Energy

Preparatory Studies for Eco-design Requirements of EuPs

(Tender TREN/D1/40-2005)

LOT 14: Domestic Dishwashers & Washing Machines

Part I – PRESENT SITUATION

Task 4: Product Systems Analysis Rev. 1.0

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ABSTRACT

In the real use of **washing machines** two strong impact factors were found: the use of low temperature washing programmes and a under-utilization of capacity, both requiring the upgrading of the European standard before any modification in policy measures could be hypothesised. The resulting difference in electricity consumption can be presented in two ways: with the same number of cycles, in which the real life machine has 35% less consumption than the standard average machine; or with the same amount of clothes washed (in kg), in which the real life machine has a 5% less consumption than the standard average machine.

Regarding the future of consumer trends, there is some hope of modifying the low utilization, in particular with the re-enforcement of the correct behaviour by making the load utilization available with a display on the machine. A long-term improvement from 68% to 73%-78% is hypothesized for the next decade.

The trend toward even lower temperature programmes will probably continue also with the collaboration of the detergent manufacturers. A continued decrease of 3-5 °C appears reasonable. With the reduced temperatures of washing and increased use of detergents, coupled with the tendency to reduce the water consumption, rinsing quality has become an issue. Rinsing quality must be evaluated through an appropriate testing procedure, presently absent in the European standard. This may complicate somewhat previous energy labelling scheme, as good rinsing might require more water and energy. In order to know the amount of detergent used in the machine and better control the situation of rinsing, it would be helpful if the detergent producers provided all washing chemicals in forms suitable for automatic dosing.

The trend towards larger capacity washing machines should be monitored.

Concerning **dishwashers**, the real life machine revealed a 24% higher energy consumption with respect to the consumption under standardised conditions, including a 15% increase for hand pre-rinsing. The real load utilization is 70% and the temperatures actually used are generally higher than in the programme used under standardised conditions for the energy labelling declaration. As in the case of the washing machine, there is the need to update these two aspects.

Regarding the consumer trends, the habits concerning the low utilization appear to be more difficult to modify than those concerning the situation of the washing machine for the various reasons discussed. Some progress might be made on reducing the pre-rinsing and a small decrease could be hypothesized.

A summary of the real life impact factors for dishwashers and washing machines is given in the following table.

Summary of real life impact factors

Impact Factors	Nature of Change
Real consumer use of washing machines	– the real life machine uses 35% less energy than the standard average (at constant cycles): lower washing temperatures accounts for a 29%; – electricity reduction; a reduced load -9,8 %; and various low power modes and standby consumption adds +3,5%; – the nominal load utilization is only 68%; – considering that in the real life a family has to wash 1,47 (=1/68%) times that of the standard case, to wash the same amount of wash, the real life consumption is 5% percent less than the standard average machine for equal amounts of wash;
Washing machine consumer trends	– with the indication of the percentage load on the machine, a 5 to 10% improvement in load factor is hypothesized; – trends to lower temperature programmes will continue: a 3 to 5 °C decrease is forecast; – the quality of the rinse has come into question; – there is a trend towards larger machines that requires monitoring
Real consumer use of dishwashers	– the electricity consumption of the real life is 24% higher, including a 15% increase for hand pre-rinsing; – the nominal load utilization is 70% and the used wash temperature used is higher than the cycle used for the energy labelling declaration;
Dishwasher consumer trends	– habits concerning utilization appear more stable and contemporarily more difficult to change than those of the washing machine; – some progress might be made on pre-rinsing. A small decrease could be hypothesized.

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NOTE: according to international standards dealing with quantities and units, the numbers in this study are written according to the following rules:

−   the comma "," is the separator between the integer and the decimal part of a number

−   numbers with more than three digits are divided by a blank in groups of three digits

−   in case of monetary values the numbers are divided by a dot in groups of three digits.

4 Task 4: Product System Analysis

4.1 THE STUDY TASKS

Washing machines and dishwashers, also known as "wash appliances", have been the second and most studied EuP in the European Union with the goal to reduce their energy consumption. In 1995, the study of the Group for Efficient Appliances (GEA, 1995) provided the technical basis for the energy labelling Directive, and later also partially for the Eco-label awarding criteria. Its results and methodology were the starting point for the second study on washing machines (NOVEM, 2000, known as the WASH-2 study) promoted by DG TREN in 1998, which took into consideration the methodological, technical, economical and market developments and proposed a new structure for a revised label and the possible setting of efficiency targets, which then for various reasons were not fully accepted by Member States.

Contemporarily, the European Eco-label Board started to address these two product groups more from the environmental impact point of view with other studies, which resulted in the definition of eco-labelling awarding criteria, the latest being:

- for washing machines: on December 1999[1] the Commission adopted the criteria valid until December 1st 2002. These criteria were then prolonged to November 30th 2005 (Decision 2003/240/EC);
- for dishwashers: on August 1998[2] the Commission adopted the criteria valid until January 20th 2003 through the extension given by Decision 2001/397/EC. Criteria were revised in August 2001 (AEAT, 2001) and are valid until August 26th 2006.

In the meantime, a series of monitoring studies were promoted by the SAVE Programme to evaluate the impact of the EU legislation on the market transformation of washing machines and their energy consumption (ADEME, 2000; ADEME, 2001). Dishwashers were monitored through the annual reports presented by the European Association of Household Appliance Manufacturers (CECED) to the EC and the Regulatory Committee responsible for the management of the EU energy labelling scheme, describing the effectiveness of the industry "Voluntary Commitment on Reducing the Energy Consumption of Household Dishwashers" issued in 1999 and ended in 2004. Also washing machine market was monitored through CECED annual reports under the two Voluntary Commitments issued in 1997 and in 2002 for this product group.

Since markets and technologies change continually, including in response to past policy settings, the present study proposal takes the results and methodology defined in the last decade of studies as the starting point to be updated and upgraded where necessary to evaluate the technical, economic and market developments of cold appliances and the new aspects of these products to be covered following the indications of the eco-design directive 2005/32/EC[3]. This is necessary in order to define the need of implementing measures and possible targets for voluntary or mandatory policies.

The study is divided in two working phases or study Parts and seven Tasks or Chapters:

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[1] Commission Decision of 17 December 1999 establishing the ecological criteria for the award of the Community eco-label to washing machines (2000/45/EC).

[2] Commission Decision of 20 July 1998 establishing the ecological criteria for the award of the Community eco-label to dishwashers (98/483/EC).

[3] Directive 2005/32/EC of the European Parliament and of the Council of 6 July 2005 establishing a framework for the setting of ecodesign requirements for Energy-Using Products and amending Council Directive 92/42/EEC and Directives 96/57/EC and 2000/55/EC of the European Parliament and of the Council.

Part I: Present Situation, that envisages the following five Tasks:
- Task 1 - General Situation
- Task 2 - Economic and Market Analysis
- Task 3 - Consumer Behaviour
- Task 4 - Product System Analysis
- Task 5 - Definition of base case

Part II : Improvement Potential, with the following two Tasks:
- Task 6 - Technical Analysis
- Task 7 - Scenario, Policy, Impact and Sensitivity analysis.

Within the first part (Present Situation) the project team will set the study boundaries (Task 1), collect and organise the data for the economic, market (Task 2) and consumers behaviour analysis (Task 3), analyse the interaction of the studied appliances on the energy system to which the product belongs (Task 4) and set up the reference parameters, material, energy and costs inputs to define the starting base case (Task 5). All the data and information analysed within the first part of the study will serve as an input for the second part (Improvement Potential) during which the project team will carry out the technical and economic analysis to set up the optimal eco-design options of the analysed appliance (Task 6) and finally suggest the most suitable policies to achieve the recommended energy and ecological improvements (Task 7). A Glossary and References will be also included in the study.

This report refers to Task 2: Product System Analysis.

4.2   DESCRIPTION OF TASK 4

The Eco-design Directive is clearly on product design and does not regulate systems or installations as a whole. However, Annex VII.4 of the directive looks into the interaction of the EuP with the installation/system in which it operates and implies that the possible effects of the EuP being part of a larger system are to be identified and evaluated. This task includes therefore a functional analysis of the system to which the product belongs, including a rough estimate of the overall impacts, for example from IPP studies like EIPRO and an assessment of how the integration of the product into the system and its design can improve its overall environmental performance.

Hot fill options, with a second input for hot water, will be examined from the technical and economic point of view. To date, except for the possibility of a small niche market, the economics for a general EU27 market appear to be discouraging. This is due to the high cost of installation in most houses and extra costs of the price increase, with no offsetting benefits, for great majority of non-users.

While dishwashers and washing machines do not have a strong impact on the immediate installation system within the house, they can have an important impact on the electricity production and distribution system by utilizing off-peak hours of electricity primarily during the night.

The machines will have to be modified to be more silent and to have a timer or other device to permit use of off-peak electricity. These modifications will be made in the design phase and included as options in Tasks 6.1 and 6.2.

The purpose of this Task is thus to simulate the environmental impact with the CEDA EU25 (product and environmental) input output model, for the normal use of electricity and for the off-peak hour use of electricity of the improved machines. Unfortunately in input output model the dishwasher is not given as a separate product or service and thus cannot be modelled. Instead

washing machines are included, also as the service, 'washing with household laundry equipment,' CEDA code 540300 and will be studied.

It is also important to make the comparison with the bottom-up LCC (including environmental impact) method and top-down input output approach. Thus the inputs to the two methods should be same. Namely, the number of base case models and other models sold in year 2005 that is total models sold estimated in the bottom up approach should be the same as that used in the input output model. Of course the input output method will use the monetary value, or the number of models times the average price. Likewise the total amount of electricity required in 2005 for washing should be the same in both the input output and bottom-up approach.

The comparison of these results is should give us a better understanding of the two different methods. The primary difference should be due to the fact that the input output approach includes a more complete accounting for secondary input requirements, such the capital goods required to make the steel used in electricity production and in the production of washing machines etc. Another source of difference will be the use of slightly different environmental impact coefficients no doubt.

One of the most interesting aspects of comparison will include the modelling of the impact of the use of off-peak electricity. A hypothesis of increased off-peak load will be made compatible with the situation of the new sales and existing stock that could have timers and be relatively silent. The first aspect of the new simulation will be to change the electricity product mix part of the input output table in favour of a base load and less off-peak electricity. The second aspect is more complicated, and after an analysis of the literature, lower investments in capital goods will be introduced for electricity generation and distribution. This is due to the higher degree of utilization made possible by the load shifting.

At this point the two simulations of the CEDA EU25 input output model will be performed one with the normal load and one with the load optimizing. The environmental impacts for 'washing with household laundry equipment,' CEDA code 540300, will be compared and discussed. Sensitivity analysis will also be performed. In the simulation with CEDA EU25, a minimum amount of support by the authors or the EC will be required.

4.3   SYSTEM BOUNDARY

The Eco-design directive is referred to product design and not to systems or installations as a whole. However, Annex VII.4 considers the interaction of the specific EuP with the installation/system where it operates, implicitly stating that the possible effects of the EuP being part of a larger system are to be identified and evaluated. This task includes therefore a functional analysis of the system to which the product belongs, including an assessment of how the integration of the product into the system can change overall energy and environmental performance.

Particular attention is given to the actual ambient conditions in which the washing machine and dishwasher are used and the other aspects of utilization that are not included in the base cases to be defined in Task 5. Probably the most important element in the system is man himself, in the form of user of the appliance and electric utility.

The primary objective of this Task is to explore from a systematic point of view the elements, not considered in the base cases, which influence the present and future energy/environmental impact of the wash appliances. Thus a brief review of the results of the consumer habits, fully presented in Task 3, will be developed, to then proceed to the analysis of changing consumer needs, the enriched user/appliance interface and finally the utility/appliance interface. The part of the task regarding the use of the CEDA EU25 Product and Environmental Model is in a preliminary phase and not yet

presented. It was preferred to give priority to specific systems issues that emerged in real use of the appliance and future needs and trends of the consumer. This was necessary for a better understanding of the base cases and long-term scenarios.

After the first energy crises in 1973, appliance producers began looking at possible ways to integrate and save otherwise wasted energy or capacity. This included looking at the kitchen as a system and looking at the home as part of the national energy system. Initial efforts included ideas such as possible heat recovery between appliances such as using the refrigerator cooling coils to preheat water for other appliances such as clothes washers. This required considerable co-ordination and possible common design standards among appliances, or the consumer purchasing appliances in blocks, both of which were considered unrealistic and these complex schemes for heat recovery were dropped. At the thermal level there remained the possibility of the use of hot water from more efficient sources such as gas-fired hot water heaters that was available in any case for other purposes. In fact, in the UK this scheme is in use for washing machines with hot water fill. A more general case can be made for reducing the peak electricity load by more opportune timing of washing machines and dishwashers. As energy efficiencies have been drastically improved, other external system aspects have come into play such as the amount of water and the detergents utilized and their impacts. With the introduction of less and less expensive electronics, home computing, and the possibility of the connection of the appliance to the home computer, internet, and cell phones: the appliance/human interface assumes new dimensions and possibilities.

The considered system boundary is widened to include: i) the kitchen or place of use within the home; ii) the product user, in particular how he/she actually uses the appliance and his/her changing needs for clothes and dish washing; iii) the enriched user/appliance interface made possible by less and less expensive electronic, displays and Internet; iv) the utility/appliance interface regarding demand side management and the successive use washing machines and dishwashers. This is illustrated graphically in Figure 4.1.

Figure 4.1: System elements and boundary
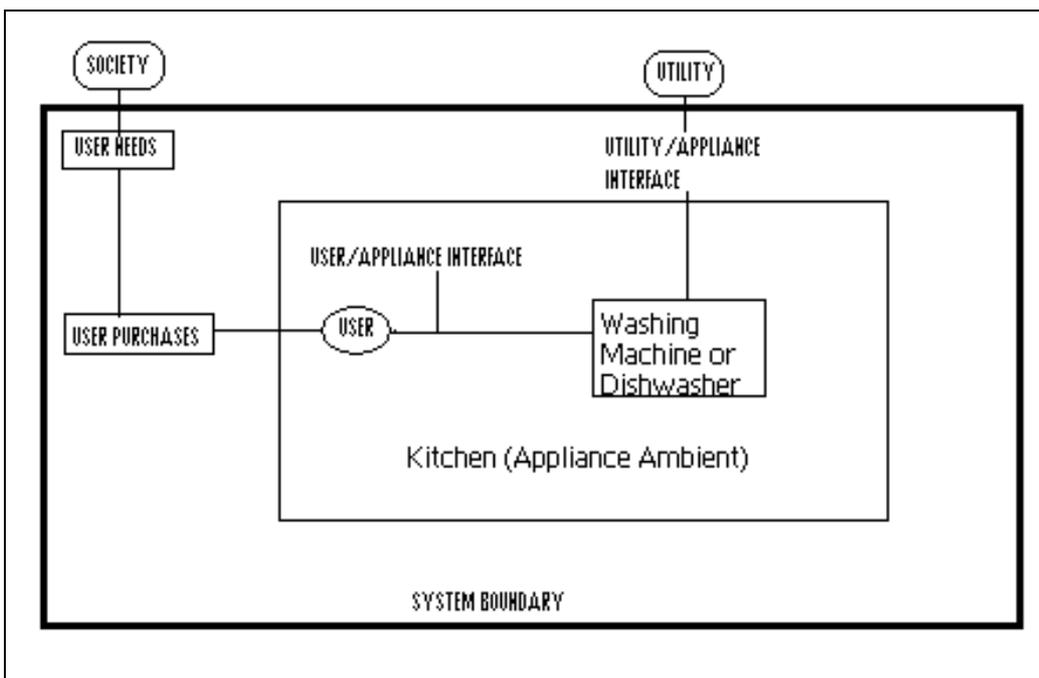
Within the kitchen the use of hot tub fill for washing machine and how householders perform in washing dishes by hand are examined. The consumer is at the centre of attention in understanding the real-life base cases: in particular, the program selection (including manual pre-rinsing for dishwashers), the amount of effective loading, the use of water, and the impact of various modes of low power and standby, including that of delayed start for night tariffs. Attention is drawn to the possible tradeoffs between energy and detergent in the choice of programme temperatures. The possibility of an improved user/appliance interface is discussed and finally the variation of spinning speeds for subsequent machine or natural drying is introduced as a system topic.

4.4 HOT TUB FILL

This practice of using warm water heated by more efficient sources such as gas fired instantaneous water heaters is used in only one Member State, the UK. Here washers with inputs for cold and hot water are offered. However, the use of hot tub fill has been declining. Informal estimates are that less than one-half of the UK market uses the option. Some producers are no long offering it.

The reasons for the decline are multiple. Probably most of the easy installations have been realised, the ones available now are farther from the available hot water source, more costly and bothersome because walls may have to be modified and repainted. At the same time energy savings, water saving and lower washing temperature realized by technological improvements introduced in these appliances has greatly reduced the impact of hot fill. The most popular temperature for washing is now at 40 °C. and the amount of water utilized has gone from 66,8 litre in 1997 to 50,7 litre in 2005, a 24% reduction. With a reduced amount of hot water required at the various stages of washing, there is the risk that the lukewarm water in the pipes and heater will actually supply most of this, before the hot water actually becomes available. System savings by hot water fill undoubtedly has been reduced, which corresponds to its lower use in the UK and lack of growth to other Member States. Most manufacturers no longer produce hot fill washing machines for the UK market because it is considered to be unnecessary[4].

One of the problems typical of linkage to special external systems (supply of more efficient hot water) is that of partial use. From the economic point of view, it would important that the extra cost of hot water fill is a minimum so that it does not unduly penalize those users that do not have non-electric sources of hot water. To reduce such costs, in theory, a single water input for cold or warm water would be possible with the addition of sensors. The idea is that the water coming in, warm or cold, would be heated to the desired temperature, if necessary. The problem of course is the presence of only warm water input for cooler 30-40°C washing or cold rinse. The rinse might be more effective at warm temperatures and perhaps less water could be used; however, in the case of having to allow for cooling of the warm water, the hot fill benefits would be lost. In any case the limited amount of any benefit and the reduced number of opportunities for its use make the matter unfeasible.

4.5 REAL CONSUMER USE OF WASHING MACHINES

The consumer behaviour using washing machines, fully described in Task 3, is only summarized here. Instead greater detail is given to improvements for electricity peak loads, energy and detergent

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[4] Market Transformation Programme, Briefing Note W15: Washing machine – efficient use FAQS, 30 March 2007, www.mtprog.com

tradeoffs in the selection of programme temperatures, performance with partial loads, spin speed tradeoffs, and finally changing consumer needs and an improved user/appliance interface.

4.5.1 Washing machine consumer behaviour

The major finding is that the real consumer base case is estimated to consume 35% less than the same machine measured according to the European standard (described in Task 1) for the average household.

This lower electricity consumption is due primarily to the use of lower temperature programs: households on the average wash with 46°C programmes compared to the 60°C standard cotton cycle, and the 46°C programme consumes only 71% of the 60°C one. Loading is also not at the nominal machine capacity: users filled the washing machines at 68% of the rated capacity (the capacity declared in the energy labelling). Most of all models have sensors for the amount of water absorbed or the weight of the wash load and can reduce water and electricity requirements for a lighter load. This saves 9,8% of the energy consumption under standard conditions, on a per load basis. Various forms of low power modes (for delayed start, program end, and 'left on" mode) add energy relative to the standard washing cycle, but only 1,7%; finally standby mode is expected to contribute another 1,7% arriving to the total for of 65% for the real-life use, or 35% less than the consumption measured according to the European standard, on a load basis.

However, as reported the load factor was 68% of the rated capacity. Thus a 'standard average' family stuffing their machine full at 5,4 kg washes[5] in ten washings does 54 kg of laundry, whereas the 'real-life' family gets only 68% of that or 37 kg in ten loads. For comparison we must presume that the families have the same amount of wash, so the "real life family" has to wash 1,47 (=1/0,68) times the cycles of the "standard average family". Thus if the standard average family consumes 4,890 kWh per week (standard average machine consumption per week at 4,9 washes/week), for the same amount of kg of wash per week, the real-life family consumes 4,644 kWh (real life machine consumption per week times 1,47) , only 5,0% less.

The resulting difference in electricity consumption can be presented in two ways: with the same number of cycles, in which the real life washing machine has 35% less consumption than the standard average machine; or with the same amount of clothes washed (in kg), in which the real life machine has a 5% less consumption than the standard average machine.

The lower temperature wash and the low real load size are such significant and compensating deviations from the standard conditions that both should be incorporated in revisions to the measurement method in the washing machine European standard.

4.5.2 Energy and detergent tradeoffs in the choice of programme temperatures

This most important reduction in the use of energy has been realized by the use of lower temperature water for washing, achieved by using more improved detergents with enzymes, and perhaps in some cases a better washing action from the machine itself.

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[5] The average load of the 2005 washing machines models in the CECED database, as found in Task 2.

Energy values measured in a recent Germany study[6] illustrate the strong influence of wash temperatures on electricity consumption (Figure 4.2). Also the amount of detergent used for the same washing efficiency at different temperature was recently simulated[7]: these changes in programme efficiency are possible for all programmes types and temperatures and are closely linked to the type and amount of detergent used; temperature and amount of detergent are balanced in such a way, that one may be substituted by the other to a large extend without sacrificing the washing performance; this was shown by tests using nominal (100%) amounts of detergent at 40, 60 and 90°C cotton programmes. In addition, the machines were operated with reduced (50%) and increased (150%) doses of detergent in the standard 60°C cotton programme, to take account of the flexibility of users in adjusting the performance of their washing machines by choosing different temperatures or by varying the amount of detergent. The results are presented in terms of the index system and class definitions of washing efficiency as known from European energy labelling, although the test conditions were not all according to the definitions for this system. The conclusions of the authors were that it is evident that the same level of performance can be achieved in a 90°C programme with only 50% of the rated detergent dose, in a 60°C programme with rated detergent dosage, or in a 40°C programme with 150% of the rated detergent dose. Thus, consumers are basically free to select any one of these options to achieve a specific level of cleaning performance, the only limitation being the temperature stability of the fabrics to be washed.

Figure 4.2: Average energy consumption observed at the different wash temperatures
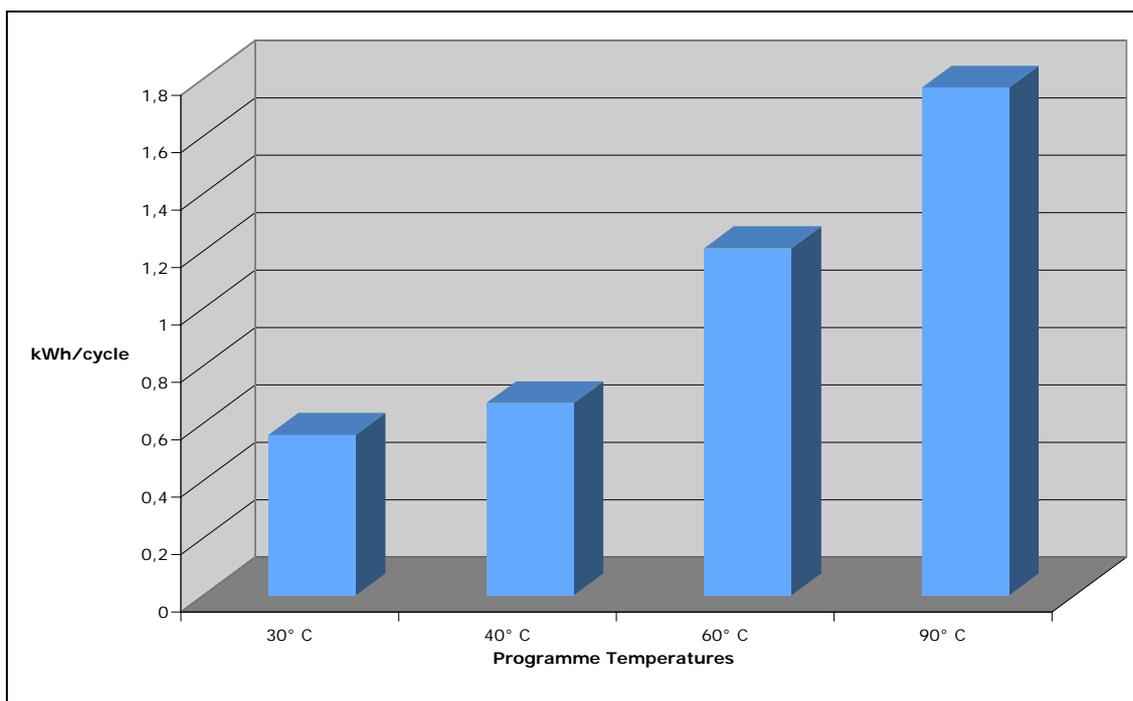
Using the standard prices, 0,17 €/kWh and 0,07 €cents detergent/standard wash, these tradeoffs can be shown (Figure 4.3): the total costs still favour lower temperatures, but the comparative environmental impacts are not shown, and will be subject to further investigation.

With this increase in the concentration of detergents, particularly in the more popular low temperature programmes, the quality of the rinse has come into question. The laundry may be clean

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[6] Wash Diary 2006.

[7] Stamminger, R., Barth, A., Dörr, S.; Old Washing Machines Wash Less Efficiently and Consume More Resources. In: Hauswirtschaft und Wissenschaft 3/2005, p. 124-131

but does it feel or behave differently due to residuals left by the rinse? The problem is complicated by the fact that we do not yet have a European standard to measure effectiveness of the rinse. This could be a major concern of households and their consumer organizations. An energy and/or water savings that results in high or unacceptable residuals could be jeopardized. The introduction of a European rinsing efficiency evaluation is a recommended action; however, this could have the impact of raising water consumption to reach a good performance level (at constant washing temperature). The total costs still favour lower temperatures, but the comparative environmental impacts are not shown, and will be subject to further investigation.

Figure 4.3: Tradeoffs between energy and detergent costs with variation in programme temperature
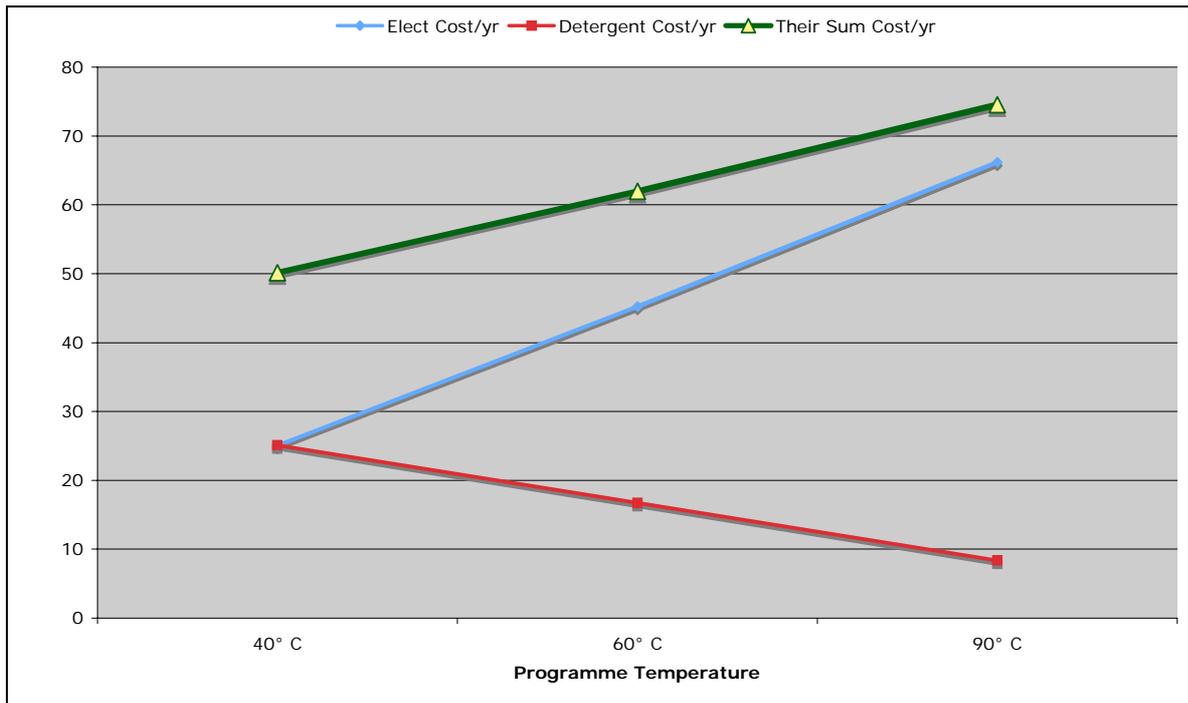
With this increase in the concentration of detergents and enzymes particularly in the more popular low temperature programmes, the quality of the rinse has come into question. The laundry may be clean but does it feel or behave differently due to residuals left by the rinse? The problem is complicated by the fact that a European standard to measure effectiveness of the rinse is at present not available. This could be a major concern of households and their consumer organizations. An energy or water savings that results in high or unacceptable residuals could be jeopardized. The introduction of the rinsing performance evaluation is thus a recommended action; however, this could have the impact of raising energy/water consumption and/or altering the present Energy labelling declarations.

4.5.3 Partial loading

Eighty-nine percent of the washing machines sold in 2005 have load detection. These models do compensate for the under or over-loading (compared to the nominal rated capacity) by modifying the washing program parameters.

How well this adjustment works and how large the differences between the machines are was recently investigated[8]: the results show a very different behaviour of the machines (Figure 4.4) with load adjustment factors between 0,12 kWh/kg and -0,02 kWh/kg for a cotton 60°C programme. The later value means, that this machine consumes actually more energy when only partly loaded. It should be further investigated if this specific machine has a load detection system, to allow a fair comparison of the different machines results. All together the average of this load dependency is at 0,08 kWh/kg and implies, that such a machine taking 1,0 kWh at 5kg load will still take 0,6 kWh of energy when almost no laundry is put in.

Figure 4.4: Energy consumption of 20 washing machines at various load size at 60 °C cotton programme (lines are trend lines for one washing machine; the black line indicates the average behaviour of the 20 machines.)
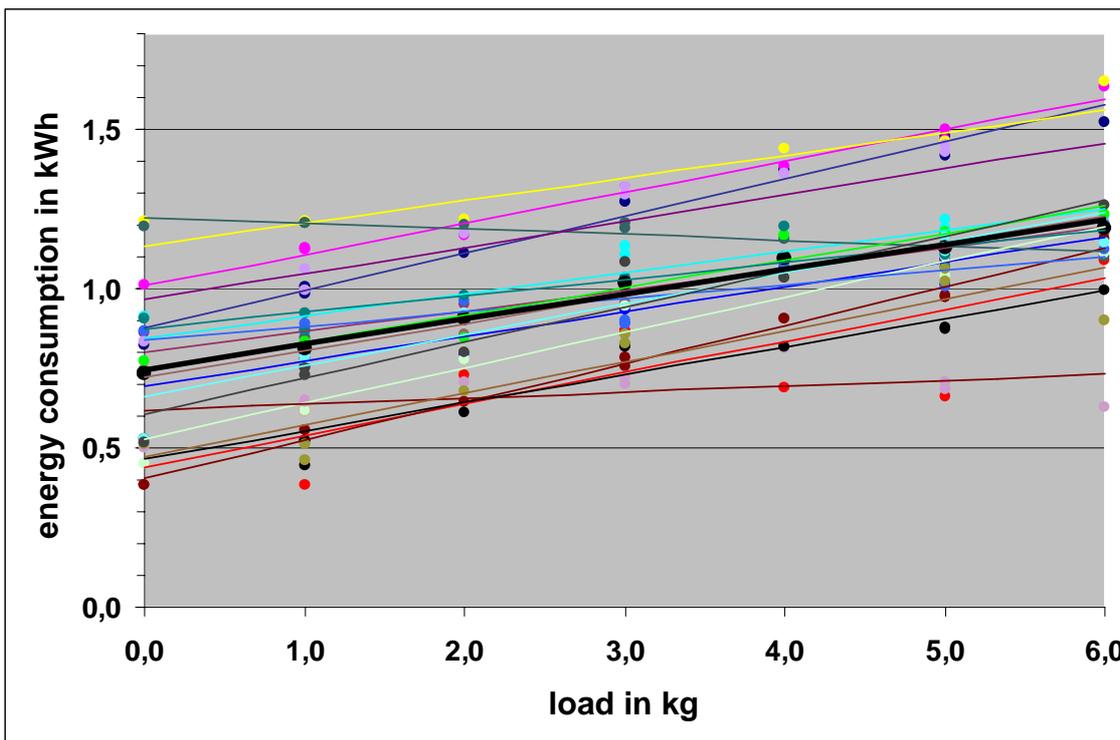
This figure is significant also because it illustrates the variety of the responses at partial load among the different models and manufacturers. Thus a measurement method within a European standard that took partial load into consideration would presumably offer manufacturers a means of product differentiation.

Unfortunately, presently the machine does not have control over the amount of detergent. The user may have added more detergent for lower temperature washing and less for high temperature, or he/she may have not changed the amount. This makes it difficult for the machine to optimize the rinsing.

Detergent makers should be encouraged to make partial dosing more available, also in forms for automatic dosing.

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[8] R.Stamminger, P.Berkholz, A.Brückner, A.Kruschwitz: Definition und Ermittlung verhaltensabhängiger Energieeinsparpotentiale beim Betrieb elektrischer Haushaltswaschmaschinen; Research report Uni Bonn for Bundesministerium f. Wirtschaft und Technologie BMWI - Projektnummer: 86/05 (to be published)

4.5.4 Consumer needs and trends

Also from a systems point of view both of the key variable program temperature and loading should be studied in a dynamic sense. Lower temperatures probably represent a consumer trend for more delicate washing also made possible by new enzymes introduced by detergent manufacturers. It also saves the consumer energy and total costs as previously shown, thus it is not unreasonable to forecast a continuation of lower average temperatures, at least of several degrees.

Instead the *need* to wash at very partial loads of 68% may in part be due unawareness of the actual load level and be due to unwillingness to wait longer to accumulate more of that type of laundry to make a full load. The first can be improved through better communication and is addressed in the section on enriched user/appliance interface. The second can be a valid time preference of the user. If all the loads were made at such a partial level one might conclude that in Europe there is a significant market for a smaller 3,7 kg load machine. Naturally this is probably not the case, if there is an occasional full load, and consumers likely want to have the full capacity in case they need it. Actually the trend in the EU is toward moderately larger capacity machines: 6kg capacity machines are becoming more and more common in Europe and also higher capacities, up to 9kg, have been introduced, but they represent at present a very minor share of the EU market, largely dominated by the 5-6kg machines.

The situation is different in other markets: larger machines are common in Asia where family size is greater and in the US where washing habits are different.

From the manufacturing point of view it would be better to have a standard size worldwide and this makes the position of the EU market quite critical since pressure from at least some manufacturers is for larger machines, as a way for product differentiation and possibly larger profits (new or perceived different appliances are usually sold at a higher price) while the actual load is 3,7kg in a nominal 5-6kg machine.

The trade-off between the amount of washed load and the nominal machine capacity will be further investigated in Task 6.

4.5.5 Improvement in electricity peak loads

The most important measure to be considered is the addition of acoustic insulation and any necessary controls to facilitate the use of night tariffs. Most washing machines already have timers permitting delayed start. Since most families should be able to program a high percentage of washes for the nighttime performance, the potential utilization should be high. However, certain washes may have high priority and cannot wait, some families may not want to bother with night washing, and many countries have not introduced such tariffs, so the penetration is still quite partial, estimated as 10% of total washes.

Consequently the improvement has the drawbacks of partial use previously mentioned. However, one may consider that it is pleasant to be around a quieter machine even during the day, so there is some benefit to customers not using the special tariffs. The technological option of decreasing the machine noise is analyzed in detail in Task 6.

As an example, a 10% decrease in average EU25 tariffs for night tariffs will yield a 42 € savings over the lifetime (15 years) of a standard average machine used 220 cycles per year, always during the night. If this was the maximum tariff decrease available for night tariff, it would set the

economic breakeven point for the consumer price increase for the acoustic insulation. A price increase equal to or less than 42 €would be convenient for the consumer, more would not.

4.5.6 Spinning speed tradeoffs

In areas with warm sunny climate, frequently the wet clothes are hung and dried outside (or inside) without machine drying. In these cases the high spins speeds are not used, and in fact in these areas models with lower spin speeds are generally offered. However, there is a general tendency to increase spin speeds, also offering higher pinning speed models in southern Europe an even more high spinning machines in northern Europe.

If the drying takes place inside the house, on top of radiators for example, the space heating system is heating and drying the clothing and heating the home less, thus the drying is not cost free. To the extent that the household is a 'sun-dryer' and does not want or use the higher speeds, this becomes a feature of partial use with all the related issues of extra costs for the user and producer.

The other issue is the trade-off between high spin velocity and the subsequent use of a dryer. At some point it is probably preferable to limit the spin speed and use the tumble dryer because the over-all efficiency is greater. At present this limitation does not appear to be reached. Some of these questions will be addressed in Task 6.

4.5.7 Improved user/appliance interface

One important interface improvement comes to mind: provide *during loading* the percentage of full load utilized. The percentage of full load could appear on a display on the machine. This is possible with the top-of-the-line machines that measure the weight of the load. It would tackle the problem of the low 68% present level of capacity utilization. The other machines measure the amount of water absorbed (after the door is closed) and could tell the user how well they filled tub only afterwards, which still might have some learning impact. Now the user knows nothing about how well the washing machine is filled.

It is hard to imagine all the possible other interfaces. Certainly user friendliness will continue to be a direction of emphasis. Given the demographic trends, user friendliness for the elderly appears to be appropriate. Voice recognition of the basic commands might be helpful. Some washing machines make an analysis of the nature of the fabrics being loaded into the machine and automatically suggest the appropriate washing programs. This kind of 'thinking' by the machine could be extended. Early diagnosis of potential maintenance problems is another area, although probably costly. The washing history could be kept and updated through the PC in the home. Knowing what and when the family washed, the system could even make suggestions of wash schedules, also more in keeping with the capacity of the machine.

4.6 HAND WASHING OF DISHES

An innovative study reports that in a laboratory setting, hand washing uses much more water and secondary energy (and time) than machine dishwashing. It was found that manual dishwashing required on the average 103 litres of water and 2,5 kWh of secondary energy compared to 15-22 litres and 1,0-2,0 kWh for machine dish washing, per setting of twelve. However, the machine dish washing may have been artificially near the maximum utilization of the dishwasher capacity, because the amount of tableware used in the experiment was that required to completely fill the

dishwasher and because it was outside the real setting of variable time requirements of the family. In a real setting, the dishwasher is probably used at lower levels of capacity utilization.

This factor may be corrected with the recent findings on utilization from the consumer behaviour analysis. Using an average of 70% utilization for washing tableware, a reduction in the cost of hand washing by 70% is achieved and the cost of machine washing remains essentially the same. Actually there is a savings of 7 to 8% due to the heating of fewer load, which was subtracted.

The results, in Table 4.1, show that there is at least a savings in 50 litres of water and a likely savings of electricity depending on the dishwasher model and consumption, which was between 0,9 and 1,8 kWh7cycle in the laboratory experiment (in 2005, a 12ps A class dishwasher has an energy consumption a value of 1,050 kWh/cycle).

Table 4.1: Comparison of hand and machine dishwashing at 70% load

Washing method	Resources (12ps)	
	Water (litre/cycle)	Electricity (kWh/cycle)
Hand wash	72	1,75
Machine wash	15-22	0,9-1,8

However, hand dish washing utilizes, in part, more efficient heating of hot water and thus less primary energy than 100% electricity. This primary energy calculation is to be made when the intermediate results of EuP - Lot 2 (water heaters) are known. In any case, due to the importance of the general finding, additional field studies are recommended.

4.7 REAL CONSUMER USE OF DISHWASHERS

The consumer behaviour, improvements in electricity peak loads, the changing consumer needs and improved user/appliance interface are examined.

4.7.1 Dishwasher real-life use

Surprisingly the consumer behaviour results in energy consumption of a dishwasher that is 24% higher than the consumption of the same machine under standard conditions (see Task 1 for the description of the European standard for dishwashers).

The largest increase, 15%, comes from hand pre-rinsing obviously not considered under standard conditions, as not necessary. This makes for a more realistic picture of actual consumption, given that only 15% of households reported no pre-treatment of dishes. A 13% increase results in the use of higher temperature programmes that the temperature of the programme used for the energy labelling declaration. The problem of partial load is also significant and estimated to be 70%, which causes a 9% decrease due to heating of a lighter load. Finally the various standby and low power modes are estimated to add 5%, resulting in the grand total of a 24% increase.

If we consider only the user impact on machine performance, ignoring hand pre-rinse, the real life dishwashing is about 9% higher than under standard conditions.

The European measurement method should better define the programme temperature and lower amount of filling the machine, which are the two most significant impact factors concerning the machine performance. The former problem could be also addressed by a mandatory common definition and disclosure of the programme used for energy labelling declaration.

Water consumption is 29% greater in the real life, mainly due to the additional pre-rinsing done by the consumer before loading the tableware into the dishwasher.

4.7.2 Improvement in electricity peak loads

The technical options to be considered are the addition of acoustic insulation and any necessary controls to facilitate the use of night tariffs. Most dishwashers already have timers permitting delayed starts. Since most families should be able to program a high percentage of washes for the night time performance, the potential utilization should be high. However, certain dishwashing may have high priority and cannot wait, some families may not want to bother with night washing, and many countries have not introduced such tariffs, so the penetration is still quite partial, about 25% of households use the delay start option for an estimated 10% of total washes.

The technological and LCC analysis, including noise reduction, will be carried out in Task 6. The cost and price limits of the additional insulation are dictated by the night tariffs, not counting the pleasure of having a more silent machine in general.

4.7.3 Changing consumer needs and an improved user/appliance interface

The issue of pre-rinse has implications beyond the re-setting of consumption starting point in the energy scenarios. It hopefully is dynamic and can be reduced since it amounts to an increase of 16% of the energy consumption of a machine tested under standard conditions. In part, this pre-rinse may be due to ignorance of the cleaning efficacy of the modern dishwashers. Perhaps earlier models were less effective. In part it may be the desire to remove foods on dishes to avoid odours or unsightly dishware, not all of them being placed in the washer immediately. Some very soiled items such as pots and pans may actually require some form of soaking or pre-treatment. The household should be advised to scrape foods off without water and to use cold water for unavoidable soaking, keeping the pre-treatment phase to a minimum.

Some moderate improvement may be made, but it may be difficult to change these types of habit also concerning hygiene. The consumer may prefer to error on what he/she perceives as the conservative side.

The low capacity utilization is somewhat similar to that of washing machines, both appliances having a low level of fill around 70%. However in the case of dishwashers the degree of utilization is much more apparent; in loading the user readily sees the available space available. Also the dishwasher utilization would appear to be *lumpy* and more rigid, regarding the amount of dishware available for washing after one or two meals. In the case where a meal provides more than enough dishware for a full load, the washer would be completely used; in other cases the user may prefer to not wait and proceed with a half-load or fraction of a full load. Waiting to fully load the machine might also involve hand washing those items that are in excess of the full load. The idea of a 'clean kitchen', without a fraction of the dishware to be washed, may contribute to this and lower levels of utilization. These habits do not appear to be very easy to change.

Regarding the user/appliance interface, if the amount of load could be measured, the degree of utilization could be communicated to the user. However, the user sees the free space and such a message might even be counterproductive.

Some of the same general consumer trends will apply: user friendliness will continue to be a direction of emphasis. Given the demographic trends, user friendliness for the elderly appears to be appropriate. Voice recognition of the basic commands might be helpful. This kind of 'thinking' by the machine could be extended. Early diagnosis of potential maintenance problems is another area, although probably costly.

4.8 CEDA EU25 PRODUCT AND ENVIRONMENTAL MODEL

The outputs of CEDA I/O model of EIPRO are given for year 2003. Unfortunately data and outputs do not exist for more recent years and it outside the scope and means of the present study to update and run this model on more recent data. Therefore we have attempted to take the output of our study and convert it to the conditions of CEDA I/O model.

The first step to use the CEDA model is to extract the total environmental impacts for all economic activity. These are given as scores per impact category in Table 5.1.1 Normalisation values for the EU-25 used in the EIPRO study.[9]

The total EU-25 impacts in year 2003 for the three impact categories (in common) are:

Global warming GWP100: 4,71E+12   kg CO2 eq/yr

Acidification: (incl. fate, average Europe total , A&B)
4,31E+10 kg SO2 eq/yr

Eutrophication: (fate not incl.) 1,05E+10 kg PO4 eq/yr

The other impact categories are not in common with that of the methods used in the present study.

These totals are multiplied times their fractional shares of impact for the use of washing with household laundry equipment (code 540300) from the shares table of the same report.[10]

The above vector product is divided by the number of families in EU-25 in year 2003, namely 182,126,800 as indicated in the Table4.2. The result is the EU-25 environmental impacts per family, per year, for the use of washing machines as shown in the sixth column of the table. This is divided by the washing machine ownership level for that year (89,73%) to give the annual impact per washing machine as illustrated in the seventh column of Table 4.2.

From our study, we utilize the environmental impacts reported in Task 3, dividing them by 15 years to obtain the annual impact given in column eight.

This now can be compared with the impacts of the I/O model, shown in the adjacent column.

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[9] Page 97, Annex 5: Annexes to Chapter 5, Environmental Impact of Products (EIPRO), Annex Report, May 2006, Report EUR 22284 EN.

[10] Page 179, Annex 5: Annexes to Chapter 5, Environmental Impact of Products (EIPRO), Annex Report, May 2006, Report EUR 22284 EN.

Table 4.2: Comparison of Environmental Annual Impact Per Family (EU -25) for the Use of Laundry Washing Equipment

Units	EU25 (2003) Value (from I/O Model)	Summarized Themes	Comparison for Washing Machines: EU25 (2003) Fraction due to: Use of W. M.	EU25 (2003) Total due to Use of W. M.	EU25 (2003) Aver. Family due to Use of W. M.	EU25 (2003) Aver. W.M. (family/0,8973)	Present Study Aver. W.M. (for one year)
kg antimony eq./yr.	1,33E+10	Abiotic depletion	1,64E-02	2,18E+08	1,20E+00	1,33	
kg CO2 eq./yr.	4,71E+12	Global Warming GWP100	2,37E-02	1,12E+11	6,13E+02	683,06	118,53
kg CFC-11 eq./yr.	3,69E+07	Ozone layer depletion	8,91E-03	3,29E+05	1,81E-03	0,00	
kg 1,4-dichlorobenzene eq./yr.	1,91E+12	Human toxicity htp inf.	1,52E-02	2,90E+10	1,59E+02	177,65	
kg 1,4-dichlorobenzene eq./yr.	1,29E+12						
kg 1,4-dichlorobenzene eq./yr.	5,75E+15						
kg 1,4-dichlorobenzene eq./yr.	2,64E+11						
	1,92E+15	Ecotoxicity score(avg.of 3)	1,46E-02	2,80E+13	1,54E+05		
kg ethylene eq./yr.	3,84E+10	Photochemical oxidation	1,07E-02	4,11E+08	2,26E+00	2,51	
kg SO2 eq./yr.	4,31E+10	Acidification	4,00E-02	1,72E+09	9,47E+00	10,55	0,71
kg PO4---eq./yr.	1,05E+10	Eutrophication	5,63E-03	5,91E+07	3,25E-01	0,36	0,0027

As can be seen the values are considerably different. If we take the ratio of the I/O model values to that of the present study the ratios are: 5, 15 and 130 for global warming, acidification and eutrophication respectively. While in general the I/O values could be expected to be higher, due to the fact that the EU-25 average washing machines are older and less efficient than our average model and due to the fact that with the indirect inputs of the I/O model the requirements should be more inclusive and thus somewhat greater; such large differences in global warming, acidification and eutrophication are not reasonable.

Furthermore, the same methodology of comparison was applied to the cold appliances and the ratio of the I/O model impact to present study impacts resulted in factors of 1,4, 4 and 5 respectively.

We could continue to apply such large difference to the various totals and scenarios; however, it is meaningless without understanding the differences at the more fundamental single family or single appliance level, including the inputs to the I/O model. We do not rule out the possibility that we have misread or misunderstood the I/O model results. It is suggested that these results be posted for comments.