boiler is rather restricted. In some areas in Europe it might be more realistic to assume that the water is warmed using different means. Therefore and so far as this improvement option is regarded as the most beneficial in the majority of the investigated base cases, we consider it necessary to broaden and extend the investigation to other water heating systems.	See answer below.
2.1	The design options as named in the given bullets on page 2 should be extensively presented and described (see also general comments above). Furthermore, cross reference to the respective sections of Task 6 should be added. The improvement options should be re-numbered in a continuous manner because using the coding given in Draft Task 6 (e.g. M 2.1.1 for exhaust air heat exchanger and M 1.5 for auxiliary rinsing) is confusing.	Have been added. We did not re-number the improvement options to keep consistency with Task 6 report.
2.1	Where the presented tables are based on information found in the draft Task 6, they should be given exact cross-references. The source of information should be traceable (e.g. in which table, in which section and from which source the data is found). Moreover, when the tables are based on information of stakeholders this should be clearly stated in the text and in the table title. Calculations based on rough stakeholders' estimations should be differentiated from calculations relied on a stronger evidence basis.	Has been added.
2.2	It is reasonable to start investigating with only one combination of options for each product category. However, based on the first findings especially for base case 5 and 6 the improvement potentials seem to also be significant for different combinations of options. Thus, we consider it supportive especially in the impact analysis of these base cases in Section 3.5 and 3.6 and respectively later in Section 4.5 and 4.6 to extend the investigation to include different combinations of options.	As explained in the task 6 comments, the data was limited regarding all the possible combinations of options.
2.3	It is not clear if in the environmental performance calculation is the investigated product system expanded including the life cycle and the operation of a gas boiler (see also general comments above). Moreover, the investigation of different water heating systems is considered necessary in order to make this improvement option more realistic.	The way the boiler is taken into account in the environmental and economic analysis has been explained more clearly. The study is supposed to reflect an average situation which is why a “common” boiler was defined.
5.7	It would be desirable to provide additional figures similar to Figures 19–23 presenting the results in percentages instead of absolute values as that way some important aspects and differences among the numerous options could be better reflected. In addition, the 'y axis as given in Figures 19–23 regarding the costs should be re-scaled in such way as to allow for obtaining a clear picture among the different options and comparing the different base cases.	Has been added.
5	A final conclusion section summing up the findings given in Sections 5.1–5.6 is missing. This conclusion section should provide in short a clear overview of the ranking of the different improvement options for each investigated base case.	Has been added.

Preparatory Studies for Eco-design Requirements of Energy-using Products

Lot 24: Professional Washing Machines, Dryers and Dishwashers

Tender No. TREN/D3/91-2007

May 2011

Final Report, Part: Dishwashers

Task 8: Scenario, Policy, Impact and Sensitivity Analysis

Öko-Institut e.V.
Institute for Applied Ecology, Germany
Ina Rüdenauer
Markus Blepp
Eva Brommer
Carl-Otto Gensch
Kathrin Graulich

BIO Intelligence Service, France
Shailendra Mudgal
Raul Cervantes
Thibault Faninger
Lorcan Lyons

Büro Ö-Quadrat, Germany
Dieter Seifried

Öko-Institut e.V.
Freiburg Head Office
P.O. Box 17 71
79017 Freiburg, Germany
Street Address
Merzhauser Str. 173
79100 Freiburg, Germany
Tel. +49 (0) 761 – 4 52 95-0
Fax +49 (0) 761 – 4 52 95-88

Darmstadt Office
Rheinstr. 95
64295 Darmstadt, Germany
Tel. +49 (0) 6151 – 81 91-0
Fax +49 (0) 6151 – 81 91-33

Berlin Office
Schicklerstr. 5-7
10179 Berlin, Germany
Tel. +49 (0) 30 – 40 50 85-0
Fax +49 (0) 30 – 40 50 85-388

www.oeko.de

For reasons of better readability, two Task 8 reports were prepared.

The report at hand covers ***professional dishwashers***.

The Task 8 report on *professional washing machines and dryers* is published separately.

For the benefit of the environment, this document has been optimised for **double-sided printing**.

Part: Professional Dishwashers

Table of Contents – Task 8: Scenario and Policy Analysis

List of figures V

List of tables XI

1 Introduction: Objective of Task 8 1

2 Policy and scenario analysis 1

2.1 Scope 1

2.2 Generic eco-design requirements 2

2.2.1 Need for the definition of a standard programme 2

2.2.2 Information requirements 2

2.2.3 Detergent consumption 3

2.2.4 Water consumption 4

2.3 Specific eco-design requirements 5

2.3.1 Need for the development of harmonised standards and definitions 5

2.3.2 Labelling requirements 7

2.3.3 Benchmarking 9

2.3.4 Minimum energy efficiency requirements 10

2.3.5 Verification procedure for market surveillance purposes 12

2.3.6 Criteria for Green public procurement 13

2.4 Policy scenario analysis 14

2.4.1 Business-as-Usual (BAU) scenario 17

2.4.2 Least Life cycle Cost (LLCC) scenario 22

2.4.3 Best Available Technology (BAT) scenario 26

2.4.4 Eco-design requirements 30

2.4.5 Comparison of BAT, LLCC and MEPS scenarios with BAU 34

3 Impact analysis 41

3.1 Impacts on manufacturers and competition 41

3.2 Monetary impacts 42

3.3 Impacts on consumer use 42

3.4 Impacts on innovation and development 43

3.5 Social impacts 43

4 Sensitivity analysis of the main parameters 43

4.1 Resource and consumables consumption 44

4.1.1 Assumptions 44

4.1.2 Results 46

4.2 Intensity of use 65
4.2.1 Assumptions 65
4.2.2 Results 66
4.3 Product lifetime 73
4.3.1 Assumptions 73
4.3.2 Results 74
4.4 Resources and consumable rates 80
4.4.1 Assumptions 80
4.4.2 Results 81
4.5 Product purchase price 90
4.5.1 Assumptions 90
4.5.2 Results 91
4.6 Discount rate 94
4.6.1 Assumptions 94
4.6.2 Results 94
4.7 Combined parameters 97
4.7.1 Assumptions 97
4.7.2 Results 99
5 Conclusions 106

List of figures

Figure 2-1 Domestic dishwashers label 8
Figure 2-2 Breakdown of energy consumption of the six base cases over the period 2010-2025 18
Figure 2-3 Breakdown of total expenditure of the six base cases over the period 2010-2025 18
Figure 2-4 Primary energy consumption and expenditure by scenario, base case 1 35
Figure 2-5 Primary energy consumption and expenditure by scenario, base case 2 35
Figure 2-6 Primary energy consumption and expenditure by scenario, base case 3 36
Figure 2-7 Primary energy consumption and expenditure by scenario, base case 4 36
Figure 2-8 Primary energy consumption and expenditure by scenario, base case 5 37
Figure 2-9 Primary energy consumption and expenditure by scenario, base case 6 37
Figure 2-10 Primary energy consumption and expenditure by scenario, total for all base cases 38
Figure 2-11 Primary energy consumption and expenditure by scenario, over the period 2010-2025 38
Figure 2-12 Extrapolation of cumulated expenditure of the BAU and LLCC scenarios, total for all base cases 39
Figure 2-13 Extrapolation of cumulated expenditure of the BAU and MEPS scenarios, total for all base cases 40
Figure 4-1 Base case 1 and improvement options – impact of electricity consumption on total energy over lifetime by product 46
Figure 4-2 Base case 1 and improvement options – impact of electricity consumption on LCC by product 47
Figure 4-3 Base case 2 and improvement options – impact of electricity consumption on total energy over lifetime by product 47
Figure 4-4 Base case 2 and improvement options – impact of electricity consumption on LCC by product 48
Figure 4-5 Base case 3 and improvement options – impact of electricity consumption on total energy over lifetime by product 48

Figure 4-6 Base case 3 and improvement options – impact of electricity consumption on LCC by product 49
Figure 4-7 Base case 4 and improvement options – impact of electricity consumption on total energy over lifetime by product 49
Figure 4-8 Base case 4 and improvement options – impact of electricity consumption on LCC by product 50
Figure 4-9 Base case 5 and improvement options – impact of electricity consumption on total energy over lifetime by product 50
Figure 4-10 Base case 5 and improvement options – impact of electricity consumption on LCC by product 51
Figure 4-11 Base case 6 and improvement options – impact of electricity consumption on total energy over lifetime by product 51
Figure 4-12 Base case 6 and improvement options – impact of electricity consumption on LCC by product 52
Figure 4-13 Base case 1 and improvement options – impact of water consumption on total energy over lifetime by product 52
Figure 4-14 Base case 1 and improvement options – impact of water consumption on LCC by product 53
Figure 4-15 Base case 2 and improvement options – impact of water consumption on total energy over lifetime by product 53
Figure 4-16 Base case 2 and improvement options – impact of water consumption on LCC by product 54
Figure 4-17 Base case 3 and improvement options – impact of water consumption on total energy over lifetime by product 54
Figure 4-18 Base case 3 and improvement options – impact of water consumption on LCC by product 55
Figure 4-19 Base case 4 and improvement options – impact of water consumption on total energy over lifetime by product 55
Figure 4-20 Base case 4 and improvement options – impact of water consumption on LCC by product 56
Figure 4-21 Base case 5 and improvement options – impact of water consumption on total energy over lifetime by product 56
Figure 4-22 Base case 5 and improvement options – impact of water consumption on LCC by product 57
Figure 4-23 Base case 6 and improvement options – impact of water consumption on total energy over lifetime by product 57
Figure 4-24 Base case 6 and improvement options – impact of water consumption on LCC by product 58
Figure 4-25 Base case 1 and improvement options – impact of detergent consumption on eutrophication over lifetime by product 59

Figure 4-26 Base case 1 and improvement options – impact of detergent consumption on LCC by product 59
Figure 4-27 Base case 2 and improvement options – impact of detergent consumption on eutrophication over lifetime by product 60
Figure 4-28 Base case 2 and improvement options – impact of detergent consumption on LCC by product 60
Figure 4-29 Base case 3 and improvement options – impact of detergent consumption on eutrophication over lifetime by product 61
Figure 4-30 Base case 3 and improvement options – impact of detergent consumption on LCC by product 61
Figure 4-31 Base case 4 and improvement options – impact of detergent consumption on eutrophication over lifetime by product 62
Figure 4-32 Base case 4 and improvement options – impact of detergent consumption on LCC by product 62
Figure 4-33 Base case 5 and improvement options – impact of detergent consumption on eutrophication over lifetime by product 63
Figure 4-34 Base case 5 and improvement options – impact of detergent consumption on LCC by product 63
Figure 4-35 Base case 6 and improvement options – impact of detergent consumption on eutrophication over lifetime by product 64
Figure 4-36 Base case 6 and improvement options – impact of detergent consumption on LCC by product 64
Figure 4-37 Base case 1 and improvement options – impact of use intensity on total energy over lifetime by product 67
Figure 4-38 Base case 1 and improvement options – impact of use intensity on LCC by product 68
Figure 4-39 Base case 2 and improvement options – impact of use intensity on total energy over lifetime by product 68
Figure 4-40 Base case 2 and improvement options – impact of use intensity on LCC by product 69
Figure 4-41 Base case 3 and improvement options – impact of use intensity on total energy over lifetime by product 69
Figure 4-42 Base case 3 and improvement options – impact of use intensity on LCC by product 70
Figure 4-43 Base case 4 and improvement options – impact of use intensity on total energy over lifetime by product 70
Figure 4-44 Base case 4 and improvement options – impact of use intensity on LCC by product 71
Figure 4-45 Base case 5 and improvement options – impact of use intensity on total energy over lifetime by product 71

Figure 4-46 Base case 5 and improvement options – impact of use intensity on LCC by product 72
Figure 4-47 Base case 6 and improvement options – impact of use intensity on total energy over lifetime by product 72
Figure 4-48 Base case 6 and improvement options – impact of use intensity on LCC by product 73
Figure 4-49 Base case 1 and improvement options – impact of lifetime on total energy over lifetime by product 74
Figure 4-50 Base case 1 and improvement options – impact of lifetime on LCC by product 75
Figure 4-51 Base case 2 and improvement options – impact of lifetime on total energy over lifetime by product 75
Figure 4-52 Base case 2 and improvement options – impact of lifetime on LCC by product 76
Figure 4-53 Base case 3 and improvement options – impact of lifetime on total energy over lifetime by product 76
Figure 4-54 Base case 3 and improvement options – impact of lifetime on LCC by product 77
Figure 4-55 Base case 4 and improvement options – impact of lifetime on total energy over lifetime by product 77
Figure 4-56 Base case 4 and improvement options – impact of lifetime on LCC by product 78
Figure 4-57 Base case 5 and improvement options – impact of lifetime on total energy over lifetime by product 78
Figure 4-58 Base case 5 and improvement options – impact of lifetime on LCC by product 79
Figure 4-59 Base case 6 and improvement options – impact of lifetime on total energy over lifetime by product 79
Figure 4-60 Base case 6 and improvement options – impact of lifetime on LCC by product 80
Figure 4-61 Base case 1 and improvement options – impact of electricity rate on LCC by product 81
Figure 4-62 Base case 1 and improvement options – impact of water rate on LCC by product 82
Figure 4-63 Base case 1 and improvement options – impact of detergent rate on LCC by product 82
Figure 4-64 Base case 2 and improvement options – impact of electricity rate on LCC by product 83
Figure 4-65 Base case 2 and improvement options – impact of water rate on LCC by product 83

Figure 4-66 Base case 2 and improvement options – impact of detergent rate on LCC by product 84
Figure 4-67 Base case 3 and improvement options – impact of electricity rate on LCC by product 84
Figure 4-68 Base case 3 and improvement options – impact of water rate on LCC by product 85
Figure 4-69 Base case 3 and improvement options – impact of detergent rate on LCC by product 85
Figure 4-70 Base case 4 and improvement options – impact of electricity rate on LCC by product 86
Figure 4-71 Base case 4 and improvement options – impact of water rate on LCC by product 86
Figure 4-72 Base case 4 and improvement options – impact of detergent rate on LCC by product 87
Figure 4-73 Base case 5 and improvement options – impact of electricity rate on LCC by product 87
Figure 4-74 Base case 5 and improvement options – impact of water rate on LCC by product 88
Figure 4-75 Base case 5 and improvement options – impact of detergent rate on LCC by product 88
Figure 4-76 Base case 6 and improvement options – impact of electricity rate on LCC by product 89
Figure 4-77 Base case 6 and improvement options – impact of water rate on LCC by product 89
Figure 4-78 Base case 6 and improvement options – impact of detergent rate on LCC by product 90
Figure 4-79 Base case 1 and improvement options – impact of purchase price on LCC by product 91
Figure 4-80 Base case 2 and improvement options – impact of purchase price on LCC by product 91
Figure 4-81 Base case 3 and improvement options – impact of purchase price on LCC by product 92
Figure 4-82 Base case 4 and improvement options – impact of purchase price on LCC by product 92
Figure 4-83 Base case 5 and improvement options – impact of purchase price on LCC by product 93
Figure 4-84 Base case 6 and improvement options – impact of purchase price on LCC by product 93
Figure 4-85 Base case 1 and improvement options – impact of discount rate on LCC by product 94

Figure 4-86 Base case 2 and improvement options – impact of discount rate on LCC by product 95
Figure 4-87 Base case 3 and improvement options – impact of discount rate on LCC by product 95
Figure 4-88 Base case 4 and improvement options – impact of discount rate on LCC by product 96
Figure 4-89 Base case 5 and improvement options – impact of discount rate on LCC by product 96
Figure 4-90 Base case 6 and improvement options – impact of discount rate on LCC by product 97
Figure 4-91 Base case 1 and improvement options – impact of combined parameters on total energy over lifetime by product 100
Figure 4-92 Base case 1 and improvement options – impact of combined parameters on LCC by product 100
Figure 4-93 Base case 2 and improvement options – impact of combined parameters on total energy over lifetime by product 101
Figure 4-94 Base case 2 and improvement options – impact of combined parameters on LCC by product 101
Figure 4-95 Base case 3 and improvement options – impact of combined parameters on total energy over lifetime by product 102
Figure 4-96 Base case 3 and improvement options – impact of combined parameters on LCC by product 102
Figure 4-97 Base case 4 and improvement options – impact of combined parameters on total energy over lifetime by product 103
Figure 4-98 Base case 4 and improvement options – impact of combined parameters on LCC by product 103
Figure 4-99 Base case 5 and improvement options – impact of combined parameters on total energy over lifetime by product 104
Figure 4-100 Base case 5 and improvement options – impact of combined parameters on LCC by product 104
Figure 4-101 Base case 6 and improvement options – impact of combined parameters on total energy over lifetime by product 105
Figure 4-102 Base case 6 and improvement options – impact of combined parameters on LCC by product 105

List of tables

Table 2-1	Proposals for eco-design requirements by product category	12
Table 2-2	Proposed GPP energy performance levels	14
Table 2-3	Market inputs of the policy analysis model	15
Table 2-4	Market data of the policy analysis model	16
Table 2-5	BAU scenario outcomes: market data, energy consumption and expenditure	19
Table 2-6	LLCC improvement option for each base case	22
Table 2-7	LLCC scenario outcomes and comparison with BAU scenario: market data, energy consumption and expenditure	23
Table 2-8	BAT improvement option for each base case	26
Table 2-9	BAT scenario outcomes and comparison with BAU scenario: market data, energy consumption and expenditure	27
Table 2-10	BAT improvement option for each base case	30
Table 2-11	MEPS scenario outcomes and comparison with BAU scenario: market data, energy consumption and expenditure	31
Table 4-1	Electricity consumption range for the sensitivity analysis	45
Table 4-2	Water consumption range for the sensitivity analysis	45
Table 4-3	Detergent consumption range for the sensitivity analysis	45
Table 4-4	Use intensity range for the sensitivity analysis	65
Table 4-5	Electricity consumption range corresponding to the use intensity range for the sensitivity analysis	65
Table 4-6	Water consumption range corresponding to the use intensity range for the sensitivity analysis	66
Table 4-7	Detergent consumption range corresponding to the use intensity range for the sensitivity analysis	66
Table 4-8	Product lifetime ranges for the sensitivity analysis	73
Table 4-9	Electricity rate ranges for the sensitivity analysis	80
Table 4-10	Water and detergent rates ranges for the sensitivity analysis	81
Table 4-11	Purchase prices ranges for the sensitivity analysis	90
Table 4-12	Discount rate range for the sensitivity analysis	94
Table 4-13	Use intensity range for the combined sensitivity analysis	98
Table 4-14	Product lifetime ranges for the combined sensitivity analysis	98
Table 4-15	Electricity rate ranges for the combined sensitivity analysis	98
Table 4-16	Water and detergent rates ranges for the combined sensitivity analysis	98

Table 4-17 Purchase price ranges for the combined sensitivity analysis 99
Table 4-18 Discount rate range for the combined sensitivity analysis 99

1 Introduction: Objective of Task 8

This task summarises the previous tasks and looks at suitable policy means to achieve the potential reduction in environmental impacts identified. Among the policy options to be considered are implementing Least Life Cycle Cost (LLCC) as a minimum and Best Available Technology (BAT) as a promotional target, using legislative or voluntary agreements, labelling public procurement, and other incentives.

The policy options considered and the conclusions are the opinions of the project team and do not represent the view of the European Commission. Unlike chapters 1-7, which will serve as the baseline data for future work (impact assessment, further discussions in the Consultation Forum, and possibly development of implementing measures) to be conducted by the European Commission, this chapter simply serves as a summary of policy implications as seen by the project team. Some parts of this chapter may be analysed in greater detail at the impact assessment stage.

The task draws up scenarios for the period 2010–2030 quantifying the improvements that can be achieved with respect to a Business-as-Usual (BAU) scenario, compares the outcomes with EU energy and environmental targets.

It makes an estimate of the impact on consumers and industry as described in Annex 2 of the Directive, explicitly describing and taking into account the typical design cycle (platform change) in a product sector as well as the cost of redesign necessary to apply the policy recommendations of Task 8. Finally, in a sensitivity analysis of the main parameters it studies the robustness of the outcomes.

In addition, an analysis of which significant impacts may have to be measured under possible implementing measures, and what measurement methods would need to be developed or adapted is provided.

2 Policy and scenario analysis

This section presents suggestions of policy options and a scenario analysis for the period 2010-2030. The scenarios quantify the improvements that can be achieved in comparison with a BAU (Business-As-Usual) scenario and compare the outcomes with EU environmental targets.

2.1 Scope

The policy analysis should identify policy option(s) considering the outcomes of all previous tasks. Notably the options should:

- Be based on the exact product definitions in Task 1 as modified/confirmed by the other tasks;
- Provide measurement requirements, including test standards and/or methods;
- Where appropriate, apply existing standards or propose needs/generic requirements for harmonised standards to be developed;
- Provide eco-design requirements, such as minimum (or maximum) requirements, considering the sensitivity analysis carried out in this Task;
- Be complemented, where appropriate, with (dynamic) labelling and benchmark categories linked to possible incentives relating to public procurement or direct and indirect fiscal instruments;
- Consider possible self-regulation, such as voluntary agreement or sectoral benchmark initiatives.

2.2 Generic eco-design requirements

Generic eco-design requirements aim at improving the environmental performance of products, focusing on significant environmental aspects thereof without setting limit values. According to Ecodesign Directive 2009/125/EC they method must be applied when it is not appropriate to set limit values for the product group under examination.

Generic eco-design requirements for professional dishwashers may enable the customer to know more about the products on the market, in order to allow easier comparison.

2.2.1 Need for the definition of a standard programme

Similarly to the recent Regulation for household dishwashers (N°1016/2010), also for professional dishwashers a ‘standard programme’ should be defined. Thus, for the calculation of the energy consumption and other parameters for professional dishwashers, a typical cycle which cleans typically soiled washware (hereafter standard cleaning cycle) shall be used within each dishwasher category. This cycle shall be clearly understandable by the user and as much as possible representative for the main customer segments for each dishwasher category. Further, it shall be clearly identifiable on the programme selection device of the professional dishwasher or the professional dishwasher display, if any, or both, and named ‘standard programme’ and shall be set as the default cycle for professional dishwashers equipped with automatic programme selection or any function for automatically selecting a cleaning programme or maintaining the selection of a programme.

2.2.2 Information requirements

Further, the **booklet of instructions** should provide information on:

- the standard cleaning cycle referred to as ‘standard programme’, which would be the most energy and water efficient programme for normally soiled washware.

- Power consumption of the operating modes, left-on or ready-to-use modes, off modes, etc.
- Indicative information on the main characteristics of the different programmes available (energy and water efficiency, temperature, time, etc.).

This information would not be sufficient to achieve large savings on its own. Taking into account the fact that dishwashers are frequently operated by untrained personnel, the development of **user guided programme menus** directly indicating the above information could further support changing the user behaviour. Making information about energy consumption available on the internet and in sales brochures would be another approach (e.g. basic information on resource efficient dishwashing processes). In parallel, harmonised information could be provided by the European Commission, such as:

a) Examples for best practice.

b) Overview on consumption values and benchmarks of appliances currently being on the market (based on a standardised measurement method).

c) Life cycle costs calculator which can be individually adapted according to the in-situ parameters.

However, precondition for implementing these generic eco-design requirements is a harmonised measurement standard which is currently not available. It would considerably help manufacturers in establishing the ecological profile of their products in a harmonised and understandable way (cf. Section 2.3.1).

2.2.3 Detergent consumption

As shown in Task 5, detergent consumption can have important environmental impacts, especially on eutrophication potential. In this study, detergents have been treated for the most part indirectly, since detergent consumption by dishwashers is closely linked to water consumption. Improvement options such as automatic detergent dispensing were not considered among the most relevant for professional machines. Besides, the washing process is a complex balance between the duration of the process, the strength of the detergent used, the quantity of water consumed and the temperature of the process. In the frame of the study, a typical temperature of process, a typical time and a typical detergent had been considered in order to study the machines from an energy and water performance perspective.

Nevertheless, different detergent types may have different levels of environmental impact. Some new detergents such as enzymatic detergents may allow a slightly lower washing temperature, and thus lower energy consumption, than regular detergents. Low-temperature detergents were analysed as an improvement option in the Lot 14 preparatory study on domestic dishwashers. If such detergents establish themselves in the market, they should be

considered for promotional measures (e.g. **recommendations on European Ecolabel for detergents**).

In general, lower temperatures might imply larger doses or another composition of detergents in order to maintain the same wash performance. A new measurement standard and performance requirements should take these relationships into account.

It is commonly considered that misuse of detergent is more likely to involve over-dosage than under-dosage and would thus exacerbate negative environmental impacts. Optimum detergent dosage depends on a range of factors including detergent formulation, water hardness, temperature, as well as filling and soiling. Although consumer behaviour is partly beyond the scope of eco-design, **better information on optimum dosage** could be provided to users.

Finally, it should be noted that especially for large dishwashing appliances, the detergent service and supply (cleaners system) is provided by third party companies. Thus, **green procurement requirements for detergents** could also be included in the criteria to award the service contract to the best companies.

2.2.4 Water consumption

Results from previous tasks indicate that the consumption of external steps (manually pre-soaking and pre-cleaning of the dishes; manually cleaning of the dishwashing machines after the cycles) might be rather significant with regard to the overall consumption of the dish-washing process. For example, the water consumption in the external pre-cleaning phase for category 4 (utensil / pot dishwashers) is with around eight litres hot water per item 5 to 8 times higher compared to the water consumption within the machine (cf. Task 6).

Thus, in order to give incentive to reduce the overall water consumption of dishwashing, the inclusion of the whole process from dirty to clean (including the pre-soak and pre-cleaning phase) would be rather desirable for all dishwasher categories with special focus on utensil / pot dishwashers. However, the water consumption for those manual process steps is strongly dependent on the specific user behaviour and cannot be influenced by the technology of the dishwashing machine itself. Further, there is no standard measurement method and thus no reliable data to record the average consumption of those external processes. For those reasons, within Lot 24 we excluded the manually process steps outside the dishwashing machines from the scope of the study.

However, there might be prepared generic eco-design measures regarding the overall water consumption, e.g. a **linkage to the use of efficient pre-rinse valves.** For example, under the new products to be regulated under the Canadian Energy Efficiency Act[1] inter alia are

[1] Source: http://oee.nrcan.gc.ca/regulations/home_page.cfm

pre-rinse spray valves.[2] Further, experiences and conclusions might also be drawn from a current EU pilot study on sanitary tapware (taps and showerheads)[3].

2.3 Specific eco-design requirements

Specific eco-design requirements aim at improving a selected environmental aspect of the product. According to Ecodesign Directive 2009/125/EC, they may take the form of requirements for reduced consumption of a given resource, such as a limit on the use of a resource in the various stages of an product's life cycle, as appropriate (such as a limit on water consumption in the use phase or on the quantities of a given material incorporated in the product or a requirement for minimum quantities of recycled material).

Generally, in the white goods sector energy (and water) efficiency has increased substantially in the past thirty years thanks to implementation of the most easy and straightforward technical solutions. The required effort and investment per unit of efficiency gained are now becoming larger and manufacturers may now tend to slow down their efforts in innovation and research because of this, especially in the household appliances sector. For professional appliances, the possible improvement potential seems to be more unclear as currently no standardised comparison between two different machines is possible in the EU[4] and short cycle times have been a dominating factor for product development so far. However, a common measurement standard is prerequisite for the implementation of efficiency requirements and labelling programmes, which would allow the end user to benefit from a relevant methodology providing him with reliable data and fair assessment of product performance. Therefore, the influence of the customers on the market development would be highly increased as their choices would be eased and justified by this initiative.

2.3.1 Need for the development of harmonised standards and definitions

Standard measurement methods are necessary to enable the setting of performance requirements. Today, there are no standards officially and widely used in the EU for the product categories in the scope of Lot 24, part professional dishwashers. This lack of standards is also a reason why consumption data was hard to obtain and remains uncertain

---

[2] These devices use a spray of water to remove food waste from dishes prior to cleaning in a commercial dishwasher. They are usually placed at the entrance to a commercial dishwasher or may also be located over a sink, in conjunction with a faucet fixture.

[3] This study is being carried out by the Joint Research Centre's Institute for Prospective Technological Studies (JRC-IPTS) in cooperation with the AEA consultancy for the European Commission's DG Environment. The purpose of this pilot project is to develop a joint evidence base for the development of the three different policy instruments (Ecolabel, GPP and Ecodesign) in the area of water using products (taps and showerheads). http://susproc.jrc.ec.europa.eu/ecotapware/index.html

[4] Exemption: In practice, for under-counter water change dishwashers (category 1), the EN 50242:2008-09 and EN 60436:2008-09 methods can currently be applied.

within this study. Discussions are currently ongoing at the EU level within the CENELEC Technical Committee TC 59X.

A harmonised testing methodology should take into account and define several parameters such as standard dishes in terms of size, soiling, heat capacity and dry-on time, rated cleaning capacity (maximum amount that can be cleaned in one cycle), definition of a test cycle (inter alia selection of programme), type (formulation) and dosage of detergent and rinse aid, the inclusion or not of the first filling, as well as several environmental parameters (ambient temperature and humidity, water temperature and hardness).

Relevant parameters to measure when establishing standards for professional dishwashers include:

- cleaning results and hygienic performance;
- drying performance;
- energy consumption/efficiency (in different operation modes);
- water consumption/efficiency;
- detergent/rinse aid consumption (defined quality);
- cycle time (more important for professional appliances than for household ones);
- noise level[5];
- testing under real-life use conditions (continuous vs. discontinuous cleaning process, partial load operation, use of other than standard programme).

The fact that multiple parameters have to be taken into account is crucial as some of them may conflict with each other. For instance, water efficiency could be improved by reducing the rinsing/drying performance, leading to non-satisfactory results of the washing process. Therefore, if levels of resources and consumables consumption are to be set, they should be associated with corresponding cleaning or drying performance levels.

In the commercial and industrial sectors, customers have different needs and the appliances are often customised to the demand of the customer. The goal of the standardisation process would ideally be to find one or several standard programme(s) that can be run on the machine to test it and measure its performance level, even if the washing programme wanted and used by the customer is different.

Along with the standards measurement methods, a tolerance level (taking into account the errors during the performance measurement) should be properly defined according to the product category specificities.

[5] Only in the case it is not yet covered under safety legislation.

2.3.2 Labelling requirements

Based on a harmonised standard measurement method, which would need to be developed first (see previous section), an energy labelling scheme could promote a voluntary shift in the market. Unlike performance requirements (which aim at removing the worst-performing products from the market), a label would help the costumers to pull the market towards the best-performing products via their purchase decisions. It should therefore be seen as a complementary tool to minimum requirements. To be fully effective, such a scheme should be mandatory so that all products on the market can be fairly compared.

It would be more appropriate for the smaller machines (categories 1 to 3) considered in this study because customers of larger industrial machines tend to be more sophisticated and are provided with a more detailed level of information at the time of purchase, while retailers have even more incentive to provide high efficiency machines than retailers of the smaller machines. This does not, however, mean that a labelling programme could not be implemented for heavy duty machines.

Energy consumption is intricately linked with water and detergent consumption and washing performance. Although energy consumption is the most appropriate basis for classification, any labelling scheme should take a holistic approach either by setting reference water and detergent consumption and reference washing performance associated with the energy consumption measured, or by providing clear and transparent information for all these other variables as is currently done for household dishwashers (the label indicates the energy and water consumption and the cleaning performance, see Figure 2-1). These issues have been discussed in detail earlier in the study.

The label itself could be similar in most respects to that used for household dishwashers:

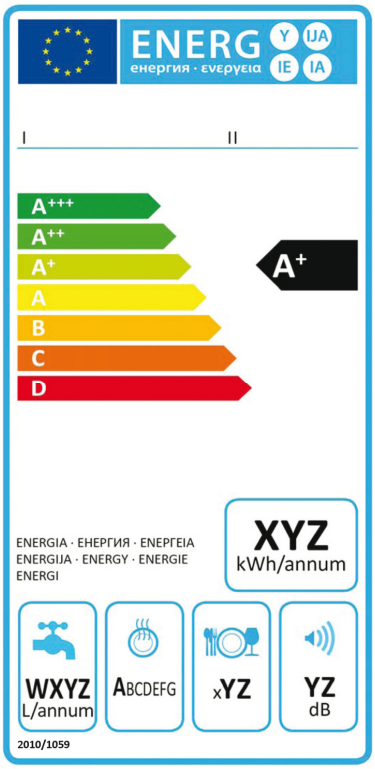


Figure 2-1 Domestic dishwashers label[6]

The following notes define the information to be included:

1. Supplier's name and name of model.
2. The energy efficiency class of the dishwasher, determined in accordance with future harmonised standards (cf. Section 2.3.1). The indicator letter should be placed at the same level as the relevant arrow. The classes would need to be revised every few years as machines become more efficient in order to maintain the incentive.
3. Specific energy consumption (kWh per cycle or 100 dishes).[7]
4. Specific water consumption (litres per cycle or 100 dishes).[7]
5. Drying efficiency.
6. Cleaning capacity (standard place settings) and cycle time, for the standard cleaning cycle.[8]
7. Airborne acoustical noise emissions expressed in dB(A) re 1 pW.
8. Option warm water supply available?

[6] EC 1059/2010 supplementing Directive 2010/30/EU with regard to energy labelling of household dishwashers.

[7] As professional dishwashing appliances are used very different according to the customer needs, data on annual consumption would not be very meaningful.

[8] Note: For efficiency calculations, real-life use should be taken into account (inter alia partial load).

The label for professional dishwashers in most respects could be similar to that one for household appliances. When drafting the labelling regulation for professional dishwashers it should be discussed whether a single labelling scheme could be applicable for all types of dishwashers (for instance undercounter dishwashers (water-change and one-tank), conveyor-type dishwashers) in order to allow comparison of products.

Along with the pictograms on the label more detailed information should be provided in the product fiche / technical information of the professional dishwasher and shall be included in the product brochure or other literature provided with the product (cf. also Section 2.2).

Specific case of warm water supply

Warm water input was analysed as a general improvement option throughout this study. However, it was not identified as the LLCC or BAT option when it should have because it is an option that considerably depends on the infrastructure available and may not be relevant for all situations. As a result, this technological choice cannot be imposed on a general basis but naturally the use of alternative energy sources should be considered by end users when relevant.

The Task 7 results clearly show that with the model used (a 90% efficiency gas boiler used to externally heat the water), the supply of warm water can be a beneficial option, both from the environmental and economic points of view, given the lower needs in primary energy (it is the virtual BAT and LLCC option for BC 1 to 4). It relies entirely on the fact that the water used in the washing process is heated outside the machines by a more efficient process than the electric resistance within the machine. It was assumed that this was available for no additional investment costs in comparison with the base case.

Thus it is important that the labelling scheme also enables the customer to choose between two products with a different heating system the one that will be the most economic for him.

2.3.3 Benchmarking

According to Ecodesign Directive 2009/125/EC, in addition to the legally binding requirements, indicative benchmarks for best available technologies should be identified to ensure the wide availability and easy accessibility of information on the lifecycle environmental performance of professional dishwashers.

The technical, environmental and economic analysis of preparatory study Lot 24 has already identified the best-performing products and technology available on the market (cf. Task 6). However, due to lack of standardised performance measurement data, this analysis should be renewed as soon as a harmonized test standard is applied. Thus, at the time of entry into force of a Regulation on professional dishwashers, data on best available technology on the market in terms of their energy efficiency, energy and water consumption, cleaning and drying efficiency and airborne acoustical noise emissions should be available and published in the Annexes of the Ecodesign Regulation.

Benchmarks are non-binding for manufacturers but would allow the evaluation of the environmental performance achieved by a new product against the best-performing products available on the EU market.

2.3.4 Minimum energy efficiency requirements

Minimum eco-design requirements on energy efficiency may be a relevant option to remove the least efficient appliances from the market and to push it towards more efficient appliances. Indicative levels are suggested in this section, based on the analysis made in previous tasks. However, because of the current lack of available and harmonised data on product performance, **these levels should be considered rather with caution and discussed again once harmonised tests, measurement methods and benchmarks have been defined, as suggested above.** For example, the cleaning performance was not assessed in the frame of the study but will be a key parameter to measure in a standardised process, in order to allow fair comparison of products. **Besides, as shown by the sensitivity analysis (see Section 4), the results are highly dependent on input parameters such as the electricity rate or the intensity of use.** As EU average parameters were estimated to carry out the environmental and economic analysis, the results may not be representative for all situations. **Finally, as an additional delay will be required before the finalisation of the standards, the market may continue to evolve and more ambitious targets could be set when the levels of eco-design requirements are decided.**

The current definition and quantification of the minimum performance levels may have to be completed or amended in accordance with the future harmonised standards. Indeed, the washing process is a complex balance between parameters that compete with each other (e.g. energy efficiency and cleaning performance). In the framework of this study, only basic quantification of the energy aspect has been possible, so the levels for eco-design requirements suggested will refer to these. In reality, more parameters will be needed (see Section 2.3.1 for more details).

Eco-design requirements could be considered in the form of “Tier 1” and “Tier 2” requirements. Tier 1 would apply from 2014 onwards, assuming a standard measurement method can be developed by the relevant organisation (CENELEC) by 2012. Tier 2 would apply from 2017 onwards, and would enable more ambitious targets to be kept as a long-term goal (e.g. heat pump efficiency levels for dryers). According to the Ecodesign Directive, minimum requirements should not exceed the LLCC level, to avoid creating difficulties for consumers. However, by 2017 new technologies will become available so that today’s BAT level will no longer be BAT in 2017. If they do not, then Tier 2 would not be implemented. The advantage of defining Tier 2 now would be that agents in the market today will have a clear signal of the direction the market is headed towards.

The proposals for eco-design requirements have been made based on the LLCC and BAT analysis in Task 7:

- For BC 1: the base case (BC) product is the LLCC. However, the improvement option M 4.2 'High efficient pumps and motors' reduces the primary energy by 3% for a small additional cost over the lifetime (1%, approximately 150 Euro). Thus it is proposed to adopt such a performance level for Tier 1.
- For BC 2: option M 4.2 'High efficient pumps and motors' was identified as the LLCC option and this energy performance level is proposed as a Tier 1 target.
- For BC 3 and 4: the base case product was identified as the LLCC option. However, similarly to BC 1, some options enable to lower the environmental impacts for reduced additional costs. Therefore, performance level of the option M 4.2 'High efficient pumps and motors' is also proposed as a Tier 1, and level of option M 3.1.1 'Waste water heat exchanger' is proposed for Tier 2.
- For BC 5: option M1.5 'Auxiliary rinsing' was identified as the LLCC and its level of performance is consequently suggested as a Tier 1 target.
- For BC 6: the BA product is the LLCC but might be too ambitious as a Tier 1 target. The performance level of the option M 4.2 'High efficient pumps and motors' is proposed for Tier 1 as it enables important energy savings for a reduced life cycle cost.

For some base cases, no Tier 2 is suggested as a further step in efficiency does not appear very cost effective (according to the outcomes of Task 7, which are based on average EU parameters).

Table 2-1 summarises the performance levels suggested as eco-design requirements for professional dishwashers.

Table 2-1 Proposals for eco-design requirements by product category[9]

Base case	Capacity	Tier 1 (2014)	Tier 2 (2017)
1. Undercounter water-change	200 dishes/hour	M 4.2 High efficient pumps and motors 4.17 kWh 76 litres	-
2. Undercounter one-tank	550 dishes/hour	M 4.2 High efficient pumps and motors 1.47 kWh 14.9 litres	-
3. Hood-type	860 dishes/hour	M 4.2 High efficient pumps and motors 1.56 kWh 14.9 litres	M 3.1.1 Waste water heat exchanger 1.44 kWh
4. Utensil/Pot	0.42 m^2 (rack area) 20 cycles per hour	M 4.2 High efficient pumps and motors 0.46 kWh 4.84 litres	M 3.1.1 Waste water heat exchanger 0.42 kWh
5. One-tank conveyor-type	1 750 dishes/hour	M 1.5 Auxiliary rinsing 1.76 kWh 11.44 litres	-
6. Multi-tank conveyor-type	3 600 dishes/hour	M 4.2 High efficient pumps and motors 1.76 kWh 10.2 litres	-

The performance levels indicated should be extrapolated for products with different capacities, according to rules that will need to be defined in the relevant standards.

The energy and water parameters in the table are quantified thanks to the parameters that were available within this study but in practice the harmonised standardisation process may result in other ways to measure product consumption and performance parameters.

The approach to checking compliance with the ecodesign requirements is based on self-declaration in the case of domestic dishwashing appliances. The information required should be measured according to harmonised standards. Once the harmonised standard has been defined, a detailed market review of the various product categories should be done to assess whether the proposed ecodesign requirements are still relevant or should be amended.

2.3.5 Verification procedure for market surveillance purposes

Member States shall apply a verification procedure when performing the market surveillance checks for compliance of products with the according requirements. In order to facilitate

[9] Energy and water consumption are given in operation mode for 100 dishes.

compliance checks, manufacturers should provide information in the technical documentation in so far as this information relates to the requirements laid down in the Regulation.

For comparison: for household dishwashers, the verification procedure for the purposes of checking conformity with the requirements, defines that authorities of the Member State shall test a single household dishwasher. If the measured parameters do not meet the values declared in the technical documentation file by the manufacturer within the range set out in the eco-design regulation, the measurements shall be carried out on three more household dishwashers. The arithmetic mean of the measured values of these three household dishwashers shall meet the requirements within the ranges defined in the regulation.

A similar approach is deemed relevant to the case of professional dishwashers: The usual procedure so far would be self-declaration with market surveillance. Framework Directive 2010/30/EG and the according implementation measures include that Member States shall test products and might require conformity in case of non-compliance; in case of recurrence the product might be taken off the market. However, practical experience e.g. from Germany[10] repeatedly shows that there are still great problems with the correct implementation of the energy labelling directive due to a lack of governmental controls and sanctions.

Based on this experience, suppliers of professional dishwashers could also be required to establish a more demanding approach. According to stakeholders' feedback, for domestic appliances a voluntary agreement (VA) enabling mutual testing between competitors is appropriate and works well; thus it could be adapted for professional appliances as well.

Basis would be sufficient technical documentation to assess the accuracy of the provided information (e.g. general description of the product, internal or independent tests reports). The information required should be measured according to harmonised standards. However, these standards are still under development at the time of the study at hand (see 2.3.1). Once the harmonised standard has been defined, a detailed market review of the various categories should be done to assess whether the minimum performance standards proposed are still relevant or should be amended.

2.3.6 Criteria for Green public procurement

Public procurement accounts for a large share of EU GDP and has a key role to play in market transformation by favouring products with the least environmental impact. Both environmental and cost criteria are important in any purchasing decision, and care must be taken that neither criterion is given undue weight. In the context of this study, an appropriate approach might be to propose more ambitious requirements for public procurement (oriented to the benchmarks, see 2.3.3) than the general eco-design requirements (see 2.3.4). Thus,

[10] According to tests of Deutsche Umwelthilfe, the provided tags and data tapes are often false or even not at all attached to the appliances. This concerns mainly air conditioning appliances being provided as special offer in the summer months in and built-in appliances (white goods) offered in kitchen studios and furniture stores (source: http://www.duh.de/energielabel.html).

all public buildings (e.g. hospitals, schools, etc.) could help drive the market towards more efficient appliances, as they represent a significant share of the markets concerned (in Task 2, Section 3.3.2, it is estimated that hospitals and other institutions account for 23% of units sold, a large proportion of which is likely to be in the public sector). Proposed levels are indicated in Table 2-2, again assuming that the needed standards are adopted in 2012.

Table 2-2 Proposed GPP energy performance levels[11]

Base case	Capacity	Tier 1 (2014)
1. Undercounter water-change	200 dishes/hour	BA product 3.96 kWh 76 litres
2. Undercounter one-tank	550 dishes/hour	M 3.1.1 Waste water heat exchanger 1.44 kWh
3. Hood-type	860 dishes/hour	M 3.1.1 Waste water heat exchanger 1.44 kWh
4. Utensil/Pot	0.42 m^2 (rack area) 20 cycles per hour	M 3.1.1 Waste water heat exchanger 0.425 kWh
5. One-tank conveyor-type	1 750 dishes/hour	M 2.1.1 Exhaust air heat exchanger 1.6 kWh
6. Multi-tank conveyor-type	3 600 dishes/hour	M 2.1.2 Exhaust air heat pump 1.5 kWh

Note: The most efficient and economically attainable solution depends on the respective cleaning capacity; thus the above table is only exemplary. Public authorities should orient their procurement activities according to the least life cycle costs, however, including an additional charge for future cost developments (e.g. energy prices) and external costs.

2.4 Policy scenario analysis

An Excel tool allowing estimates of the impacts of different scenarios was created and used in order to build the scenarios analysis (2010-2020, 2010-2025 and 2010-2030) in this section. In that respect, the tool was designed quite simply and relies on the following assumptions:

- The stock and sales estimates were obtained with an assumed annual growth rate of 1% for base cases 1-4 and 2% for base cases 5-6. Initial stock (year 2009) are extracted from the market data presented in Task 2.

[11] Energy and water consumption are given in operation mode for 100 dishes.

- The tool displays the expenditure (in Euro) and the primary energy (in Joule) related to the consumption of professional dishwashers, following different policy options. The primary energy displayed is not limited to the use phase, but takes into account the energy required over the whole lifetime (including manufacturing, distribution and end-of-life phases). The model is kept simple because the global energy consumption is allocated uniformly over the lifetime of the product even if in theory, this is only true for the use phase. Given the low shares of other life cycle phases in energy consumption (see Task 5), this assumption is considered acceptable to carry out this analysis as a more "realistic" modelling would make an insignificant difference to the overall results.
- Primary energy consumption was considered to be the most relevant and representative indicator to be modelled in the tool (see Task 7).
- Expenditure measures the yearly value of the entire market. It consists of the amount of money spent to buy the products (purchase price) which is taken into account entirely when the dishwasher is bought and of the operating costs (energy, water, detergent costs, maintenance and repair), which are split over the lifetime of the dishwasher.
- The model is built on a discrete basis (data given for each year).

In subsections, four scenarios are built: Business-as-Usual (BAU) scenario, which assumes that the products on the market do not include any improvement options in the future; Best Available Technology (BAT) scenario, which assumes that the BAT options are implemented in the near future for all product categories (ideally, that could be the target in the long term); Least Life Cycle Cost (LLCC) scenario, which assumes that the LLCC options are implemented in the near future: and Minimum Energy Performance Standard (MEPS) scenario, which will illustrate the influence of the proposals for eco-design requirements in Section 2.3.3. The BAT, LLCC and MEPS scenarios are also compared to the BAU scenario, in order to have an estimate of the improvement potential of the improvement options on a large scale. Most of the description in the sections below refers to 2025 for comparison.

The following inputs regarding the market data are used within the modelling tool:

Table 2-3 Market inputs of the policy analysis model

Category	Stock		Growth %/year	Lifetime (years)
	2009	2025		
BC1 Under-counter water change	207 223	242 985	1.0%	12
BC2 Under-counter one-tank	1 012 355	1 187 066	1.0%	8
BC3 Hood-type	482 728	566 037	1.0%	8
BC4 Utensil/Pot	19 309	22 641	1.0%	8
BC5 One-tank conveyor-type	68 425	93 933	2.0%	12
BC6 Multi-tank conveyor-type	18 015	24 731	2.0%	17

The replacement rate of products has been estimated to be inversely proportional to the dishwashers' lifetime. For example, 12.5% (1/8) of the stock of base cases 2, 3 or 4 is replaced each year. Table 2-4 presents the market data over time that result from the inputs.

Table 2-4 Market data of the policy analysis model

Year	Units	BC1	BC2	BC3	BC4	BC5	BC6
2009	Stock	207 223	1 012 355	482 728	19 309	68 425	18 015
	Sales	19 341	136 668	65 168	2 607	7 071	1 420
	Replaced	17 269	126 544	60 341	2 414	5 702	1 060
2010	Stock	209 295	1 022 479	487 555	19 502	69 794	18 375
	Sales	19 534	138 035	65 820	2 633	7 212	1 448
	Replaced	17 441	127 810	60 944	2 438	5 816	1 081
2011	Stock	211 388	1 032 703	492 431	19 697	71 189	18 743
	Sales	19 730	139 415	66 478	2 659	7 356	1 477
	Replaced	17 616	129 088	61 554	2 462	5 932	1 103
2012	Stock	213 502	1 043 030	497 355	19 894	72 613	19 118
	Sales	19 927	140 809	67 143	2 686	7 503	1 507
	Replaced	17 792	130 379	62 169	2 487	6 051	1 125
2013	Stock	215 637	1 053 461	502 329	20 093	74 065	19 500
	Sales	20 126	142 217	67 814	2 713	7 653	1 537
	Replaced	17 970	131 683	62 791	2 512	6 172	1 147
2014	Stock	217 793	1 063 995	507 352	20 294	75 547	19 890
	Sales	20 327	143 639	68 493	2 740	7 806	1 568
	Replaced	18 149	132 999	63 419	2 537	6 296	1 170
2015	Stock	219 971	1 074 635	512 425	20 497	77 058	20 288
	Sales	20 531	145 076	69 177	2 767	7 963	1 599
	Replaced	18 331	134 329	64 053	2 562	6 421	1 193
2016	Stock	222 171	1 085 382	517 550	20 702	78 599	20 694
	Sales	20 736	146 527	69 869	2 795	8 122	1 631
	Replaced	18 514	135 673	64 694	2 588	6 550	1 217
2017	Stock	224 393	1 096 235	522 725	20 909	80 171	21 107
	Sales	20 943	147 992	70 568	2 823	8 284	1 664
	Replaced	18 699	137 029	65 341	2 614	6 681	1 242
2018	Stock	226 637	1 107 198	527 953	21 118	81 774	21 530
	Sales	21 153	149 472	71 274	2 851	8 450	1 697
	Replaced	18 886	138 400	65 994	2 640	6 815	1 266
2019	Stock	228 903	1 118 270	533 232	21 329	83 410	21 960
	Sales	21 364	150 966	71 986	2 879	8 619	1 731
	Replaced	19 075	139 784	66 654	2 666	6 951	1 292
2020	Stock	231 192	1 129 452	538 564	21 542	85 078	22 399
	Sales	21 578	152 476	72 706	2 908	8 791	1 766
	Replaced	19 266	141 182	67 321	2 693	7 090	1 318
2021	Stock	233 504	1 140 747	543 950	21 758	86 779	22 847
	Sales	21 794	154 001	73 433	2 937	8 967	1 801
	Replaced	19 459	142 593	67 994	2 720	7 232	1 344
2022	Stock	235 839	1 152 154	549 389	21 975	88 515	23 304
	Sales	22 012	155 541	74 168	2 967	9 147	1 837
	Replaced	19 653	144 019	68 674	2 747	7 376	1 371

Year	Units	BC1	BC2	BC3	BC4	BC5	BC6
2023	Stock	238 197	1 163 676	554 883	22 195	90 285	23 770
	Sales	22 232	157 096	74 909	2 996	9 329	1 874
	Replaced	19 850	145 459	69 360	2 774	7 524	1 398
2024	Stock	240 579	1 175 313	560 432	22 417	92 091	24 246
	Sales	22 454	158 667	75 658	3 026	9 516	1 911
	Replaced	20 048	146 914	70 054	2 802	7 674	1 426
2025	Stock	242 985	1 187 066	566 037	22 641	93 933	24 731
	Sales	22 679	160 254	76 415	3 057	9 706	1 949
	Replaced	20 249	148 383	70 755	2 830	7 828	1 455
2026	Stock	245 415	1 198 937	571 697	22 868	95 812	25 225
	Sales	22 905	161 856	77 179	3 087	9 901	1 988
	Replaced	20 451	149 867	71 462	2 858	7 984	1 484
2027	Stock	247 869	1 210 926	577 414	23 096	97 728	25 730
	Sales	23 134	163 475	77 951	3 118	10 099	2 028
	Replaced	20 656	151 366	72 177	2 887	8 144	1 514
2028	Stock	250 348	1 223 035	583 188	23 327	99 682	26 244
	Sales	23 366	165 110	78 730	3 149	10 301	2 069
	Replaced	20 862	152 879	72 899	2 916	8 307	1 544
2029	Stock	252 851	1 235 265	589 020	23 561	101 676	26 769
	Sales	23 599	166 761	79 518	3 181	10 507	2 110
	Replaced	21 071	154 408	73 627	2 945	8 473	1 575
2030	Stock	255 380	1 247 618	594 910	23 796	103 709	27 305
	Sales	23 835	168 428	80 313	3 212	10 717	2 152
	Replaced	21 282	155 952	74 364	2 975	8 642	1 606

2.4.1 Business-as-Usual (BAU) scenario

The BAU scenario considers that the base case remains the only product sold on the market in the future: no improvement option or any other type of improvement are introduced on the market or purchased. In this model, it is consequently assumed that there is no phenomenon of continuous improvement of the products. This scenario is taken as a reference in order to compare the results with these of the BAT, LLCC and MEPS scenarios.

Figure 2-2 and Figure 2-3 show the breakdown by base case of energy consumption and expenditure over the period 2010-2025. BC 2 and BC 3 have the largest shares in energy consumption and expenditure but conveyor-types appliances (BC 5 and BC 6) also represent 32% of energy requirements and 21% of expenditure. Table 2-5 presents all the outcomes of the model.

In 2025, professional dishwashers would require 204.5 PJ of primary energy, and the total consumption over the period 2010-2025 represents 2 970 PJ. Professional dishwashers are expected to emit 132 600 $ktCO_2$ over the period 2010-2025. Regarding expenditure, 4 970

m€ are expected to be spent for professional dishwashers in 2025, and 72.8 b€[12] over the period 2010-2025.

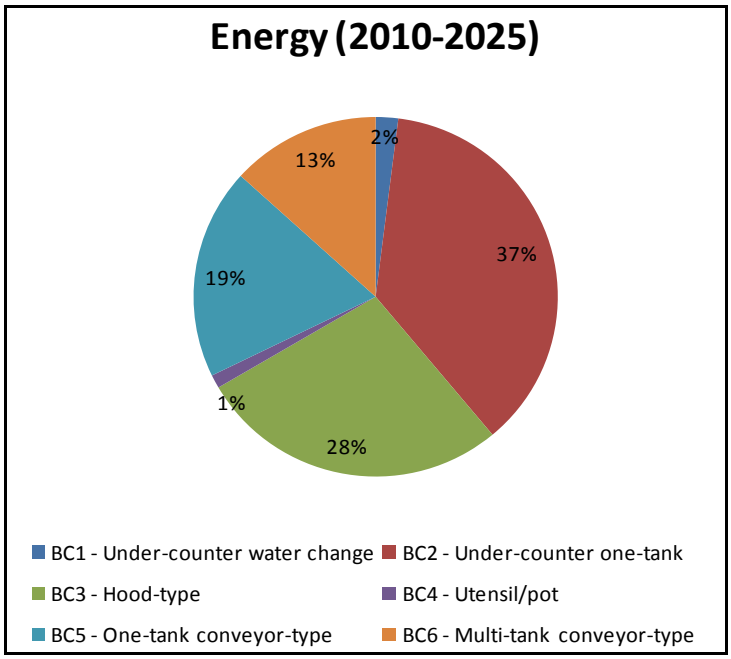


Figure 2-2 Breakdown of energy consumption of the six base cases over the period 2010-2025

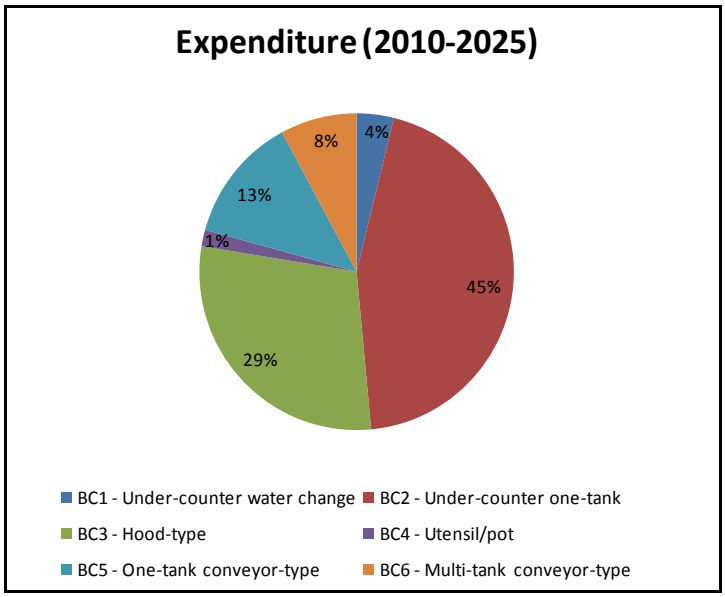


Figure 2-3 Breakdown of total expenditure of the six base cases over the period 2010-2025

[12] Billion Euros

Table 2-5 BAU scenario outcomes: market data, energy consumption and expenditure

Year	Units	BC1	BC2	BC3	BC4	BC5	BC6	Total
2009	Stock (units)	207 223	1 012 355	482 728	19 309	68 425	18 015	1 808 055
	Sales (units)	19 341	136 668	65 168	2 607	7 071	1 420	232 274
	Energy (TJ)	3 393.5	62 920.2	47 140.5	2 053.3	29 583.3	20 735.4	165 826.2
	Expenditure (m€)	159.5	1 866.0	1 212.4	70.1	492.1	302.4	4 102.6
2010	Stock (units)	209 295	1 022 479	487 555	19 502	69 794	18 375	1 827 000
	Sales (units)	19 534	138 035	65 820	2 633	7 212	1 448	234 682
	Energy (TJ)	3 427.4	63 549.4	47 611.9	2 073.9	30 175.0	21 150.1	167 987.6
	Expenditure (m€)	161.1	1 884.7	1 224.5	70.8	501.9	308.5	4 151.6
2011	Stock (units)	211 388	1 032 703	492 431	19 697	71 189	18 743	1 846 152
	Sales (units)	19 730	139 415	66 478	2 659	7 356	1 477	237 115
	Energy (TJ)	3 461.7	64 184.9	48 088.0	2 094.6	30 778.5	21 573.1	170 180.7
	Expenditure (m€)	162.7	1 903.6	1 236.8	71.5	512.0	314.7	4 201.2
2012	Stock (units)	213 502	1 043 030	497 355	19 894	72 613	19 118	1 865 512
	Sales (units)	19 927	140 809	67 143	2 686	7 503	1 507	239 575
	Energy (TJ)	3 496.3	64 826.7	48 568.9	2 115.5	31 394.1	22 004.6	172 406.1
	Expenditure (m€)	164.4	1 922.6	1 249.1	72.3	522.2	320.9	4 251.5
2013	Stock (units)	215 637	1 053 461	502 329	20 093	74 065	19 500	1 885 085
	Sales (units)	20 126	142 217	67 814	2 713	7 653	1 537	242 061
	Energy (TJ)	3 531.3	65 475.0	49 054.5	2 136.7	32 022.0	22 444.7	174 664.1
	Expenditure (m€)	166.0	1 941.8	1 261.6	73.0	532.6	327.4	4 302.4
2014	Stock (units)	217 793	1 063 995	507 352	20 294	75 547	19 890	1 904 871
	Sales (units)	20 327	143 639	68 493	2 740	7 806	1 568	244 573
	Energy (TJ)	3 566.6	66 129.7	49 545.1	2 158.1	32 662.4	22 893.6	176 955.4
	Expenditure (m€)	167.7	1 961.2	1 274.2	73.7	543.3	333.9	4 354.1
2015	Stock (units)	219 971	1 074 635	512 425	20 497	77 058	20 288	1 924 874
	Sales (units)	20 531	145 076	69 177	2 767	7 963	1 599	247 113
	Energy (TJ)	3 602.2	66 791.0	50 040.5	2 179.6	33 315.7	23 351.4	179 280.5
	Expenditure (m€)	169.3	1 980.8	1 287.0	74.5	554.2	340.6	4 406.4
2016	Stock (units)	222 171	1 085 382	517 550	20 702	78 599	20 694	1 945 097
	Sales (units)	20 736	146 527	69 869	2 795	8 122	1 631	249 679
	Energy (TJ)	3 638.3	67 458.9	50 540.9	2 201.4	33 982.0	23 818.5	181 640.0
	Expenditure (m€)	171.0	2 000.7	1 299.8	75.2	565.2	347.4	4 459.4

Year	Units	BC1	BC2	BC3	BC4	BC5	BC6	Total
2017	Stock (units)	224 393	1 096 235	522 725	20 909	80 171	21 107	1 965 541
	Sales (units)	20 943	147 992	70 568	2 823	8 284	1 664	252 274
	Energy (TJ)	3 674.6	68 133.5	51 046.4	2 223.5	34 661.6	24 294.8	184 034.4
	Expenditure (m€)	172.8	2 020.7	1 312.8	75.9	576.5	354.4	4 513.1
2018	Stock (units)	226 637	1 107 198	527 953	21 118	81 774	21 530	1 986 209
	Sales (units)	21 153	149 472	71 274	2 851	8 450	1 697	254 896
	Energy (TJ)	3 711.4	68 814.9	51 556.8	2 245.7	35 354.8	24 780.7	186 464.3
	Expenditure (m€)	174.5	2 040.9	1 326.0	76.7	588.1	361.4	4 567.5
2019	Stock (units)	228 903	1 118 270	533 232	21 329	83 410	21 960	2 007 104
	Sales (units)	21 364	150 966	71 986	2 879	8 619	1 731	257 546
	Energy (TJ)	3 748.5	69 503.0	52 072.4	2 268.1	36 061.9	25 276.4	188 930.3
	Expenditure (m€)	176.2	2 061.3	1 339.2	77.5	599.8	368.7	4 622.7
2020	Stock (units)	231 192	1 129 452	538 564	21 542	85 078	22 399	2 028 229
	Sales (units)	21 578	152 476	72 706	2 908	8 791	1 766	260 225
	Energy (TJ)	3 786.0	70 198.0	52 593.1	2 290.8	36 783.2	25 781.9	191 433.0
	Expenditure (m€)	178.0	2 081.9	1 352.6	78.2	611.8	376.0	4 678.6
2021	Stock (units)	233 504	1 140 747	543 950	21 758	86 779	22 847	2 049 586
	Sales (units)	21 794	154 001	73 433	2 937	8 967	1 801	262 933
	Energy (TJ)	3 823.8	70 900.0	53 119.0	2 313.7	37 518.8	26 297.5	193 973.0
	Expenditure (m€)	179.8	2 102.7	1 366.2	79.0	624.1	383.6	4 735.3
2022	Stock (units)	235 839	1 152 154	549 389	21 975	88 515	23 304	2 071 178
	Sales (units)	22 012	155 541	74 168	2 967	9 147	1 837	265 670
	Energy (TJ)	3 862.1	71 609.0	53 650.2	2 336.9	38 269.2	26 823.5	196 550.9
	Expenditure (m€)	181.6	2 123.7	1 379.8	79.8	636.5	391.2	4 792.7
2023	Stock (units)	238 197	1 163 676	554 883	22 195	90 285	23 770	2 093 008
	Sales (units)	22 232	157 096	74 909	2 996	9 329	1 874	268 437
	Energy (TJ)	3 900.7	72 325.1	54 186.7	2 360.2	39 034.6	27 359.9	199 167.3
	Expenditure (m€)	183.4	2 145.0	1 393.6	80.6	649.3	399.1	4 850.9
2024	Stock (units)	240 579	1 175 313	560 432	22 417	92 091	24 246	2 115 078
	Sales (units)	22 454	158 667	75 658	3 026	9 516	1 911	271 233
	Energy (TJ)	3 939.7	73 048.4	54 728.6	2 383.8	39 815.3	27 907.1	201 822.9
	Expenditure (m€)	185.2	2 166.4	1 407.6	81.4	662.3	407.0	4 909.9

Year	Units	BC1	BC2	BC3	BC4	BC5	BC6	Total
2025	Stock (units)	242 985	1 187 066	566 037	22 641	93 933	24 731	2 137 393
	Sales (units)	22 679	160 254	76 415	3 057	9 706	1 949	274 060
	Energy (TJ)	3 979.1	73 778.9	55 275.9	2 407.7	40 611.6	28 465.3	204 518.4
	Expenditure (m€)	187.1	2 188.1	1 421.6	82.2	675.5	415.2	4 969.7
2026	Stock (units)	245 415	1 198 937	571 697	22 868	95 812	25 225	2 159 953
	Sales (units)	22 905	161 856	77 179	3 087	9 901	1 988	276 917
	Energy (TJ)	4 018.9	74 516.6	55 828.6	2 431.8	41 423.8	29 034.6	207 254.3
	Expenditure (m€)	188.9	2 210.0	1 435.8	83.1	689.0	423.5	5 030.3
2027	Stock (units)	247 869	1 210 926	577 414	23 096	97 728	25 730	2 182 763
	Sales (units)	23 134	163 475	77 951	3 118	10 099	2 028	279 805
	Energy (TJ)	4 059.1	75 261.8	56 386.9	2 456.1	42 252.3	29 615.3	210 031.5
	Expenditure (m€)	190.8	2 232.1	1 450.2	83.9	702.8	432.0	5 091.7
2028	Stock (units)	250 348	1 223 035	583 188	23 327	99 682	26 244	2 205 825
	Sales (units)	23 366	165 110	78 730	3 149	10 301	2 069	282 724
	Energy (TJ)	4 099.7	76 014.4	56 950.8	2 480.6	43 097.3	30 207.6	212 850.5
	Expenditure (m€)	192.7	2 254.4	1 464.7	84.7	716.9	440.6	5 154.0
2029	Stock (units)	252 851	1 235 265	589 020	23 561	101 676	26 769	2 229 143
	Sales (units)	23 599	166 761	79 518	3 181	10 507	2 110	285 675
	Energy (TJ)	4 140.7	76 774.6	57 520.3	2 505.4	43 959.3	30 811.7	215 712.0
	Expenditure (m€)	194.7	2 276.9	1 479.3	85.6	731.2	449.4	5 217.1
2030	Stock (units)	255 380	1 247 618	594 910	23 796	103 709	27 305	2 252 719
	Sales (units)	23 835	168 428	80 313	3 212	10 717	2 152	288 658
	Energy (TJ)	4 182.1	77 542.3	58 095.5	2 530.5	44 838.5	31 428.0	218 616.9
	Expenditure (m€)	196.6	2 299.7	1 494.1	86.4	745.8	458.4	5 281.1
2010-2020	**Energy (TJ)**	**39 644**	**735 065**	**550 718**	**23 988**	**367 191**	**257 370**	**1 973 977**
	Expenditure (m€)	**1 864**	**21 800**	**14 164**	**819**	**6 108**	**3 754**	**48 509**
2010-2025	**Energy (TJ)**	**59 150**	**1 096 727**	**821 679**	**35 790**	**562 441**	**394 223**	**2 970 009**
	Expenditure (m€)	**2 781**	**32 526**	**21 133**	**1 223**	**9 355**	**5 750**	**72 767**
2010-2030	**Energy (TJ)**	**79 650**	**1 476 836**	**1 106 461**	**48 195**	**778 012**	**545 320**	**4 034 474**
	Expenditure (m€)	**3 744**	**43 799**	**28 457**	**1 646**	**12 941**	**7 954**	**98 541**

2.4.2 Least Life cycle Cost (LLCC) scenario

The LLCC scenario considers that all LLCC improvement options are implemented for each base case, as described in Task 7. The market modelling includes that from 2014, all products sold are equivalent to these LLCC options and no more base cases are sold (the market shift takes place in one single step). Table 2-6 reminds the LLCC options that were identified for each base case in Task 7. As a reminder, the warm water supply option was not eligible to be the LLCC option.

Table 2-6 LLCC improvement option for each base case

Base case	LLCC Improvement option
1. Undercounter water-change	Base case product
2. Undercounter one-tank	M 4.2 high efficient pumps and motors
3. Hood-type	Base case product
4. Utensil/Pot	Base case product
5. One-tank conveyor-type	M 1.5 Auxiliary rinsing
6. Multi-tank conveyor-type	BA product

Table 2-7 presents the outcomes of this scenario modelling. In 2025, the professional dishwashers market would require 187.4 PJ of primary energy (-8.4% compared to BAU), and would represent 4.93 b€ (-0.7% compared to BAU). Over the period 2010-2025, the total primary energy consumption would be 2 863 PJ (-3.6% compared to BAU), the total CO_2 emissions would account for 127 800 kt (-4 800 kt compared to BAU), and the total expenditure would be 73.2 b€ (+0.6% compared to BAU).

Table 2-7 LLCC scenario outcomes and comparison with BAU scenario: market data, energy consumption and expenditure

(1.5 = Auxiliary rinsing; 4.2 = High efficient pumps and motors)

Year	Indicator	BC1	BC2		BC3	BC4	BC5		BC6		Total	Difference with BAU	
		2010 BC	2010 BC	2014 4.2	2010 BC	2010 BC	2010 BC	2014 1.5	2010 BC	2014 BA product		Absolute	Relative
	Product price (€/unit)	3 200	3 500	3 955	4 700	10 500	15 000	16 950	45 000	75 600	-		
2009	Stock (units)	207 223	1 012 355	0	482 728	19 309	68 425	0	18 015	0	1 808 055	0.0	0.0%
	Sales (units)	19 341	136 668	0	65 168	2 607	7 071	0	1 420	0	232 274	0.0	0.0%
	Energy (TJ)	3 393.5	62 920.2	0.0	47 140.5	2 053.3	29 583.3	0.0	20 735.4	0.0	165 826.2	0.0	0.0%
	Expenditure (m€)	159.5	1 866.0	0.0	1 212.4	70.1	492.1	0.0	302.4	0.0	4 102.6	0.0	0.0%
2010	Stock (units)	209 295	1 022 479	0	487 555	19 502	69 794	0	18 375	0	1 827 000	0.0	0.0%
	Sales (units)	19 534	138 035	0	65 820	2 633	7 212	0	1 448	0	234 682	0.0	0.0%
	Energy (TJ)	3 427.4	63 549.4	0.0	47 611.9	2 073.9	30 175.0	0.0	21 150.1	0.0	167 987.6	0.0	0.0%
	Expenditure (m€)	161.1	1 884.7	0.0	1 224.5	70.8	501.9	0.0	308.5	0.0	4 151.6	0.0	0.0%
2011	Stock (units)	211 388	1 032 703	0	492 431	19 697	71 189	0	18 743	0	1 846 152	0.0	0.0%
	Sales (units)	19 730	139 415	0	66 478	2 659	7 356	0	1 477	0	237 115	0.0	0.0%
	Energy (TJ)	3 461.7	64 184.9	0.0	48 088.0	2 094.6	30 778.5	0.0	21 573.1	0.0	170 180.7	0.0	0.0%
	Expenditure (m€)	162.7	1 903.6	0.0	1 236.8	71.5	512.0	0.0	314.7	0.0	4 201.2	0.0	0.0%
2012	Stock (units)	213 502	1 043 030	0	497 355	19 894	72 613	0	19 118	0	1 865 512	0.0	0.0%
	Sales (units)	19 927	140 809	0	67 143	2 686	7 503	0	1 507	0	239 575	0.0	0.0%
	Energy (TJ)	3 496.3	64 826.7	0.0	48 568.9	2 115.5	31 394.1	0.0	22 004.6	0.0	172 406.1	0.0	0.0%
	Expenditure (m€)	164.4	1 922.6	0.0	1 249.1	72.3	522.2	0.0	320.9	0.0	4 251.5	0.0	0.0%
2013	Stock (units)	215 637	1 053 461	0	502 329	20 093	74 065	0	19 500	0	1 885 085	0.0	0.0%
	Sales (units)	20 126	142 217	0	67 814	2 713	7 653	0	1 537	0	242 061	0.0	0.0%
	Energy (TJ)	3 531.3	65 475.0	0.0	49 054.5	2 136.7	32 022.0	0.0	22 444.7	0.0	174 664.1	0.0	0.0%
	Expenditure (m€)	166.0	1 941.8	0.0	1 261.6	73.0	532.6	0.0	327.4	0.0	4 302.4	0.0	0.0%
2014	Stock (units)	217 793	1 063 995	0	507 352	20 294	75 547	0	19 890	0	1 904 871	0.0	0.0%
	Sales (units)	20 327	0	143 639	68 493	2 740	0	7 806	0	1 568	244 573	0.0	0.0%
	Energy (TJ)	3 566.6	66 129.7	0.0	49 545.1	2 158.1	32 662.4	0.0	22 893.6	0.0	176 955.4	0.0	0.0%
	Expenditure (m€)	167.7	1 458.5	568.1	1 274.2	73.7	426.2	132.3	263.4	118.5	4 482.6	128.6	3.0%
2015	Stock (units)	219 971	930 996	143 639	512 425	20 497	69 251	7 806	18 720	1 568	1 924 874	0.0	0.0%
	Sales (units)	20 531	0	145 076	69 177	2 767	0	7 963	0	1 599	247 113	0.0	0.0%
	Energy (TJ)	3 602.2	57 863.5	8 337.2	50 040.5	2 179.6	29 940.5	3 013.1	21 546.9	1 154.8	177 678.5	-1 602.0	-0.9%
	Expenditure (m€)	169.3	1 276.2	761.8	1 287.0	74.5	390.7	174.8	247.9	136.4	4 518.5	112.2	2.5%
2016	Stock (units)	222 171	796 666	288 715	517 550	20 702	62 830	15 769	17 527	3 167	1 945 097	0.0	0.0%
	Sales (units)	20 736	0	146 527	69 869	2 795	0	8 122	0	1 631	249 679	0.0	0.0%
	Energy (TJ)	3 638.3	49 514.6	16 757.8	50 540.9	2 201.4	27 164.2	6 086.5	20 173.3	2 332.8	178 409.8	-3 230.2	-1.8%
	Expenditure (m€)	171.0	1 092.0	957.5	1 299.8	75.2	354.4	218.1	232.1	154.7	4 554.9	95.6	2.1%

Year	Indicator	BC1	BC2		BC3	BC4	BC5		BC6		Total	Difference with BAU	
		2010 BC	2010 BC	2014 4.2	2010 BC	2010 BC	2010 BC	2014 1.5	2010 BC	2014 BA product		Absolute	Relative
2017	Stock (units)	224 393	660 994	435 242	522 725	20 909	56 280	23 891	16 309	4 798	1 965 541	**0.0**	**0.0%**
	Sales (units)	20 943	0	147 992	70 568	2 823	0	8 284	0	1 664	252 274	**0.0**	**0.0%**
	Energy (TJ)	3 674.6	41 082.3	25 262.6	51 046.4	2 223.5	24 332.4	9 221.3	18 772.2	3 534.3	179 149.5	**-4 884.9**	**-2.7%**
	Expenditure (m€)	172.8	906.1	1 155.1	1 312.8	75.9	317.5	262.3	216.0	173.3	4 591.8	**78.7**	**1.7%**
2018	Stock (units)	226 637	523 964	583 233	527 953	21 118	49 599	32 175	15 068	6 462	1 986 209	**0.0**	**0.0%**
	Sales (units)	21 153	0	149 472	71 274	2 851	0	8 450	0	1 697	254 896	**0.0**	**0.0%**
	Energy (TJ)	3 711.4	32 565.6	33 852.4	51 556.8	2 245.7	21 443.9	12 418.9	17 343.1	4 759.8	179 897.6	**-6 566.8**	**-3.5%**
	Expenditure (m€)	174.5	718.2	1 354.7	1 326.0	76.7	279.8	307.4	199.5	192.3	4 629.1	**61.6**	**1.3%**
2019	Stock (units)	228 903	385 565	732 705	533 232	21 329	42 784	40 625	13 801	8 159	2 007 104	**0.0**	**0.0%**
	Sales (units)	21 364	0	150 966	71 986	2 879	0	8 619	0	1 731	257 546	**0.0**	**0.0%**
	Energy (TJ)	3 748.5	23 963.7	42 528.2	52 072.4	2 268.1	18 497.7	15 680.4	15 885.4	6 009.8	180 654.2	**-8 276.1**	**-4.4%**
	Expenditure (m€)	176.2	528.5	1 556.3	1 339.2	77.5	241.4	353.3	182.7	211.7	4 666.9	**44.2**	**1.0%**
2020	Stock (units)	231 192	245 781	883 672	538 564	21 542	35 834	49 244	12 510	9 890	2 028 229	**0.0**	**0.0%**
	Sales (units)	21 578	0	152 476	72 706	2 908	0	8 791	0	1 766	260 225	**0.0**	**0.0%**
	Energy (TJ)	3 786.0	15 275.8	51 290.7	52 593.1	2 290.8	15 492.5	19 007.1	14 398.5	7 284.9	181 419.4	**-10 013.6**	**-5.2%**
	Expenditure (m€)	178.0	336.9	1 759.9	1 352.6	78.2	202.2	400.2	165.6	231.5	4 705.2	**26.5**	**0.6%**
2021	Stock (units)	233 504	104 599	1 036 148	543 950	21 758	28 744	58 036	11 192	11 655	2 049 586	**0.0**	**0.0%**
	Sales (units)	21 794	0	154 001	73 433	2 937	0	8 967	0	1 801	262 933	**0.0**	**0.0%**
	Energy (TJ)	3 823.8	6 501.1	60 140.8	53 119.0	2 313.7	12 427.3	22 400.3	12 882.0	8 585.4	182 193.4	**-11 779.6**	**-6.1%**
	Expenditure (m€)	179.8	143.4	1 965.5	1 366.2	79.0	162.2	448.0	148.2	251.7	4 743.9	**8.6**	**0.2%**
2022	Stock (units)	235 839	0	1 152 154	549 389	21 975	21 512	67 003	9 848	13 456	2 071 178	**0.0**	**0.0%**
	Sales (units)	22 012	0	155 541	74 168	2 967	0	9 147	0	1 837	265 670	**0.0**	**0.0%**
	Energy (TJ)	3 862.1	0.0	66 874.1	53 650.2	2 336.9	9 300.7	25 861.4	11 335.1	9 911.9	183 132.5	**-13 418.4**	**-6.8%**
	Expenditure (m€)	181.6	0.0	2 123.5	1 379.8	79.8	121.4	496.8	130.4	272.2	4 785.5	**-7.2**	**-0.2%**
2023	Stock (units)	238 197	0	1 163 676	554 883	22 195	14 136	76 149	8 477	15 293	2 093 008	**0.0**	**0.0%**
	Sales (units)	22 232	0	157 096	74 909	2 996	0	9 329	0	1 874	268 437	**0.0**	**0.0%**
	Energy (TJ)	3 900.7	0.0	67 542.9	54 186.7	2 360.2	6 111.6	29 391.8	9 757.2	11 265.0	184 516.1	**-14 651.2**	**-7.4%**
	Expenditure (m€)	183.4	0.0	2 144.7	1 393.6	80.6	79.7	546.6	112.2	293.2	4 834.1	**-16.8**	**-0.3%**
2024	Stock (units)	240 579	0	1 175 313	560 432	22 417	6 612	85 479	7 079	17 167	2 115 078	**0.0**	**0.0%**
	Sales (units)	22 454	0	158 667	75 658	3 026	0	9 516	0	1 911	271 233	**0.0**	**0.0%**
	Energy (TJ)	3 939.7	0.0	68 218.3	54 728.6	2 383.8	2 858.7	32 992.7	8 147.8	12 645.1	185 914.8	**-15 908.1**	**-7.9%**
	Expenditure (m€)	185.2	0.0	2 166.2	1 407.6	81.4	37.3	597.3	93.7	314.6	4 883.3	**-26.6**	**-0.5%**
2025	Stock (units)	242 985	0	1 187 066	566 037	22 641	0	93 933	5 653	19 078	2 137 393	**0.0**	**0.0%**
	Sales (units)	22 679	0	160 254	76 415	3 057	0	9 706	0	1 949	274 060	**0.0**	**0.0%**
	Energy (TJ)	3 979.1	0.0	68 900.5	55 275.9	2 407.7	0.0	36 255.7	6 506.2	14 052.9	187 378.0	**-17 140.4**	**-8.4%**
	Expenditure (m€)	187.1	0.0	2 187.8	1 421.6	82.2	0.0	643.7	74.8	336.5	4 933.7	**-36.0**	**-0.7%**

Year	Indicator	BC1	BC2		BC3	BC4	BC5		BC6		Total	Difference with BAU	
		2010 BC	2010 BC	2014 4.2	2010 BC	2010 BC	2010 BC	2014 1.5	2010 BC	2014 BA product		Absolute	Relative
2026	Stock (units)	245 415	0	1 198 937	571 697	22 868	0	95 812	4 198	21 027	2 159 953	**0.0**	**0.0%**
	Sales (units)	22 905	0	161 856	77 179	3 087	0	9 901	0	1 988	276 917	**0.0**	**0.0%**
	Energy (TJ)	4 018.9	0.0	69 589.5	55 828.6	2 431.8	0.0	36 980.8	4 831.8	15 488.8	189 170.2	**-18 084.2**	**-8.7%**
	Expenditure (m€)	188.9	0.0	2 209.7	1 435.8	83.1	0.0	656.6	55.6	358.7	4 988.4	**-41.9**	**-0.8%**
2027	Stock (units)	247 869	0	1 210 926	577 414	23 096	0	97 728	2 714	23 016	2 182 763	**0.0**	**0.0%**
	Sales (units)	23 134	0	163 475	77 951	3 118	0	10 099	0	2 028	279 805	**0.0**	**0.0%**
	Energy (TJ)	4 059.1	0.0	70 285.4	56 386.9	2 456.1	0.0	37 720.5	3 123.9	16 953.4	190 985.2	**-19 046.3**	**-9.1%**
	Expenditure (m€)	190.8	0.0	2 231.8	1 450.2	83.9	0.0	669.7	35.9	381.4	5 043.8	**-48.0**	**-0.9%**
2028	Stock (units)	250 348	0	1 223 035	583 188	23 327	0	99 682	1 200	25 044	2 205 825	**0.0**	**0.0%**
	Sales (units)	23 366	0	165 110	78 730	3 149	0	10 301	0	2 069	282 724	**0.0**	**0.0%**
	Energy (TJ)	4 099.7	0.0	70 988.3	56 950.8	2 480.6	0.0	38 474.9	1 381.8	18 447.3	192 823.3	**-20 027.2**	**-9.4%**
	Expenditure (m€)	192.7	0.0	2 254.1	1 464.7	84.7	0.0	683.1	15.9	404.6	5 099.9	**-54.1**	**-1.1%**
2029	Stock (units)	252 851	0	1 235 265	589 020	23 561	0	101 676	0	26 769	2 229 143	**0.0**	**0.0%**
	Sales (units)	23 599	0	166 761	79 518	3 181	0	10 507	0	2 110	285 675	**0.0**	**0.0%**
	Energy (TJ)	4 140.7	0.0	71 698.1	57 520.3	2 505.4	0.0	39 244.4	0.0	19 718.2	194 827.1	**-20 884.9**	**-9.7%**
	Expenditure (m€)	194.7	0.0	2 276.7	1 479.3	85.6	0.0	696.7	0.0	424.8	5 157.8	**-59.3**	**-1.1%**
2030	Stock (units)	255 380	0	1 247 618	594 910	23 796	0	103 709	0	27 305	2 252 719	**0.0**	**0.0%**
	Sales (units)	23 835	0	168 428	80 313	3 212	0	10 717	0	2 152	288 658	**0.0**	**0.0%**
	Energy (TJ)	4 182.1	0.0	72 415.1	58 095.5	2 530.5	0.0	40 029.3	0.0	20 112.6	197 365.0	**-21 251.8**	**-9.7%**
	Expenditure (m€)	196.6	0.0	2 299.4	1 494.1	86.4	0.0	710.7	0.0	433.3	5 220.6	**-60.5**	**-1.1%**
2010-2020	**Energy (TJ)**	**39 644.2**	**544 431.3**	**178 028.9**	**550 718.5**	**23 987.9**	**293 903.3**	**65 427.2**	**218 185.5**	**25 076.3**	**1 939 403.0**	**-34 573.6**	**-1.8%**
	Expenditure (m€)	**1 863.7**	**13 969.1**	**8 113.3**	**14 163.8**	**819.4**	**4 280.8**	**1 848.4**	**2 778.6**	**1 218.6**	**49 055.8**	**547.2**	**1.1%**
2010-2025	**Energy (TJ)**	**59 149.6**	**550 932.4**	**509 705.6**	**821 678.9**	**35 790.3**	**324 601.6**	**212 329.2**	**266 813.7**	**81 536.7**	**2 862 537.9**	**-107 471.3**	**-3.6%**
	Expenditure (m€)	**2 780.7**	**14 112.5**	**18 701.0**	**21 132.5**	**1 222.5**	**4 681.4**	**4 580.9**	**3 338.0**	**2 686.8**	**73 236.4**	**469.3**	**0.6%**
2010-2030	**Energy (TJ)**	**79 650.0**	**550 932.4**	**864 682.0**	**1 106 461.1**	**48 194.7**	**324 601.6**	**404 779.0**	**276 151.1**	**172 256.9**	**3 827 708.7**	**-206 765.6**	**-5.1%**
	Expenditure (m€)	**3 744.5**	**14 112.5**	**29 972.8**	**28 456.8**	**1 646.2**	**4 681.4**	**7 997.6**	**3 445.4**	**4 689.7**	**98 746.9**	**205.5**	**0.2%**

2.4.3 Best Available Technology (BAT) scenario

The BAT scenario considers that all BAT improvement options are implemented for each base case, as described in Task 7. The market modelling includes that from 2014, all products sold are equivalent to these BAT options and no more base cases are sold (the market shift takes place in one single step). Table 2-8 reminds the BAT options that were identified for each base case in Task 7. As a reminder, the warm water supply option was not eligible to be the BAT option.

Table 2-8 BAT improvement option for each base case

Base case	BAT Improvement option
1. Undercounter water-change	BA product
2. Undercounter one-tank	BA product
3. Hood-type	BA product
4. Utensil/Pot	BA product
5. One-tank conveyor-type	BA product
6. Multi-tank conveyor-type	BA product

Table 2-9 presents the outcomes of this scenario modelling. In 2025, the professional dishwashers market would require 168.4 PJ of primary energy (-17.7% compared to BAU), and would represent 5.65 b€ (+13.7% compared to BAU). Over the period 2010-2025, the total primary energy consumption would be 2 733 PJ (-8.0% compared to BAU) and the total expenditure 81.2 b€ (+11.6% compared to BAU). Also, 122 000 $ktCO_2$ would be emitted by professional dishwashers over the period 2010-2025.

Table 2-9 BAT scenario outcomes and comparison with BAU scenario: market data, energy consumption and expenditure

Year	Indicator	BC1		BC2		BC3		BC4		BC5		BC6		Total	Difference with BAU	
		2010 Base case	2014 BA product	2010 Base case	2014 BA product	2010 Base case	2014 BA product	2010 Base case	2014 BA product	2010 Base case	2014 BA product	2010 Base case	2014 BA product		Absolute	Relative
	Product price (€/unit)	**3 200**	**3 712**	**3 500**	**5 600**	**4 700**	**8 319**	**10 500**	**18 585**	**15 000**	**27 150**	**45 000**	**75 600**			
2009	**Stock (units)**	207 223	0	1 012 355	0	482 728	0	19 309	0	68 425	0	18 015	0	1 808 055	**0.0**	**0.0%**
	Sales (units)	19 341	0	136 668	0	65 168	0	2 607	0	7 071	0	1 420	0	232 274	**0.0**	**0.0%**
	Energy (TJ)	3 393.5	0.0	62 920.2	0.0	47 140.5	0.0	2 053.3	0.0	29 583.3	0.0	20 735.4	0.0	165 826.2	**0.0**	**0.0%**
	Expenditure (m€)	159.5	0.0	1 866.0	0.0	1 212.4	0.0	70.1	0.0	492.1	0.0	302.4	0.0	4 102.6	**0.0**	**0.0%**
2010	**Stock (units)**	209 295	0	1 022 479	0	487 555	0	19 502	0	69 794	0	18 375	0	1 827 000	**0.0**	**0.0%**
	Sales (units)	19 534	0	138 035	0	65 820	0	2 633	0	7 212	0	1 448	0	234 682	**0.0**	**0.0%**
	Energy (TJ)	3 427.4	0.0	63 549.4	0.0	47 611.9	0.0	2 073.9	0.0	30 175.0	0.0	21 150.1	0.0	167 987.6	**0.0**	**0.0%**
	Expenditure (m€)	161.1	0.0	1 884.7	0.0	1 224.5	0.0	70.8	0.0	501.9	0.0	308.5	0.0	4 151.6	**0.0**	**0.0%**
2011	**Stock (units)**	211 388	0	1 032 703	0	492 431	0	19 697	0	71 189	0	18 743	0	1 846 152	**0.0**	**0.0%**
	Sales (units)	19 730	0	139 415	0	66 478	0	2 659	0	7 356	0	1 477	0	237 115	**0.0**	**0.0%**
	Energy (TJ)	3 461.7	0.0	64 184.9	0.0	48 088.0	0.0	2 094.6	0.0	30 778.5	0.0	21 573.1	0.0	170 180.7	**0.0**	**0.0%**
	Expenditure (m€)	162.7	0.0	1 903.6	0.0	1 236.8	0.0	71.5	0.0	512.0	0.0	314.7	0.0	4 201.2	**0.0**	**0.0%**
2012	**Stock (units)**	213 502	0	1 043 030	0	497 355	0	19 894	0	72 613	0	19 118	0	1 865 512	**0.0**	**0.0%**
	Sales (units)	19 927	0	140 809	0	67 143	0	2 686	0	7 503	0	1 507	0	239 575	**0.0**	**0.0%**
	Energy (TJ)	3 496.3	0.0	64 826.7	0.0	48 568.9	0.0	2 115.5	0.0	31 394.1	0.0	22 004.6	0.0	172 406.1	**0.0**	**0.0%**
	Expenditure (m€)	164.4	0.0	1 922.6	0.0	1 249.1	0.0	72.3	0.0	522.2	0.0	320.9	0.0	4 251.5	**0.0**	**0.0%**
2013	**Stock (units)**	215 637	0	1 053 461	0	502 329	0	20 093	0	74 065	0	19 500	0	1 885 085	**0.0**	**0.0%**
	Sales (units)	20 126	0	142 217	0	67 814	0	2 713	0	7 653	0	1 537	0	242 061	**0.0**	**0.0%**
	Energy (TJ)	3 531.3	0.0	65 475.0	0.0	49 054.5	0.0	2 136.7	0.0	32 022.0	0.0	22 444.7	0.0	174 664.1	**0.0**	**0.0%**
	Expenditure (m€)	166.0	0.0	1 941.8	0.0	1 261.6	0.0	73.0	0.0	532.6	0.0	327.4	0.0	4 302.4	**0.0**	**0.0%**
2014	**Stock (units)**	217 793	0	1 063 995	0	507 352	0	20 294	0	75 547	0	19 890	0	1 904 871	**0.0**	**0.0%**
	Sales (units)	0	20 327	0	143 639	0	68 493	0	2 740	0	7 806	0	1 568	244 573	**0.0**	**0.0%**
	Energy (TJ)	3 566.6	0.0	66 129.7	0.0	49 545.1	0.0	2 158.1	0.0	32 662.4	0.0	22 893.6	0.0	176 955.4	**0.0**	**0.0%**
	Expenditure (m€)	102.6	75.5	1 458.5	804.4	952.3	569.8	44.9	50.9	426.2	211.9	263.4	118.5	5 079.0	**724.9**	**16.6%**
2015	**Stock (units)**	199 644	20 327	930 996	143 639	443 933	68 493	17 757	2 740	69 251	7 806	18 720	1 568	1 924 874	**0.0**	**0.0%**
	Sales (units)	0	20 531	0	145 076	0	69 177	0	2 767	0	7 963	0	1 599	247 113	**0.0**	**0.0%**
	Energy (TJ)	3 269.4	310.6	57 863.5	7 980.6	43 352.0	5 633.5	1 888.3	256.0	29 940.5	2 449.8	21 546.9	1 154.8	175 645.9	**-3 634.7**	**-2.0%**
	Expenditure (m€)	94.1	85.6	1 276.2	1 008.7	833.3	703.6	39.3	58.1	390.7	253.9	247.9	136.4	5 127.7	**721.3**	**16.4%**

Year	Indicator	BC1		BC2		BC3		BC4		BC5		BC6		Total	Difference with BAU	
		2010 Base case	2014 BA product	2010 Base case	2014 BA product	2010 Base case	2014 BA product	2010 Base case	2014 BA product	2010 Base case	2014 BA product	2010 Base case	2014 BA product		Absolute	Relative
2016	Stock (units)	181 313	40 858	796 666	288 715	379 880	137 670	15 195	5 507	62 830	15 769	17 527	3 167	1 945 097	**0.0**	**0.0%**
	Sales (units)	0	20 736	0	146 527	0	69 869	0	2 795	0	8 122	0	1 631	249 679	**0.0**	**0.0%**
	Energy (TJ)	2 969.2	624.2	49 514.6	16 041.0	37 096.9	11 323.3	1 615.8	514.5	27 164.2	4 948.7	20 173.3	2 332.8	174 318.6	**-7 321.4**	**-4.0%**
	Expenditure (m€)	85.4	95.8	1 092.0	1 215.0	713.1	838.8	33.7	65.4	354.4	296.7	232.1	154.7	5 177.0	**717.6**	**16.1%**
2017	Stock (units)	162 799	61 594	660 994	435 242	315 186	207 539	12 607	8 302	56 280	23 891	16 309	4 798	1 965 541	**0.0**	**0.0%**
	Sales (units)	0	20 943	0	147 992	0	70 568	0	2 823	0	8 284	0	1 664	252 274	**0.0**	**0.0%**
	Energy (TJ)	2 666.0	941.1	41 082.3	24 182.1	30 779.3	17 070.1	1 340.7	775.6	24 332.4	7 497.5	18 772.2	3 534.3	172 973.3	**-11 061.1**	**-6.0%**
	Expenditure (m€)	76.7	106.1	906.1	1 423.4	591.6	975.3	27.9	72.7	317.5	340.4	216.0	173.3	5 226.9	**713.8**	**15.8%**
2018	Stock (units)	144 099	82 537	523 964	583 233	249 845	278 107	9 994	11 124	49 599	32 175	15 068	6 462	1 986 209	**0.0**	**0.0%**
	Sales (units)	0	21 153	0	149 472	0	71 274	0	2 851	0	8 450	0	1 697	254 896	**0.0**	**0.0%**
	Energy (TJ)	2 359.8	1 261.0	32 565.6	32 404.5	24 398.5	22 874.3	1 062.7	1 039.4	21 443.9	10 097.2	17 343.1	4 759.8	171 609.8	**-14 854.6**	**-8.0%**
	Expenditure (m€)	67.9	116.5	718.2	1 633.8	469.0	1 113.1	22.1	80.1	279.8	384.9	199.5	192.3	5 277.3	**709.8**	**15.5%**
2019	Stock (units)	125 213	103 690	385 565	732 705	183 851	349 381	7 354	13 975	42 784	40 625	13 801	8 159	2 007 104	**0.0**	**0.0%**
	Sales (units)	0	21 364	0	150 966	0	71 986	0	2 879	0	8 619	0	1 731	257 546	**0.0**	**0.0%**
	Energy (TJ)	2 050.5	1 584.2	23 963.7	40 709.2	17 953.9	28 736.5	782.0	1 305.7	18 497.7	12 749.0	15 885.4	6 009.8	170 227.7	**-18 702.7**	**-9.9%**
	Expenditure (m€)	59.0	127.0	528.5	1 846.4	345.1	1 252.4	16.3	87.5	241.4	430.3	182.7	211.7	5 328.4	**705.7**	**15.3%**
2020	Stock (units)	106 138	125 054	245 781	883 672	117 197	421 367	4 688	16 855	35 834	49 244	12 510	9 890	2 028 229	**0.0**	**0.0%**
	Sales (units)	0	21 578	0	152 476	0	72 706	0	2 908	0	8 791	0	1 766	260 225	**0.0**	**0.0%**
	Energy (TJ)	1 738.1	1 910.6	15 275.8	49 096.9	11 444.8	34 657.4	498.5	1 574.8	15 492.5	15 453.8	14 398.5	7 284.9	168 826.7	**-22 606.3**	**-11.8%**
	Expenditure (m€)	50.0	137.6	336.9	2 061.1	220.0	1 393.0	10.4	95.1	202.2	476.7	165.6	231.5	5 380.1	**701.5**	**15.0%**
2021	Stock (units)	86 872	146 632	104 599	1 036 148	49 877	494 073	1 995	19 763	28 744	58 036	11 192	11 655	2 049 586	**0.0**	**0.0%**
	Sales (units)	0	21 794	0	154 001	0	73 433	0	2 937	0	8 967	0	1 801	262 933	**0.0**	**0.0%**
	Energy (TJ)	1 422.6	2 240.3	6 501.1	57 568.5	4 870.7	40 637.5	212.2	1 846.5	12 427.3	18 212.7	12 882.0	8 585.4	167 406.6	**-26 566.4**	**-13.7%**
	Expenditure (m€)	40.9	148.4	143.4	2 277.9	93.6	1 535.1	4.4	102.7	162.2	523.9	148.2	251.7	5 432.4	**697.1**	**14.7%**
2022	Stock (units)	67 413	168 426	0	1 152 154	0	549 389	0	21 975	21 512	67 003	9 848	13 456	2 071 178	**0.0**	**0.0%**
	Sales (units)	0	22 012	0	155 541	0	74 168	0	2 967	0	9 147	0	1 837	265 670	**0.0**	**0.0%**
	Energy (TJ)	1 103.9	2 573.3	0.0	64 013.8	0.0	45 187.2	0.0	2 053.2	9 300.7	21 026.8	11 335.1	9 911.9	166 506.0	**-30 044.9**	**-15.3%**
	Expenditure (m€)	31.8	159.2	0.0	2 445.0	0.0	1 644.7	0.0	108.7	121.4	572.2	130.4	272.2	5 485.5	**692.7**	**14.5%**
2023	Stock (units)	47 760	190 438	0	1 163 676	0	554 883	0	22 195	14 136	76 149	8 477	15 293	2 093 008	**0.0**	**0.0%**
	Sales (units)	0	22 232	0	157 096	0	74 909	0	2 996	0	9 329	0	1 874	268 437	**0.0**	**0.0%**
	Energy (TJ)	782.1	2 909.6	0.0	64 653.9	0.0	45 639.1	0.0	2 073.7	6 111.6	23 897.2	9 757.2	11 265.0	167 089.5	**-32 077.8**	**-16.1%**
	Expenditure (m€)	22.5	170.1	0.0	2 469.5	0.0	1 661.1	0.0	109.7	79.7	621.3	112.2	293.2	5 539.5	**688.6**	**14.2%**
2024	Stock (units)	27 910	212 669	0	1 175 313	0	560 432	0	22 417	6 612	85 479	7 079	17 167	2 115 078	**0.0**	**0.0%**
	Sales (units)	0	22 454	0	158 667	0	75 658	0	3 026	0	9 516	0	1 911	271 233	**0.0**	**0.0%**

Year	Indicator	BC1		BC2		BC3		BC4		BC5		BC6		Total	Difference with BAU	
		2010 Base case	2014 BA product	2010 Base case	2014 BA product	2010 Base case	2014 BA product	2010 Base case	2014 BA product	2010 Base case	2014 BA product	2010 Base case	2014 BA product		Absolute	Relative
	Energy (TJ)	457.1	3 249.2	0.0	65 300.5	0.0	46 095.5	0.0	2 094.5	2 858.7	26 825.0	8 147.8	12 645.1	167 673.4	**-34 149.6**	**-16.9%**
	Expenditure (m€)	13.2	181.2	0.0	2 494.2	0.0	1 677.7	0.0	110.8	37.3	671.5	93.7	314.6	5 594.2	**684.3**	**13.9%**
2025	Stock (units)	7 862	235 124	0	1 187 066	0	566 037	0	22 641	0	93 933	5 653	19 078	2 137 393	**0.0**	**0.0%**
	Sales (units)	0	22 679	0	160 254	0	76 415	0	3 057	0	9 706	0	1 949	274 060	**0.0**	**0.0%**
	Energy (TJ)	128.7	3 592.3	0.0	65 953.5	0.0	46 556.5	0.0	2 115.4	0.0	29 478.0	6 506.2	14 052.9	168 383.5	**-36 134.9**	**-17.7%**
	Expenditure (m€)	3.7	192.3	0.0	2 519.1	0.0	1 694.5	0.0	111.9	0.0	717.5	74.8	336.5	5 650.4	**680.7**	**13.7%**
2026	Stock (units)	0	245 415	0	1 198 937	0	571 697	0	22 868	0	95 812	4 198	21 027	2 159 953	**0.0**	**0.0%**
	Sales (units)	0	22 905	0	161 856	0	77 179	0	3 087	0	9 901	0	1 988	276 917	**0.0**	**0.0%**
	Energy (TJ)	0.0	3 749.5	0.0	66 613.0	0.0	47 022.0	0.0	2 136.6	0.0	30 067.5	4 831.8	15 488.8	169 909.2	**-37 345.1**	**-18.0%**
	Expenditure (m€)	0.0	197.9	0.0	2 544.3	0.0	1 711.4	0.0	113.1	0.0	731.9	55.6	358.7	5 712.9	**682.6**	**13.6%**
2027	Stock (units)	0	247 869	0	1 210 926	0	577 414	0	23 096	0	97 728	2 714	23 016	2 182 763	**0.0**	**0.0%**
	Sales (units)	0	23 134	0	163 475	0	77 951	0	3 118	0	10 099	0	2 028	279 805	**0.0**	**0.0%**
	Energy (TJ)	0.0	3 787.0	0.0	67 279.2	0.0	47 492.3	0.0	2 157.9	0.0	30 668.9	3 123.9	16 953.4	171 462.5	**-38 569.0**	**-18.4%**
	Expenditure (m€)	0.0	199.9	0.0	2 569.8	0.0	1 728.6	0.0	114.2	0.0	746.5	35.9	381.4	5 776.3	**684.5**	**13.4%**
2028	Stock (units)	0	250 348	0	1 223 035	0	583 188	0	23 327	0	99 682	1 200	25 044	2 205 825	**0.0**	**0.0%**
	Sales (units)	0	23 366	0	165 110	0	78 730	0	3 149	0	10 301	0	2 069	282 724	**0.0**	**0.0%**
	Energy (TJ)	0.0	3 824.9	0.0	67 951.9	0.0	47 967.2	0.0	2 179.5	0.0	31 282.3	1 381.8	18 447.3	173 034.9	**-39 815.6**	**-18.7%**
	Expenditure (m€)	0.0	201.9	0.0	2 595.4	0.0	1 745.8	0.0	115.3	0.0	761.4	15.9	404.6	5 840.5	**686.5**	**13.3%**
2029	Stock (units)	0	252 851	0	1 235 265	0	589 020	0	23 561	0	101 676	0	26 769	2 229 143	**0.0**	**0.0%**
	Sales (units)	0	23 599	0	166 761	0	79 518	0	3 181	0	10 507	0	2 110	285 675	**0.0**	**0.0%**
	Energy (TJ)	0.0	3 863.1	0.0	68 631.5	0.0	48 446.8	0.0	2 201.3	0.0	31 907.9	0.0	19 718.2	174 768.9	**-40 943.1**	**-19.0%**
	Expenditure (m€)	0.0	203.9	0.0	2 621.4	0.0	1 763.3	0.0	116.5	0.0	776.7	0.0	424.8	5 906.6	**689.5**	**13.2%**
2030	Stock (units)	0	255 380	0	1 247 618	0	594 910	0	23 796	0	103 709	0	27 305	2 252 719	**0.0**	**0.0%**
	Sales (units)	0	23 835	0	168 428	0	80 313	0	3 212	0	10 717	0	2 152	288 658	**0.0**	**0.0%**
	Energy (TJ)	0.0	3 901.8	0.0	69 317.8	0.0	48 931.3	0.0	2 223.3	0.0	32 546.1	0.0	20 112.6	177 032.8	**-41 584.0**	**-19.0%**
	Expenditure (m€)	0.0	206.0	0.0	2 647.6	0.0	1 780.9	0.0	117.7	0.0	792.2	0.0	433.3	5 977.7	**696.6**	**13.2%**
2010-2020	Energy (TJ)	**32 536.0**	**6 631.7**	**544 431.3**	**170 414.3**	**407 893.6**	**120 295.2**	**17 766.8**	**5 465.9**	**293 903.3**	**53 196.1**	**218 185.5**	**25 076.3**	**1 895 795.9**	**-78 180.7**	**-4.0%**
	Expenditure (m€)	**1 190.0**	**744.0**	**13 969.1**	**9 992.7**	**9 096.4**	**6 846.0**	**482.3**	**509.8**	**4 280.8**	**2 394.9**	**2 778.6**	**1 218.6**	**53 503.1**	**4 994.6**	**10.3%**
2010-2025	Energy (TJ)	**36 430.5**	**21 196.3**	**550 932.4**	**487 904.5**	**412 764.3**	**344 411.0**	**17 979.0**	**15 649.2**	**324 601.6**	**172 635.8**	**266 813.7**	**81 536.7**	**2 732 854.8**	**-237 154.4**	**-8.0%**
	Expenditure (m€)	**1 302.0**	**1 595.2**	**14 112.5**	**22 198.4**	**9 190.0**	**15 059.1**	**486.7**	**1 053.6**	**4 681.4**	**5 501.3**	**3 338.0**	**2 686.8**	**81 205.1**	**8 438.0**	**11.6%**
2010-2030	Energy (TJ)	**36 430.5**	**40 322.7**	**550 932.4**	**827 697.8**	**412 764.3**	**584 270.6**	**17 979.0**	**26 547.9**	**324 601.6**	**329 108.4**	**276 151.1**	**172 256.9**	**3 599 063.1**	**-435 411.2**	**-10.8%**
	Expenditure (m€)	**1 302.0**	**2 604.8**	**14 112.5**	**35 176.9**	**9 190.0**	**23 789.2**	**486.7**	**1 630.4**	**4 681.4**	**9 310.0**	**3 445.4**	**4 689.7**	**110 419.0**	**11 877.7**	**12.1%**

2.4.4 Eco-design requirements

The eco-design requirements consider that the suggested policy options presented in Section 2.3.3 are implemented for each base case. Depending on the Tier targets, the market modelling includes that from 2014 (Tier 1) and/or 2017 (Tier 2), all products sold are equivalent to options indicated in Table 2-10.

Table 2-10 BAT improvement option for each base case

Base case	Tier 1 (2014)	Tier 2 (2017)
1. Undercounter water-change	M 4.2 High efficient pumps and motors	-
2. Undercounter one-tank	M 4.2 High efficient pumps and motors	-
3. Hood-type	M 4.2 High efficient pumps and motors	M 3.1.1 Waste water heat exchanger
4. Utensil/Pot	M 4.2 High efficient pumps and motors	M 3.1.1 Waste water heat exchanger
5. One-tank conveyor-type	M 1.5 Auxiliary rinsing	-
6. Multi-tank conveyor-type	M 4.2 High efficient pumps and motors	-

Table 2-11 presents the outcomes of this scenario modelling (in the following referred to as “MEPS” – Minimum Energy Performance Standard – scenario). In 2025, the professional dishwashers market would require 186.5 PJ of primary energy (-8.8% compared to BAU), and would represent 4.96 b€ (-0.1% compared to BAU). Over the period 2010-2025, the total primary energy consumption would be 2 854 PJ (-3.9% compared to BAU) and the total expenditure 73.5 b€ (-1.0% compared to BAU). Also, 127 400 ktCO_2 would be emitted by professional dishwashers over the period 2010-2025.

Table 2-11 MEPS scenario outcomes and comparison with BAU scenario: market data, energy consumption and expenditure

(BC = Base case; 4.2 HEPM = High efficiency pumps and motors; 3.1.1 WWHE = Waste water heat exchanger; 1.5 AR = Auxiliary rinsing)

Year	Indicator	BC1		BC2		BC3			BC4			BC5		BC6		Total	Difference with BAU	
		2010	2014	2010	2014	2010	2014	2017	2010	2014	2017	2010	2014	2010	2014		Absolute	Relative
		BC	4.2	BC	4.2	BC	4.2	3.1.1	BC	4.2	3.1.1	BC	1.5	BC	4.2			
	Product price (€/unit)	3200	3456	3500	3955	4700	5405	5546	10500	11550	11445	15000	16950	45000	51750	-		
2009	Stock (units)	207223	0	1012355	0	482728	0	0	19309	0	0	68425	0	18015	0	1808055	**0.0**	**0.0%**
	Sales (units)	19341	0	136668	0	65168	0	0	2607	0	0	7071	0	1420	0	232274	**0.0**	**0.0%**
	Energy (TJ)	3393.5	0.0	62920.2	0.0	47140.5	0.0	0.0	2053.3	0.0	0.0	29583.3	0.0	20735.4	0.0	165826.2	**0.0**	**0.0%**
	Expenditure (m€)	159.5	0.0	1866.0	0.0	1212.4	0.0	0.0	70.1	0.0	0.0	492.1	0.0	302.4	0.0	4102.6	**0.0**	**0.0%**
2010	Stock (units)	209295	0	1022479	0	487555	0	0	19502	0	0	69794	0	18375	0	1827000	**0.0**	**0.0%**
	Sales (units)	19534	0	138035	0	65820	0	0	2633	0	0	7212	0	1448	0	234682	**0.0**	**0.0%**
	Energy (TJ)	3427.4	0.0	63549.4	0.0	47611.9	0.0	0.0	2073.9	0.0	0.0	30175.0	0.0	21150.1	0.0	167987.6	**0.0**	**0.0%**
	Expenditure (m€)	161.1	0.0	1884.7	0.0	1224.5	0.0	0.0	70.8	0.0	0.0	501.9	0.0	308.5	0.0	4151.6	**0.0**	**0.0%**
2011	Stock (units)	211388	0	1032703	0	492431	0	0	19697	0	0	71189	0	18743	0	1846152	**0.0**	**0.0%**
	Sales (units)	19730	0	139415	0	66478	0	0	2659	0	0	7356	0	1477	0	237115	**0.0**	**0.0%**
	Energy (TJ)	3461.7	0.0	64184.9	0.0	48088.0	0.0	0.0	2094.6	0.0	0.0	30778.5	0.0	21573.1	0.0	170180.7	**0.0**	**0.0%**
	Expenditure (m€)	162.7	0.0	1903.6	0.0	1236.8	0.0	0.0	71.5	0.0	0.0	512.0	0.0	314.7	0.0	4201.2	**0.0**	**0.0%**
2012	Stock (units)	213502	0	1043030	0	497355	0	0	19894	0	0	72613	0	19118	0	1865512	**0.0**	**0.0%**
	Sales (units)	19927	0	140809	0	67143	0	0	2686	0	0	7503	0	1507	0	239575	**0.0**	**0.0%**
	Energy (TJ)	3496.3	0.0	64826.7	0.0	48568.9	0.0	0.0	2115.5	0.0	0.0	31394.1	0.0	22004.6	0.0	172406.1	**0.0**	**0.0%**
	Expenditure (m€)	164.4	0.0	1922.6	0.0	1249.1	0.0	0.0	72.3	0.0	0.0	522.2	0.0	320.9	0.0	4251.5	**0.0**	**0.0%**
2013	Stock (units)	215637	0	1053461	0	502329	0	0	20093	0	0	74065	0	19500	0	1885085	**0.0**	**0.0%**
	Sales (units)	20126	0	142217	0	67814	0	0	2713	0	0	7653	0	1537	0	242061	**0.0**	**0.0%**
	Energy (TJ)	3531.3	0.0	65475.0	0.0	49054.5	0.0	0.0	2136.7	0.0	0.0	32022.0	0.0	22444.7	0.0	174664.1	**0.0**	**0.0%**
	Expenditure (m€)	166.0	0.0	1941.8	0.0	1261.6	0.0	0.0	73.0	0.0	0.0	532.6	0.0	327.4	0.0	4302.4	**0.0**	**0.0%**
2014	Stock (units)	217793	0	1063995	0	507352	0	0	20294	0	0	75547	0	19890	0	1904871	**0.0**	**0.0%**
	Sales (units)	0	20327	0	143639	0	68493	0	0	2740	0	0	7806	0	1568	244573	**0.0**	**0.0%**
	Energy (TJ)	3566.6	0.0	66129.7	0.0	49545.1	0.0	0.0	2158.1	0.0	0.0	32662.4	0.0	22893.6	0.0	176955.4	**0.0**	**0.0%**
	Expenditure (m€)	102.6	70.3	1458.5	568.1	952.3	370.2	0.0	44.9	31.6	0.0	426.2	132.3	263.4	81.1	4501.6	**147.5**	**3.4%**
2015	Stock (units)	199644	20327	930996	143639	443933	68493	0	17757	2740	0	69251	7806	18720	1568	1924874	**0.0**	**0.0%**
	Sales (units)	0	20531	0	145076	0	69177	0	0	2767	0	0	7963	0	1599	247113	**0.0**	**0.0%**
	Energy (TJ)	3269.4	322.1	57863.5	8337.2	43352.0	6250.0	0.0	1888.3	277.1	0.0	29940.5	3013.1	21546.9	1601.5	177661.4	**-1619.1**	**-0.9%**
	Expenditure (m€)	94.1	80.3	1276.2	761.8	833.3	496.9	0.0	39.3	37.9	0.0	390.7	174.8	247.9	101.2	4534.3	**128.0**	**2.9%**
2016	Stock (units)	181313	40858	796666	288715	379880	137670	0	15195	5507	0	62830	15769	17527	3167	1945097	**0.0**	**0.0%**
	Sales (units)	0	20736	0	146527	0	69869	0	0	2795	0	0	8122	0	1631	249679	**0.0**	**0.0%**
	Energy (TJ)	2969.2	647.3	49514.6	16757.8	37096.9	12562.4	0.0	1615.8	556.9	0.0	27164.2	6086.5	20173.3	3235.0	178380.0	**-3260.1**	**-1.8%**
	Expenditure (m€)	85.4	90.5	1092.0	957.5	713.1	624.9	0.0	33.7	44.2	0.0	354.4	218.1	232.1	121.7	4567.5	**108.1**	**2.4%**
2017	Stock (units)	162799	61594	660994	435242	315186	207539	0	12607	8302	0	56280	23891	16309	4798	1965541	**0.0**	**0.0%**
	Sales (units)	0	20943	0	147992	0	0	70568	0	0	2823	0	8284	0	1664	252274	**0.0**	**0.0%**
	Energy (TJ)	2666.0	975.9	41082.3	25262.6	30779.3	18938.0	0.0	1340.7	839.5	0.0	24332.4	9221.3	18772.2	4901.2	179111.2	**-4923.2**	**-2.7%**

Year	Indicator	BC1		BC2		BC3			BC4			BC5		BC6		Total	Difference with BAU	
		2010	2014	2010	2014	2010	2014	2017	2010	2014	2017	2010	2014	2010	2014		Absolute	Relative
		BC	4.2	BC	4.2	BC	4.2	3.1.1	BC	4.2	3.1.1	BC	1.5	BC	4.2			
	Expenditure (m€)	76.7	100.7	906.1	1155.1	591.6	372.8	391.4	27.9	17.9	32.3	317.5	262.3	216.0	142.5	4610.8	**97.7**	**2.2%**
2018	Stock (units)	144099	82537	523964	583233	249845	207539	70568	9994	8302	2823	49599	32175	15068	6462	1986209	**0.0**	**0.0%**
	Sales (units)	0	21153	0	149472	0	0	71274	0	0	2851	0	8450	0	1697	254896	**0.0**	**0.0%**
	Energy (TJ)	2359.8	1307.7	32565.6	33852.4	24398.5	18938.0	6138.2	1062.7	839.5	276.4	21443.9	12418.9	17343.1	6600.7	179545.3	**-6919.0**	**-3.7%**
	Expenditure (m€)	67.9	111.1	718.2	1354.7	469.0	372.8	524.1	22.1	17.9	38.8	279.8	307.4	199.5	163.8	4647.2	**79.6**	**1.7%**
2019	Stock (units)	125213	103690	385565	732705	183851	207539	141841	7354	8302	5674	42784	40625	13801	8159	2007104	**0.0**	**0.0%**
	Sales (units)	0	21364	0	150966	0	0	71986	0	0	2879	0	8619	0	1731	257546	**0.0**	**0.0%**
	Energy (TJ)	2050.5	1642.8	23963.7	42528.2	17953.9	18938.0	12337.8	782.0	839.5	555.6	18497.7	15680.4	15885.4	8334.2	179989.6	**-8940.8**	**-4.7%**
	Expenditure (m€)	59.0	121.6	528.5	1556.3	345.1	372.8	658.2	16.3	17.9	45.4	241.4	353.3	182.7	185.5	4684.0	**61.3**	**1.3%**
2020	Stock (units)	106138	125054	245781	883672	117197	207539	213828	4688	8302	8553	35834	49244	12510	9890	2028229	**0.0**	**0.0%**
	Sales (units)	0	21578	0	152476	0	0	72706	0	0	2908	0	8791	0	1766	260225	**0.0**	**0.0%**
	Energy (TJ)	1738.1	1981.3	15275.8	51290.7	11444.8	18938.0	18599.4	498.5	839.5	837.6	15492.5	19007.1	14398.5	10102.3	180444.2	**-10988.9**	**-5.7%**
	Expenditure (m€)	50.0	132.2	336.9	1759.9	220.0	372.8	793.6	10.4	17.9	52.0	202.2	400.2	165.6	207.7	4721.3	**42.7**	**0.9%**
2021	Stock (units)	86872	146632	104599	1036148	49877	207539	286534	1995	8302	11461	28744	58036	11192	11655	2049586	**0.0**	**0.0%**
	Sales (units)	0	21794	0	154001	0	0	73433	0	0	2937	0	8967	0	1801	262933	**0.0**	**0.0%**
	Energy (TJ)	1422.6	2323.1	6501.1	60140.8	4870.7	18938.0	24923.6	212.2	839.5	1122.4	12427.3	22400.3	12882.0	11905.8	180909.3	**-13063.7**	**-6.7%**
	Expenditure (m€)	40.9	142.8	143.4	1965.5	93.6	372.8	930.3	4.4	17.9	58.7	162.2	448.0	148.2	230.3	4759.1	**23.8**	**0.5%**
2022	Stock (units)	67413	168426	0	1152154	0	189422	359967	0	7577	14399	21512	67003	9848	13456	2071178	**0.0**	**0.0%**
	Sales (units)	0	22012	0	155541	0	0	74168	0	0	2967	0	9147	0	1837	265670	**0.0**	**0.0%**
	Energy (TJ)	1103.9	2668.4	0.0	66874.1	0.0	17284.8	31311.0	0.0	766.2	1410.0	9300.7	25861.4	11335.1	13745.4	181661.2	**-14889.7**	**-7.6%**
	Expenditure (m€)	31.8	153.6	0.0	2123.5	0.0	340.2	1068.4	0.0	16.4	65.4	121.4	496.8	130.4	253.3	4801.3	**8.5**	**0.2%**
2023	Stock (units)	47760	190438	0	1163676	0	120749	434135	0	4830	17365	14136	76149	8477	15293	2093008	**0.0**	**0.0%**
	Sales (units)	0	22232	0	157096	0	0	74909	0	0	2996	0	9329	0	1874	268437	**0.0**	**0.0%**
	Energy (TJ)	782.1	3017.2	0.0	67542.9	0.0	11018.3	37762.3	0.0	488.4	1700.6	6111.6	29391.8	9757.2	15621.8	183194.2	**-15973.1**	**-8.0%**
	Expenditure (m€)	22.5	164.5	0.0	2144.7	0.0	216.9	1207.9	0.0	10.4	72.3	79.7	546.6	112.2	276.8	4854.7	**3.8**	**0.1%**
2024	Stock (units)	27910	212669	0	1175313	0	51388	509044	0	2056	20362	6612	85479	7079	17167	2115078	**0.0**	**0.0%**
	Sales (units)	0	22454	0	158667	0	0	75658	0	0	3026	0	9516	0	1911	271233	**0.0**	**0.0%**
	Energy (TJ)	457.1	3369.4	0.0	68218.3	0.0	4689.2	44278.1	0.0	207.9	1994.0	2858.7	32992.7	8147.8	17535.7	184748.9	**-17074.1**	**-8.5%**
	Expenditure (m€)	13.2	175.5	0.0	2166.2	0.0	92.3	1348.8	0.0	4.4	79.2	37.3	597.3	93.7	300.8	4908.8	**-1.1**	**0.0%**
2025	Stock (units)	7862	235124	0	1187066	0	0	566037	0	0	22641	0	93933	5653	19078	2137393	**0.0**	**0.0%**
	Sales (units)	0	22679	0	160254	0	0	76415	0	0	3057	0	9706	0	1949	274060	**0.0**	**0.0%**
	Energy (TJ)	128.7	3725.1	0.0	68900.5	0.0	0.0	49235.5	0.0	0.0	2217.2	0.0	36255.7	6506.2	19487.9	186456.9	**-18061.5**	**-8.8%**
	Expenditure (m€)	3.7	186.7	0.0	2187.8	0.0	0.0	1457.1	0.0	0.0	84.5	0.0	643.7	74.8	325.3	4963.6	**-6.2**	**-0.1%**
2026	Stock (units)	0	245415	0	1198937	0	0	571697	0	0	22868	0	95812	4198	21027	2159953	**0.0**	**0.0%**
	Sales (units)	0	22905	0	161856	0	0	77179	0	0	3087	0	9901	0	1988	276917	**0.0**	**0.0%**
	Energy (TJ)	0.0	3888.2	0.0	69589.5	0.0	0.0	49727.9	0.0	0.0	2239.4	0.0	36980.8	4831.8	21479.2	188736.7	**-18517.6**	**-8.9%**
	Expenditure (m€)	0.0	192.2	0.0	2209.7	0.0	0.0	1471.7	0.0	0.0	85.3	0.0	656.6	55.6	350.2	5021.2	**-9.1**	**-0.2%**
2027	Stock (units)	0	247869	0	1210926	0	0	577414	0	0	23096	0	97728	2714	23016	2182763	**0.0**	**0.0%**
	Sales (units)	0	23134	0	163475	0	0	77951	0	0	3118	0	10099	0	2028	279805	**0.0**	**0.0%**
	Energy (TJ)	0.0	3927.1	0.0	70285.4	0.0	0.0	50225.1	0.0	0.0	2261.8	0.0	37720.5	3123.9	23510.2	191053.9	**-18977.6**	**-9.0%**
	Expenditure (m€)	0.0	194.1	0.0	2231.8	0.0	0.0	1486.4	0.0	0.0	86.2	0.0	669.7	35.9	375.6	5079.7	**-12.0**	**-0.2%**

Year	Indicator	BC1		BC2		BC3			BC4			BC5		BC6		Total	Difference with BAU	
		2010	2014	2010	2014	2010	2014	2017	2010	2014	2017	2010	2014	2010	2014		Absolute	Relative
		BC	4.2	BC	4.2	BC	4.2	3.1.1	BC	4.2	3.1.1	BC	1.5	BC	4.2			
2028	Stock (units)	0	250348	0	1223035	0	0	583188	0	0	23327	0	99682	1200	25044	2205825	**0.0**	**0.0%**
	Sales (units)	0	23366	0	165110	0	0	78730	0	0	3149	0	10301	0	2069	282724	**0.0**	**0.0%**
	Energy (TJ)	0.0	3966.3	0.0	70988.3	0.0	0.0	50727.4	0.0	0.0	2284.4	0.0	38474.9	1381.8	25581.9	193404.9	**-19445.5**	**-9.1%**
	Expenditure (m€)	0.0	196.0	0.0	2254.1	0.0	0.0	1501.2	0.0	0.0	87.1	0.0	683.1	15.9	401.6	5139.0	**-15.0**	**-0.3%**
2029	Stock (units)	0	252851	0	1235265	0	0	589020	0	0	23561	0	101676	0	26769	2229143	**0.0**	**0.0%**
	Sales (units)	0	23599	0	166761	0	0	79518	0	0	3181	0	10507	0	2110	285675	**0.0**	**0.0%**
	Energy (TJ)	0.0	4006.0	0.0	71698.1	0.0	0.0	51234.7	0.0	0.0	2307.3	0.0	39244.4	0.0	27344.4	195834.8	**-19877.3**	**-9.2%**
	Expenditure (m€)	0.0	198.0	0.0	2276.7	0.0	0.0	1516.2	0.0	0.0	87.9	0.0	696.7	0.0	424.0	5199.6	**-17.5**	**-0.3%**
2030	Stock (units)	0	255380	0	1247618	0	0	594910	0	0	23796	0	103709	0	27305	2252719	**0.0**	**0.0%**
	Sales (units)	0	23835	0	168428	0	0	80313	0	0	3212	0	10717	0	2152	288658	**0.0**	**0.0%**
	Energy (TJ)	0.0	4046.1	0.0	72415.1	0.0	0.0	51747.0	0.0	0.0	2330.3	0.0	40029.3	0.0	27891.2	198459.0	**-20157.9**	**-9.2%**
	Expenditure (m€)	0.0	200.0	0.0	2299.4	0.0	0.0	1531.4	0.0	0.0	88.8	0.0	710.7	0.0	432.5	5262.8	**-18.3**	**-0.3%**
2010-2020	**Energy (TJ)**	**32536.0**	**6876.9**	**544431.3**	**178028.9**	**407893.6**	**94564.5**	**37075.3**	**17766.8**	**4191.9**	**1669.6**	**293903.3**	**65427.2**	**218185.5**	**34774.8**	**1937325.7**	**-36651.0**	**-1.9%**
2010-2020	**Expenditure (m€)**	**1190.0**	**706.7**	**13969.1**	**8113.3**	**9096.4**	**2983.2**	**2367.2**	**482.3**	**185.4**	**168.5**	**4280.8**	**1848.4**	**2778.6**	**1003.6**	**49173.4**	**664.9**	**1.4%**
2010-2025	**Energy (TJ)**	**36430.5**	**21980.2**	**550932.4**	**509705.6**	**412764.3**	**146494.9**	**224585.8**	**17979.0**	**6493.9**	**10113.8**	**324601.6**	**212329.2**	**266813.7**	**113071.6**	**2854296.2**	**-115712.9**	**-3.9%**
2010-2025	**Expenditure (m€)**	**1302.0**	**1529.9**	**14112.5**	**18701.0**	**9190.0**	**4005.4**	**8379.8**	**486.7**	**234.5**	**528.5**	**4681.4**	**4580.9**	**3338.0**	**2390.1**	**73460.8**	**693.7**	**1.0%**
2010-2030	**Energy (TJ)**	**36430.5**	**41813.8**	**550932.4**	**864682.0**	**412764.3**	**146494.9**	**478247.8**	**17979.0**	**6493.9**	**21536.9**	**324601.6**	**404779.0**	**276151.1**	**238878.5**	**3821785.5**	**-212688.8**	**-5.3%**
2010-2030	**Expenditure (m€)**	**1302.0**	**2510.2**	**14112.5**	**29972.8**	**9190.0**	**4005.4**	**15886.7**	**486.7**	**234.5**	**963.8**	**4681.4**	**7997.6**	**3445.4**	**4374.1**	**99163.2**	**621.8**	**0.6%**

2.4.5 Comparison of BAT, LLCC and MEPS scenarios with BAU

Figure 2-4 to Figure 2-11 show the evolution of total primary energy consumption and expenditure in time (between 2010 and 2030) by base cases and according to the BAT, LLCC and MEPS scenarios previously described.

The figures show that the initial larger investment due to higher product prices can be counterbalanced by the lower operating costs: for example this is the case for base case 5 and base case 6 in the MEPS scenario. For base case 5, the MEPS and LLCC scenario annual expenditures become lower than the BAU annual expenditure in 2018. For base case 6, the MEPS scenario annual expenditure becomes lower than the BAU annual expenditure in 2019 while this is the case in 2024 for the LLCC scenario (which overlaps with BAT).

Looking at the overall results, the LLCC and the MEPS scenarios almost overlap, both in terms of energy consumption and expenditure. This is due to the fact that results of base cases with slightly more ambitious targets than the LLCC options (this is the case for base cases 1, 3, 4 as the LLCC was the base case product) counterbalance the effects of base case 6, for which the eco-design requirements (MEPS) are less ambitious than the LLCC option.

As planned, the BAT scenario is therefore the scenario that enables the largest primary energy savings (both annually and over the period 2010-2025) while the LLCC scenario results in the smallest annual expenditure. By extrapolating the trend of the cumulated expenditure from 2010, the LLCC scenario is expected to become economic from 2029 in comparison with the BAU scenario (see Figure 2-12) while this should happen in 2031 for the MEPS scenario (see Figure 2-13).

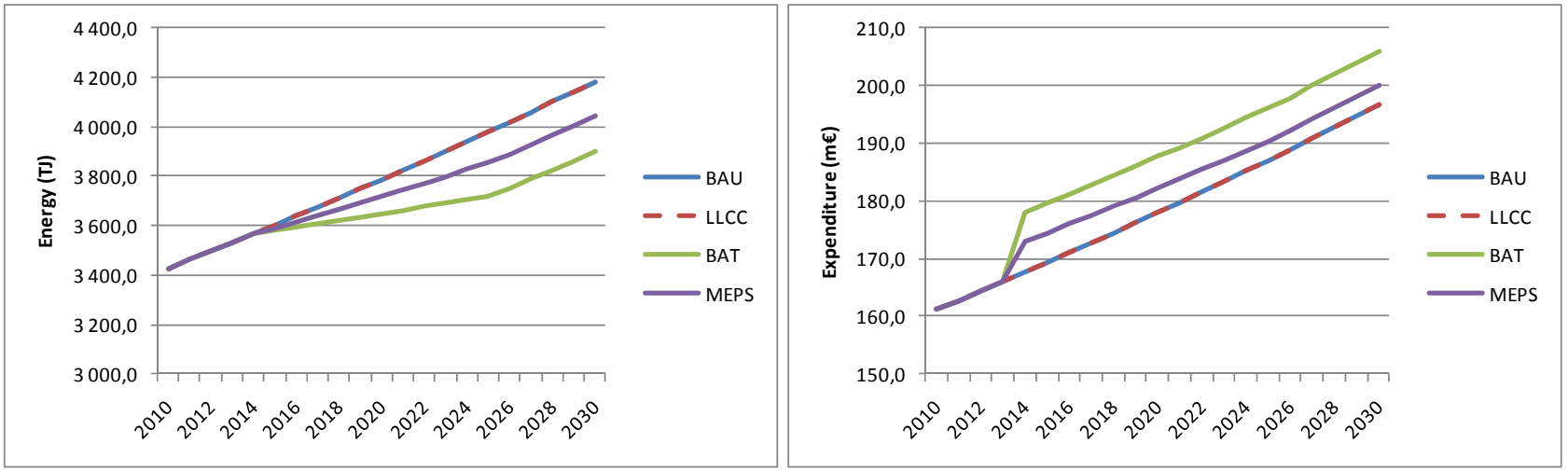


Figure 2-4 Primary energy consumption and expenditure by scenario, base case 1

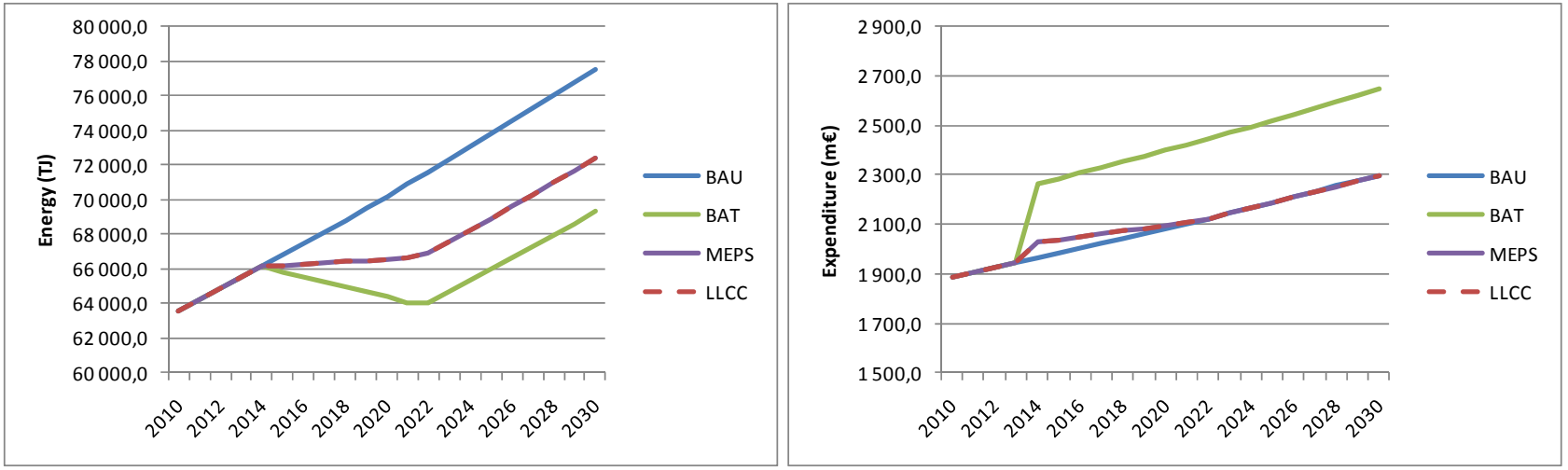


Figure 2-5 Primary energy consumption and expenditure by scenario, base case 2

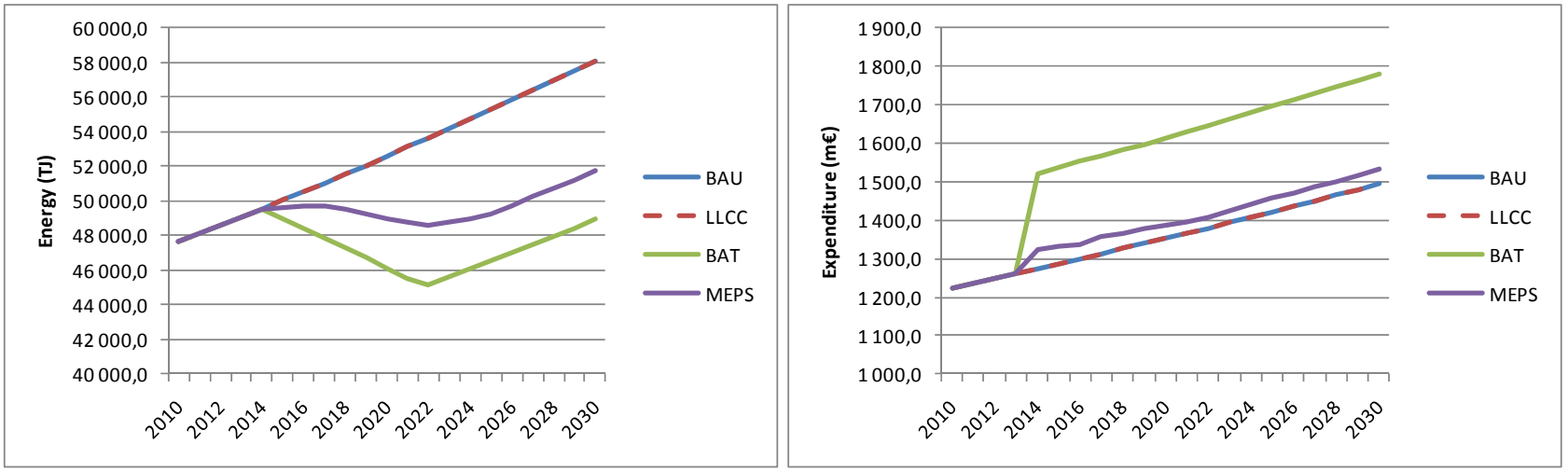


Figure 2-6 Primary energy consumption and expenditure by scenario, base case 3

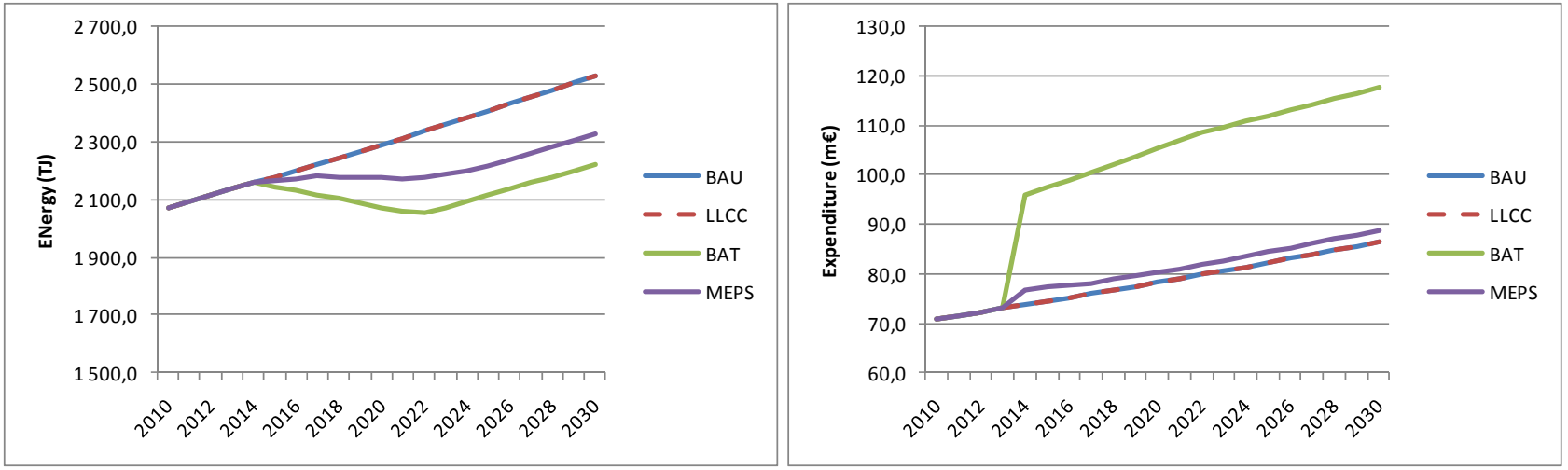


Figure 2-7 Primary energy consumption and expenditure by scenario, base case 4

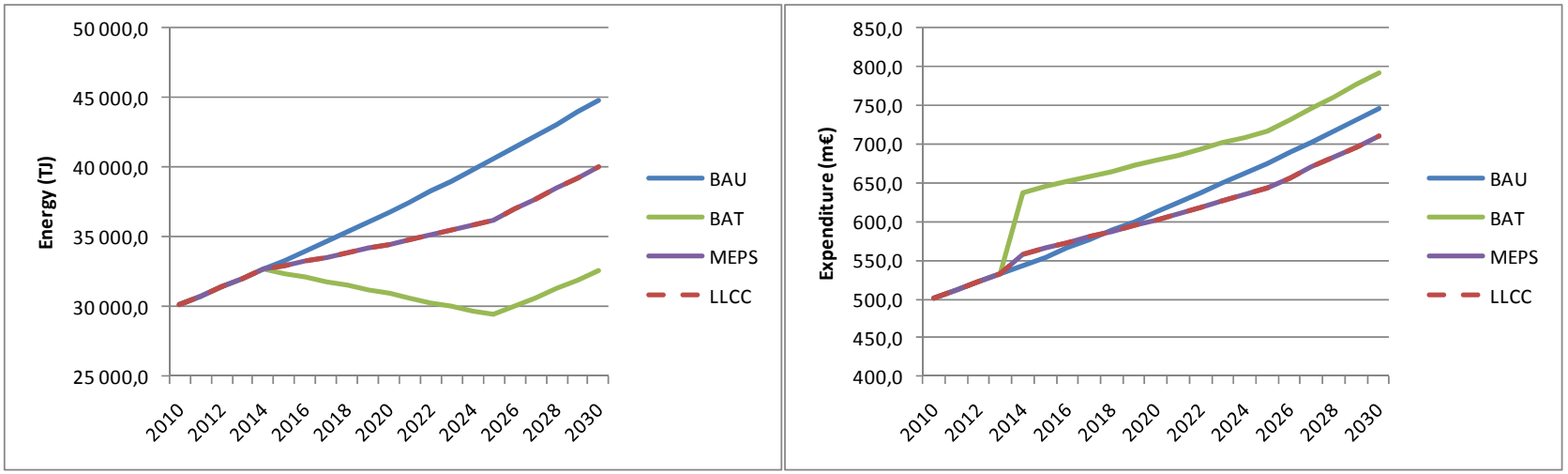


Figure 2-8 Primary energy consumption and expenditure by scenario, base case 5

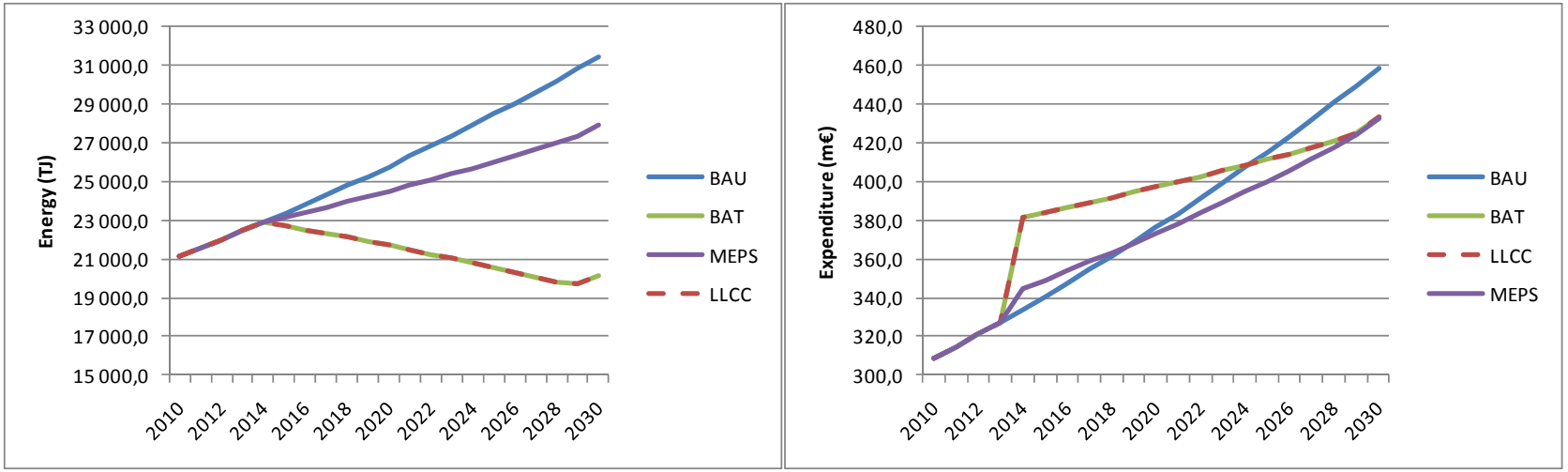


Figure 2-9 Primary energy consumption and expenditure by scenario, base case 6

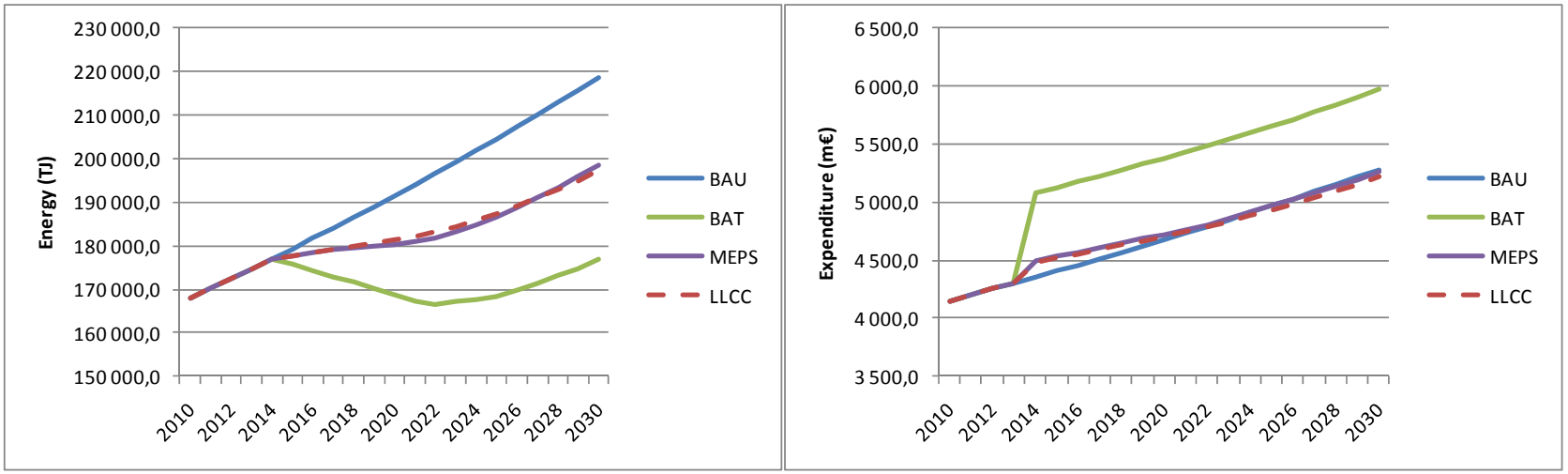


Figure 2-10 Primary energy consumption and expenditure by scenario, total for all base cases

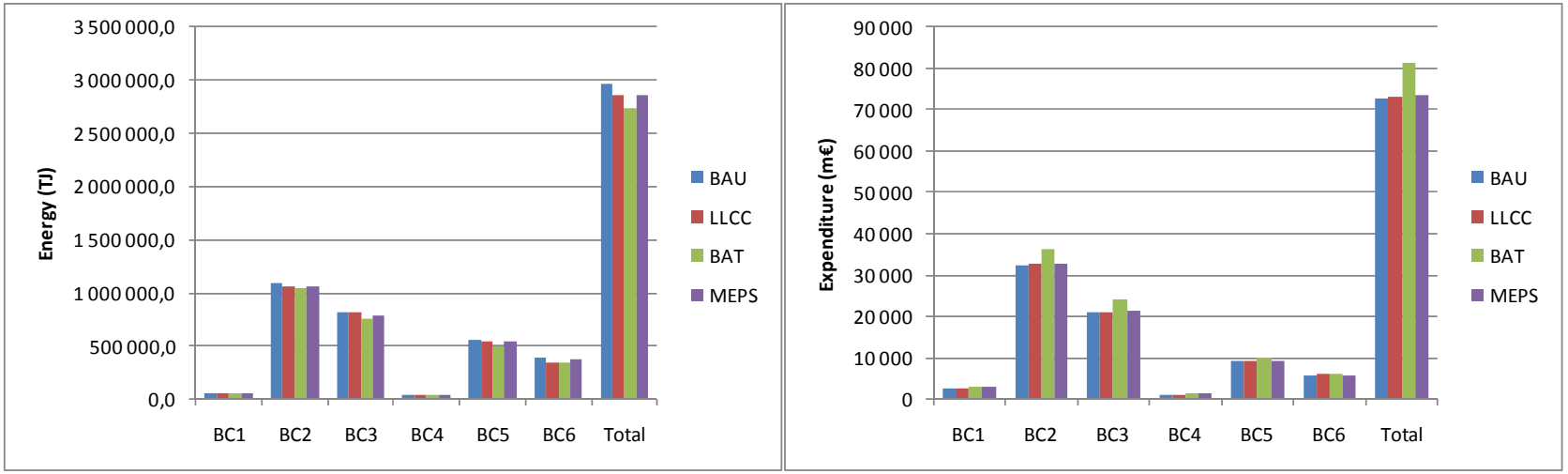


Figure 2-11 Primary energy consumption and expenditure by scenario, over the period 2010-2025

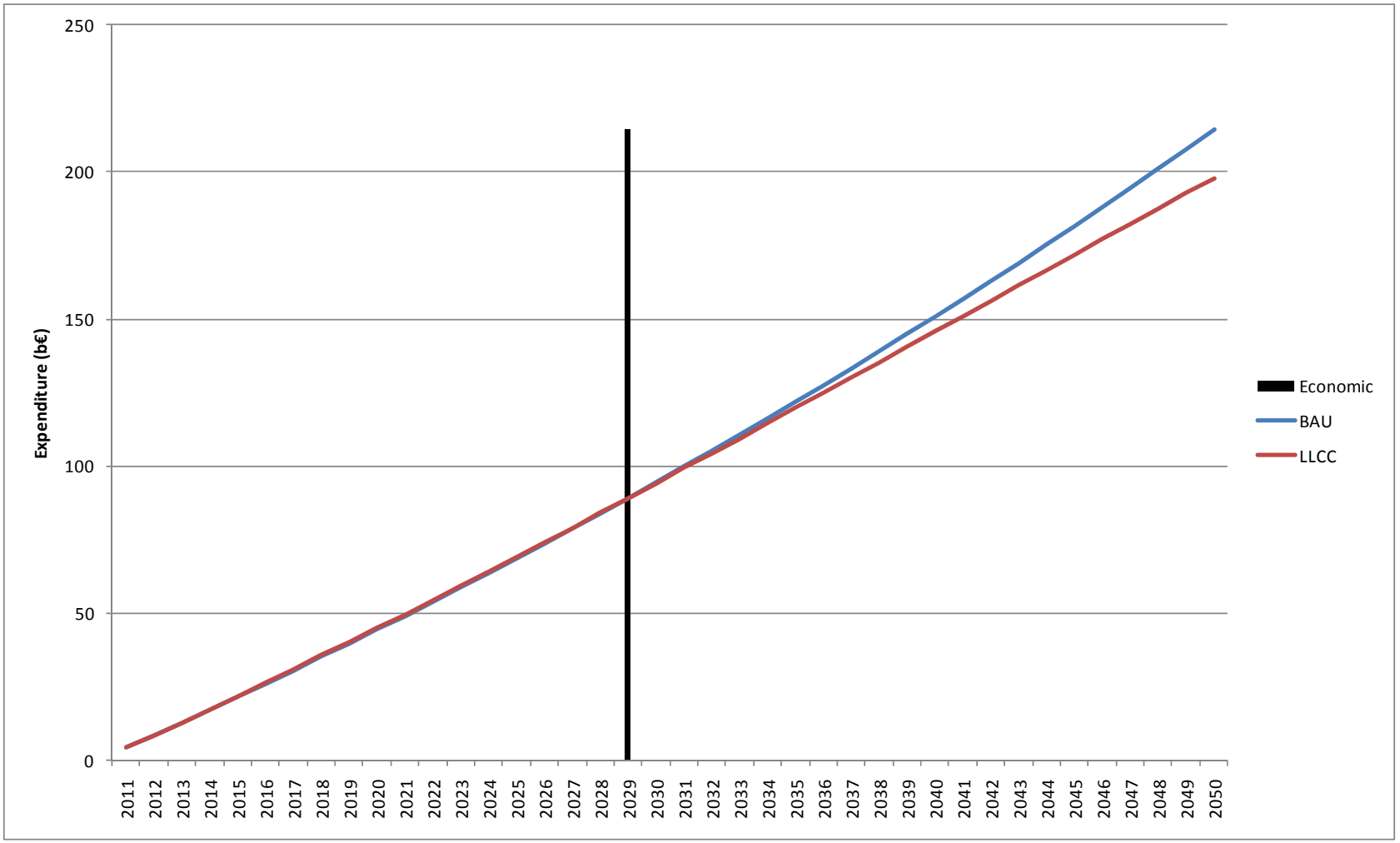


Figure 2-12 Extrapolation of cumulated expenditure of the BAU and LLCC scenarios, total for all base cases

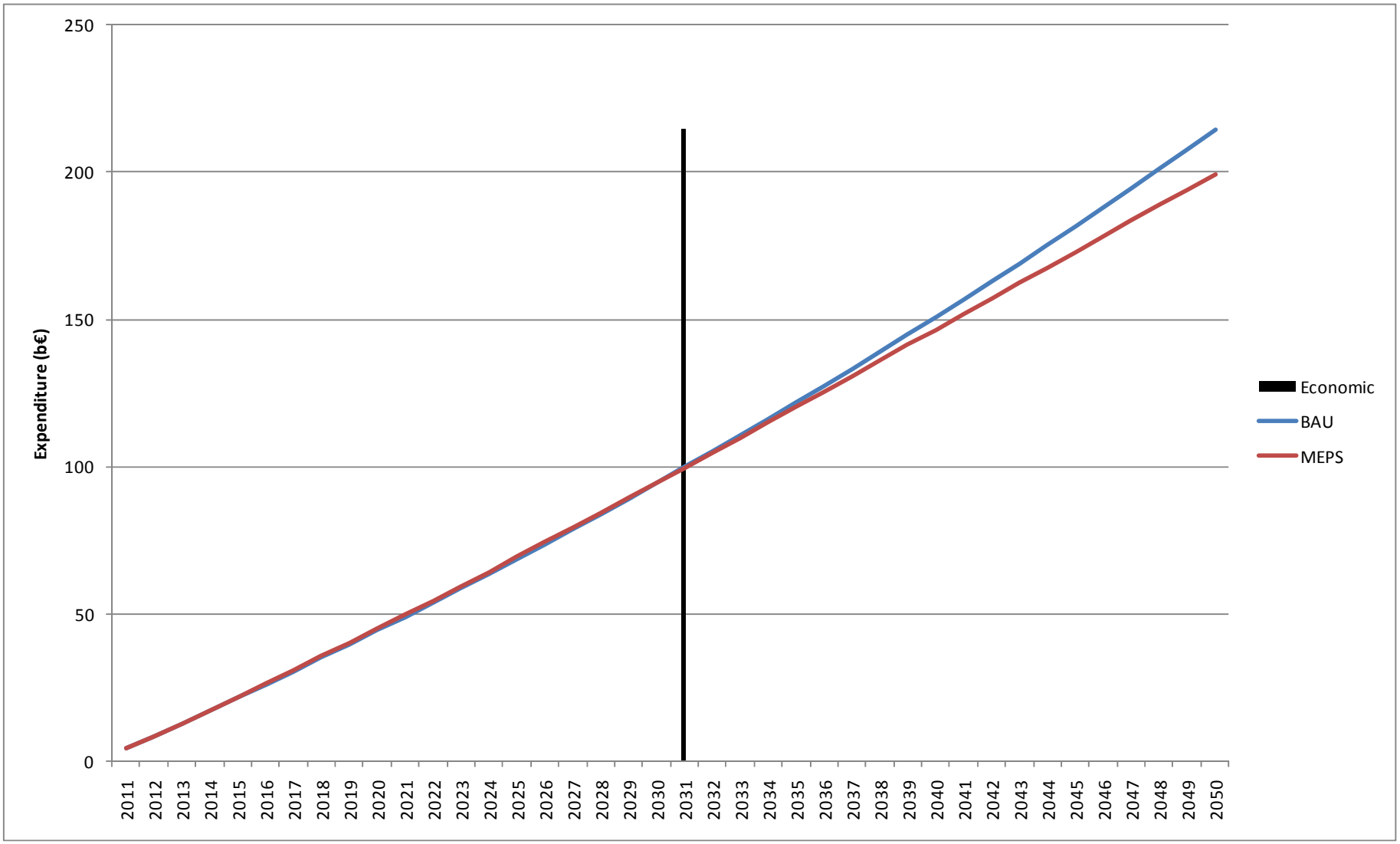


Figure 2-13 Extrapolation of cumulated expenditure of the BAU and MEPS scenarios, total for all base cases

3 Impact analysis

This section presents the impact analysis. It consists of an estimate of the impact on consumers (purchasing power, societal costs) and industry (employment, profitability, competitiveness, investment level, etc.), explicitly describing and taking into account the typical design cycle (platform change) in this product sector.

3.1 Impacts on manufacturers and competition

All the technologies described in this study and considered as improvement options in the scenarios are already available on the market today. As a result, the possible implementation of minimum performance standards dealing with relevant targets should not have a major negative impact on manufacturers; especially because the professional dishwasher sector is very competitive and has been continuously improving product performance (see Task 2).

Regarding the definition of a timeline to implement standards, it should take into account the time necessary to adapt production lines. This redesign time is very variable depending on the type of change to be achieved: it has been estimated that between 6 and 36 months are needed for a change of a single part of the appliance (see Task 2), being the case for every improvement option as presented within the study. The full redesign cycle might take even longer. Assuming the development of the required standards (see Section 2.3.1) is finished by 2012, Tier 1 has thus been set at 2014 for the minimum eco-design requirements and the scenario model.

Most manufacturers seem to have similar BAT products, with the implementation of the same improvement options. Manufacturers of professional dishwashers are mostly large international companies, but smaller manufacturers are also present, especially in Spain and Italy. If minimum performance standards were set, all manufacturers should be able to keep up with the market requirements, using common technology or their own technological developments. However, smaller manufacturers might have some difficulty to react as quickly as the larger ones. Therefore, appropriate and progressive targets should be set, both in terms of performance and timeline.

EU manufacturers claim to produce amongst the most efficient professional dishwashers manufactured worldwide. Therefore, the implementation of minimum performance standards is not expected to hamper the economic development of large EU manufacturers to the benefit of extra-EU competitors. However, impacts on smaller manufacturers deserve further assessment.

3.2 Monetary impacts

The scenario analysis partly addresses monetary impacts. The MEPS scenario provides monetary benefits in 2018 for base case 5 and in 2019 for base case 6, and from 2031 in terms of cumulative expenditure.

The possible implementation of minimum performance standards may require additional capital investment from manufacturers to adapt manufacturing techniques to efficiently produce the more efficient products (e.g. changing production lines). It is however not estimated that these investments would represent a significant burden for manufacturers as they are used to continuously improving the efficiency of their appliances. Investment costs may also be partly counterbalanced by slightly higher selling prices of more efficient dishwashers. Besides, economies of scale may enable manufacturers to have a larger margin and/or drop prices when selling efficient appliances.

On the consumer side, purchasing a more efficient professional dishwasher may represent a larger initial investment, but if performance requirements are set based on LCC calculations, the investment becomes beneficial in the long term. Buyers that use a Total Cost of Ownership (purchase price and running costs) approach could even be eager to buy more efficient products provided they are economic in the long run, and policy options could also aim to encourage this long-term vision, which is beneficial both from the environmental and economic points of view.

3.3 Impacts on consumer use

For the improvement options presented, the functional unit and the service given by the improved product remain the same as the base case (being a necessary condition to make a relevant comparative life cycle assessment): this is a paramount condition to assess their implementation in professional dishwashers. Thus, there should be no trade-off in terms of functionality (e.g. increase of noise, moisture in the room), for the increase of energy, water or detergent efficiency. In particular, the measurement of the cleaning and drying performance should appear in the standards to be developed (see 2.3.1).

For conveyor-type machines, reduction of life cycle costs via energy and water savings may form an important part of the marketing strategy as customers tend to be more aware of the long term operational costs of machines. Manufacturers try to sell more efficient (and expensive) appliances to the end user by reducing their operating costs.

3.4 Impacts on innovation and development

Best not yet Available Technologies (BNAT) and current axes of research in the sector were not very thoroughly described throughout this study because of a serious lack of available data. Such information is very sensitive and manufacturers were obviously not willing to share. In addition, little or no independent research has been carried out. The possible implementation of minimum performance standards can be seen as an opportunity for manufacturers to look for innovative and efficient technological solutions in order to decrease costs. Again, given the competitiveness of the sector, it seems that following the current trend regarding research and development is feasible for the manufacturers and should enable them to meet proposed requirements.

3.5 Social impacts

Most EU manufacturers have their production plants within the EU. If performance standards were set, they should not have a detrimental impact on the number of jobs or the well-being of the EU manufacturers' employees. Indeed, the professional dishwasher sector has been improving performance continuously over the last 30-40 years so that the companies have experience in carrying out continuous production transitions.

Regarding the security of supply, the improvement options presented do not require any specific material that might be difficult to obtain within the EU so that the supply chain would not be unduly affected nor EU industries disadvantaged.

4 Sensitivity analysis of the main parameters

The sensitivity analysis checks the robustness of the overall outcomes. It should cover the main parameters as described in Annex II of the ErP directive (such as the price of energy, the cost of raw materials or production costs, discount rates, including, where appropriate, external environmental costs, such as avoided greenhouse gas emissions), to check if there are significant changes and if the overall conclusions are reliable and robust.

As a reminder, the improvement options that were studied in detail in Task 7 are listed below:

- **M 1.5 Auxiliary rinsing:** for conveyor-type dishwashers, lower fresh-water consumption can be achieved thanks to a two- or three-step rinsing zone.
- **M 2.1.1 Exhaust air heat exchanger:** the heat from exhaust air can be used to preheat the incoming water of the machine through a counter-flow exchanger.

- **M 2.1.2 Exhaust air heat pump**: thanks to a heat pump, an electric device with cooling and heating capabilities, the energy contained in the exhaust air can be recovered more efficiently than with a heat exchanger.
- **M 3.1.1 Waste water heat exchanger**: the process is the same as for an exhaust air heat exchanger except that the heat is extracted from the waste water.
- **M 4.1 Insulation**, closed bottom: the wash tank and other parts of the dishwasher can be thermally insulated to reduce convection losses in the operating and ready-to-use modes.
- **M 4.2 High efficiency pumps and motors:** the efficiency of the whole hydraulic system (including pumps, motors and pipes) can be optimised, thus reducing energy losses.

The parameters that were considered most relevant for this sensitivity analysis (because of their importance and/or uncertainty) in the case of professional dishwashers are listed below:

- Electricity, water and detergent consumption;
- Intensity of use of the machines (number of cycles per year);
- Lifetime;
- Electricity, water and detergent prices;
- Product price;
- Discount rate.

Parameters such as resource and consumables prices, product purchase prices and discount rate have a direct influence on the LCC calculations of the base cases and their improvement options (but not on the environmental impacts of the products) while others (resource and consumables consumption, lifetime) will influence both the environmental impacts of the products and the LCC through operating costs.

The influence of the single parameters on the results will be first studied separately and the analysis of combined changes in several parameters at the same time will be made in Section 4.7.

4.1 Resource and consumables consumption

4.1.1 Assumptions

In Task 4, average energy, water and detergent consumption data were determined for the base cases. Given the uncertainty that remains regarding the definition of “average market” products, the sensitivity analysis will consider an error margin of 20% on the given values, both for minimum and maximum values.[13] The tested values are therefore presented in

[13] This error margin was discussed and agreed during the final stakeholder meeting, 9 December 2010 in Paris.

Table 4-1, Table 4-2 and Table 4-3. This error margin is also used for the consumption values of improvement options as the consumption is calculated relatively (in %) with the base cases consumption.

Table 4-1 Electricity consumption range for the sensitivity analysis

Base case	Base total electricity consumption (kWh/year)	Min	Max
1. Undercounter water-change	1 254	1 003	1 505
2. Undercounter one-tank	5 253	4 202	6 304
3. Hood-type	8 258	6 606	9 910
4. Utensil/Pot	8 913	7 130	10 696
5. One-tank conveyor-type	37 703	30 162	45 244
6. Multi-tank conveyor-type	102 229	81 783	122 675

Table 4-2 Water consumption range for the sensitivity analysis

Base case	Base water consumption (m^3/year)	Min	Max
1. Undercounter water-change	25.92	21	31
2. Undercounter one-tank	55.82	45	67
3. Hood-type	86.65	69	104
4. Utensil/Pot	89.52	72	107
5. One-tank conveyor-type	255.686	205	307
6. Multi-tank conveyor-type	643.645	515	772

Table 4-3 Detergent consumption range for the sensitivity analysis

Base case	Base detergent consumption (in kg per year)	Min	Max
1. Undercounter water-change	87	70	104
2. Undercounter one-tank	188	150	226
3. Hood-type	292	234	350
4. Utensil/Pot	294	235	353
5. One-tank conveyor-type	865	692	1 038
6. Multi-tank conveyor-type	2 146	1 717	2 575

4.1.2 Results

4.1.2.1 Influence of the variation of the electricity consumption

Figure 4-1 to Figure 4-12 show the influence of the variation of the electricity consumption on the total energy consumption and the life cycle costs of the different base cases and associated improvement options. No relative change in the rankings of options happen concerning the primary energy consumption.

Regarding costs, for base cases 1, 4 and 6, despite the expected variations in absolute values, the ranking of the different improvement options remains the same whether the minimum or maximum parameter is used.

For base case 2, with the minimum value the option M 4.2 is no longer the LLCC option, as the base case product gets a lower LCC.

On the contrary, for base case 3, option M 4.2 becomes the LLCC when the maximum value is considered, at the expense of the base case product.

For base case 5, the BA product almost becomes economic in comparison with the base case product; in particular, it gets a lower LCC than option M 4.1. By extrapolation, it can be assumed that with even larger electricity consumption than the current maximum, the BA product would become economically beneficial. Using the minimum value, the option M 3.1.1 gets a higher LCC than the base case product.

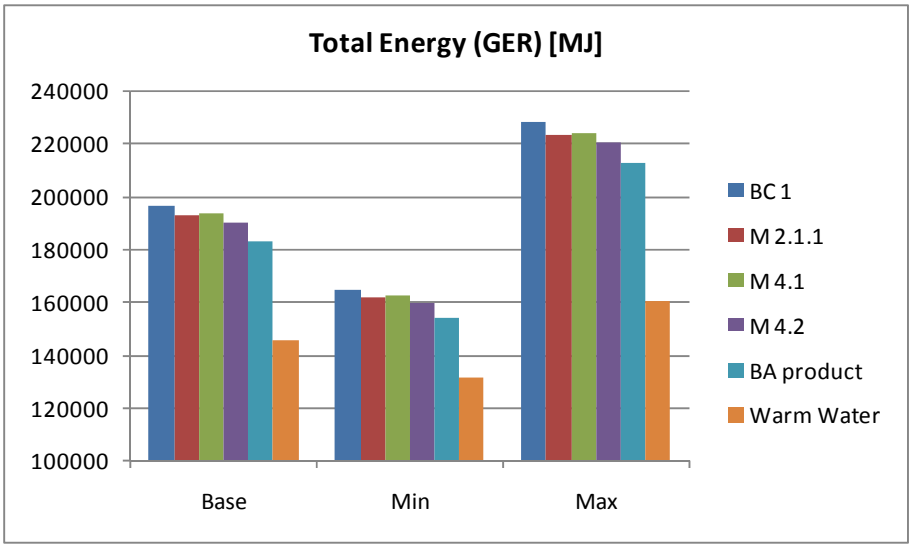


Figure 4-1 Base case 1 and improvement options – impact of electricity consumption on total energy over lifetime by product

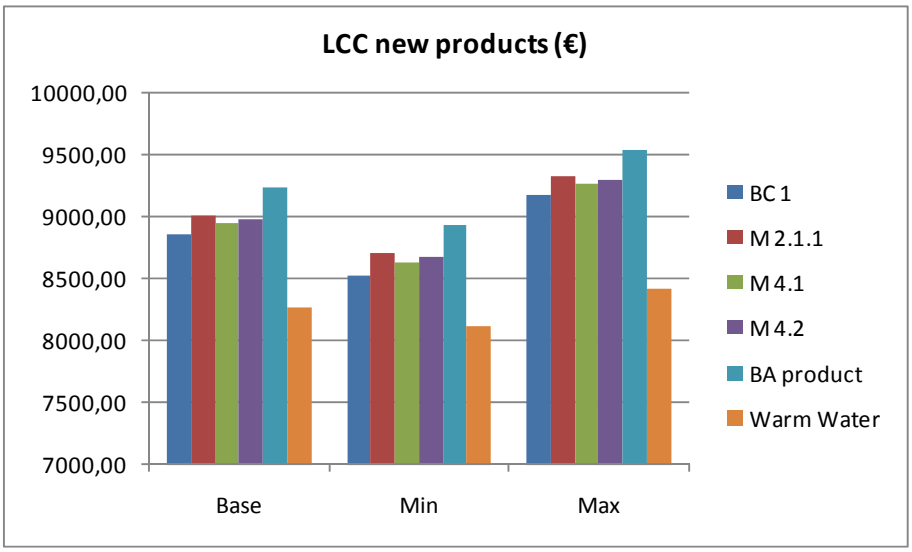


Figure 4-2 Base case 1 and improvement options – impact of electricity consumption on LCC by product

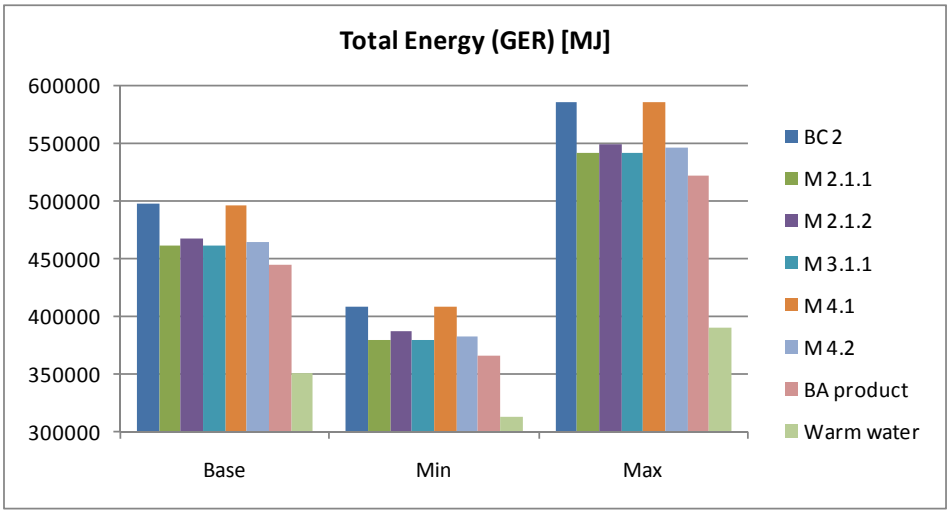


Figure 4-3 Base case 2 and improvement options – impact of electricity consumption on total energy over lifetime by product

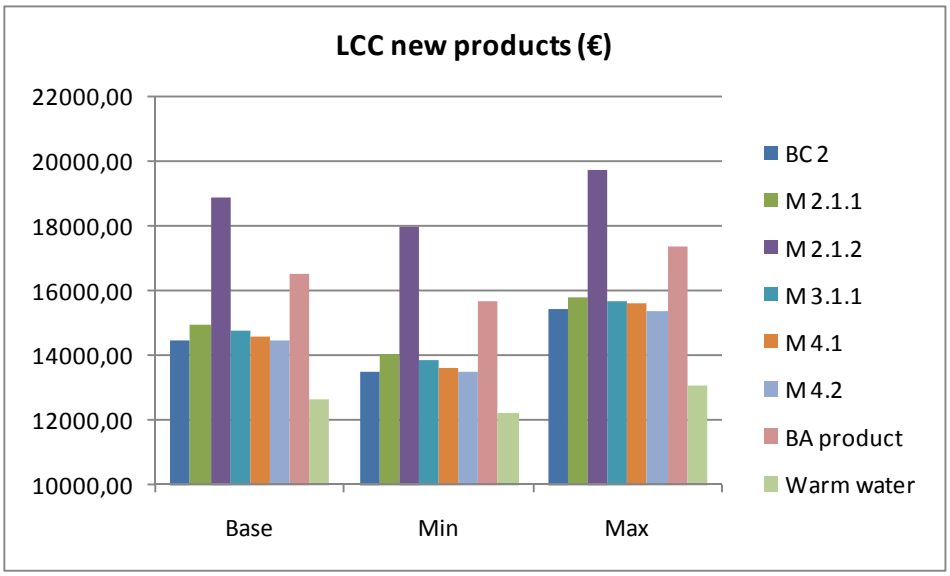


Figure 4-4 Base case 2 and improvement options – impact of electricity consumption on LCC by product

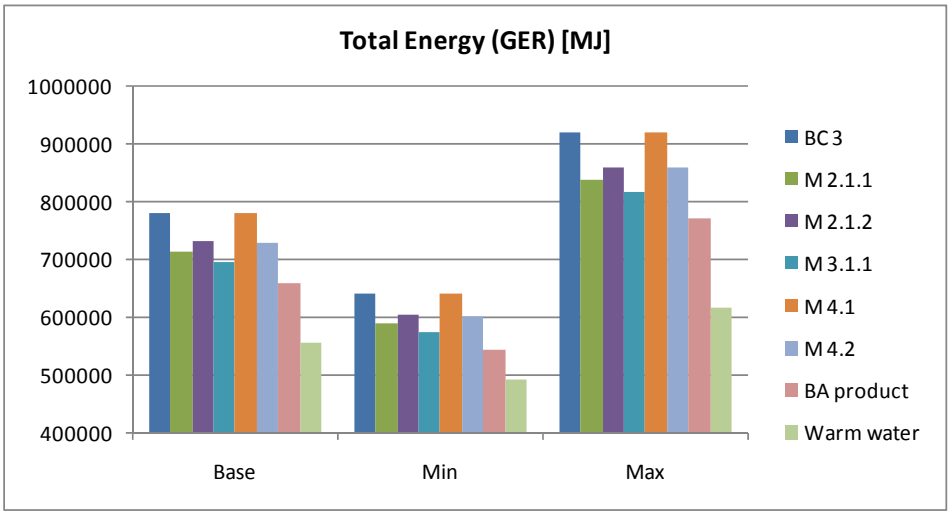


Figure 4-5 Base case 3 and improvement options – impact of electricity consumption on total energy over lifetime by product

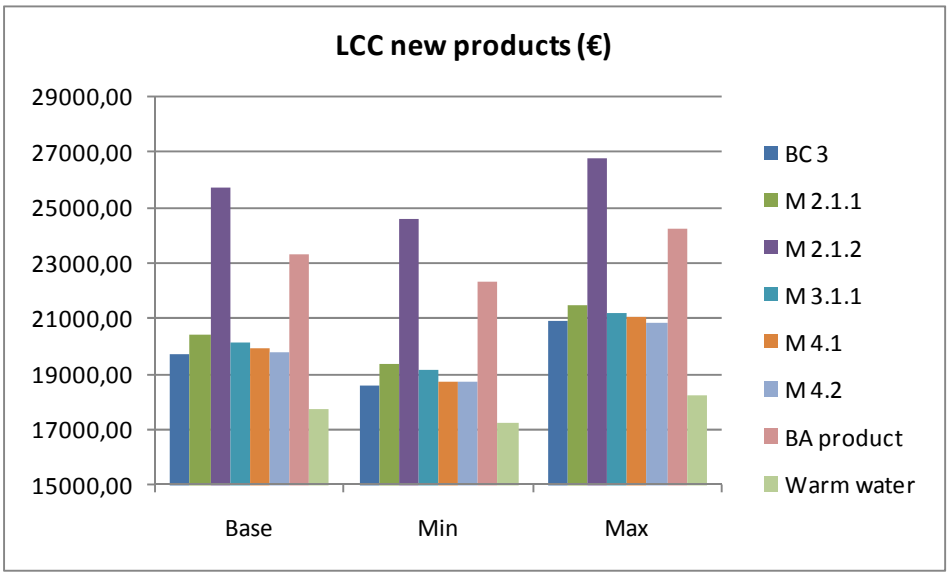


Figure 4-6 Base case 3 and improvement options – impact of electricity consumption on LCC by product

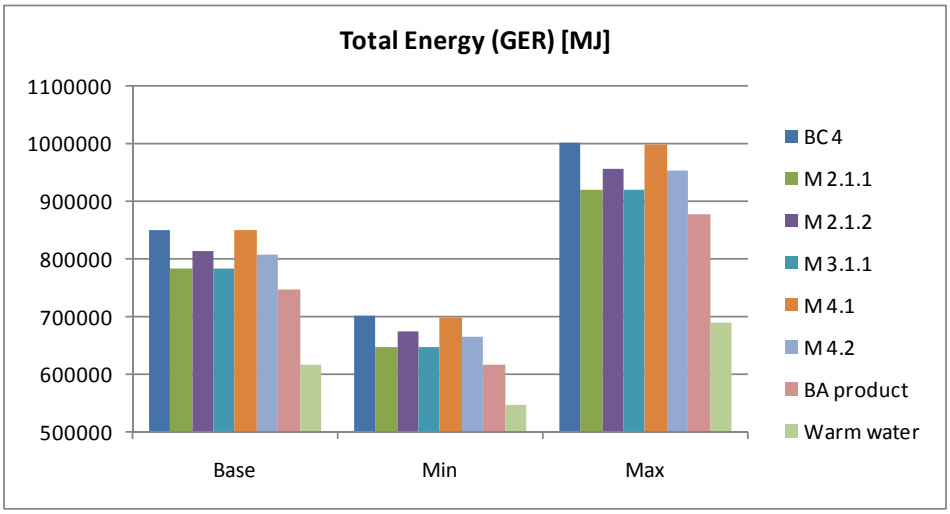


Figure 4-7 Base case 4 and improvement options – impact of electricity consumption on total energy over lifetime by product

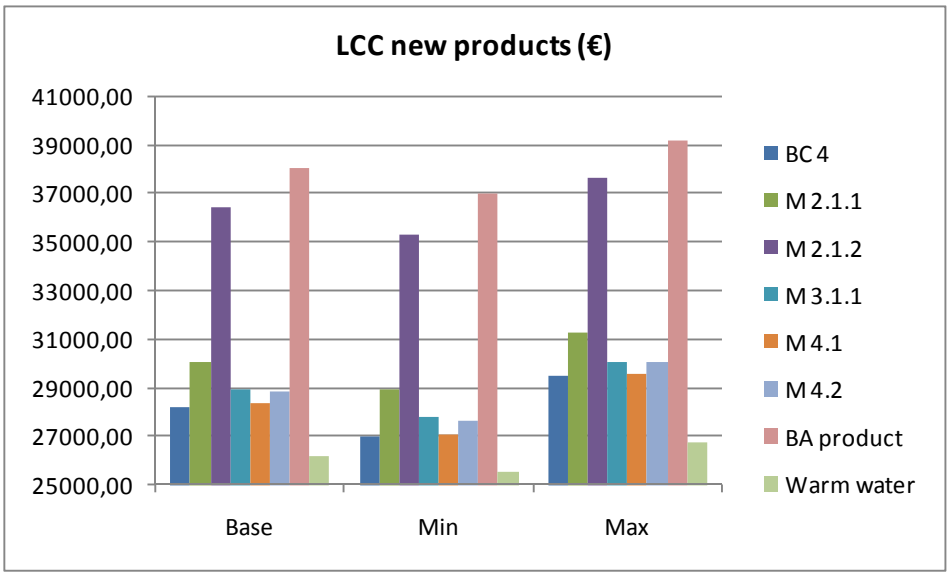


Figure 4-8 Base case 4 and improvement options – impact of electricity consumption on LCC by product

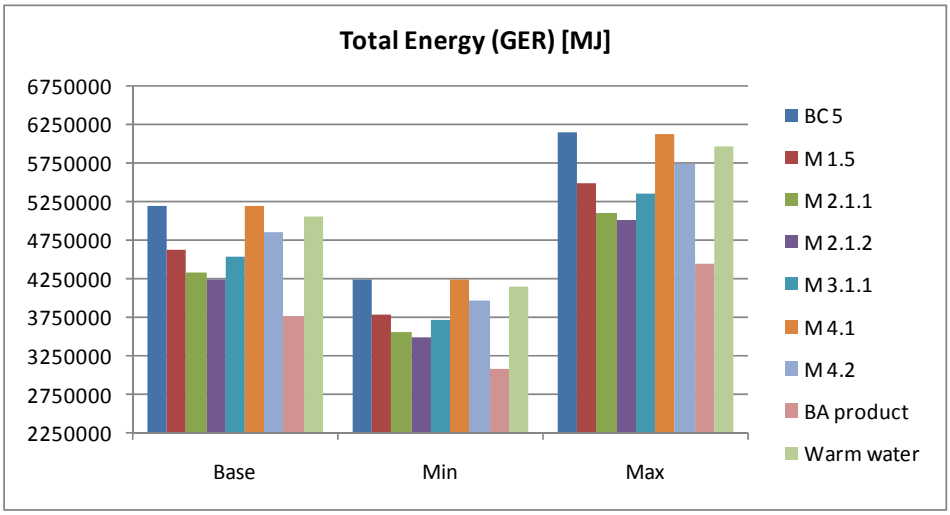


Figure 4-9 Base case 5 and improvement options – impact of electricity consumption on total energy over lifetime by product

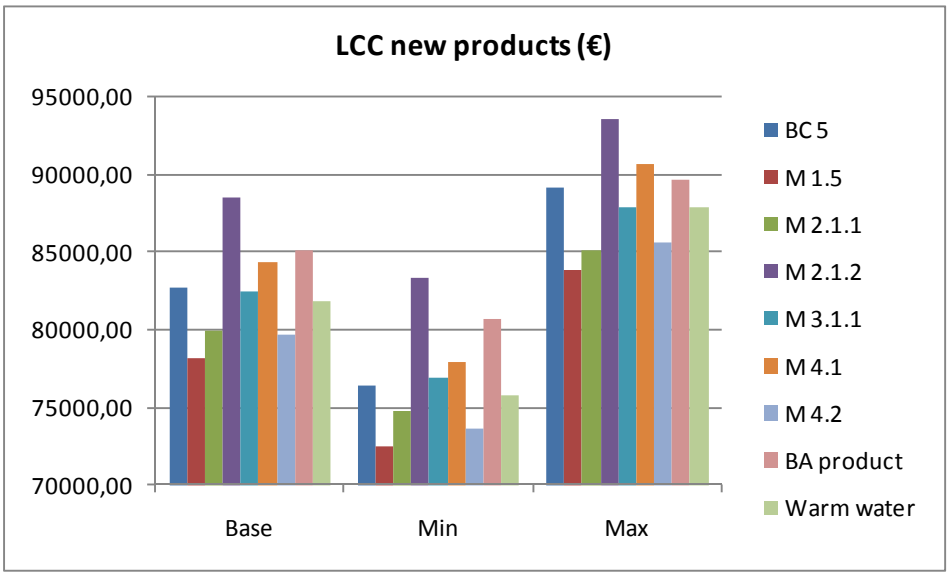


Figure 4-10 Base case 5 and improvement options – impact of electricity consumption on LCC by product

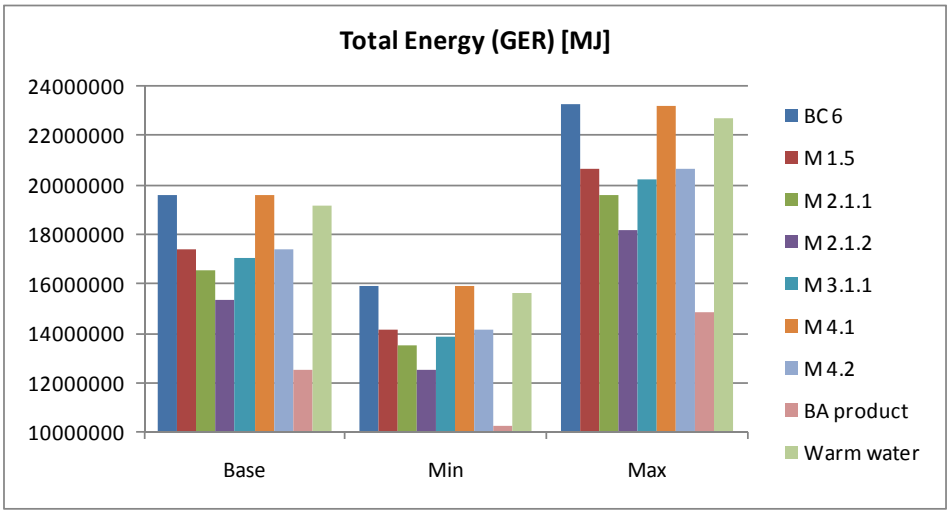


Figure 4-11 Base case 6 and improvement options – impact of electricity consumption on total energy over lifetime by product

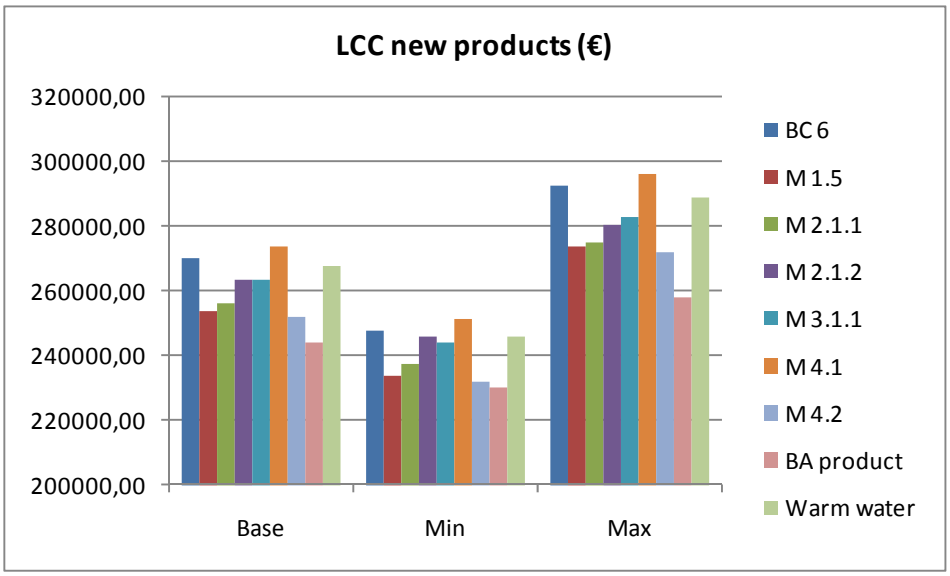


Figure 4-12 Base case 6 and improvement options – impact of electricity consumption on LCC by product

4.1.2.2 Influence of the variation of the water consumption

Figure 4-13 to Figure 4-24 show the influence of the variation of the water consumption on the total energy consumption and life cycle costs of the different base cases and associated improvement options. For all situations, despite the expected variations in absolute values, the ranking of the different improvement options remains the same whether the minimum or maximum parameter is used.

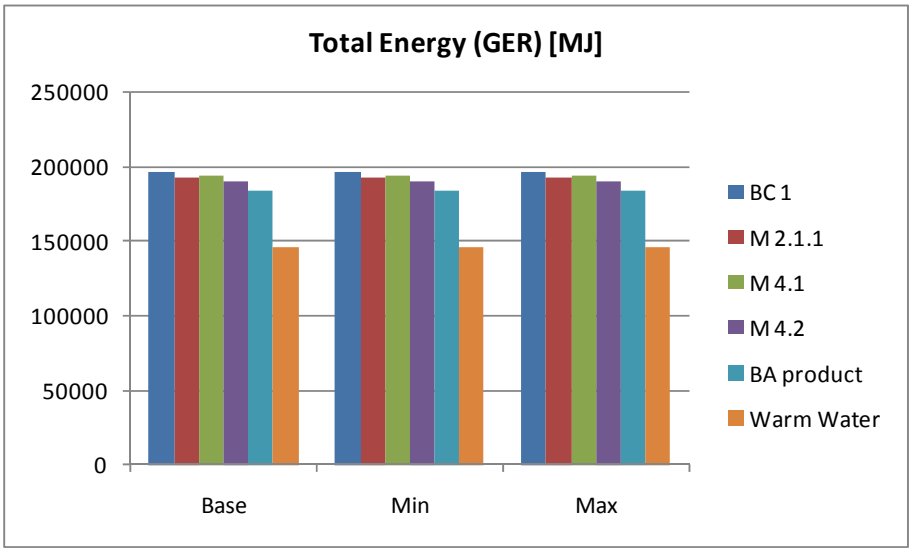


Figure 4-13 Base case 1 and improvement options – impact of water consumption on total energy over lifetime by product

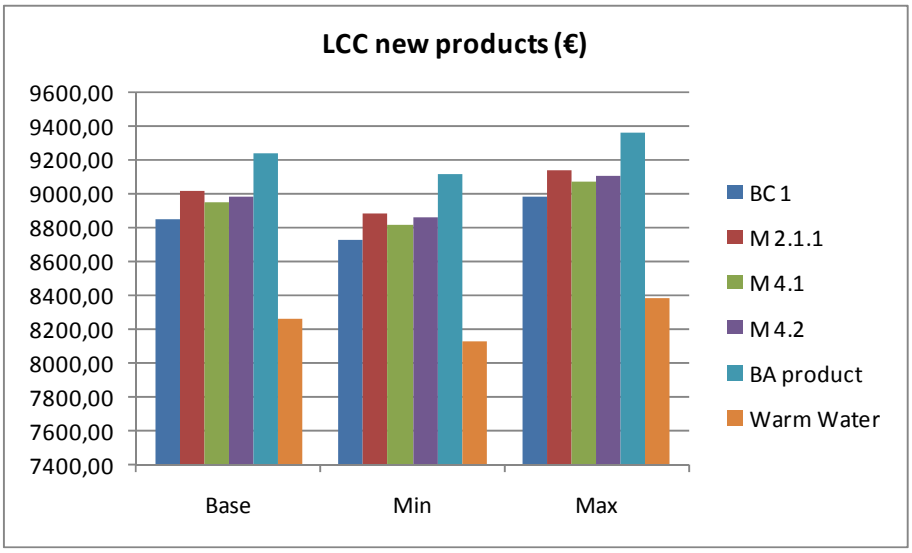


Figure 4-14 Base case 1 and improvement options – impact of water consumption on LCC by product

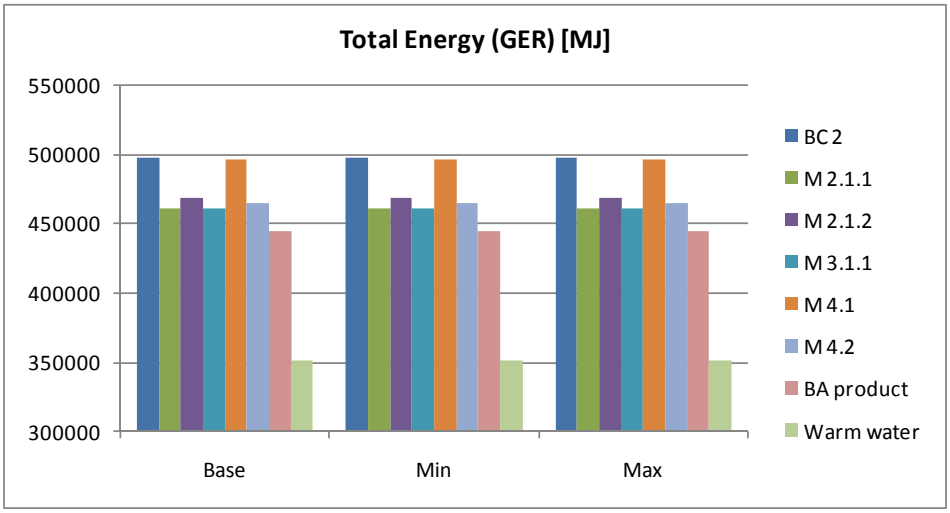


Figure 4-15 Base case 2 and improvement options – impact of water consumption on total energy over life-time by product

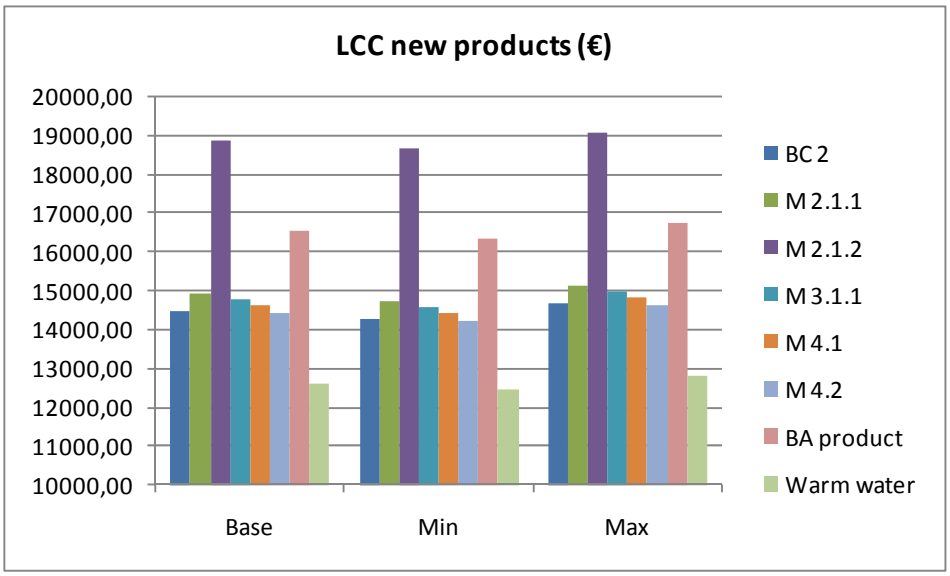


Figure 4-16 Base case 2 and improvement options – impact of water consumption on LCC by product

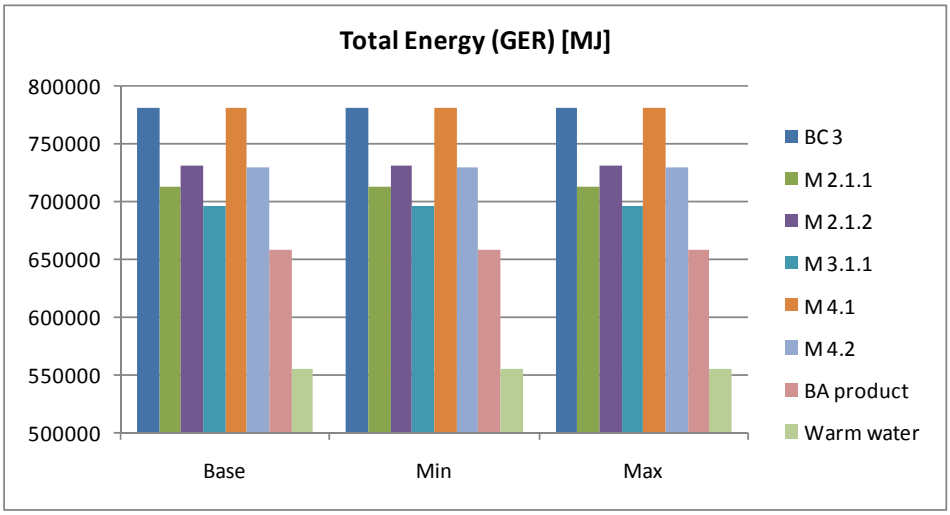


Figure 4-17 Base case 3 and improvement options – impact of water consumption on total energy over life-time by product

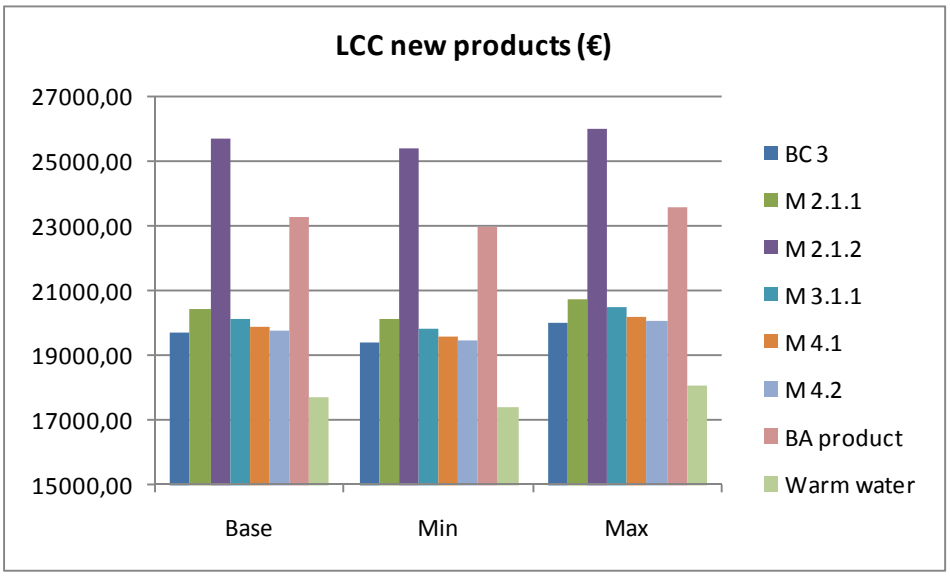


Figure 4-18 Base case 3 and improvement options – impact of water consumption on LCC by product

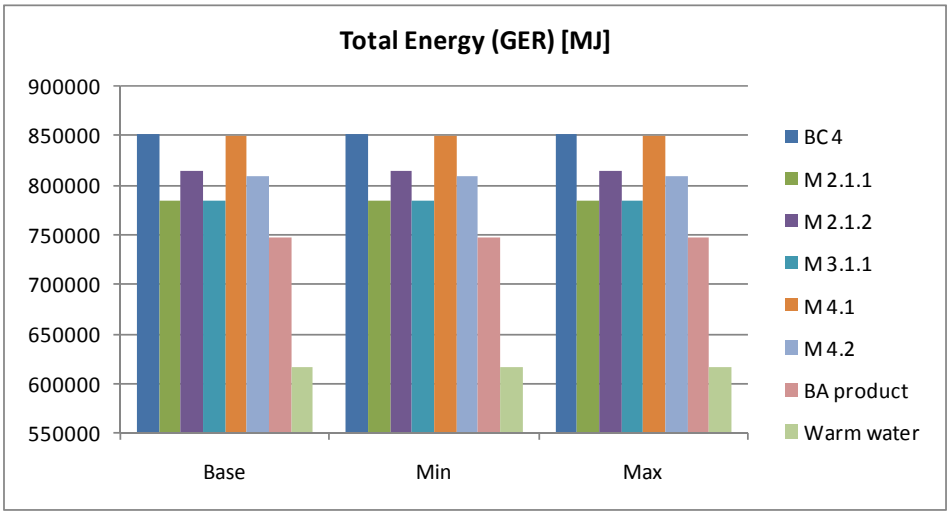


Figure 4-19 Base case 4 and improvement options – impact of water consumption on total energy over life-time by product

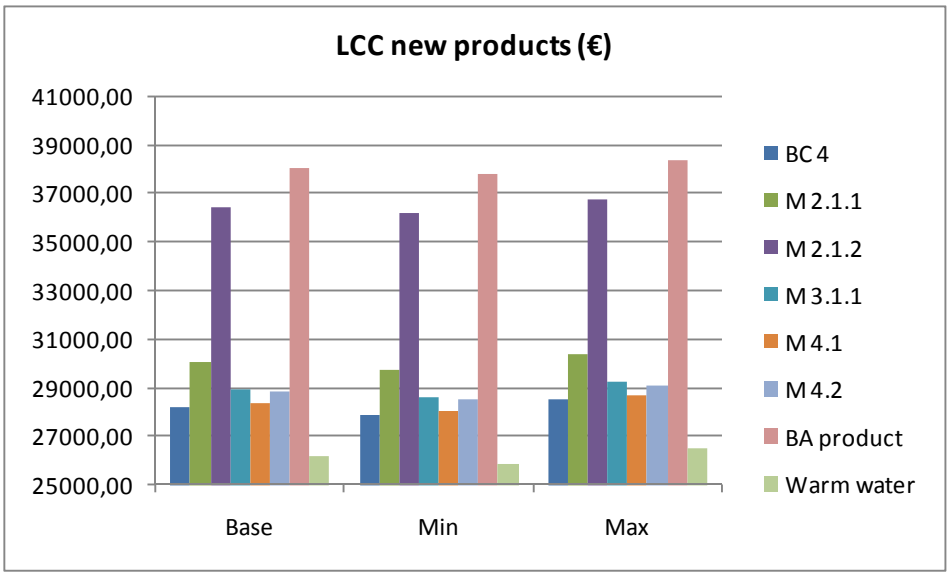


Figure 4-20 Base case 4 and improvement options – impact of water consumption on LCC by product

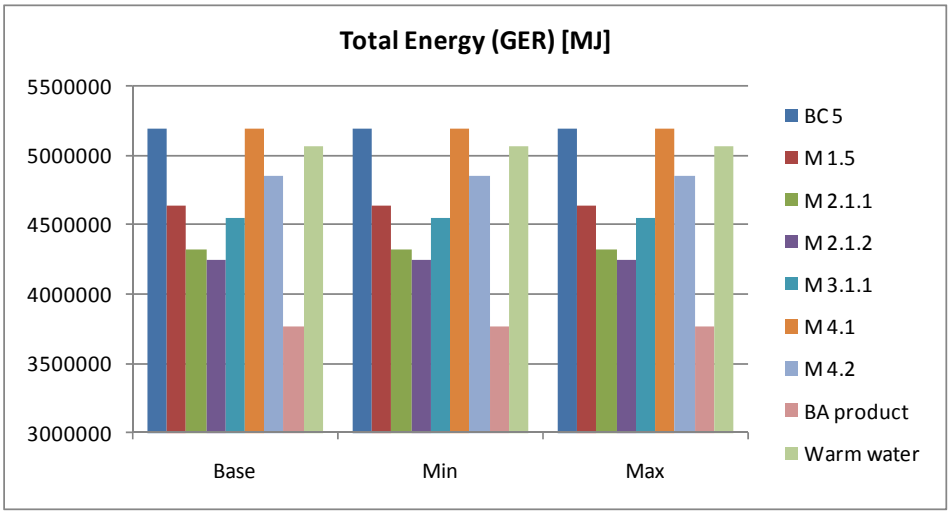


Figure 4-21 Base case 5 and improvement options – impact of water consumption on total energy over life-time by product

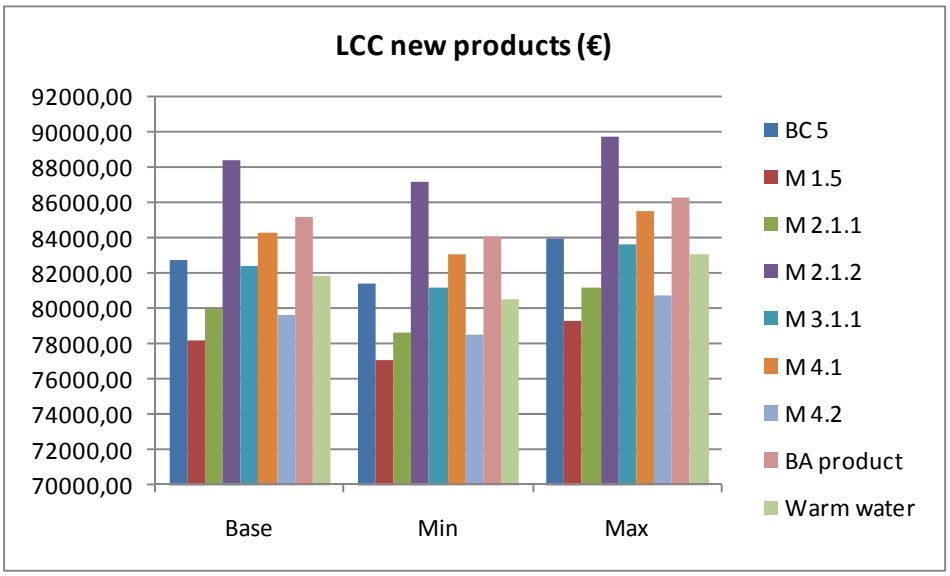


Figure 4-22 Base case 5 and improvement options – impact of water consumption on LCC by product

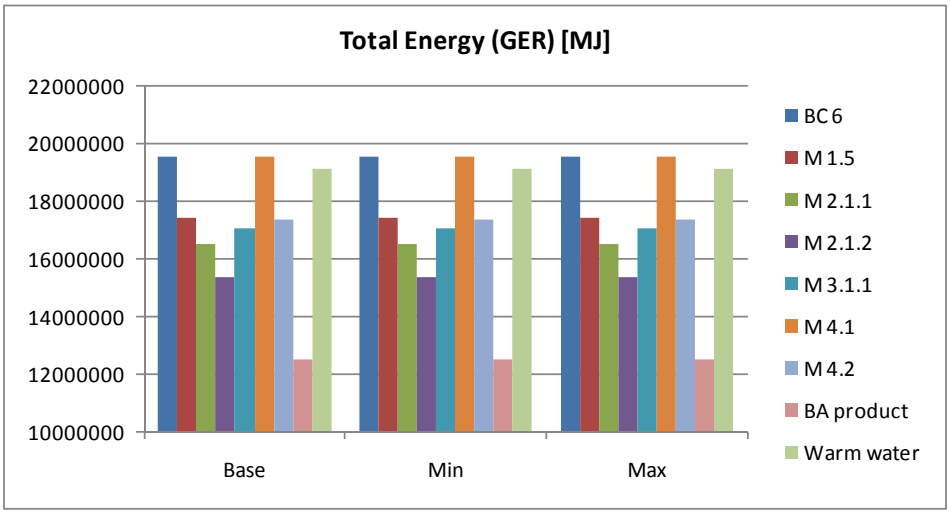


Figure 4-23 Base case 6 and improvement options – impact of water consumption on total energy over life-time by product

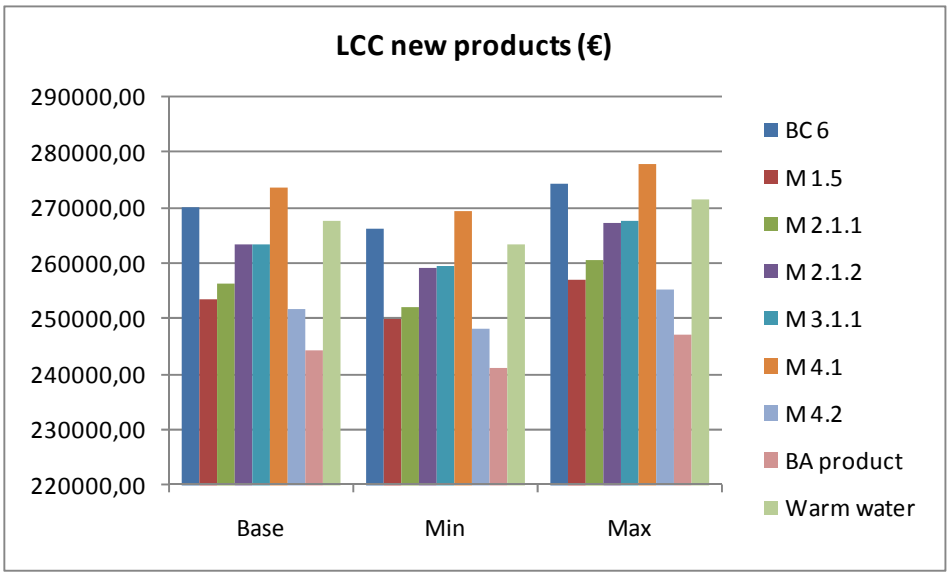


Figure 4-24 Base case 6 and improvement options – impact of water consumption on LCC by product

4.1.2.3 Influence of the variation of the detergent consumption

Figure 4-25 to Figure 4-36 show the influence of the variation of the detergent consumption on the eutrophication potential and the life cycle costs of the different base cases and associated improvement options.

For base cases 1, 4 and 6, despite the expected variations in absolute values, the ranking of the different improvement options remains the same whether the minimum of maximum parameter is used.

For base case 2, the option M 4.2 gets a higher LCC than the base case product when the minimum value is used: thus it is not the LLCC option anymore.

For base case 3, on the contrary, the option M 4.2 becomes the LLCC option when the maximum value is used, at the expense of the base case product.

Finally, for base case 5, no major change occurs. The option M 2.1.1 gets a lower LCC than option M 4.2 with the minimum parameter.

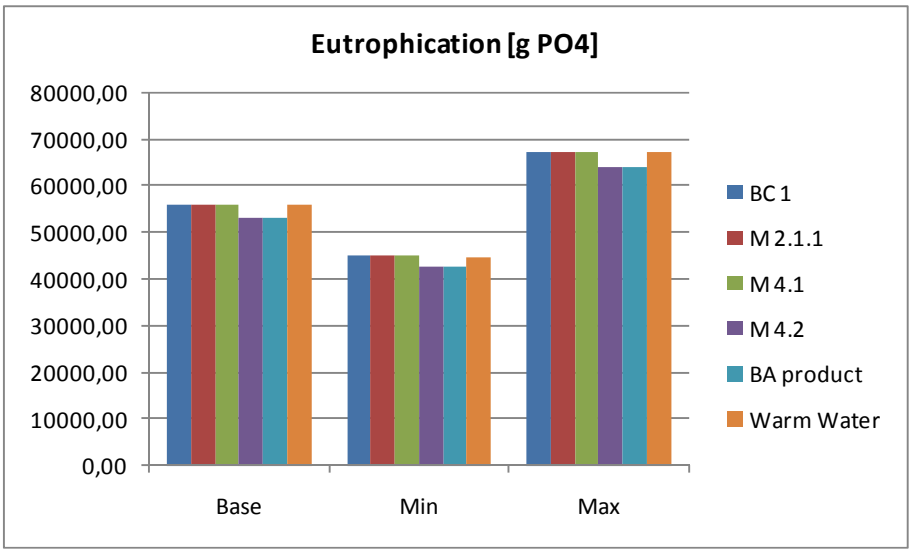


Figure 4-25 Base case 1 and improvement options – impact of detergent consumption on eutrophication over lifetime by product

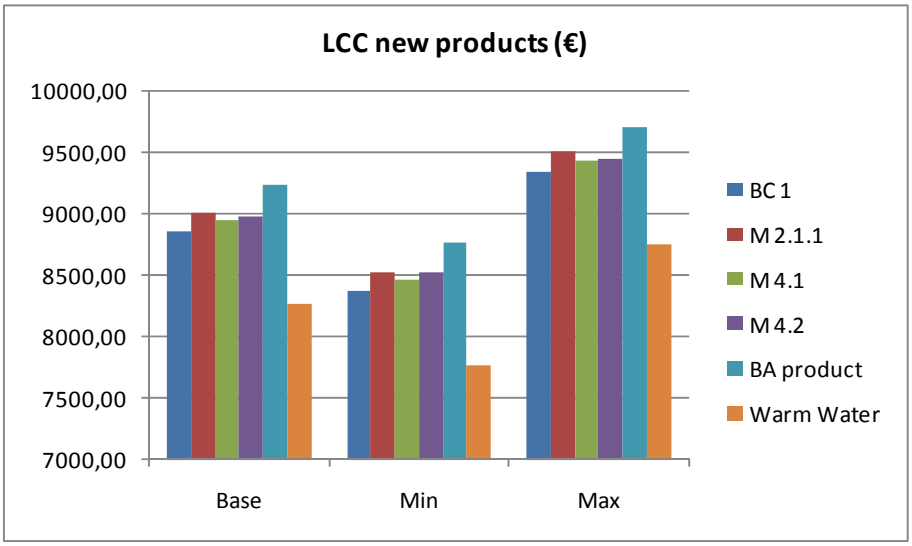


Figure 4-26 Base case 1 and improvement options – impact of detergent consumption on LCC by product

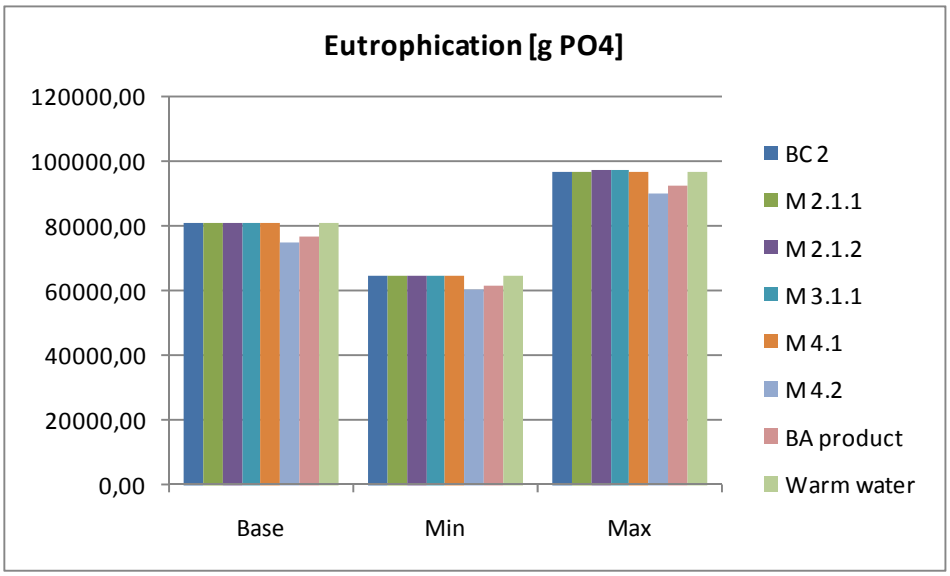


Figure 4-27 Base case 2 and improvement options – impact of detergent consumption on eutrophication over lifetime by product

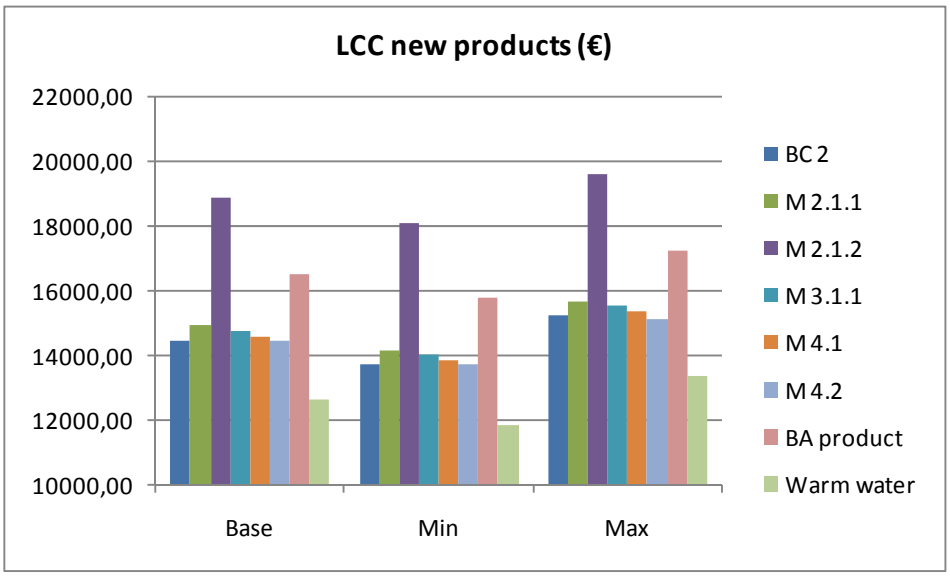


Figure 4-28 Base case 2 and improvement options – impact of detergent consumption on LCC by product

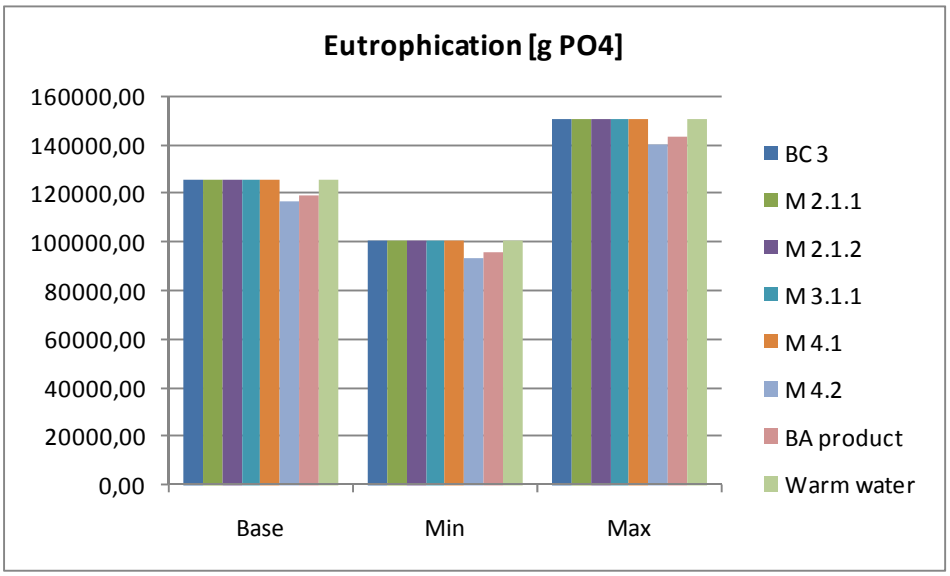


Figure 4-29 Base case 3 and improvement options – impact of detergent consumption on eutrophication over lifetime by product

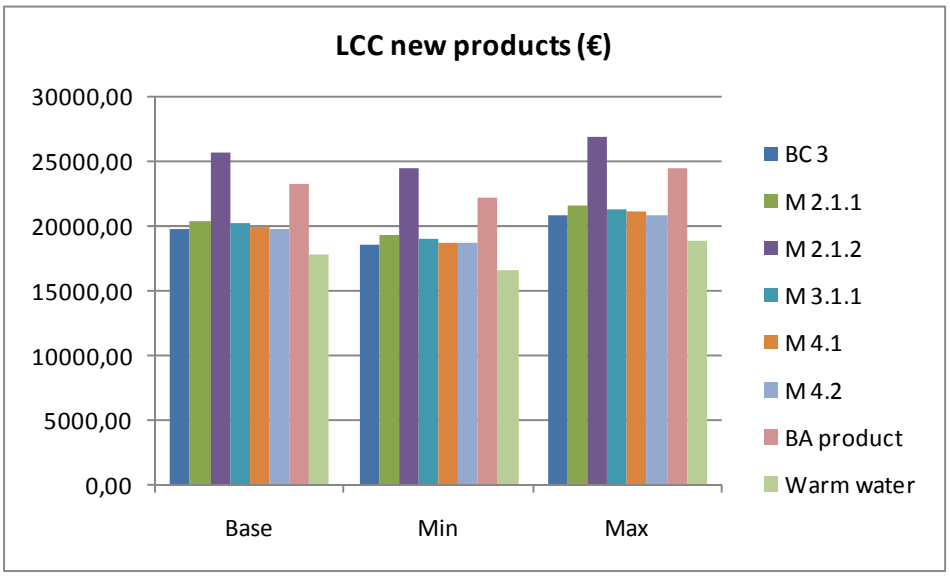


Figure 4-30 Base case 3 and improvement options – impact of detergent consumption on LCC by product

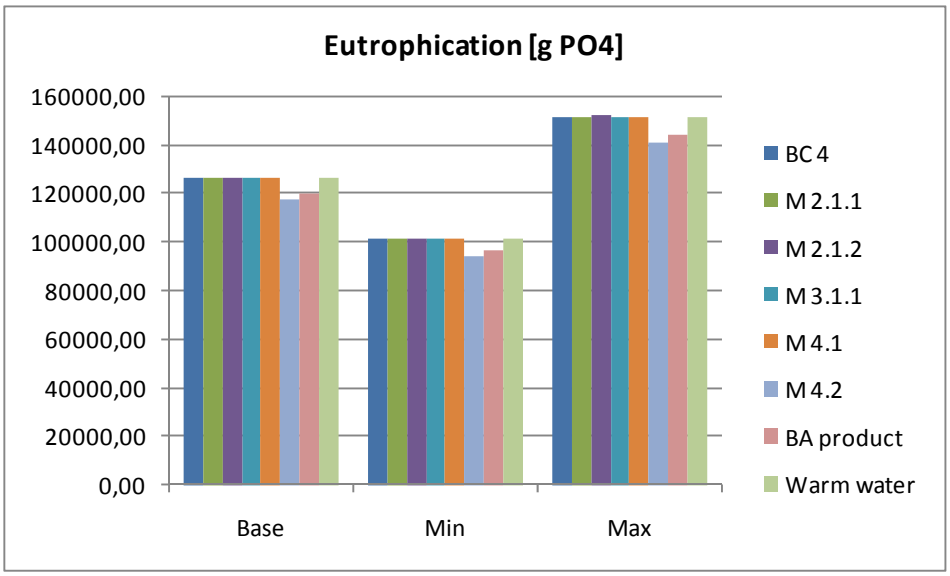


Figure 4-31 Base case 4 and improvement options – impact of detergent consumption on eutrophication over lifetime by product

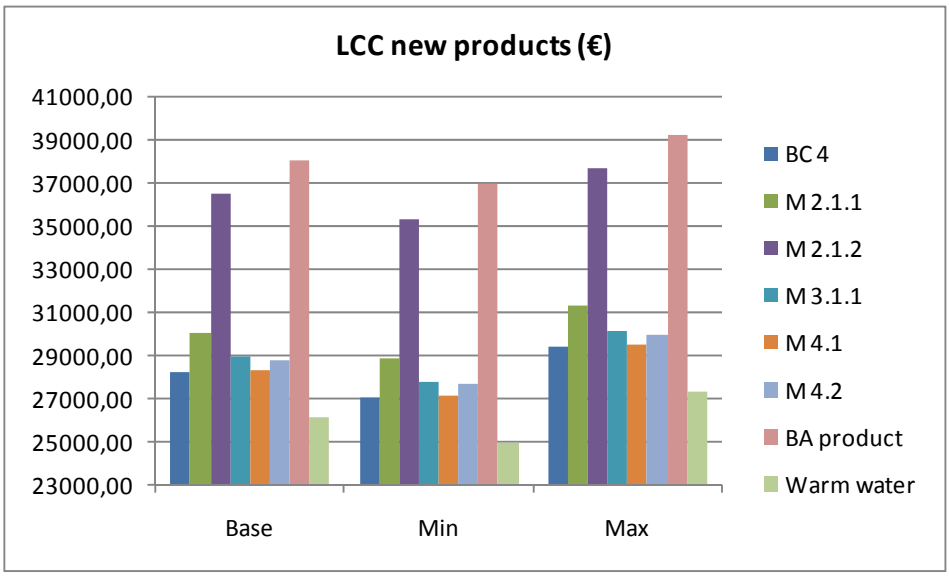


Figure 4-32 Base case 4 and improvement options – impact of detergent consumption on LCC by product

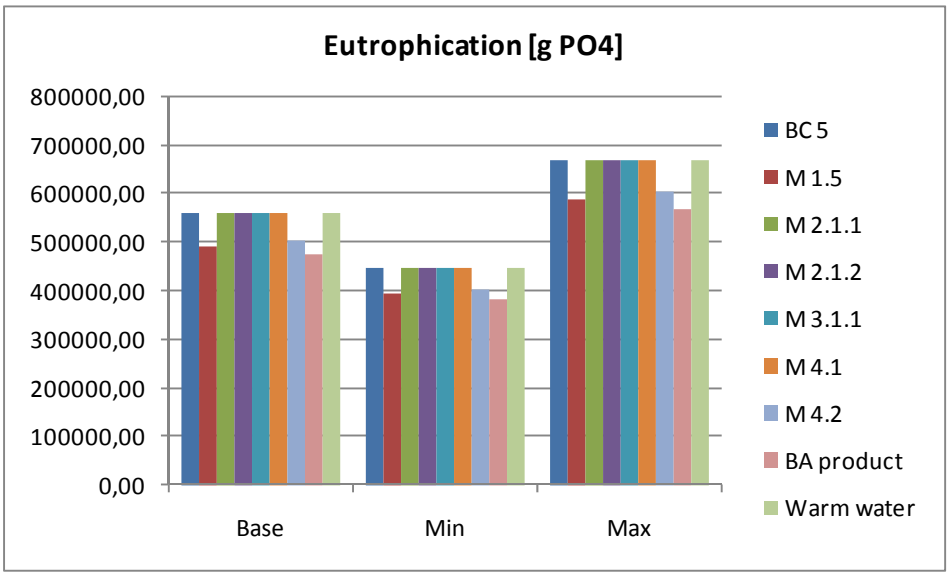


Figure 4-33 Base case 5 and improvement options – impact of detergent consumption on eutrophication over lifetime by product

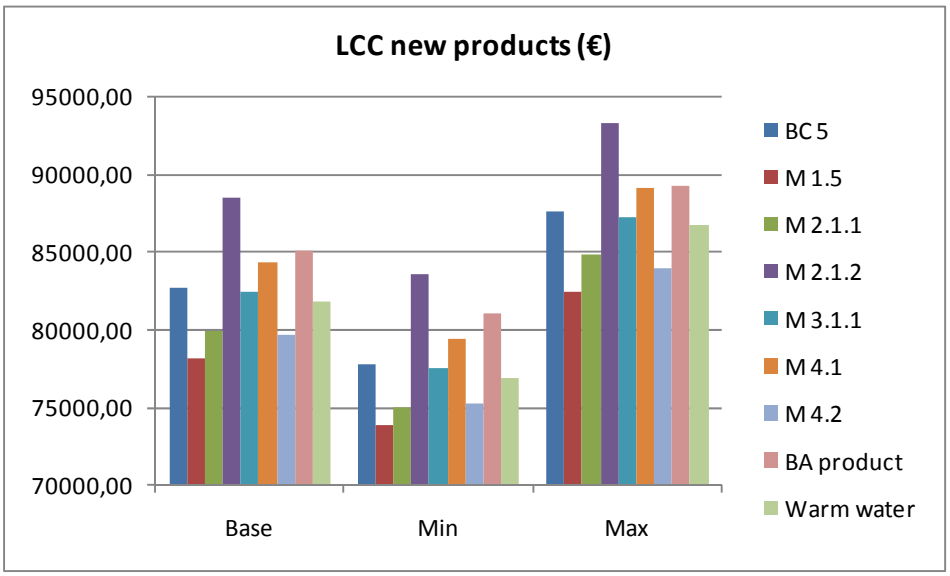


Figure 4-34 Base case 5 and improvement options – impact of detergent consumption on LCC by product

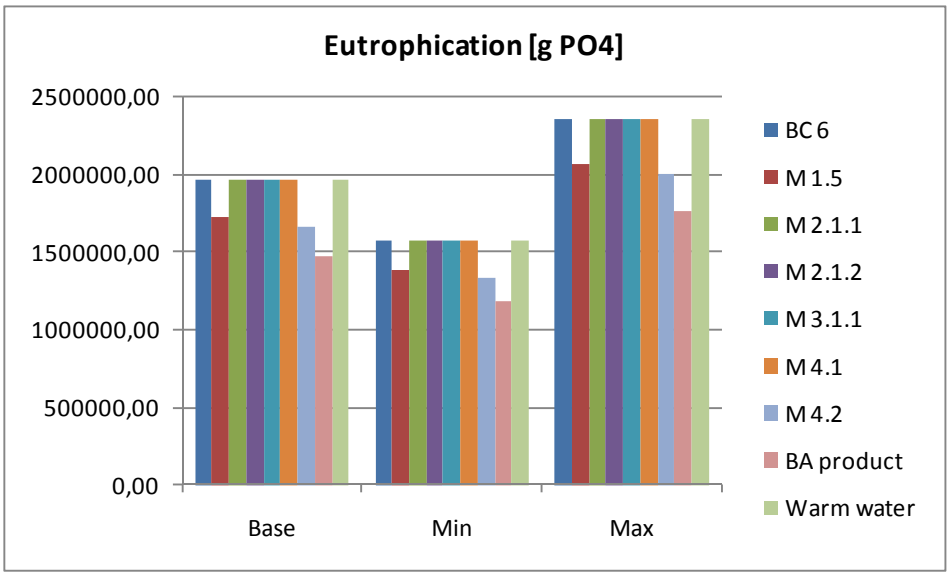


Figure 4-35 Base case 6 and improvement options – impact of detergent consumption on eutrophication over lifetime by product

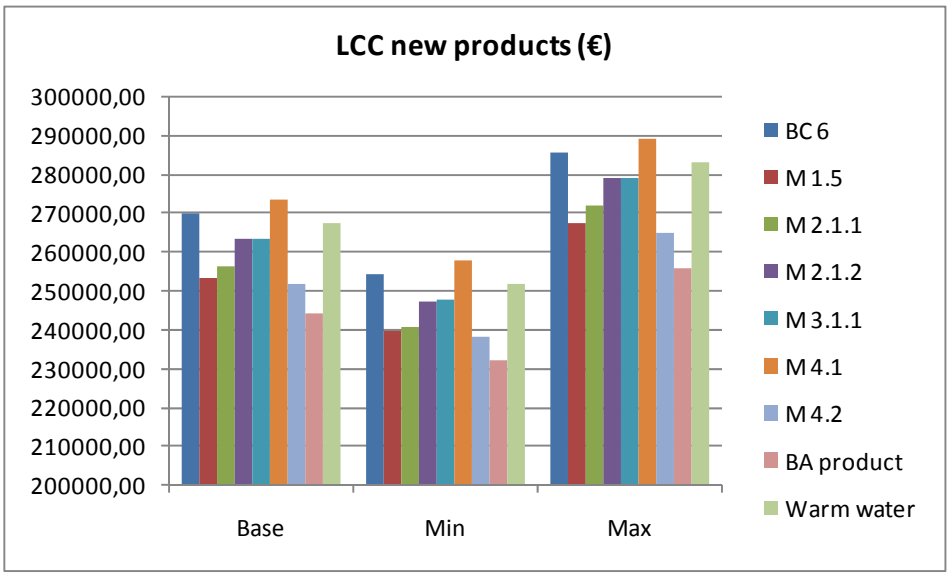


Figure 4-36 Base case 6 and improvement options – impact of detergent consumption on LCC by product

4.2 Intensity of use

4.2.1 Assumptions

In Task 4, average energy, water and detergent consumption data were determined for the base cases. These parameters are directly dependent on the intensity of use of the machines (i.e. the number of dishes washed per year). This intensity can be variable depending on the end user and the type of application and assumptions on this parameter have been made in Task 4.

The sensitivity analysis will consider an error margin of 20% on the given values, both for minimum and maximum values.[14] The tested values are therefore presented in Table 4-4. Table 4-5 to Table 4-7 present the calculated values of the electricity, water and detergent consumption corresponding to the minimum and maximum intensity of use: on the contrary to Section 4.1, these consumption values now vary simultaneously in the analysis.

Table 4-4 Use intensity range for the sensitivity analysis

Base case	Base typical use intensity (in number of dishes per year)	Min	Max
1. Undercounter water-change	24 000	19 200	28 800
2. Undercounter one-tank	237 600	190 080	285 120
3. Hood-type	345 600	276 480	414 720
4. Utensil/Pot	9 000	7 200	10 800
5. One-tank conveyor-type	1 515 900	1 212 720	1 819 080
6. Multi-tank conveyor-type	4 009 500	3 207 600	4 811 400

Table 4-5 Electricity consumption range corresponding to the use intensity range for the sensitivity analysis

Base case	Base total Electricity consumption (in kWh per year)	Min	Max
1. Undercounter water-change	1 254	1 004	1 503
2. Undercounter one-tank	5 253	4 375	6 131
3. Hood-type	8 258	6 889	9 627
4. Utensil/Pot	8 913	7 828	9 997
5. One-tank conveyor-type	37 703	30 851	44 555
6. Multi-tank conveyor-type	102 229	83 304	121 154

[14] This error margin was discussed and agreed during the final stakeholder meeting, 9 December 2010 in Paris.

Table 4-6 Water consumption range corresponding to the use intensity range for the sensitivity analysis

Base case	Base water consumption (in m^3 per year)	Min	Max
1. Undercounter water-change	25.92	20.736	31.104
2. Undercounter one-tank	55.82	45.557	66.086
3. Hood-type	86.65	71.720	101.580
4. Utensil/Pot	89.52	76.416	102.624
5. One-tank conveyor-type	255.686	211.149	300.223
6. Multi-tank conveyor-type	643.645	530.096	757.194

Table 4-7 Detergent consumption range corresponding to the use intensity range for the sensitivity analysis

Base case	Base detergent consumption (in kg per year)	Min	Max
1. Undercounter water-change	87	69	104
2. Undercounter one-tank	188	154	223
3. Hood-type	292	242	342
4. Utensil/Pot	294	251	337
5. One-tank conveyor-type	865	714	1 015
6. Multi-tank conveyor-type	2 146	1 768	2 525

4.2.2 Results

Figure 4-37 to Figure 4-48 show the influence of the variation of the intensity of use on the total energy consumption and the life cycle costs of the different base cases and associated improvement options.

For base case 1, only minor changes appear in the LCC results between the rankings of the options M 2.1.1, M 4.2 and M 4.1. With the minimum value, option M 4.2 gets a higher LCC than M 2.1.1 and for the maximum value, the M 4.1 LCC gets very close the M 4.2 LCC. However, no changes in the BAT and LLCC options occur.

For base case 2, nothing changes about the primary energy consumption. Regarding the LCC, the option M 4.2 which was identified as the LLCC remains the LLCC option when the maximum value of the intensity use is considered, but not with the minimum value: in this case, the BC 2 becomes the LLCC option.

For base case 3, the situation also remains the same for energy consumption but not for the economic analysis. With the default parameter, the base case was identified as the LLCC option (option M4.2 was second) while with the maximum value, option M 4.2 becomes the LLCC option. On the contrary, with the minimum value, this option only scores third, behind the base case, and option M 4.1.

For base case 4, no changes in the rankings of options occur, either the energy consumption or LCC: the base case remains the LLCC.

For base case 5, the LLCC option remains the same (option M 1.5). While option M 3.1.1 has a lower LCC than the base case with the default parameter, it is not the case anymore with the minimum value. On the contrary, the BA product was not an economical solution with the default parameter but its LCC becomes lower than the base case LCC when the maximum value is used.

Finally, for base case 6, The BA product remains the LLCC option for all values. However, with the minimum value, option M 4.2 has a very close LCC to the BA product one and it can be extrapolated that with even lower use intensity, this option would become the LLCC. The only other change is that option M 3.1.1 gets a smaller LCC than M 2.1.2 with the minimum value, which is not the case with the default value used.

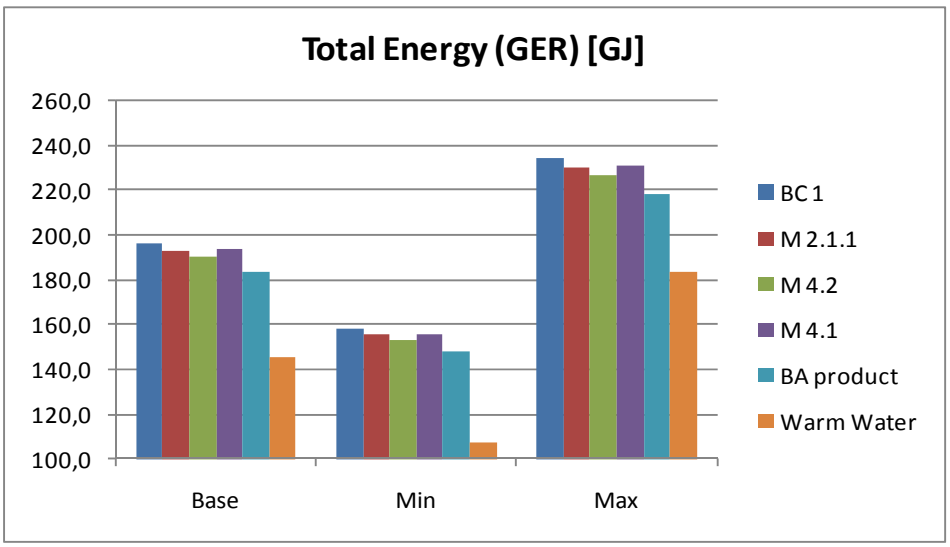


Figure 4-37 Base case 1 and improvement options – impact of use intensity on total energy over lifetime by product

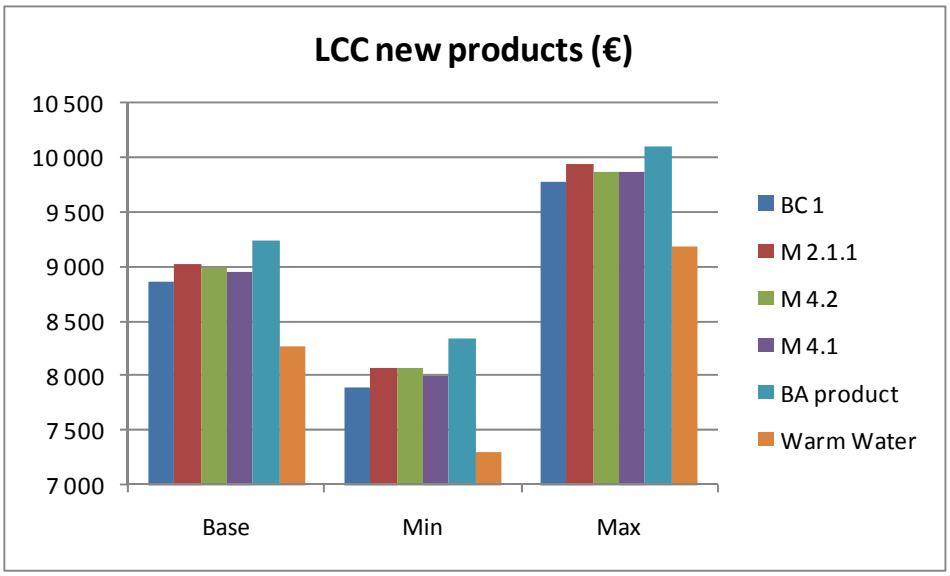


Figure 4-38 Base case 1 and improvement options – impact of use intensity on LCC by product

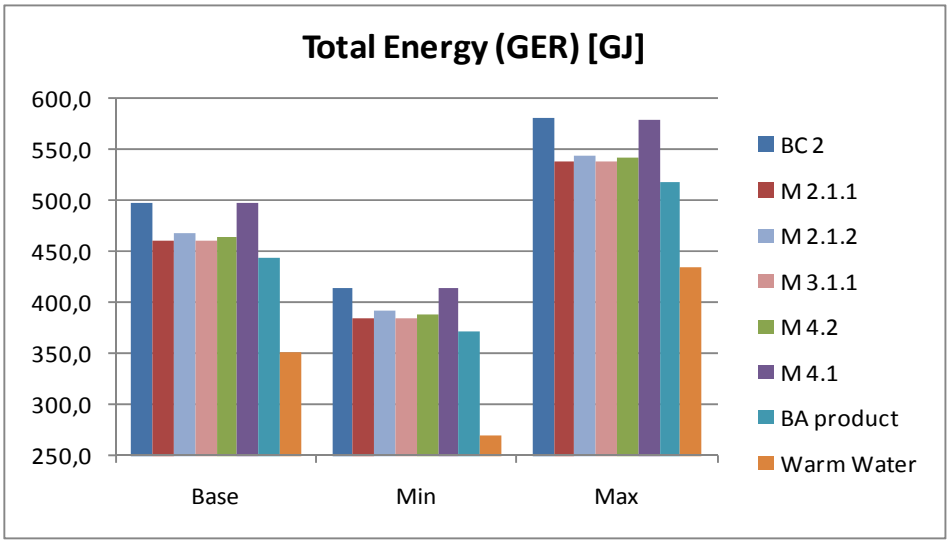


Figure 4-39 Base case 2 and improvement options – impact of use intensity on total energy over lifetime by product

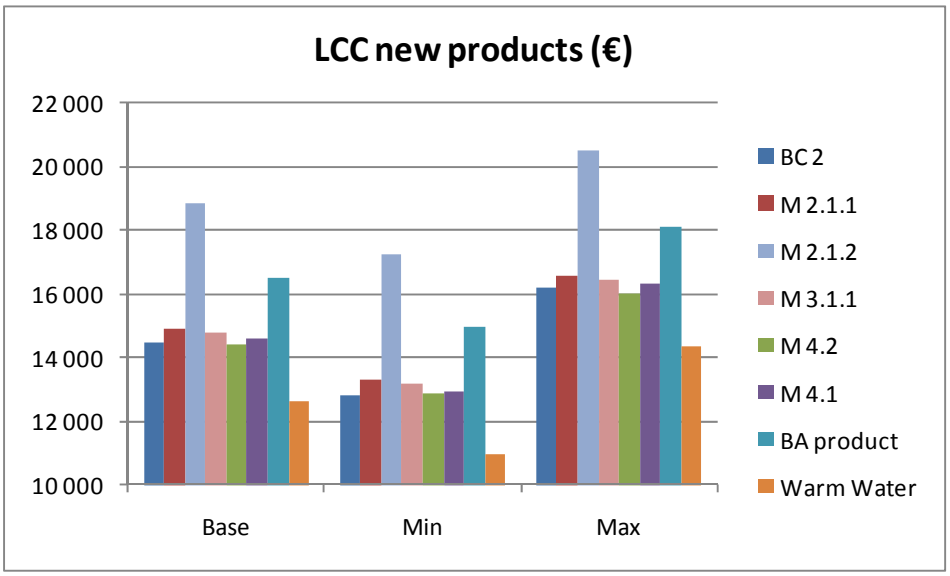


Figure 4-40 Base case 2 and improvement options – impact of use intensity on LCC by product

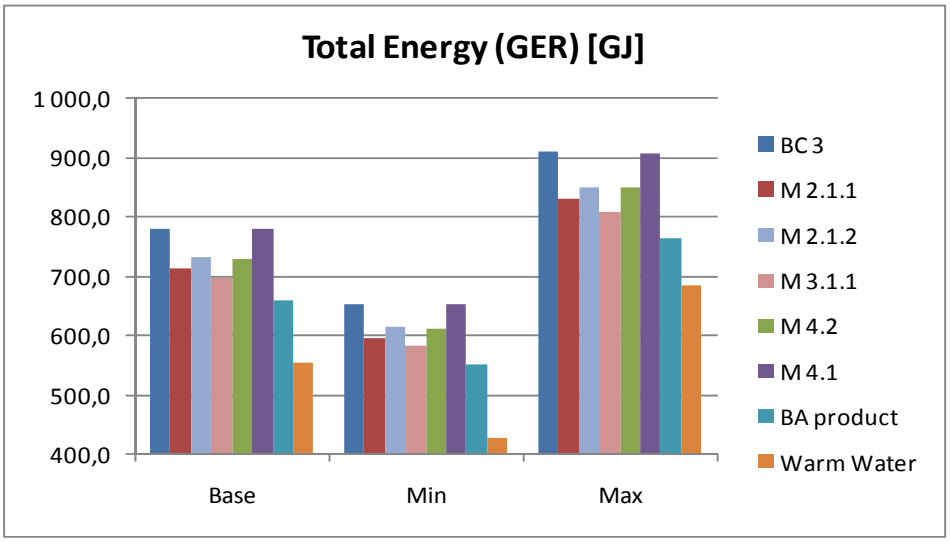


Figure 4-41 Base case 3 and improvement options – impact of use intensity on total energy over lifetime by product

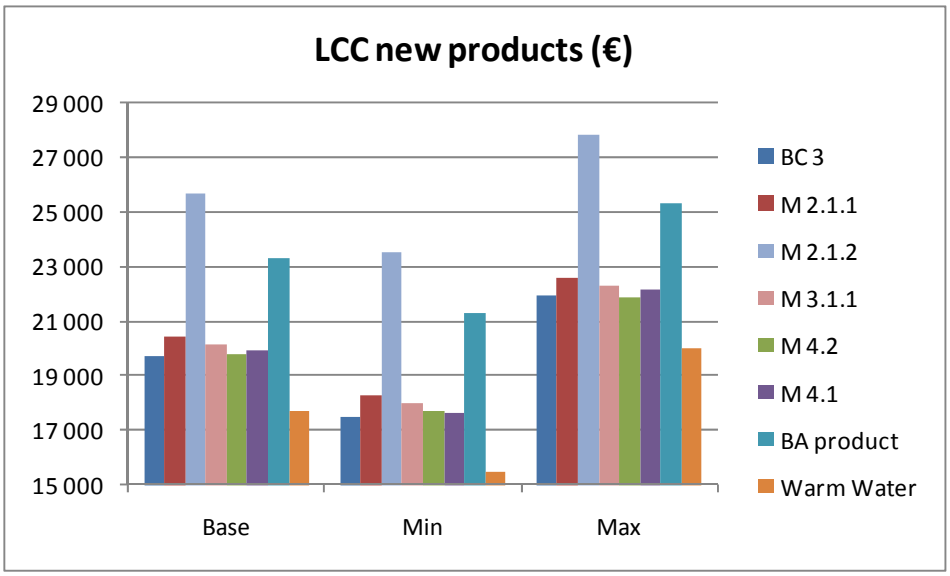


Figure 4-42 Base case 3 and improvement options – impact of use intensity on LCC by product

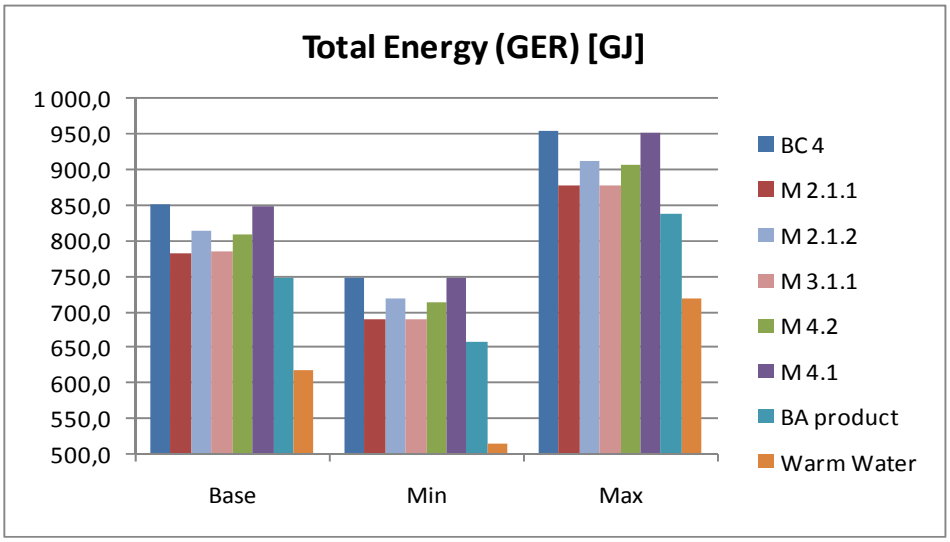


Figure 4-43 Base case 4 and improvement options – impact of use intensity on total energy over lifetime by product

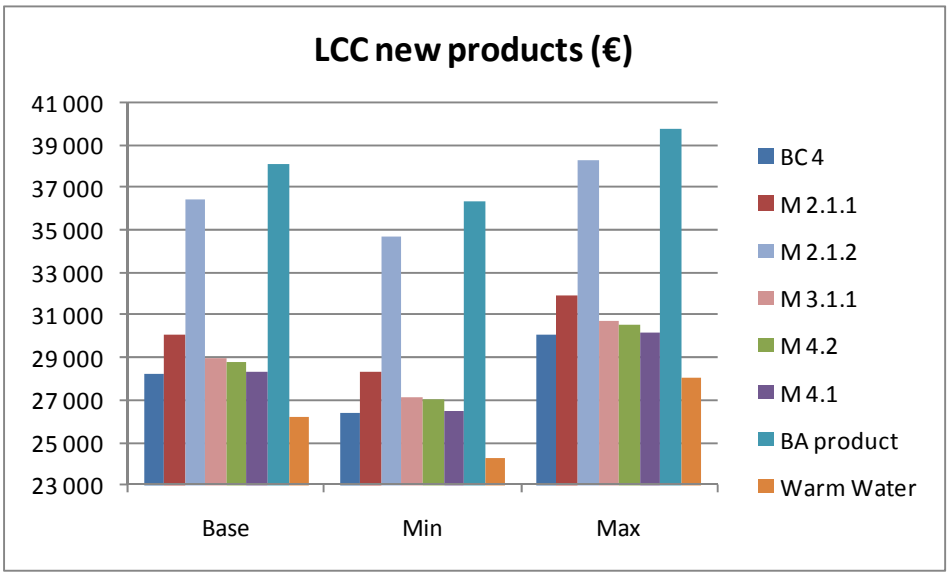


Figure 4-44 Base case 4 and improvement options – impact of use intensity on LCC by product

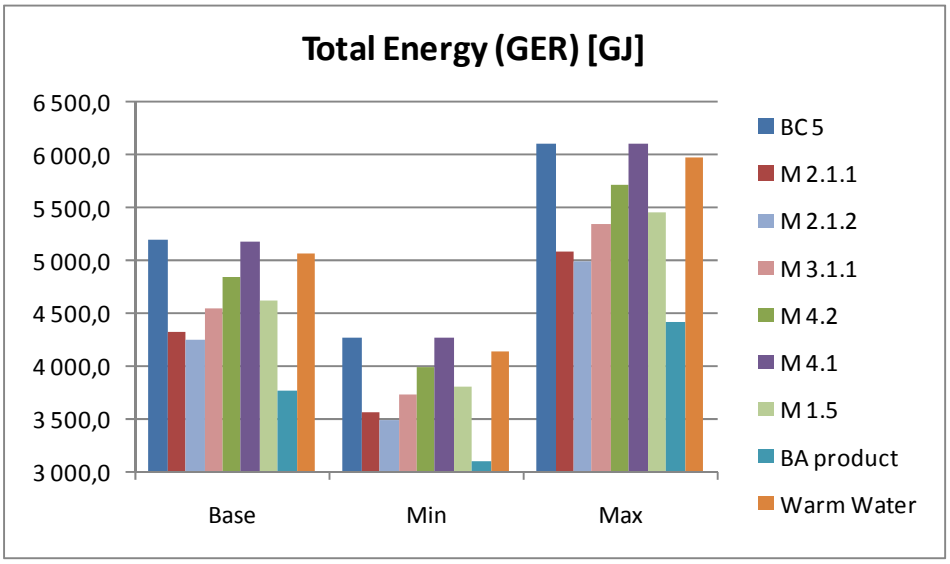


Figure 4-45 Base case 5 and improvement options – impact of use intensity on total energy over lifetime by product

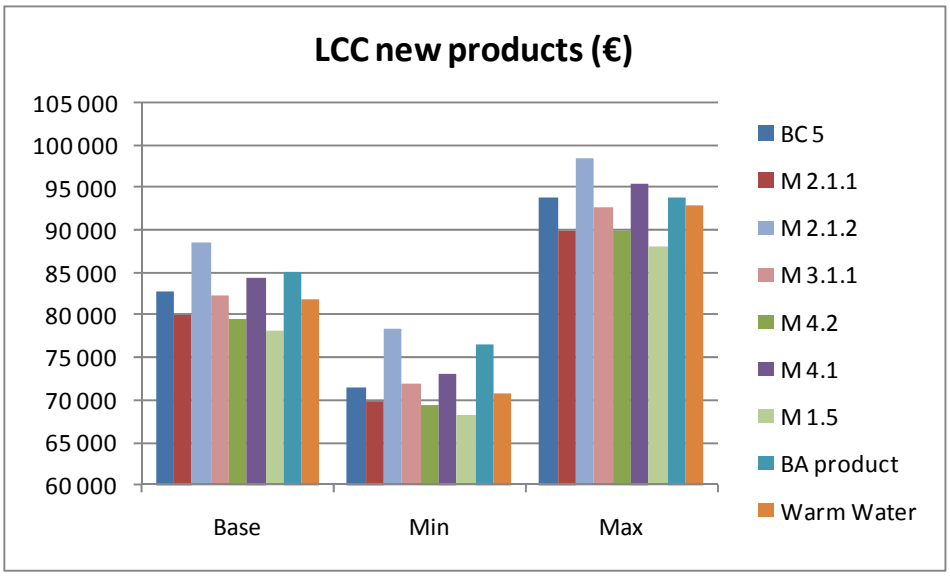


Figure 4-46 Base case 5 and improvement options – impact of use intensity on LCC by product

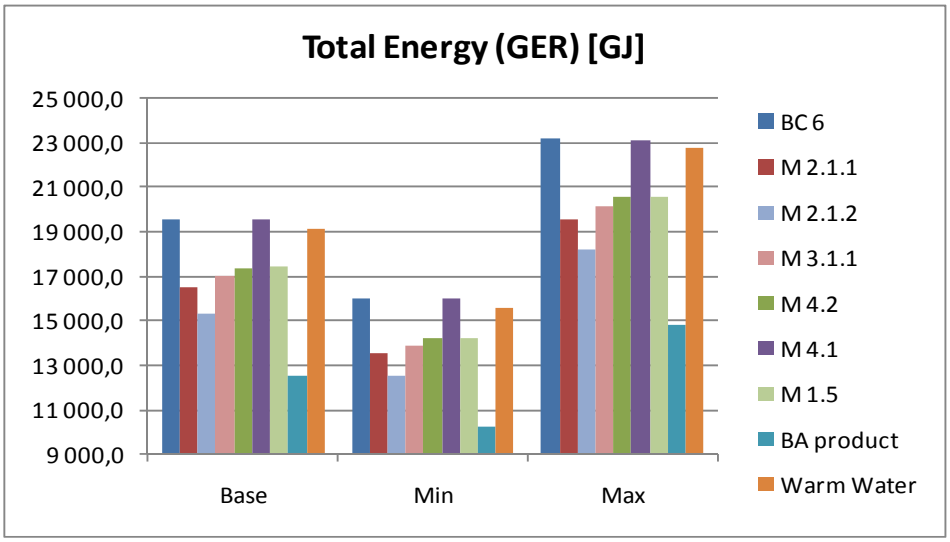


Figure 4-47 Base case 6 and improvement options – impact of use intensity on total energy over lifetime by product

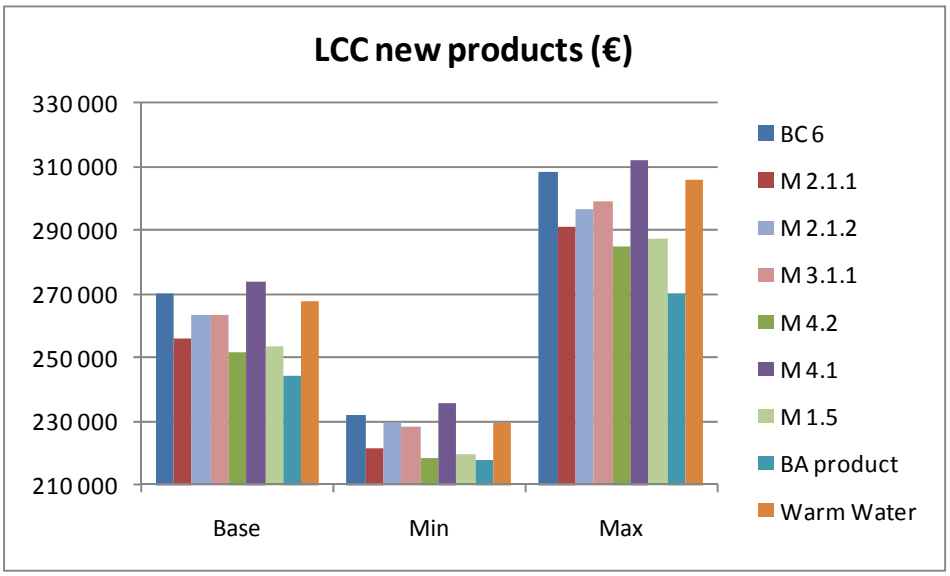


Figure 4-48 Base case 6 and improvement options – impact of use intensity on LCC by product

4.3 Product lifetime

4.3.1 Assumptions

The product lifetime is a major assumption as it has an influence on both the environmental impacts (by increasing the impacts of the use phase) and the life cycle costs (by increasing the operating costs during the use phase). Given the importance of the use phase as discussed in Task 5, it is paramount to take this parameter into account in the sensitivity analysis. Table 4-8 presents the minimum and maximum values that will be used for each base case: an error of 2 years is assumed between extreme values and the average lifetimes considered in the study.

Table 4-8 Product lifetime ranges for the sensitivity analysis

Base case	Base product lifetime (in years)	Min	Max
1. Undercounter water-change	12	10	14
2. Undercounter one-tank	8	6	10
3. Hood-type	8	6	10
4. Utensil/Pot	8	6	10
5. One-tank conveyor-type	12	10	14
6. Multi-tank conveyor-type	17	15	19

4.3.2 Results

Figure 4-49 to Figure 4-60 show the influence of the variation of the product lifetime on the total energy consumption and the life cycle costs of the different base cases and associated improvement options.

For base cases 1 and 4, despite the expected variations in absolute values, the ranking of the different improvement options remains the same whether the minimum of maximum parameter is used.

For base case 2, nothing changes about the primary energy consumption. Regarding the LCC, the option M 4.2 that was identified as the LLCC remains the LLCC option when the maximum value of the intensity use is considered (with a bigger gap to the base case LCC), but not with the minimum value: in this case, the BC 2 becomes the LLCC option.

For base case 3, the situation also remains the same for energy consumption but not for the economic analysis. With the default parameter, the base case was identified as the LLCC option (option M 4.2 was second) while with the maximum value, option M 4.2 becomes the LLCC option.

For base case 5, option M 3.1.1 is not economically beneficial compared to the base case product with the minimum value; the BA product almost becomes advantageous with the maximum lifetime.

For base case 6, no major changes occur: M 3.1.1 gets a smaller LLC than M 2.1.2 with the minimum lifetime.

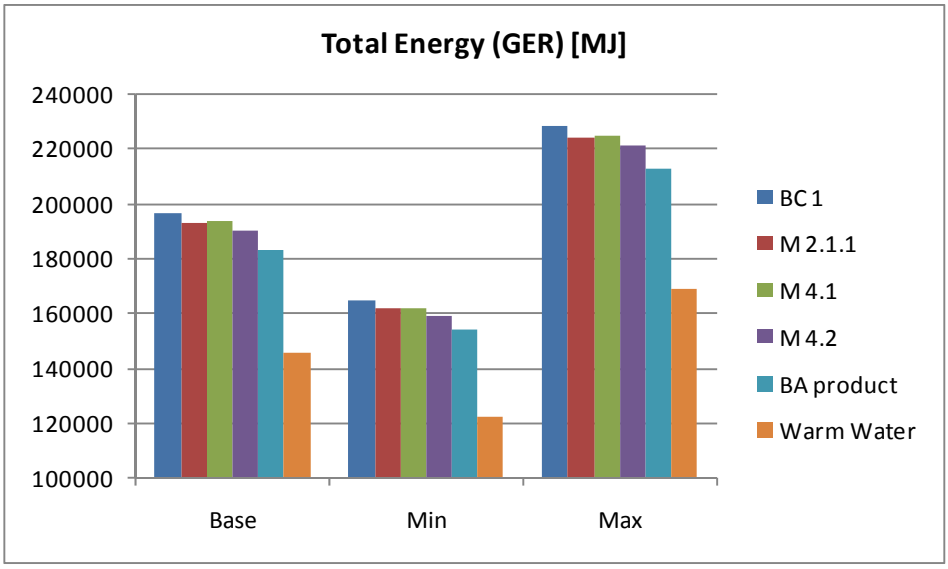


Figure 4-49 Base case 1 and improvement options – impact of lifetime on total energy over lifetime by product

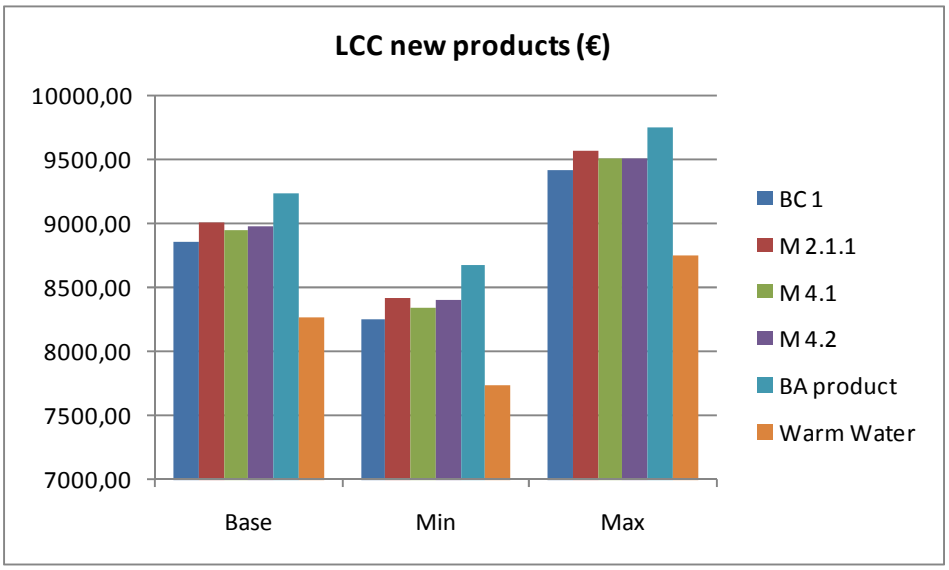


Figure 4-50 Base case 1 and improvement options – impact of lifetime on LCC by product

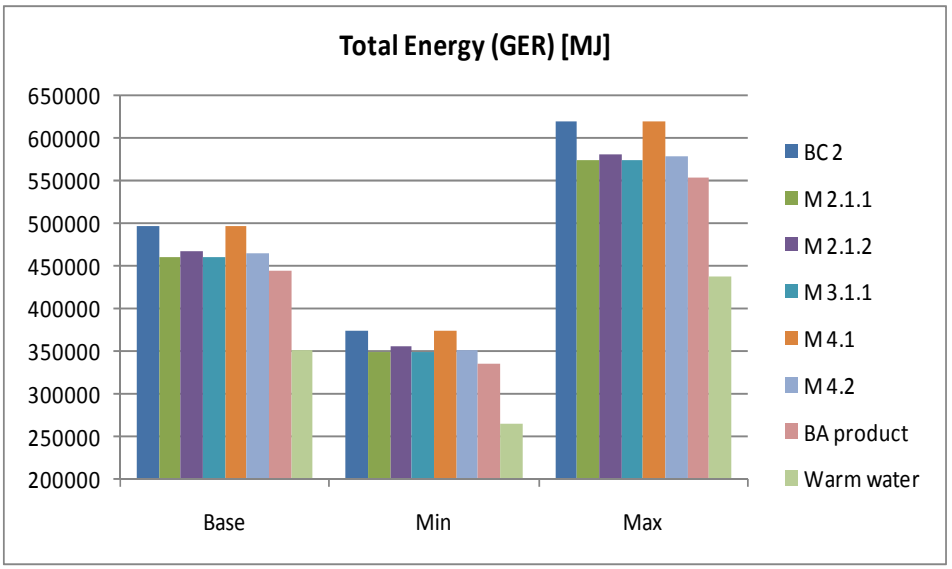


Figure 4-51 Base case 2 and improvement options – impact of lifetime on total energy over lifetime by product

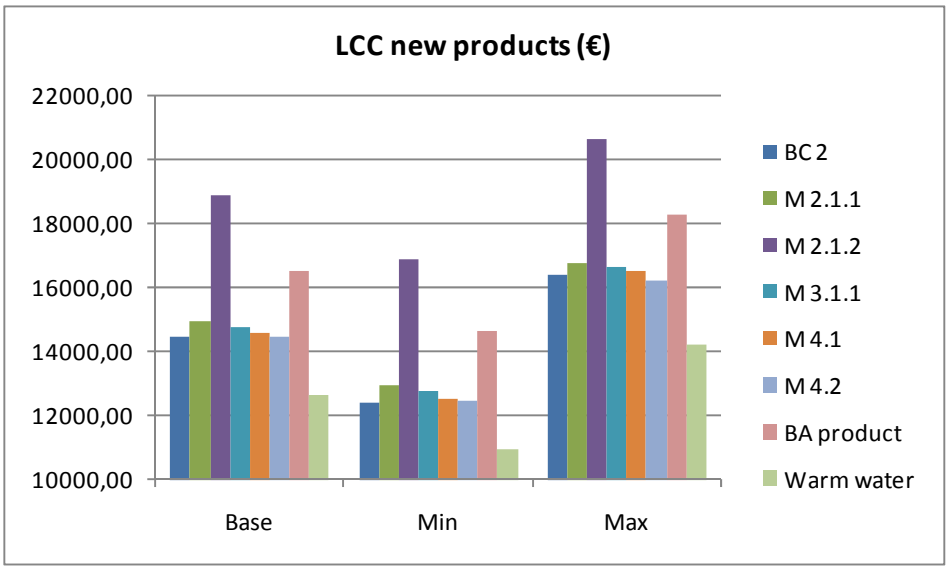


Figure 4-52 Base case 2 and improvement options – impact of lifetime on LCC by product

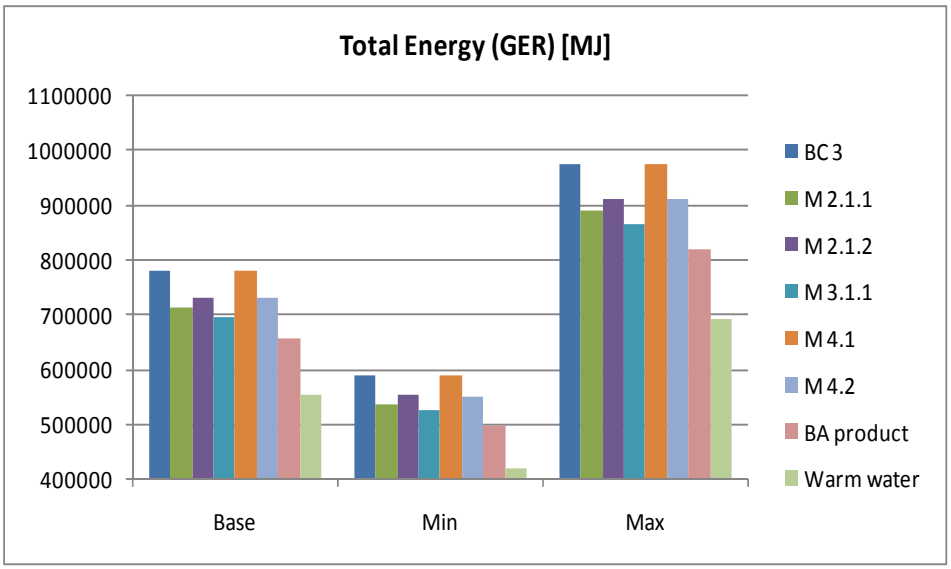


Figure 4-53 Base case 3 and improvement options – impact of lifetime on total energy over lifetime by product

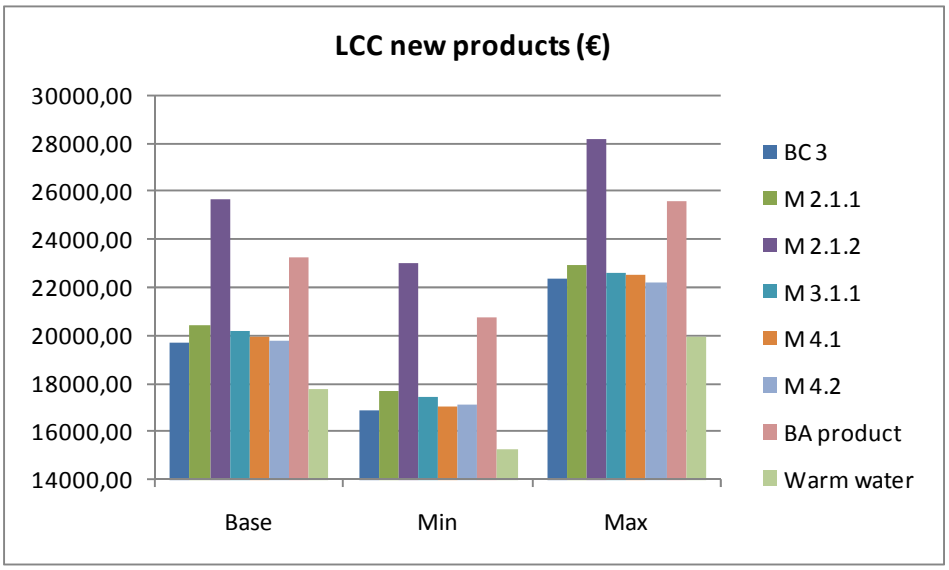


Figure 4-54 Base case 3 and improvement options – impact of lifetime on LCC by product

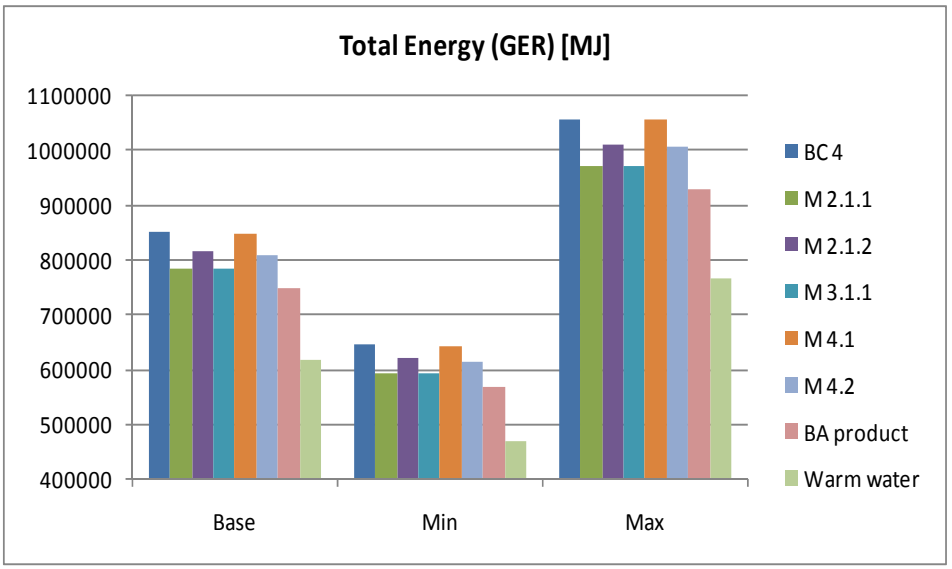


Figure 4-55 Base case 4 and improvement options – impact of lifetime on total energy over lifetime by product

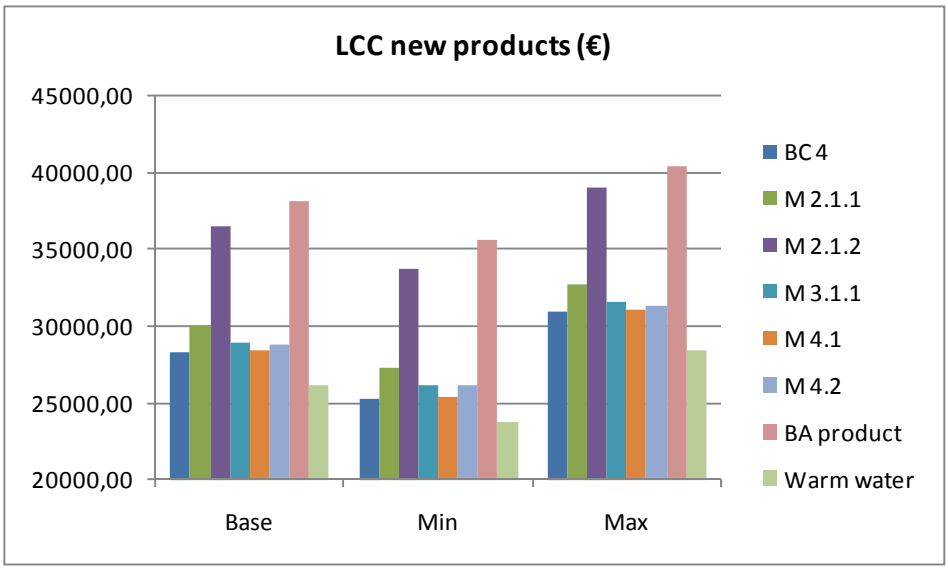


Figure 4-56 Base case 4 and improvement options – impact of lifetime on LCC by product

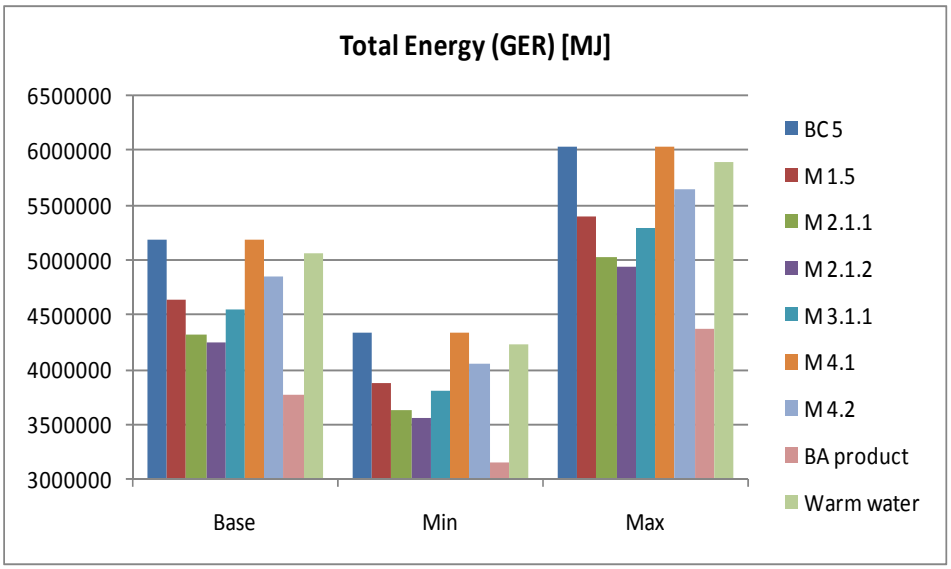


Figure 4-57 Base case 5 and improvement options – impact of lifetime on total energy over lifetime by product

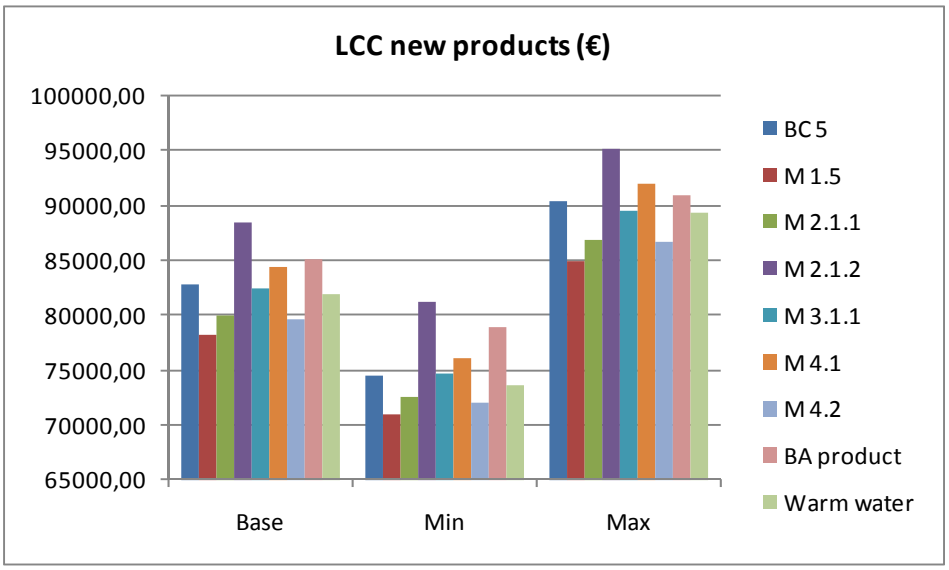


Figure 4-58 Base case 5 and improvement options – impact of lifetime on LCC by product

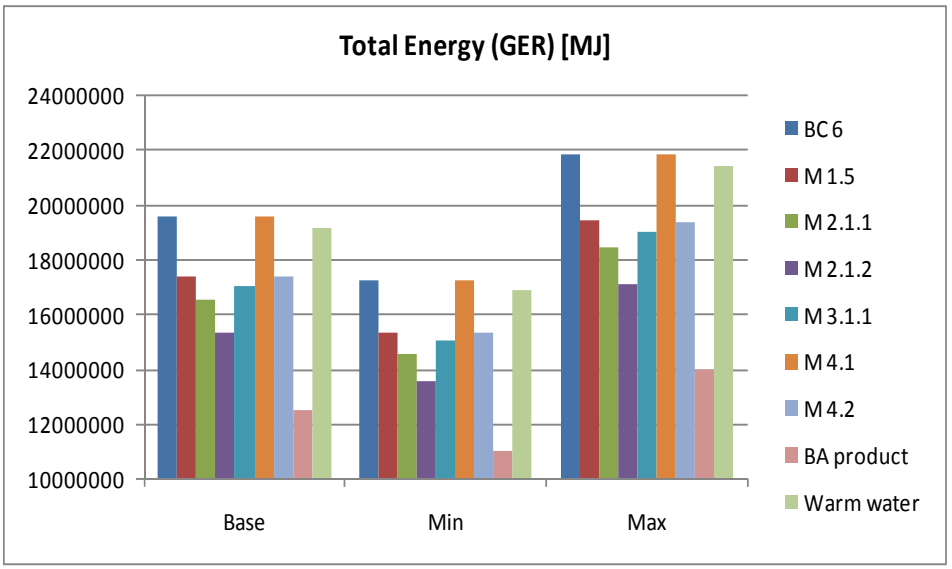


Figure 4-59 Base case 6 and improvement options – impact of lifetime on total energy over lifetime by product

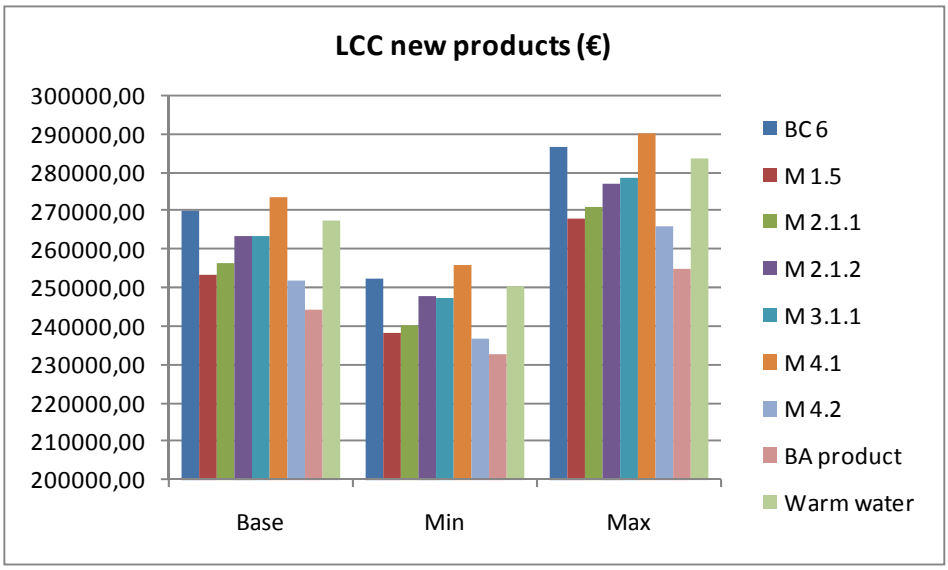


Figure 4-60 Base case 6 and improvement options – impact of lifetime on LCC by product

4.4 Resources and consumable rates

4.4.1 Assumptions

Table 4-9 and Table 4-10 present the ranges for the resources and consumables prices that will be used for the sensitivity analysis. These parameters only have an economic influence on the outcomes so that only the influence on LCC is displayed in Figure 4-61 to Figure 4-78. The minimum and maximum electricity values correspond to the extreme values found in Eurostat statistics (see Task 2); for water, they were also extracted from extreme values found during the estimation of the EU average price (see Task 2); for detergent, a wide range was deliberately chosen given the high variability of prices found during the internet market research (see Task 2).

Again, we use average EU prices for all calculations but there are significant differences between Member States.

Table 4-9 Electricity rate ranges for the sensitivity analysis

Base case	Base electricity rate (€/kWh)	Min	Max
1. Undercounter water-change	0.138	0.071 (Estonia)	0.185 (Slovakia)
2. Undercounter one-tank			
3. Hood-type	0.105	0.059 (Estonia)	0.160 (Cyprus)
4. Utensil/Pot			
5. One-tank conveyor-type	0.090	0.055 (Estonia)	0.144 (Cyprus)
6. Multi-tank conveyor-type			

Table 4-10 Water and detergent rates ranges for the sensitivity analysis

Item	Base price (for all case-cases)	Min	Max
Water	2.64 €/m^3	1.11 €/m^3 (Rome)	4.91 €/m^3 (Berlin)
Detergent	3.0 €/kg	2.0 €/kg	4.0 €/kg

4.4.2 Results

For base cases 1 and 4, the variations of the resources rates have no influence on the relative ranking of options.

For base case 2, M 4.2 is not the LLCC option anymore when the minimum value of electricity rate, or water or detergent rate is used: the base case product becomes the most economic product.

For base case 3, on the contrary, the base case loses its position of LLCC at the expense of option M 4.2 when the maximum rates of electricity, water or detergent are used. Besides, the option M 3.1.1 almost gets a lower LCC than the base case product as well when the maximum electricity rate is considered.

For base case 5, the BA product becomes economically beneficial in comparison with the base case with the maximum electricity rate while M 3.1.1 loses this status with the minimum value. Concerning the detergent rate, the BA product gets a lower LCC than option M 4.1 with the maximum value used.

For base case 6, option M 4.2 becomes the LLCC option with the minimum electricity rate at the expense of the BA product (option M 1.5 also gets a smaller LCC than the BA product). M 2.1.2 is not economic compared to the base case product with the minimum electricity rate.

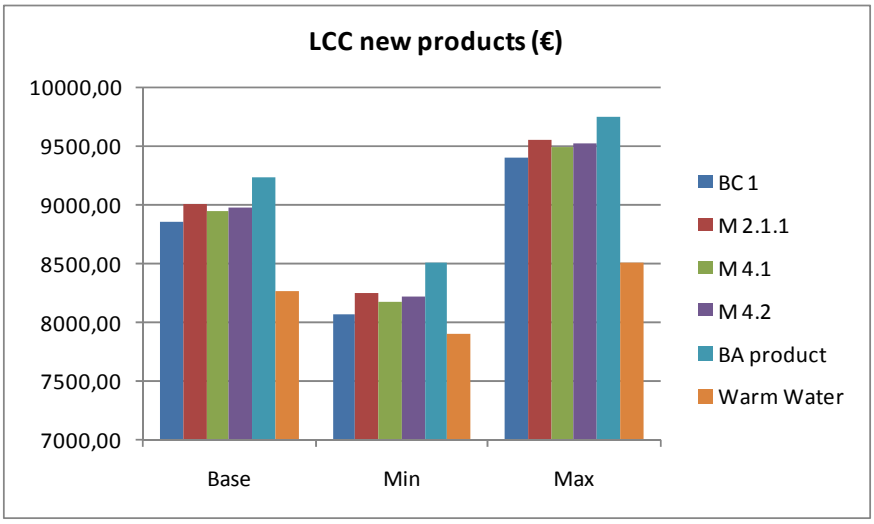


Figure 4-61 Base case 1 and improvement options – impact of electricity rate on LCC by product

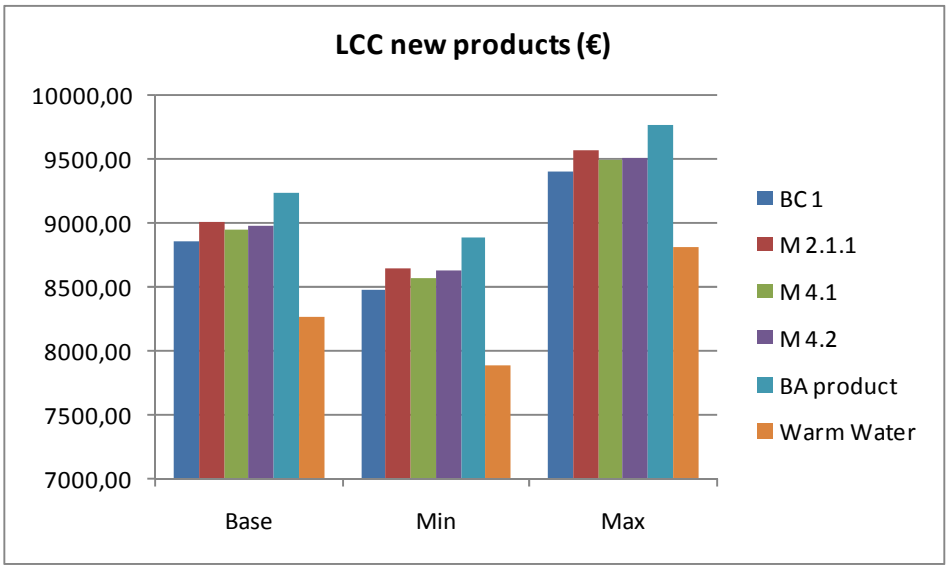


Figure 4-62 Base case 1 and improvement options – impact of water rate on LCC by product

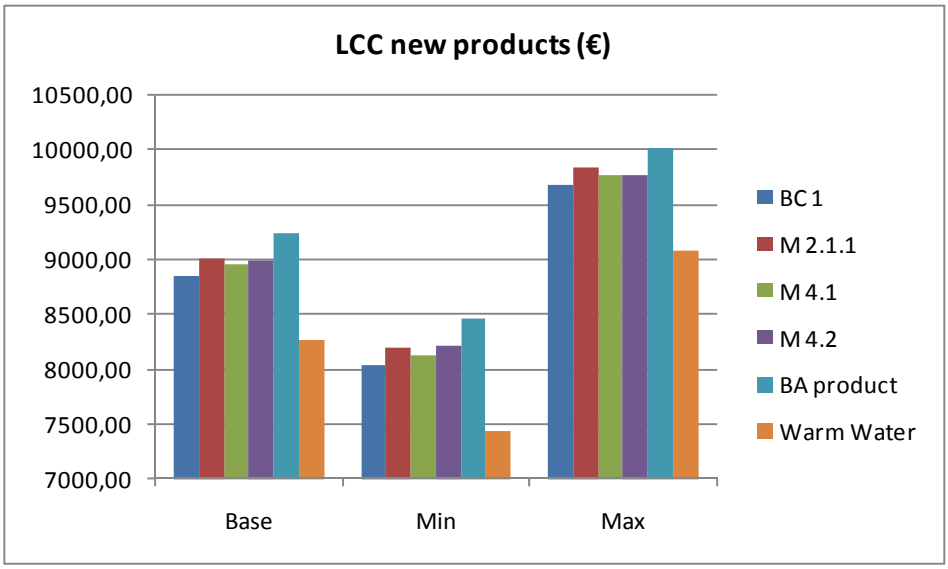


Figure 4-63 Base case 1 and improvement options – impact of detergent rate on LCC by product

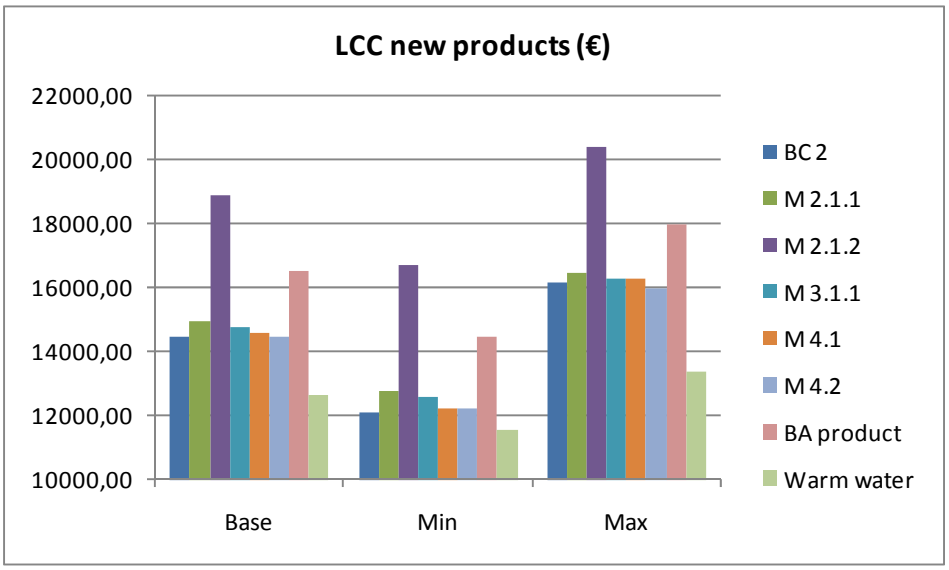


Figure 4-64 Base case 2 and improvement options – impact of electricity rate on LCC by product

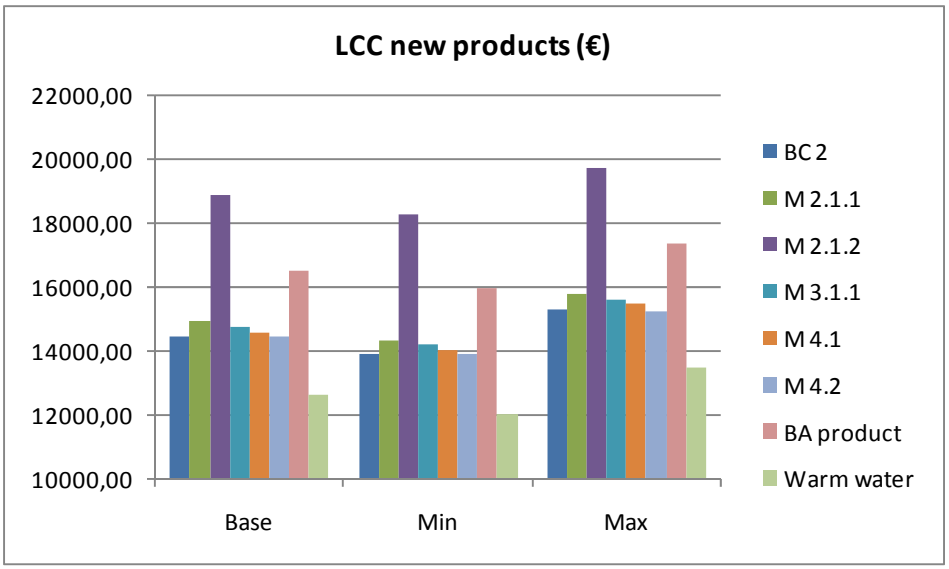


Figure 4-65 Base case 2 and improvement options – impact of water rate on LCC by product

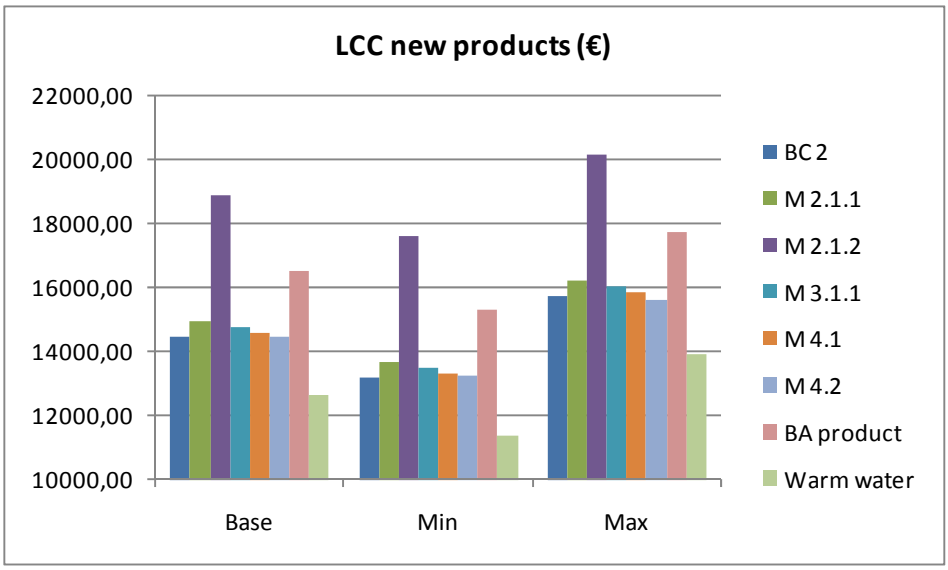


Figure 4-66 Base case 2 and improvement options – impact of detergent rate on LCC by product

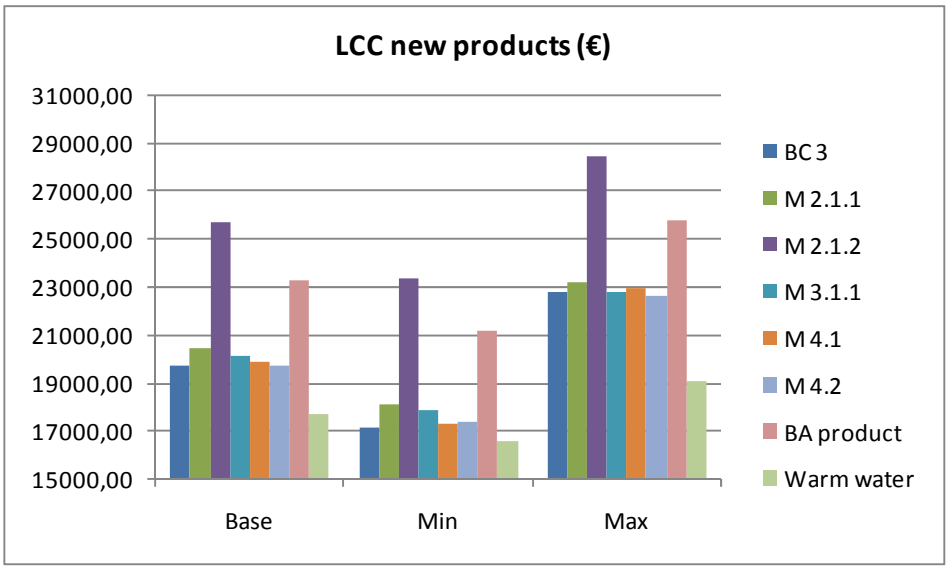


Figure 4-67 Base case 3 and improvement options – impact of electricity rate on LCC by product

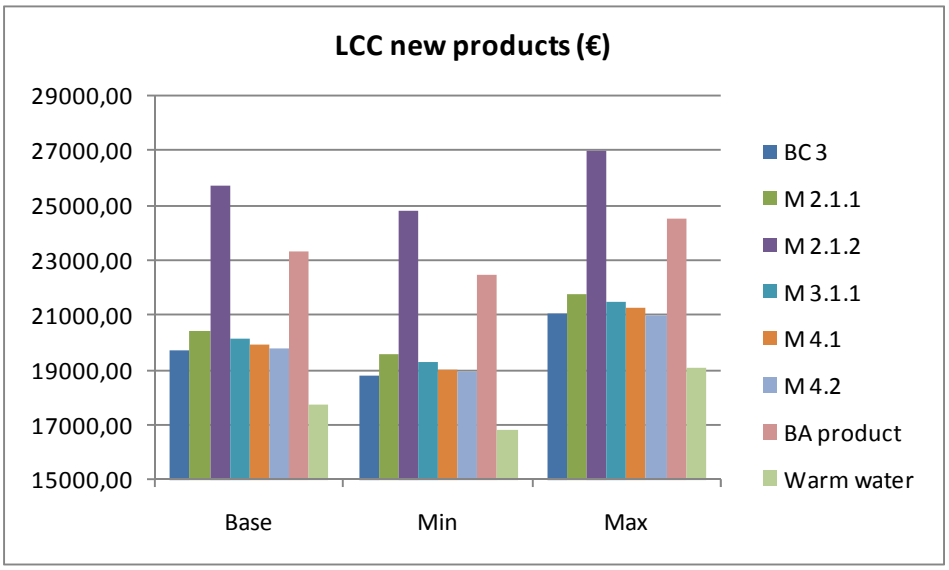


Figure 4-68 Base case 3 and improvement options – impact of water rate on LCC by product

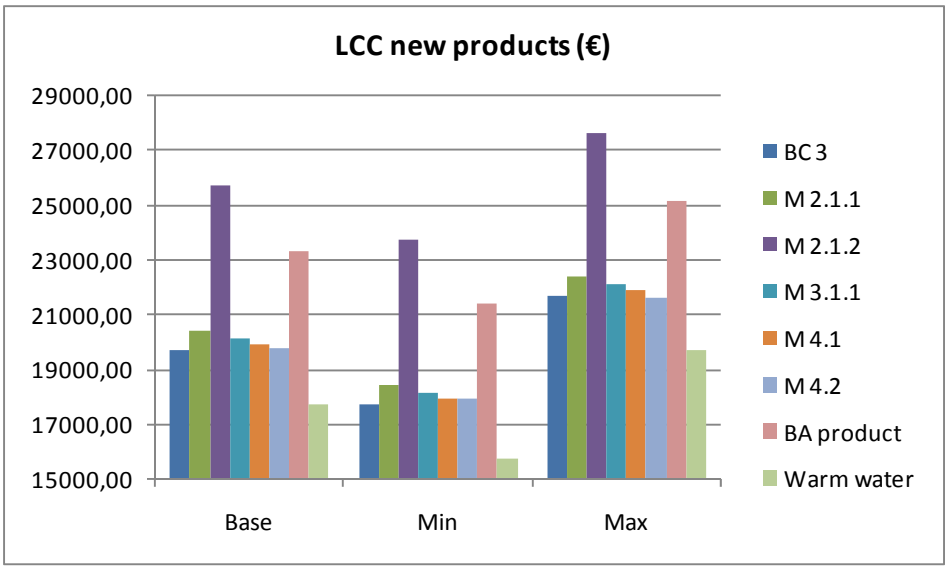


Figure 4-69 Base case 3 and improvement options – impact of detergent rate on LCC by product

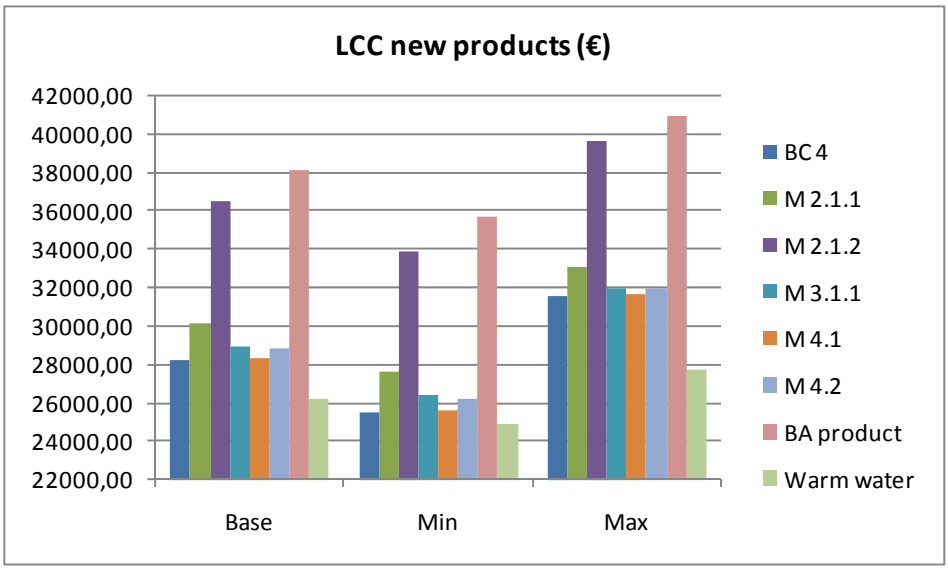


Figure 4-70 Base case 4 and improvement options – impact of electricity rate on LCC by product

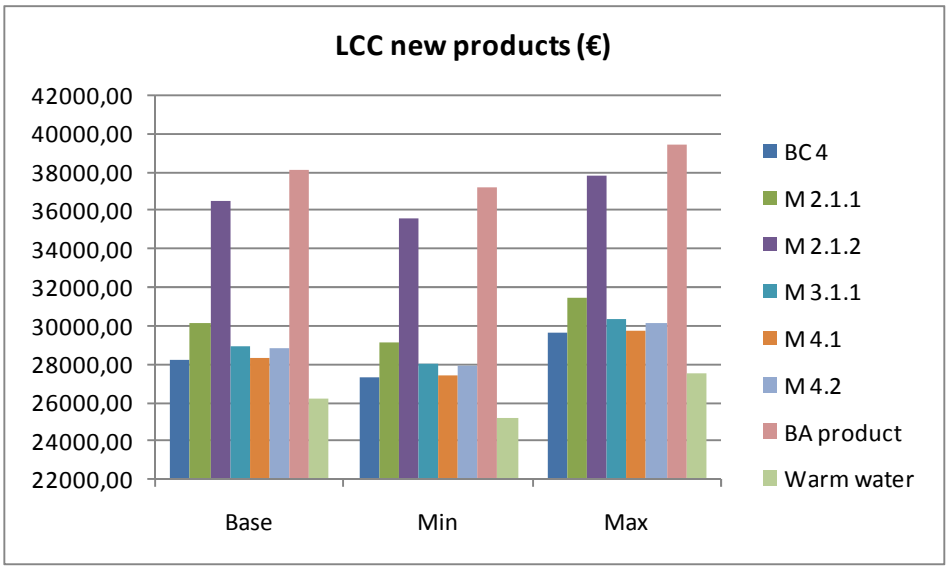


Figure 4-71 Base case 4 and improvement options – impact of water rate on LCC by product

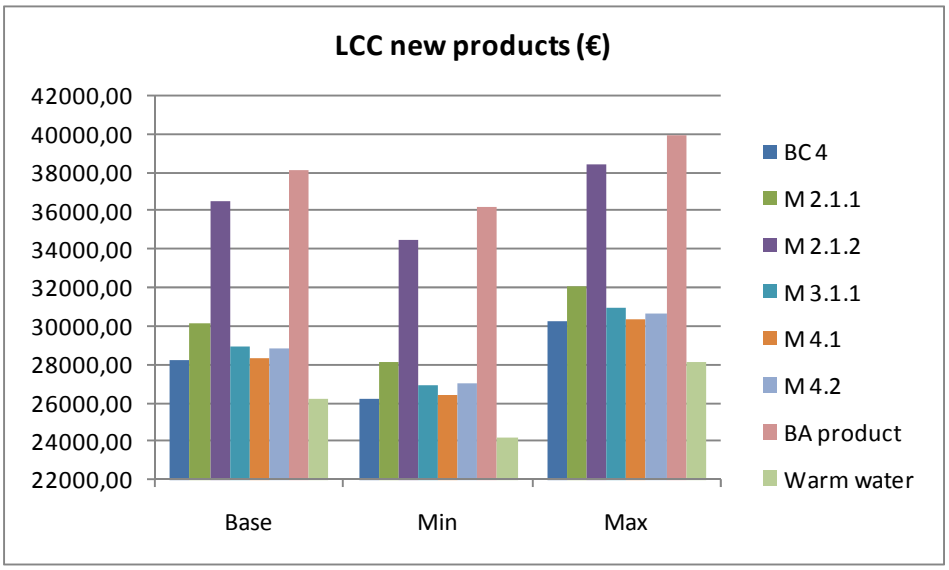


Figure 4-72 Base case 4 and improvement options – impact of detergent rate on LCC by product

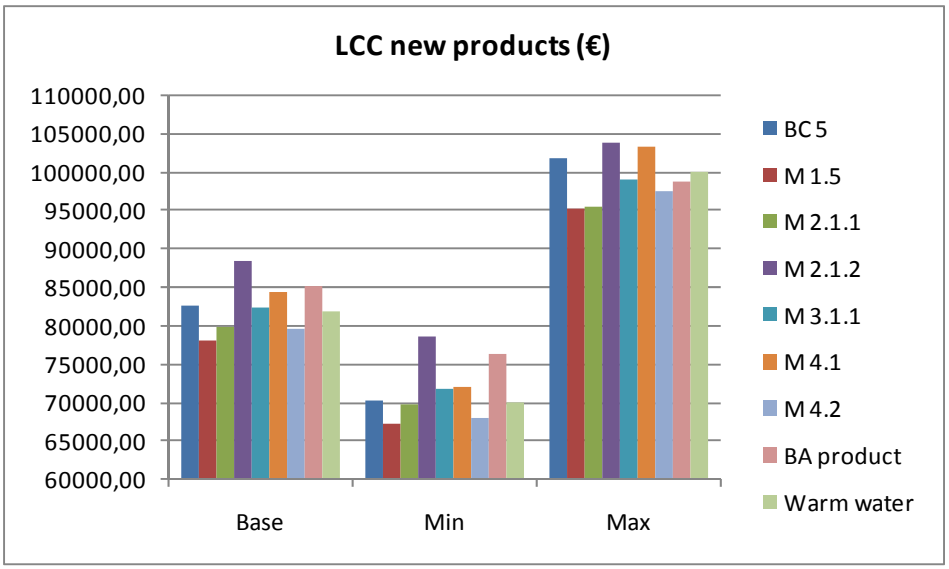


Figure 4-73 Base case 5 and improvement options – impact of electricity rate on LCC by product

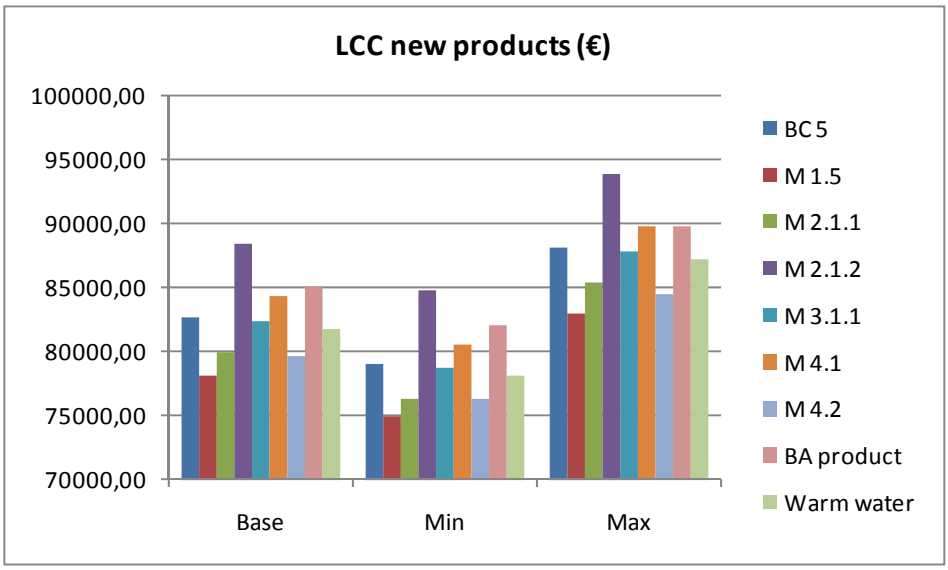


Figure 4-74 Base case 5 and improvement options – impact of water rate on LCC by product

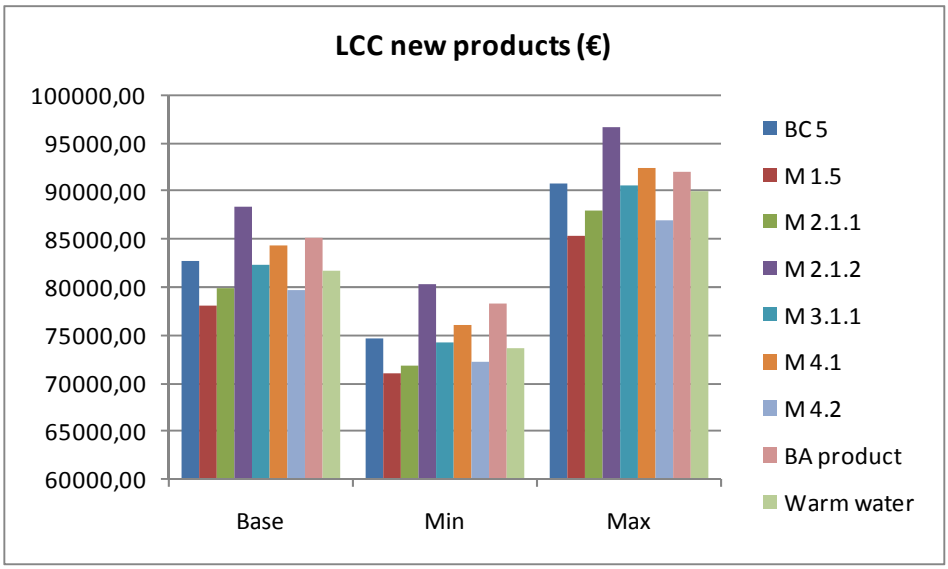


Figure 4-75 Base case 5 and improvement options – impact of detergent rate on LCC by product

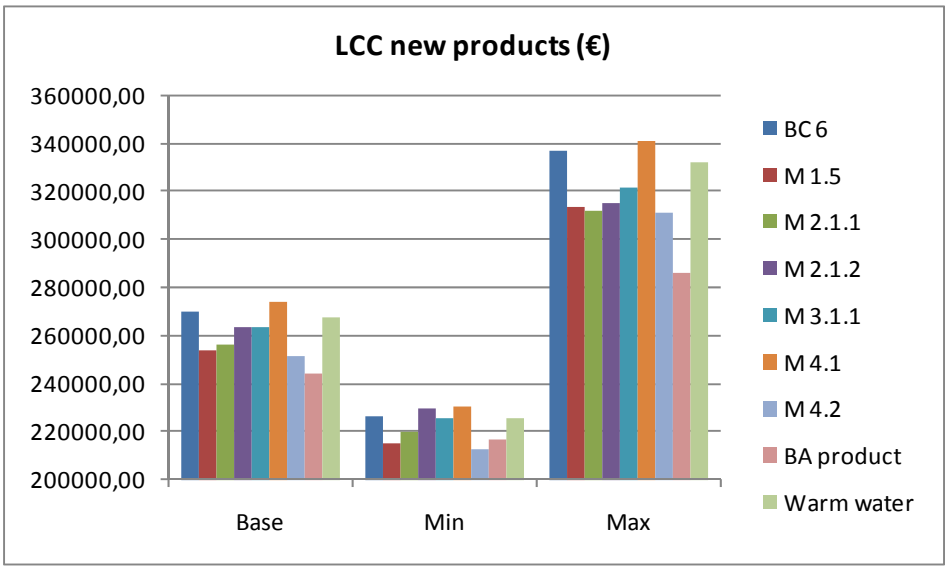


Figure 4-76 Base case 6 and improvement options – impact of electricity rate on LCC by product

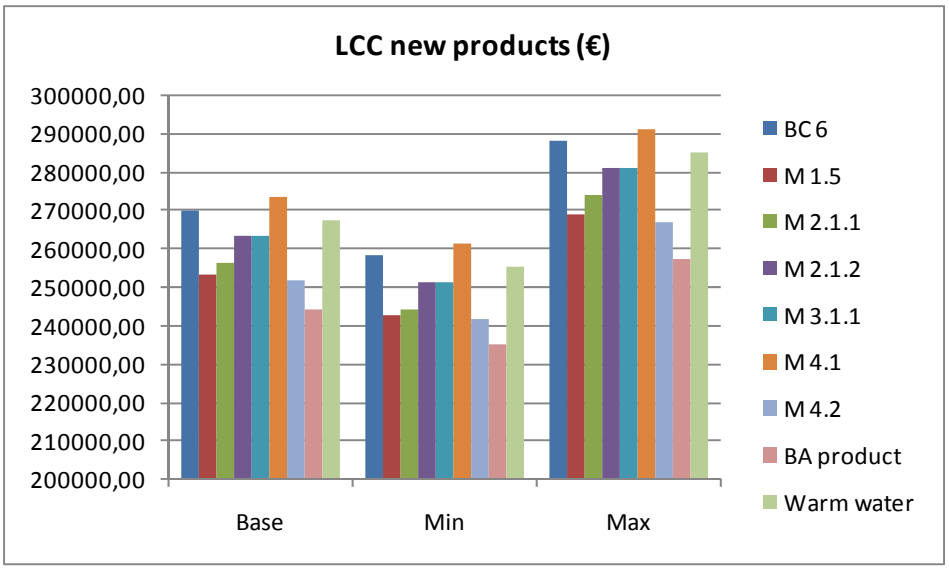


Figure 4-77 Base case 6 and improvement options – impact of water rate on LCC by product

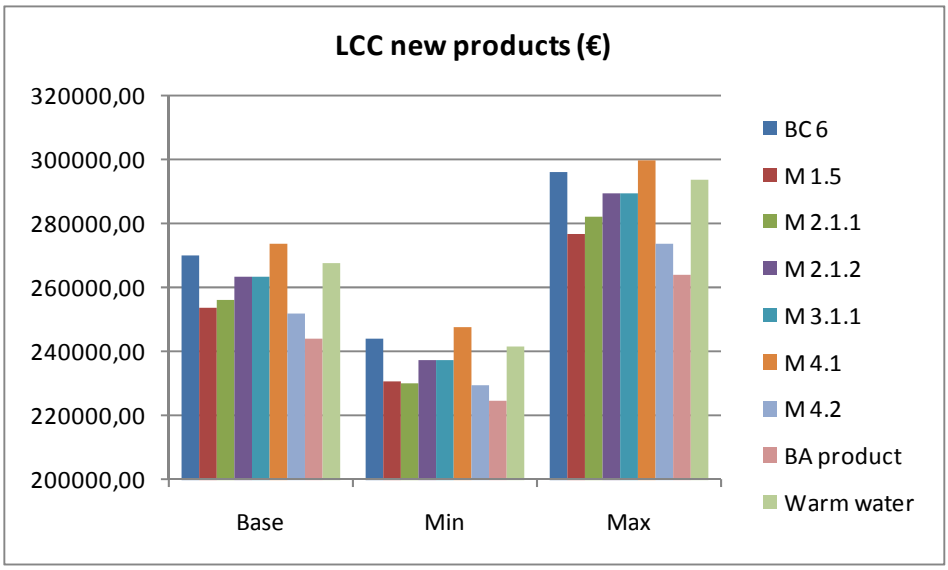


Figure 4-78 Base case 6 and improvement options – impact of detergent rate on LCC by product

4.5 Product purchase price

4.5.1 Assumptions

The product purchase price is a major parameter for the calculation of the LCC. Table 4-11 presents the ranges which will be studied for the sensitivity analysis (20% error margin[15]). Figure 4-79 to Figure 4-84 show the influence that this parameter has for the different base cases.

As the improved products' purchase prices are directly linked to the base cases' prices, the same error margin is applied to the purchase prices of the improved products.

Table 4-11 Purchase prices ranges for the sensitivity analysis

Base case	Base purchase price (in €)	Min	Max
1. Undercounter water-change	3 200	2 560	3 840
2. Undercounter one-tank	3 500	2 800	4 200
3. Hood-type	4 700	3 760	5 640
4. Utensil/Pot	10 500	8 400	12 600
5. One-tank conveyor-type	15 000	12 000	18 000
6. Multi-tank conveyor-type	45 000	36 000	54 000

[15] This error margin was discussed and agreed during the final stakeholder meeting, 9 December 2010 in Paris.

4.5.2 Results

No variation in the ranking of the different options is visible for base cases 1, 2 and 4.

For base case 3, the option M 4.2 becomes the LLCC instead of the base case product for the minimum price used.

For base case 5, the BA product becomes economical in comparison with the base case for the minimum value while option M 3.1.1 loses this situation when the maximum price is used.

For base case 6, options M 3.1.1 gets a lower LCC than option M 2.1.2 with the maximum value.

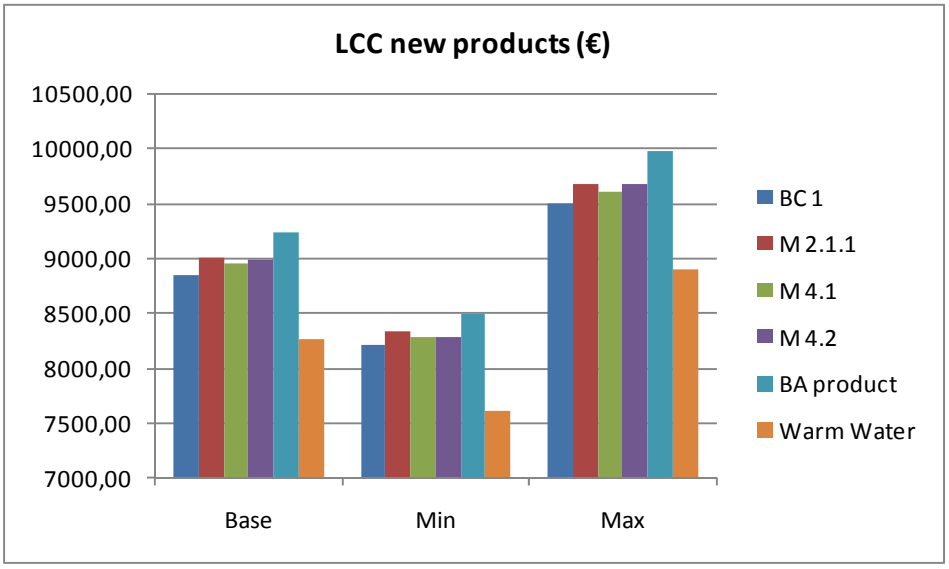


Figure 4-79 Base case 1 and improvement options – impact of purchase price on LCC by product

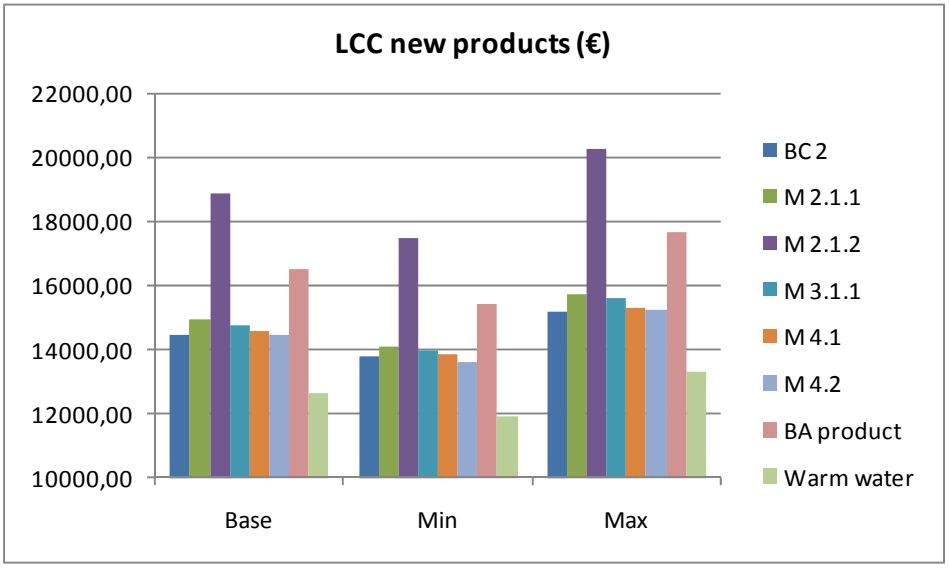


Figure 4-80 Base case 2 and improvement options – impact of purchase price on LCC by product

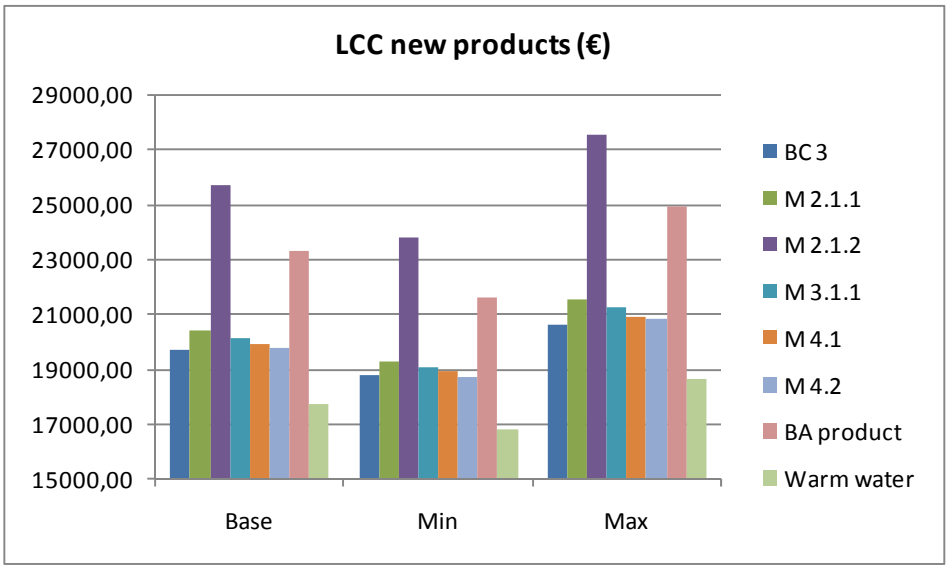


Figure 4-81 Base case 3 and improvement options – impact of purchase price on LCC by product

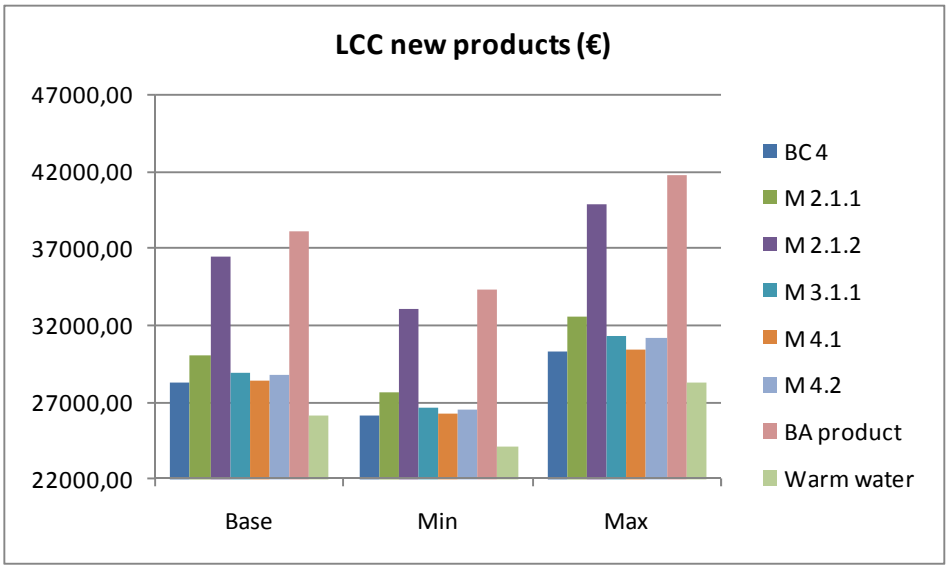


Figure 4-82 Base case 4 and improvement options – impact of purchase price on LCC by product

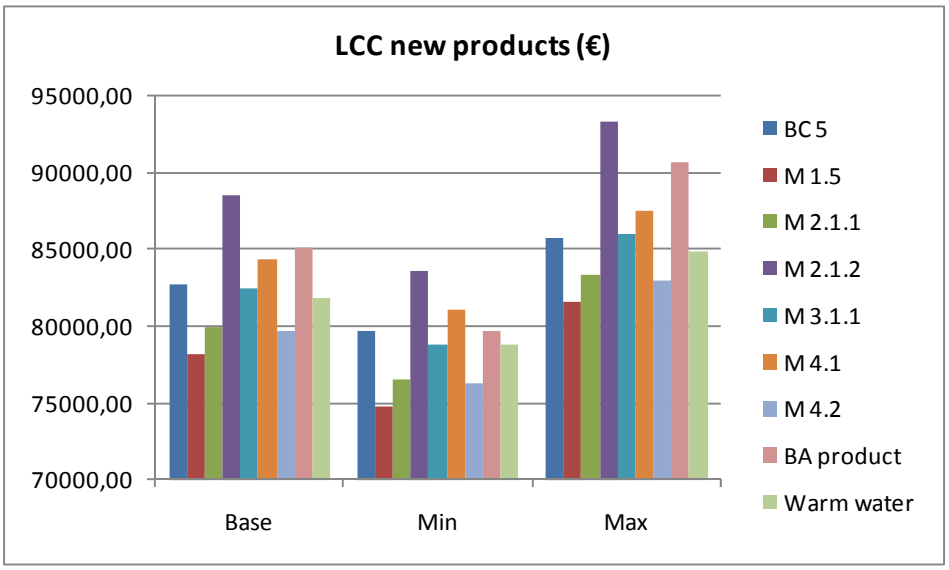


Figure 4-83 Base case 5 and improvement options – impact of purchase price on LCC by product

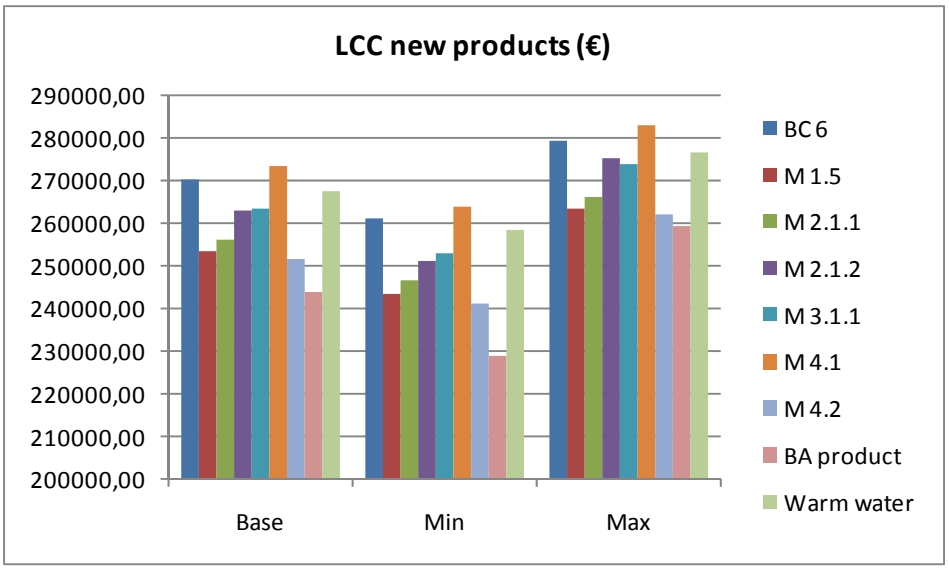


Figure 4-84 Base case 6 and improvement options – impact of purchase price on LCC by product

4.6 Discount rate

4.6.1 Assumptions

The discount rate value was provided by the European Commission and the range 2-6% will be studied in the sensitivity analysis.

Table 4-12 Discount rate range for the sensitivity analysis

Base case	Base discount rate	Min	Max
All base cases	4%	2%	6%

4.6.2 Results

Figure 4-85 to Figure 4-90 show that the variations to the minimum and maximum values of the discount rate do not induce any major changes in the options' rankings from an economic point of view.

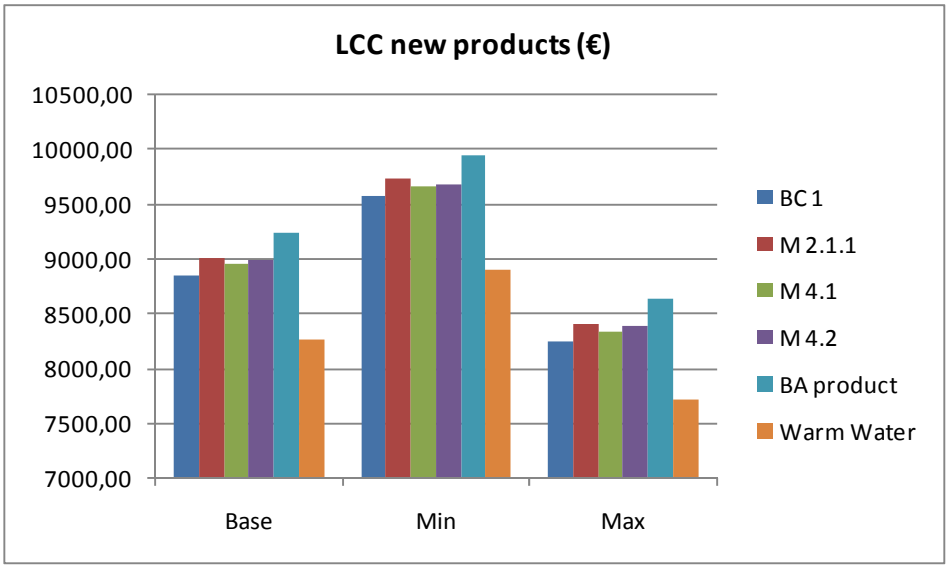


Figure 4-85 Base case 1 and improvement options – impact of discount rate on LCC by product

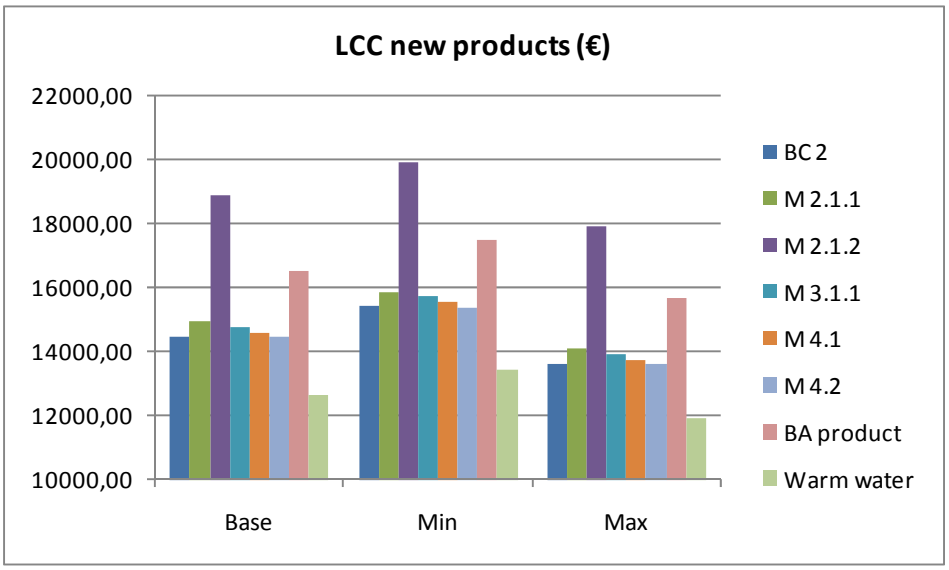


Figure 4-86 Base case 2 and improvement options – impact of discount rate on LCC by product

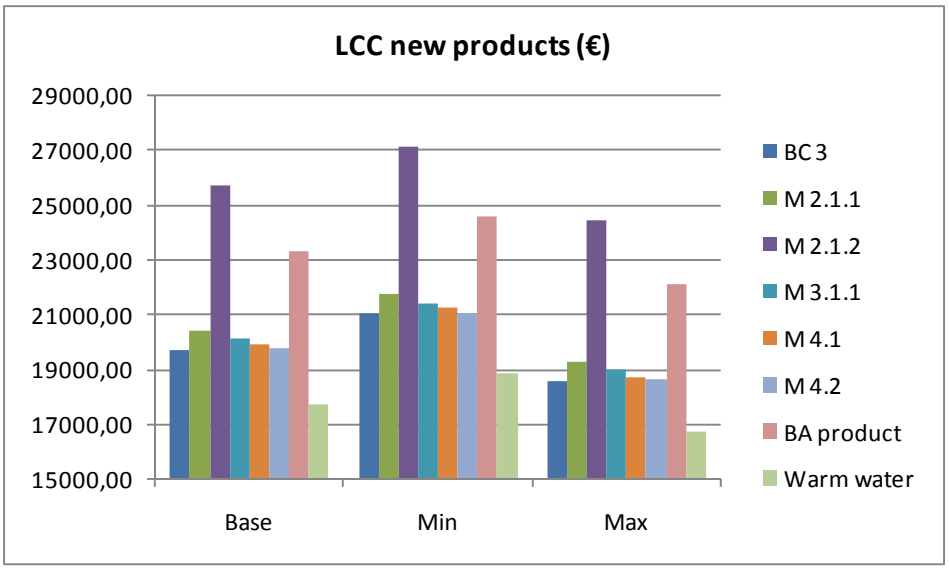


Figure 4-87 Base case 3 and improvement options – impact of discount rate on LCC by product

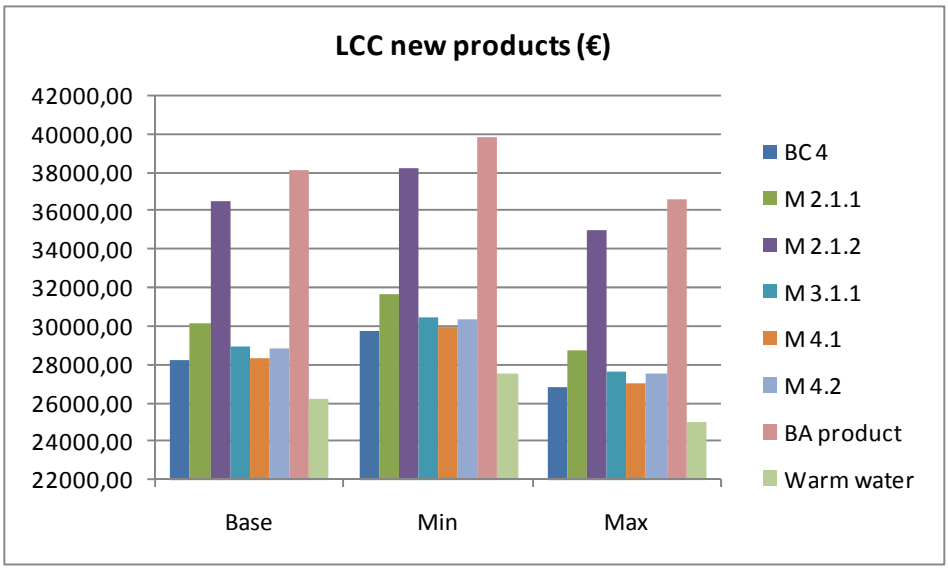


Figure 4-88 Base case 4 and improvement options – impact of discount rate on LCC by product

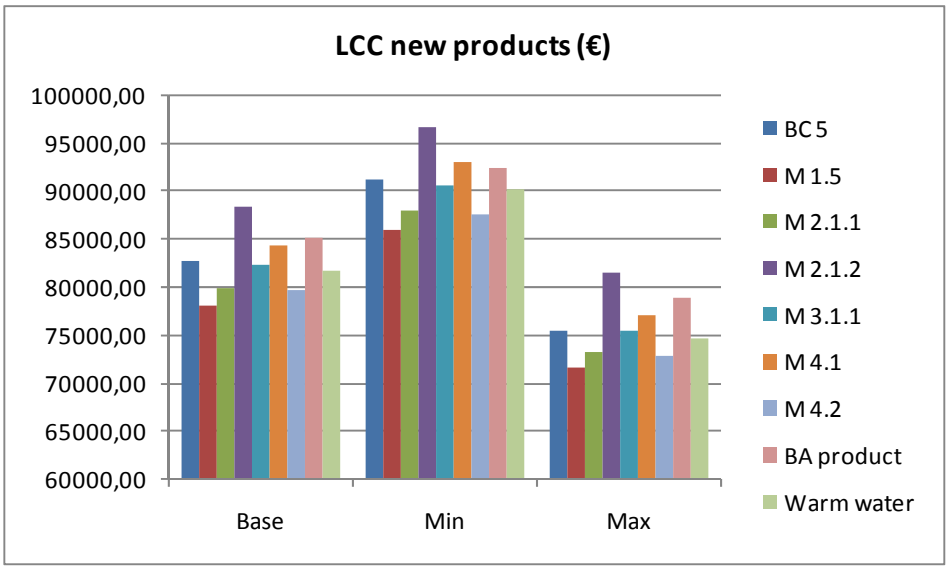


Figure 4-89 Base case 5 and improvement options – impact of discount rate on LCC by product

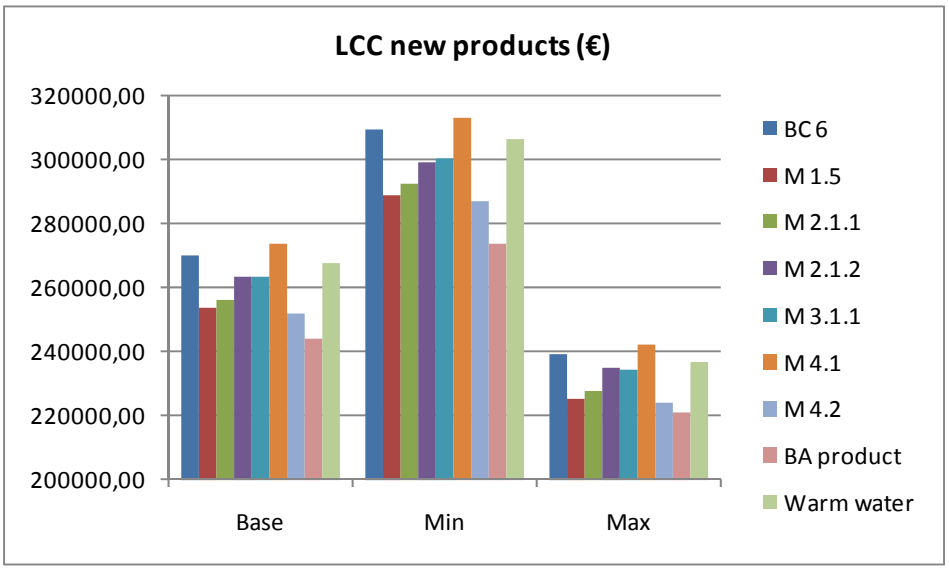


Figure 4-90 Base case 6 and improvement options – impact of discount rate on LCC by product

4.7 Combined parameters

4.7.1 Assumptions

In this subsection, all previous parameters will vary simultaneously in a common direction in order to build two extreme sets of parameters:

- The “Minimum” set minimises the importance of the use phase in the lifetime results: lowest intensity of use, lowest lifetime, lowest consumables and resources rates, highest purchase price and highest discount rate.
- The “Maximum” set maximises the importance of the use phase in the lifetime results: highest intensity of use, highest lifetime, highest consumables and resources rates, lowest purchase price and lowest discount rate.

Table 4-13 to Table 4-18 remind the parameters that will be used for the “minimum” and “maximum” sets. The error margins considered are the same that the ones presented for the sensitivity analysis of separate parameters.

Table 4-13 Use intensity range for the combined sensitivity analysis

Base case	Base typical use intensity (number of dishes per year)	Minimum set	Maximum set
1. Undercounter water-change	24 000	19 200	28 800
2. Undercounter one-tank	237 600	190 080	285 120
3. Hood-type	345 600	276 480	414 720
4. Utensil/Pot	9 000	7 200	10 800
5. One-tank conveyor-type	1 515 900	1 212 720	1 819 080
6. Multi-tank conveyor-type	4 009 500	3 207 600	4 811 400

Table 4-14 Product lifetime ranges for the combined sensitivity analysis

Base case	Base product lifetime (years)	Minimum set	Maximum set
1. Undercounter water-change	12	10	14
2. Undercounter one-tank	8	6	10
3. Hood-type	8	6	10
4. Utensil/Pot	8	6	10
5. One-tank conveyor-type	12	10	14
6. Multi-tank conveyor-type	17	15	19

Table 4-15 Electricity rate ranges for the combined sensitivity analysis

Base case	Base electricity rate (€/kWh)	Minimum set	Maximum set
1. Undercounter water-change	0.138	0.071 (Estonia)	0.185 (Slovakia)
2. Undercounter one-tank			
3. Hood-type	0.105	0.059 (Estonia)	0.160 (Cyprus)
4. Utensil/Pot			
5. One-tank conveyor-type	0.090	0.055 (Estonia)	0.144 (Cyprus)
6. Multi-tank conveyor-type			

Table 4-16 Water and detergent rates ranges for the combined sensitivity analysis

Item	Base price (for all case-cases)	Minimum set	Maximum set
Water	2.64 €/m^3	1.11 €/m^3 (Rome)	4.91 €/m^3 (Berlin)
Detergent	3.0 €/kg	2.0 €/kg	4.0 €/kg

Table 4-17 Purchase price ranges for the combined sensitivity analysis

Base case	Base purchase price(€)	Minimum set	Maximum set
1. Undercounter water-change	3 200	3 840	2 560
2. Undercounter one-tank	3 500	4 200	2 800
3. Hood-type	4 700	5 640	3 760
4. Utensil/Pot	10 500	12 600	8 400
5. One-tank conveyor-type	15 000	18 000	12 000
6. Multi-tank conveyor-type	45 000	54 000	36 000

Table 4-18 Discount rate range for the combined sensitivity analysis

Base case	Base discount rate	Minimum set	Maximum set
All base cases	4%	6%	2%

4.7.2 Results

In general, no major changes occur concerning primary energy consumption (only two parameters have an influence on this: the intensity of use and the product lifetime).

For base case 1, the situation for the minimum set is the same as for the default values. However, in the maximum set, the option M 4.2 becomes the LLCC option as it has a lower LCC than the base case product. The BA product also has a lower LCC than the base case.

For base case 2, the base case product is the LLCC option for the minimum set while the option M 4.2 had been identified as the LLCC for the default parameters. In the maximum set, several options become economical in comparison with the base case (M 2.1.1, M 3.1.1, M 4.2) and option M 4.2 remains the LLCC.

The situation is very similar for base case 3: for the minimum set and the default values, no option seems interesting compared to the base case from an economical point of view. However, for the maximum set, three options have a lower LCC than the base case (M 2.1.1, M 3.1.1, M 4.2) and M 4.2 becomes the LLCC.

Again, the same influence appears for base case 4. For the minimum set and the default values, no option seems interesting compared to the base case from an economical point of view. However, for the maximum set, two options have a lower LCC than the base case (M 3.1.1, M 4.2) and M 4.2 becomes the LLCC. Option M 4.1 also has a LCC close to the base case LCC.

For base case 5, the base case product is the LLCC for the minimum set; option M 1.5 is the LLCC for the default values and the BA product if the LLCC option for the maximum set. For this maximum set, all options except M 4.1 appear more economical than the base case product over the lifetime, even option M 2.1.2 heat pump.

For base case 6, three options appear more economical than the base case with the minimum set (M 2.1.1, M 4.2 and M 1.5) and M 2.1.1 if the LLCC. For the default set, the BA product is the LLCC and all options appear economical except option M 4.1. the situation is the same for the maximum set of values, except that the gaps in that case are much more important: the LCC of the BA products is worth 120 000 € less than the base case LCC (only 25 000 € in the default set).

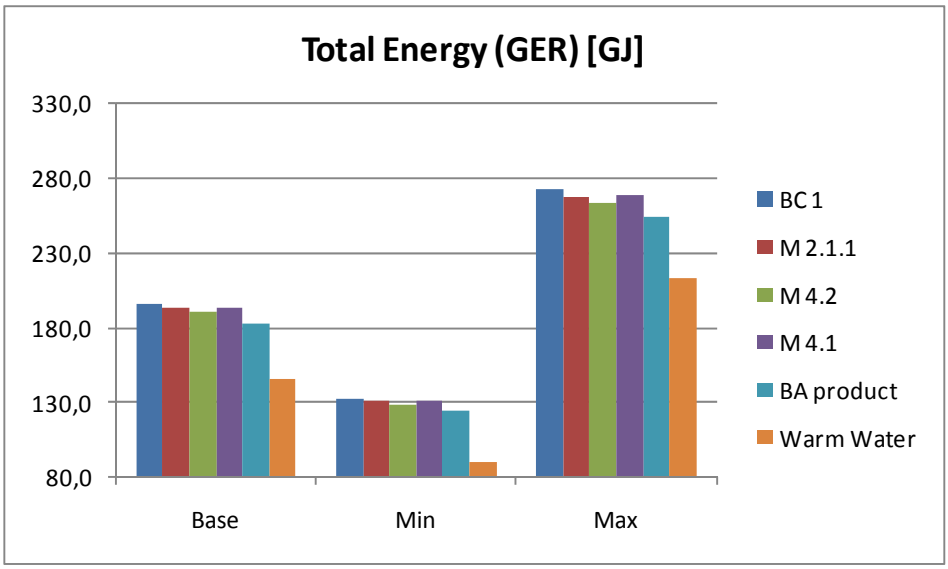


Figure 4-91 Base case 1 and improvement options – impact of combined parameters on total energy over lifetime by product

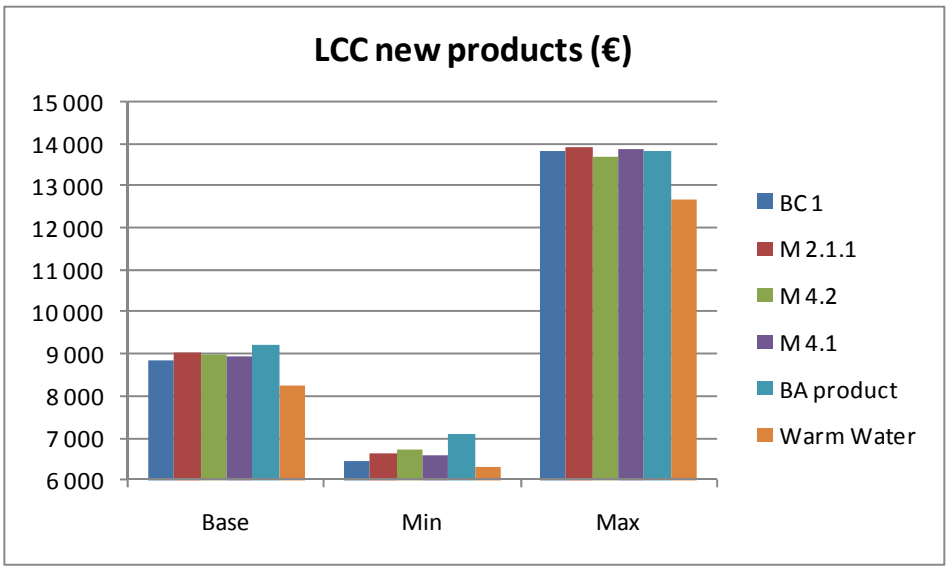


Figure 4-92 Base case 1 and improvement options – impact of combined parameters on LCC by product

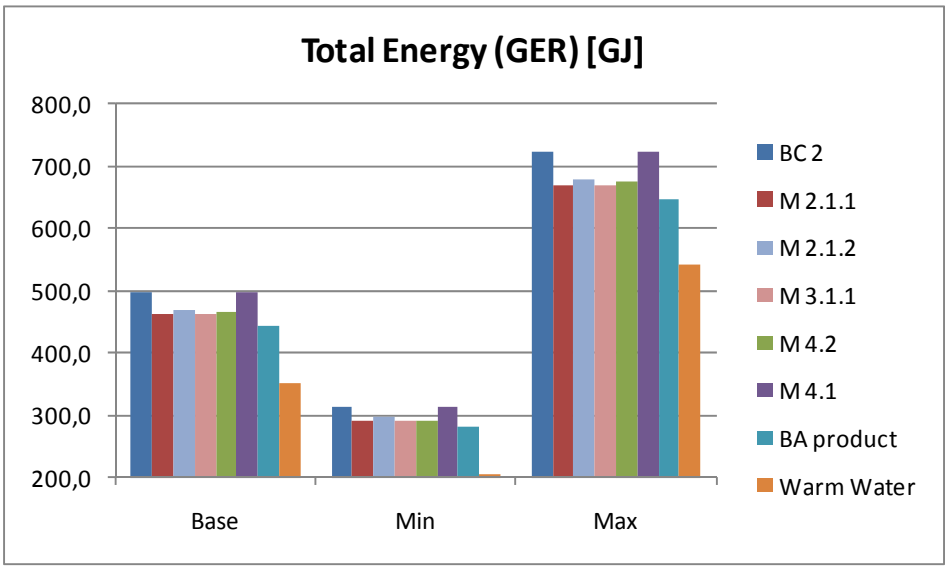


Figure 4-93 Base case 2 and improvement options – impact of combined parameters on total energy over lifetime by product

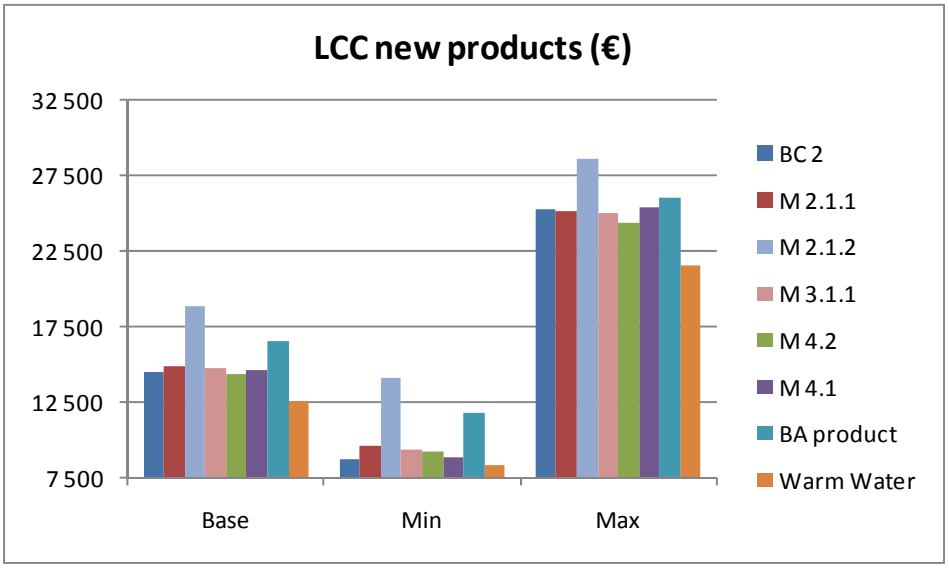


Figure 4-94 Base case 2 and improvement options – impact of combined parameters on LCC by product

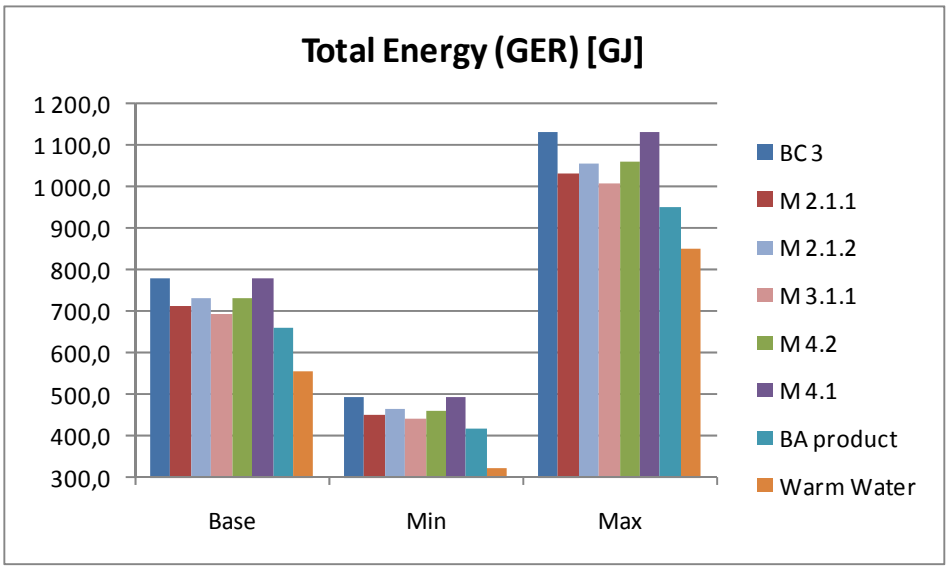


Figure 4-95 Base case 3 and improvement options – impact of combined parameters on total energy over lifetime by product

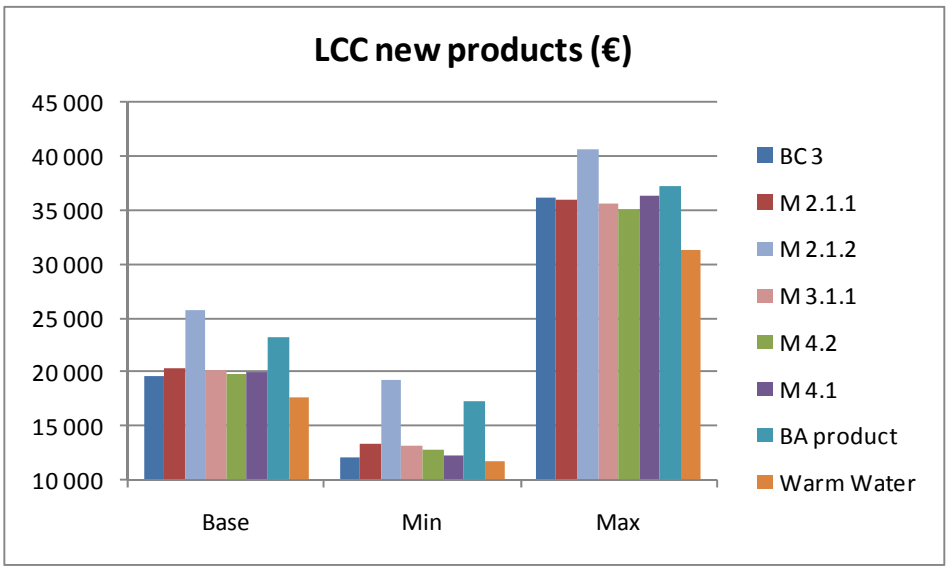


Figure 4-96 Base case 3 and improvement options – impact of combined parameters on LCC by product

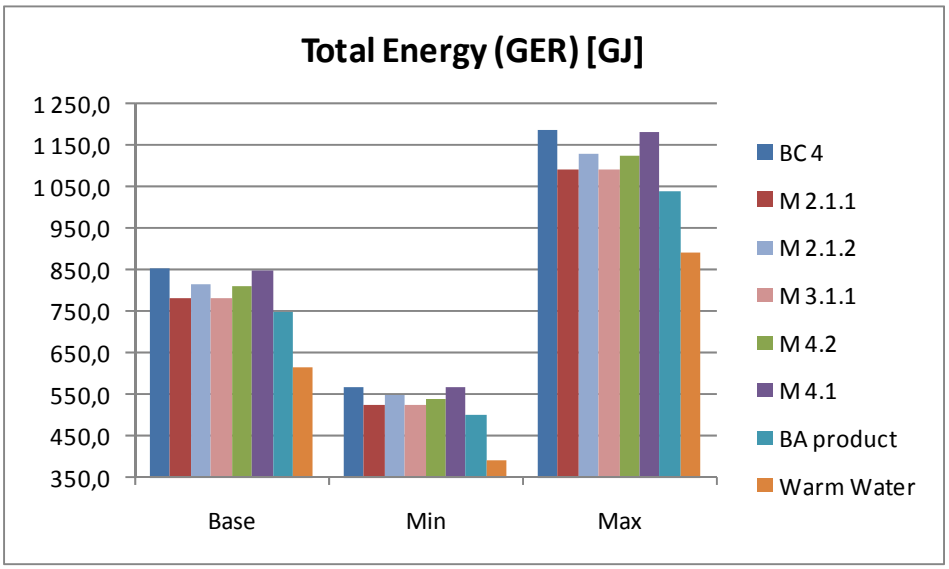


Figure 4-97 Base case 4 and improvement options – impact of combined parameters on total energy over lifetime by product

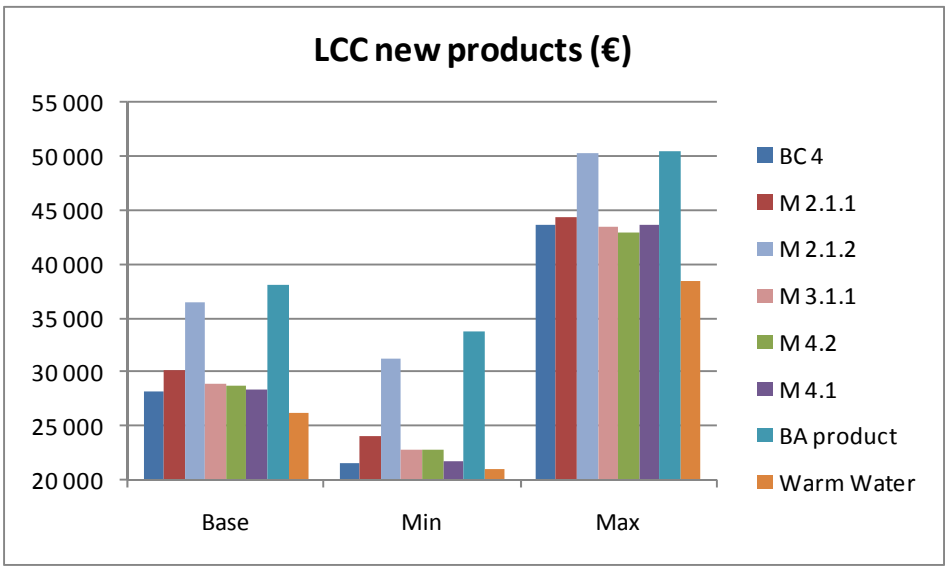


Figure 4-98 Base case 4 and improvement options – impact of combined parameters on LCC by product

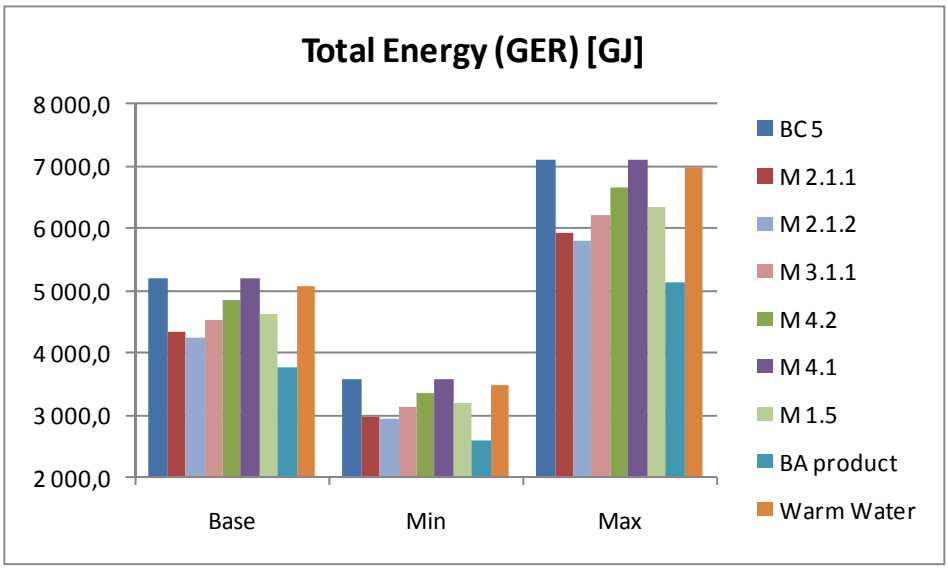


Figure 4-99 Base case 5 and improvement options – impact of combined parameters on total energy over lifetime by product

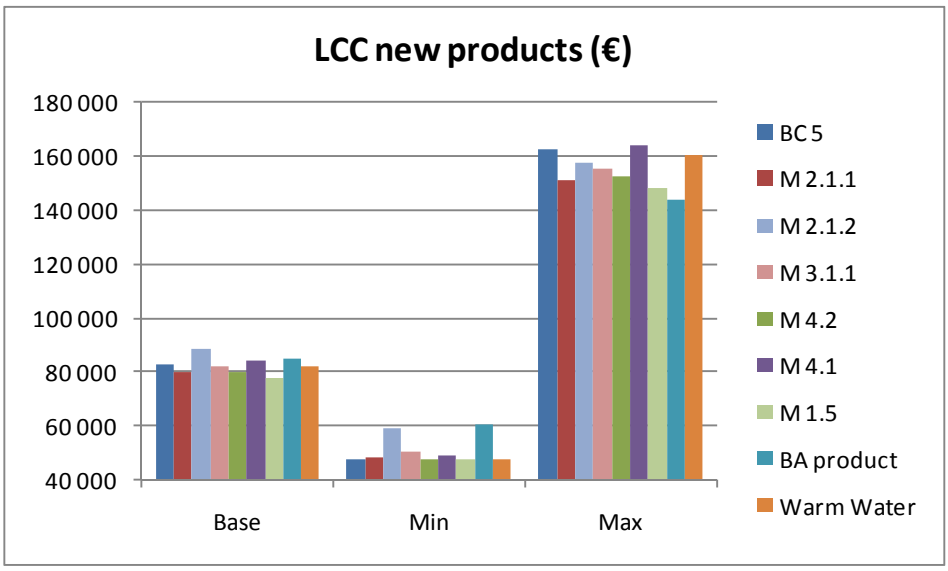


Figure 4-100 Base case 5 and improvement options – impact of combined parameters on LCC by product

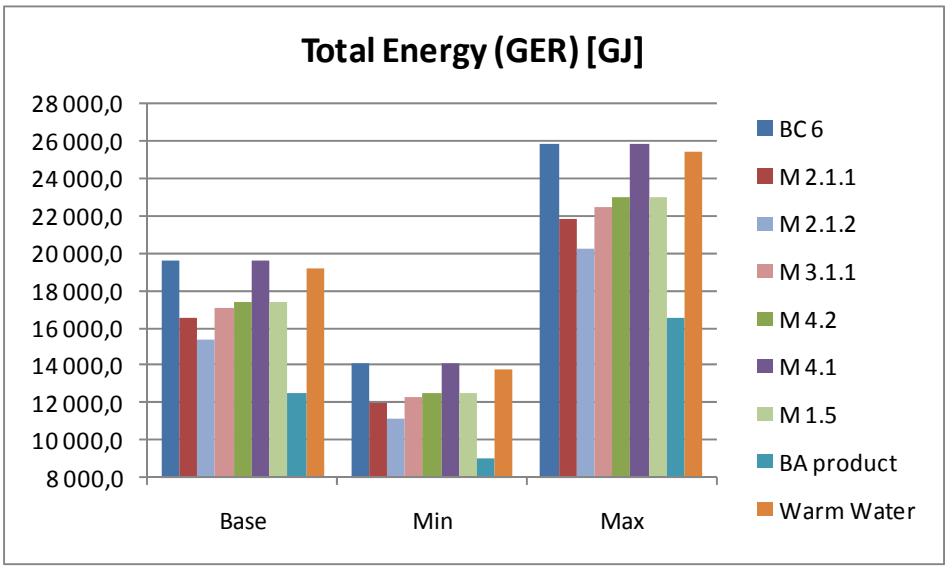


Figure 4-101 Base case 6 and improvement options – impact of combined parameters on total energy over lifetime by product

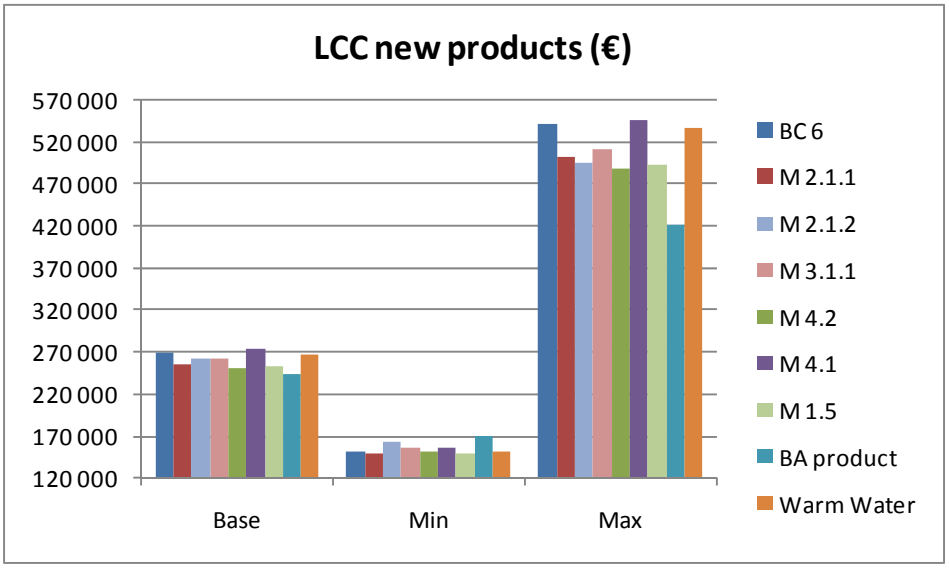


Figure 4-102 Base case 6 and improvement options – impact of combined parameters on LCC by product

5 Conclusions

Task 8 summarises the outcomes of the economic and environmental analysis of the study and puts them in the context of policy implementation.

Generic eco-design requirements are proposed, such as the general provision of information related to the performance of different programmes and modes available for a given product. Together with the definition of a 'standard programme' for each dishwasher category clearly being understandable by the users, the information might help overcoming the additional consumption due to the influence of consumer behaviour. The significant water consumption based on consumer behaviour during manual pre-cleaning of dishes and cleaning of the dishwashing machines might be addressed by accompanying eco-design requirements on the use of efficient pre-rinse spray valves or tapware.

The overall need for harmonised standards for testing and measuring the performance of professional dishwashers is seen as the most necessary step before implementing any further specific eco-design requirements like a labelling programme, benchmarking values or Minimum Energy Performance standards in the EU. Based on the combined economic and environmental analysis made in Task 7, specific eco-design requirements (Minimum Energy Performance Standards, MEPS) are suggested. However, these proposals are mostly indicative, given the uncertainty of the input data and their influence on the results. However, they show that there is room for improvement in each product category.

In the sensitivity analysis, it is shown that the variation of single or combined parameters can change the ranking of the options in terms of life cycle cost. Thus, for example, an improvement option that is worth implementing in one Member State for a given product and sector might not be a relevant solution in a different situation or location.

Task 8 also presents a scenario analysis that compares four scenarios: Business-as-Usual (BAU), Least Life cycle Cost (LLCC), Best Available Technology (BAT) and Minimum Energy Performance Standards (MEPS). The MEPS and LLCC scenarios are very similar, both in terms of energy savings and total expenditure. Over the period 2010 to 2025, the MEPS scenario would enable the saving of 3.9% (116 PJ, i.e. 32.2 TWh) of primary energy consumption compared to BAU and 1.0% of total expenditure. The energy savings of the BAT scenario amount to 8% (237 PJ, i.e. 65.8 TWh) in comparison with BAU.

These scenarios finally indicate the remaining improvement potential that could be encouraged through further policy options such as Green Public Procurement requirements.