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

Lot 24: Professional Washing Machines, Dryers and Dishwashers

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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

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.

Part: Professional Dishwashers

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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.

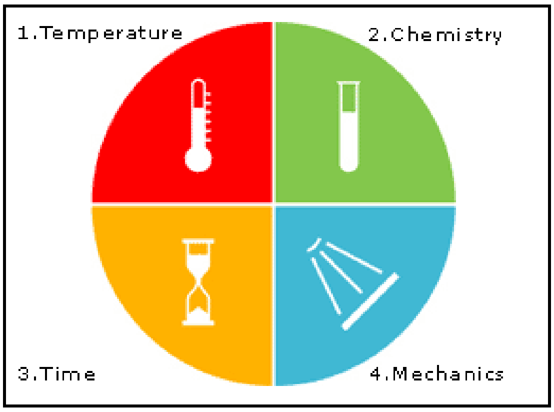

Figure 1 Factors influencing the dishwashing process: Sinner's Circle ("Sinner'scher Kreis")[3]

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

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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-

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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)

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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 (continu-ous 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 dishwashers 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

Dishwasher category	Electricity consumption (range) [kWh/100 dishes][35]		
	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 Geschirr-spülmaschinen (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.